Higher Physics Past Papers

Mr Davie

September 2025 Update (Mr White)

1 Intro

This document was created in order to make it easier to find past paper questions, both for teachers and students. I will do my best to keep this document up to date and include new past paper questions as they become available. If you spot any mistakes, or want to suggest any improvements, send me an email at MrDaviePhysics@gmail.com. I am more than happy to send you the Tex file used to produce the document so that you can modify it as you wish.

2 How to Use

The table on the next page contains links to questions sorted by topic and year. Clicking on a link will take you to that question. The marking instructions follow directly after each question with the exception of multiple choice questions and open ended questions. The answers to multiple choice are at the end of that section of multiple choice questions. I have not included the marking instructions for open ended questions as they do not contain enough information for you to mark your own work. Instead ask your teacher to have a look at what you have written. To return to the table click on **Question Table** at the top or bottom of any page. Trying to navigate the document without doing this is tedious.

Before starting any past paper questions I recommend that you have paper copies of the Relationships Sheet and Data Sheet to avoid wasting time. If you don't have them then they are linked at the top of each page allow you to print them or open them in a separate tab.

3 September 2025 Update

Full credit for the creation of this document goes to Mr Davie. This has been an invaluable resource for Physics teachers and students across Scotland, who I know are very grateful for his work. In March 2025, the original document was updated by Mr White, adding the 2023 and 2024 papers (maintaining the same style as the original) along with links to the Data Sheet and Relationship Sheet. I have also added links to the answers in the bottom corner of each multiple-choice question page to make them easier to find. The 2025 paper was added in September 2025.

By clicking the Data Sheet and Relationship Sheet links with the middle mouse button or by right-clicking on the links, you can open them in another tab. If there are any issues with the papers after 2023, please send me an email at twhite@lenzieacademy.e-dunbarton.sch.uk and I will try to fix them. I will also do my best to keep the document updated and add new past paper questions every year.

	2015		2016		2017		2018		SPQ		2019	
	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
motion - equations and graphs	1, 2		1,2		1	1a,3	1,2		1,2	1a,b,3a(i)	1,3,4	1a,c
forces, energy and power	3,4,5,6		3	2c	2, 3		3,4	2	3,4	1c,d,2,3b	5	2
collisions, explosions, and impulse		2	4	3		2		3	5,6	3a(ii,iii)	6	1b
gravitation		1,3	5	1		5a(ii), 5b(ii)	5	1	7,8		2	4
special relativity	7			4	4	7d	6,7		9	4	8	7c(ii)
the expanding Universe	8	4b,5	6,7	5	5,6,7	1b,5b(i)		5,10c	10,11	5	9,10	5,6
forces on charged particles	10,11			7,8d		8	10	6	12,13	6	11,12	
the Standard Model	9	6	8,9			5a(i), 7a,b,c	8,9		14	7	13	7a,b,c(i)
nuclear reactions	12		10	8	8	9	11		15	7e,8	14	7d,8
inverse square law		8	15		14,15		12		16	9		9a(ii),b
wave-particle duality		7	11,12		9,10			7		10	15,16	
interference	13	9b	13	9	11	10	13	8	17	11	17	10
spectra	16	4a	16	12bii		6		10a,b	18		19	9a(i)
refraction of light	15	9a	14	10	12,13		14	9	19	12	18	11
monitoring and measuring AC	17,18		17		16			12	20,21		20,21	
current, potential difference, power, and resistance	18		19			14b(i)	15,16	2a(ii), 12b	22,23		23	
electrical sources & internal resistance		10		12a		12		11a,b	24	13		12
capacitors		11	20	13	17,18	13	17,18,19		25	14		13
semiconductors and p-n junctions	19			12bi	19	14a,b(ii)		11c		15	24	14
open ended		5,7		6,11		4,11		4,6c		5c,10c		3,13d
unseen formula/graph plotting	20	12		14	20	15		13		16	7	5b,15
uncertainties	14			2(a,b)			20			11b(ii)	22,25	

	2020		2022		2023		2024		2025	
	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
motion - equations and graphs	1,2,3	1b,c,3a	1,2	2a(i)	1, 2	1	1, 2	2b(i), 6a (iii)	1, 2	1a
forces, energy and power	4,5,6	1d,2a,3a,8a,15a	3,4,5,6	2a(ii)	4	2	3, 5	2, 4b(i), 6a (ii)	3, 4, 5	1b
collisions, explosions, and impulse	7	3		3a-c	3	3	6	1b(ii), 4b(ii)	6, 7	2a-c
gravitation		1,5a		1,5c	5, 6		4	1a, 4a(ii)		5c
special relativity	9,10	7b	7		7	4	7, 8		8	4
the expanding Universe	11,12	2b,4,6b,c	8,9	5a,b	8, 9	5a,10c(ii c)	9	1b(i), 5	9	2d, 5b, 10c
forces on charged particles	13	7a,7c(ii),8b(i,ii)	10	7	10	7b,c		6a(i), 6b	10, 11	
the Standard Model	14,15	5b(ii),7c(i),7d(i)	11,12	6a,b,e	11	7a(ii)	10, 11	4a(i)		5a, 6b, 6c
nuclear reactions	16	7d(ii)	13,14		12	7a(i)	12, 13		12	6a
inverse square law		9b(i,ii)	15	8a		8	14	8b	13	7
wave-particle duality	17	8a,b(i)		9	13, 14	5b (iii A)		9	14, 15	8
interference	18	5b(i),10	16	10	15, 16		15	10	16	9
spectra		6a,11		8b	17	10	16	11		10a, b
refraction of light	19,20	12	17	11	18	11	17	12	17, 18	
monitoring and measuring AC		13	18		19			13		11
current, potential difference, power, and resistance	21,22		19,20		20		18, 19	15a	19, 20	
electrical sources & internal resistance		14	21	12	21	12	20	14	21, 22	
capacitors	23,24,25		22,23	13	22	13a(i)	21, 22			12
semiconductors and p-n junctions		9b(iii)	24	3d	23	5b	23, 24, 25	15b	23	
open ended		4,11		4,6e		6, 9		3, 7		3, 13
unseen formula/graph plotting	8	15b	25	14	24, 25	13b, 14		8a, 16	25	14
uncertainties		10		2b		13a(ii)		8c	24	

H

National Qualifications 2015

X757/76/02

Physics Section 1—Questions

TUESDAY, 5 MAY

1:00 PM – 3:30 PM

Instructions for the completion of Section 1 are given on *Page two* of your question and answer booklet X757/76/01.

Record your answers on the answer grid on *Page three* of your question and answer booklet.

Reference may be made to the Data Sheet on *Page two* of this booklet and to the Relationships Sheet X757/76/11.

Before leaving the examination room you must give your question and answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

SQA ©

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	Symbol	Value	Quantity	Symbol	Value
Speed of light in vacuum	c	3.00×10^{8} m s^{-1}	Planck's constant	h	6.63×10^{-34} J s
Magnitude of the charge on an electron	e	1.60×10^{-19} C	Mass of electron	m_e	9.11×10^{-31} kg
Universal Constant of Gravitation	G	6.67×10^{-11} m^3 kg^{-1} s^{-2}	Mass of neutron	m_n	1.675×10^{-27} kg
Gravitational acceleration on Earth	g	9.8 m s^{-2}	Mass of proton	m_p	1.673×10^{-27} kg
Hubble's constant	H_0	2.3×10^{-18} s^{-1}	Speed of sound in air	v_{air}	3.40×10^{2} m s^{-1}

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	Refractive index	Substance	Refractive index
Diamond	2.42	Water	1.33
Crown glass	1.50	Air	1.00

SPECTRAL LINES

Element	Wavelength (nm)	Colour
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	Wavelength (nm)	Colour
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	Wavelength (nm)	Colour
Carbon dioxide	9550, 10 590	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	Density (kg m^{-3})	Melting point (K)	Boiling point (K)
Aluminium	2.70×10^{3}	933	2623
Copper	8.96×10^{3}	1357	2853
Ice	9.20×10^{2}	273	....
Sea Water	1.02×10^{3}	264	377
Water	1.00×10^{3}	273	373
Air	1.29	....	....
Hydrogen	9.0×10^{-2}	14	20

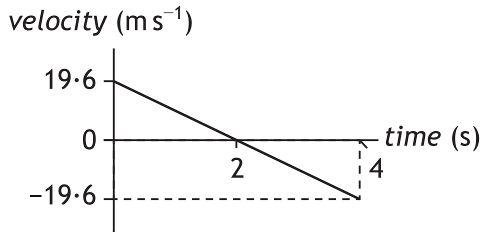
The gas densities refer to a temperature of 273 K and a pressure of 1.01×10^{5} Pa.

X857760102

SECTION 1 — 20 marks

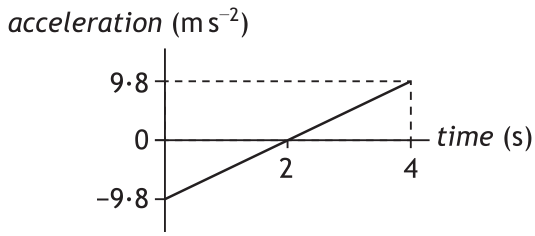
Attempt ALL questions

1. The following velocity-time graph represents the vertical motion of a ball.

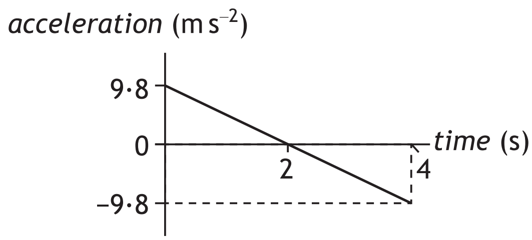


Which of the following acceleration-time graphs represents the same motion?

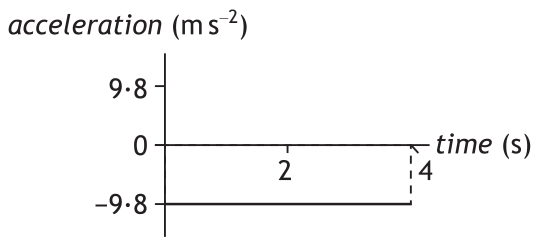
A



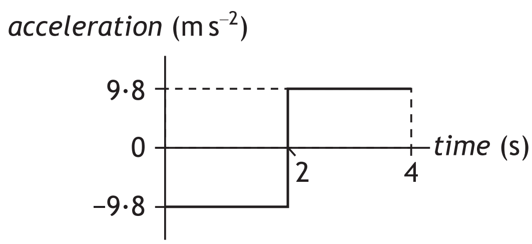
B



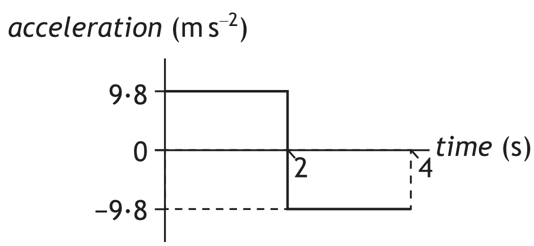
C



D



E



2. A car is travelling at $12\,m\,s^{-1}$ along a straight road. The car now accelerates uniformly at $-1{\cdot}5\,m\,s^{-2}$ for $6{\cdot}0\,s$.

The distance travelled during this time is

A 18 m

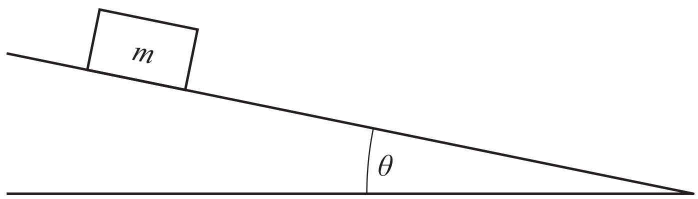
B 45 m

C 68 m

D 72 m

E 99 m.

3. A box of mass m rests on a slope as shown.



Which row in the table shows the component of the weight acting down the slope and the component of the weight acting normal to the slope?

	Component of weight acting down the slope	*Component of weight acting normal to the slope*
A	$mg\sin\theta$	$mg\cos\theta$
B	$mg\tan\theta$	$mg\sin\theta$
C	$mg\cos\theta$	$mg\sin\theta$
D	$mg\cos\theta$	$mg\tan\theta$
E	$mg\sin\theta$	$mg\tan\theta$

4. A person stands on bathroom scales in a lift.

The scales show a reading greater than the person's weight.

The lift is moving

A upwards with constant speed

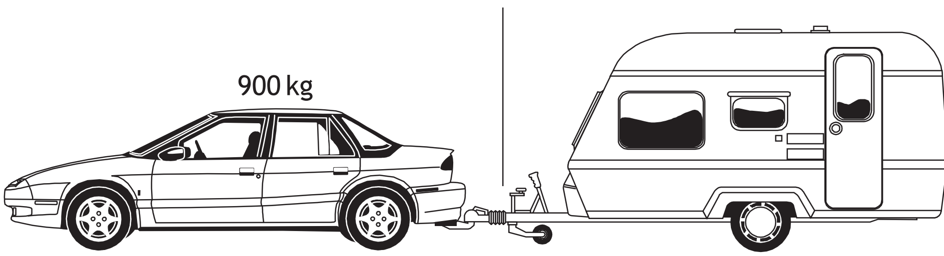
B downwards with constant speed

C downwards with increasing speed

D downwards with decreasing speed

E upwards with decreasing speed.

5. A car of mass 900 kg pulls a caravan of mass 400 kg along a straight, horizontal road with an acceleration of $2{\cdot}0\,\mathrm{m\,s^{-2}}$.



Assuming that the frictional forces on the caravan are negligible, the tension in the coupling between the car and the caravan is

A 400 N

B 500 N

C 800 N

D 1800 N

E 2600 N.

6. Water flows at a rate of $6{\cdot}25 \times 10^8$ kg per minute over a waterfall.

The height of the waterfall is 108 m.

The total power delivered by the water in falling through the 108 m is

A $1{\cdot}13 \times 10^9$ W

B $1{\cdot}10 \times 10^{10}$ W

C $6{\cdot}62 \times 10^{11}$ W

D $4{\cdot}05 \times 10^{12}$ W

E $3{\cdot}97 \times 10^{13}$ W.

7. A spacecraft is travelling at a constant speed of $0{\cdot}60c$ relative to the Moon.

An observer on the Moon measures the length of the moving spacecraft to be 190 m.

The length of the spacecraft as measured by an astronaut on the spacecraft is

A 120 m

B 152 m

C 238 m

D 297 m

E 300 m.

[Turn over

8. A siren on an ambulance emits sound at a constant frequency of 750 Hz.

The ambulance is travelling at a constant speed of 25·0 m s^{-1} towards a stationary observer.

The speed of sound in air is 340 m s^{-1}.

The frequency of the sound heard by the observer is

A 695 Hz

B 699 Hz

C 750 Hz

D 805 Hz

E 810 Hz.

9. The emission of beta particles in radioactive decay is evidence for the existence of

A quarks

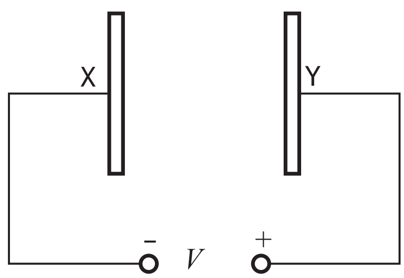
B electrons

C gluons

D neutrinos

E bosons.

10. Two parallel metal plates X and Y in a vacuum have a potential difference V across them.



An electron of charge e and mass m, initially at rest, is released from plate X.

The speed of the electron when it reaches plate Y is given by

A $\dfrac{2eV}{m}$

B $\sqrt{\dfrac{2eV}{m}}$

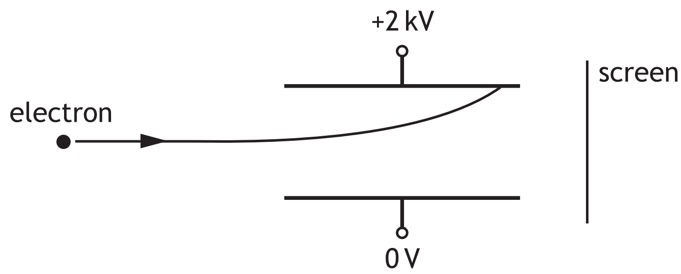
C $\sqrt{\dfrac{2V}{em}}$

D $\dfrac{2V}{em}$

E $\dfrac{2mV}{e}$

11. A potential difference of 2 kV is applied across two metal plates.

An electron passes between the metal plates and follows the path shown.



A student makes the following statements about changes that could be made to allow the electron to pass between the plates and reach the screen.

I Increasing the initial speed of the electron could allow the electron to reach the screen.

II Increasing the potential difference across the plates could allow the electron to reach the screen.

III Reversing the polarity of the plates could allow the electron to reach the screen.

Which of these statements is/are correct?

A I only

B II only

C III only

D I and II only

E I and III only

12. The following statement describes a fusion reaction.

$$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}He + ^{1}_{0}n + \text{energy}$$

The total mass of the particles before the reaction is $6{\cdot}684 \times 10^{-27}$ kg.

The total mass of the particles after the reaction is $6{\cdot}680 \times 10^{-27}$ kg.

The energy released in the reaction is

A $6{\cdot}012 \times 10^{-10}$ J

B $6{\cdot}016 \times 10^{-10}$ J

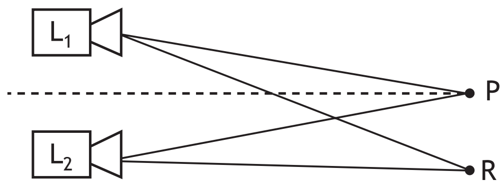
C $1{\cdot}800 \times 10^{-13}$ J

D $3{\cdot}600 \times 10^{-13}$ J

E $1{\cdot}200 \times 10^{-21}$ J.

[Turn over

13. Two identical loudspeakers, L_1 and L_2, are operated at the same frequency and in phase with each other. An interference pattern is produced.



At position P, which is the same distance from both loudspeakers, there is a maximum.

The next maximum is at position R, where $L_1R = 5{\cdot}6\,m$ and $L_2R = 5{\cdot}3\,m$.

The speed of sound in air is $340\,m\,s^{-1}$.

The frequency of the sound emitted by the loudspeakers is

A $8{\cdot}8 \times 10^{-4}\,Hz$

B $3{\cdot}1 \times 10^{1}\,Hz$

C $1{\cdot}0 \times 10^{2}\,Hz$

D $1{\cdot}1 \times 10^{3}\,Hz$

E $3{\cdot}7 \times 10^{3}\,Hz$.

14. An experiment is carried out to measure the wavelength of red light from a laser.

The following values for the wavelength are obtained.

650 nm 640 nm 635 nm 648 nm 655 nm

The mean value for the wavelength and the approximate random uncertainty in the mean is

A (645 ± 1) nm

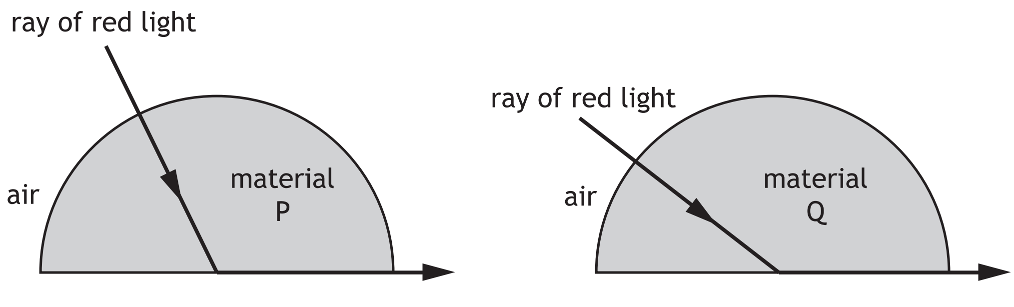
B (645 ± 4) nm

C (646 ± 1) nm

D (646 ± 4) nm

E (3228 ± 20) nm.

15. Red light is used to investigate the critical angle of two materials P and Q.



A student makes the following statements.

I Material P has a higher refractive index than material Q.

II The wavelength of the red light is longer inside material P than inside material Q.

III The red light travels at the same speed inside materials P and Q.

Which of these statements is/are correct?

A I only

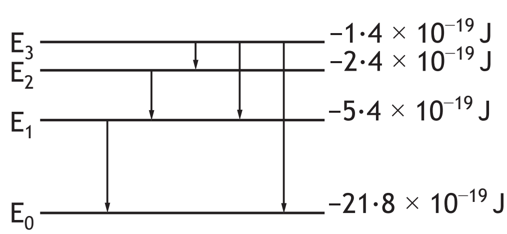
B II only

C III only

D I and II only

E I, II and III

16. The diagram represents some electron transitions between energy levels in an atom.



The radiation emitted with the shortest wavelength is produced by an electron making transition

A E_1 to E_0

B E_2 to E_1

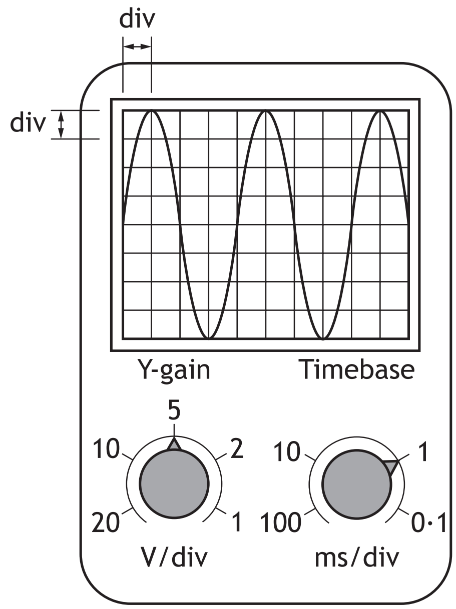
C E_3 to E_2

D E_3 to E_1

E E_3 to E_0.

[Turn over

17. The output from a signal generator is connected to the input terminals of an oscilloscope. The trace observed on the oscilloscope screen, the Y-gain setting and the timebase setting are shown.



The frequency of the signal shown is calculated using the

A timebase setting and the vertical height of the trace

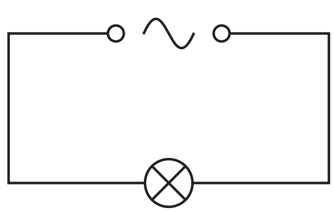
B timebase setting and the horizontal distance between the peaks of the trace

C Y-gain setting and the vertical height of the trace

D Y-gain setting and the horizontal distance between the peaks of the trace

E Y-gain setting and the timebase setting.

18. A circuit is set up as shown.



The r.m.s voltage across the lamp is 12 V.

The power produced by the lamp is 24 W.

The peak current in the lamp is

A 0·71 A

B 1·4 A

C 2·0 A

D 2·8 A

E 17 A.

19. A student makes the following statements about energy bands in different materials.

I In metals the highest occupied energy band is not completely full.

II In insulators the highest occupied energy band is full.

III The gap between the valence band and conduction band is smaller in semiconductors than in insulators.

Which of these statements is/are correct?

A I only

B II only

C I and II only

D I and III only

E I, II and III

20. The upward lift force L on the wings of an aircraft is calculated using the relationship

$$L = \tfrac{1}{2}\rho v^2 A C_L$$

where:

ρ is the density of air
v is the speed of the wings through the air
A is the area of the wings
C_L is the coefficient of lift.

The weight of a model aircraft is 80·0 N.
The area of the wings on the model aircraft is 3·0 m^2.
The coefficient of lift for these wings is 1·6.
The density of air is 1·29 $kg\,m^{-3}$

The speed required for the model aircraft to maintain a level flight is

A 2·5 $m\,s^{-1}$

B 3·6 $m\,s^{-1}$

C 5·1 $m\,s^{-1}$

D 12·9 $m\,s^{-1}$

E 25·8 $m\,s^{-1}$.

[END OF SECTION 1. NOW ATTEMPT THE QUESTIONS IN SECTION 2 OF YOUR QUESTION AND ANSWER BOOKLET]

Detailed Marking Instructions for each question

Section 1

Question	Answer	Mark
1.	C	1
2.	B	1
3.	A	1
4.	D	1
5.	C	1
6.	B	1
7.	C	1
8.	E	1
9.	D	1
10.	B	1
11.	A	1
12.	D	1
13.	D	1
14.	D	1
15.	A	1
16.	E	1
17.	B	1
18.	D	1
19.	E	1
20.	C	1

FOR OFFICIAL USE

H

National Qualifications 2015

Mark

X757/76/01

Physics
Section 1 – Answer Grid and Section 2

TUESDAY, 5 MAY

1:00 PM – 3:30 PM

* X 7 5 7 7 6 0 1 *

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth

Day Month Year

Scottish candidate number

Total marks — 130

SECTION 1 — 20 marks

Attempt ALL questions.

Instructions for the completion of Section 1 are given on *Page two*.

SECTION 2 — 110 marks

Attempt ALL questions.

Reference may be made to the Data Sheet on *Page two* of the question paper X757/76/02 and to the Relationship Sheet X757/76/11.

Care should be taken to give an appropriate number of significant figures in the final answers to calculations.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. You should score through your rough work when you have written your final copy.

Use **blue** or **black** ink.

Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

* X 7 5 7 7 6 0 1 0 1 *

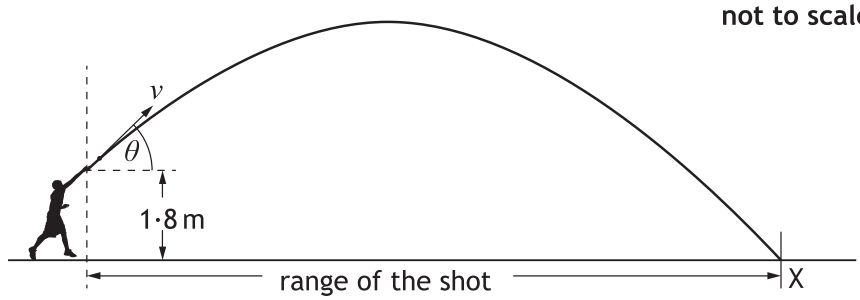
MARKS | DO NOT WRITE IN THIS MARGIN

SECTION 2 — 110 marks

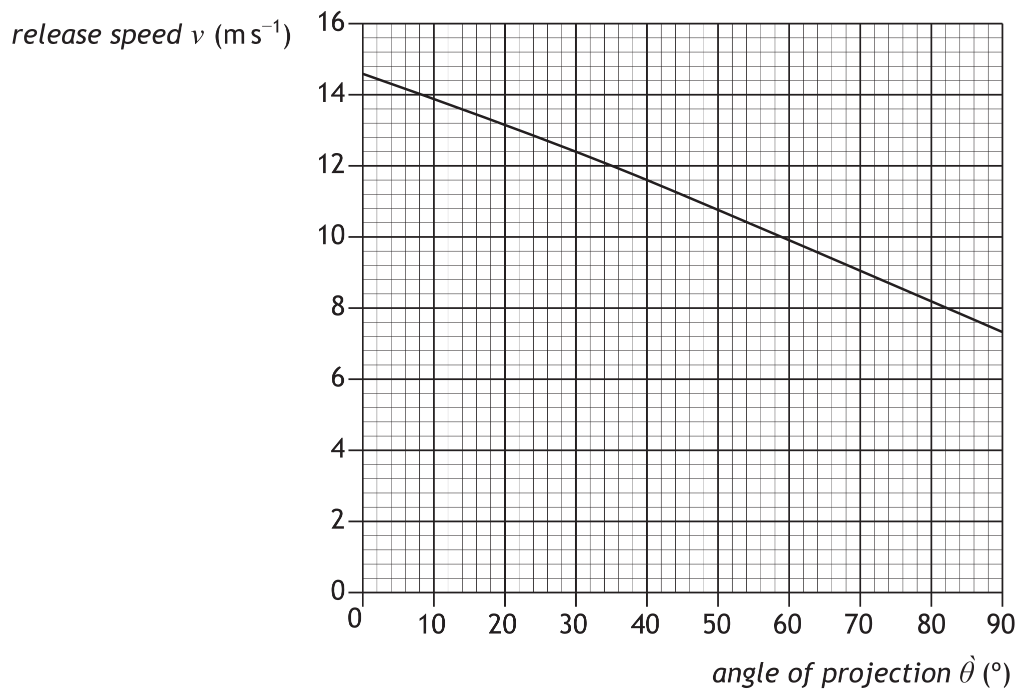
Attempt ALL questions

1. The shot put is an athletics event in which competitors "throw" a shot as far as possible. The shot is a metal ball of mass 4·0 kg. One of the competitors releases the shot at a height of 1·8 m above the ground and at an angle θ to the horizontal. The shot travels through the air and hits the ground at X. The effects of air resistance are negligible.

not to scale



The graph shows how the release speed of the shot v varies with the angle of projection . .



1. (continued)

MARKS | DO NOT WRITE IN THIS MARGIN

(a) The angle of projection for a particular throw is 40°.

(i) (A) State the release speed of the shot at this angle. **1**

(B) Calculate the horizontal component of the initial velocity of the shot. **1**

Space for working and answer

(C) Calculate the vertical component of the initial velocity of the shot. **1**

Space for working and answer

(ii) The maximum height reached by the shot is 4·7 m above the ground. The time between release and reaching this height is 0·76 s.

(A) Calculate the total time between the shot being released and hitting the ground at X. **4**

Space for working and answer

MArKS | DO NOT WRITE IN THIS MARGIN

1. (a) (ii) (continued)

(B) Calculate the range of the shot for this throw. **3**

Space for working and answer

(b) Using information from the graph, explain the effect of increasing the angle of projection on the kinetic energy of the shot at release. **2**

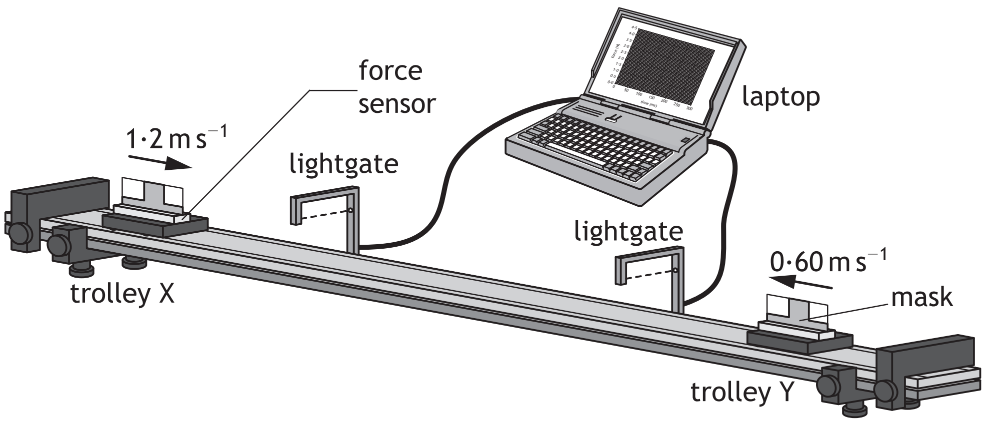
Section 2

Question			Answer	Max Mark	Additional Guidance
1.	(a)	(i)	A $v = 11{\cdot}6\ \text{m s}^{-1}$ **(1)**	1	Unit required - incorrect or missing unit award 0 Accept m/s No other value accepted.
			B $v_h = 11{\cdot}6 \cos 40$ $= 8{\cdot}9\ \text{m s}^{-1}$ **(1)**	1	Or consistent with A Accept $8{\cdot}886$, $8{\cdot}89$, 9 but <u>not</u> $9{\cdot}0$ 0 marks for mixing up B and C
			C $v_v = 11{\cdot}6 \sin 40$ $= 7{\cdot}5\ \text{m s}^{-1}$ **(1)**	1	Or consistent with A Accept $7{\cdot}456$, $7{\cdot}46$, 7 but <u>not</u> $7{\cdot}0$
		(ii)	A $s = ut + ½at^2$ **(1)** $4{\cdot}7 = 0 + ½ \times 9{\cdot}8 \times t^2$ **(1)** $t = 0{\cdot}979$ (s) **(1)** Total Time $= 0{\cdot}98 + 0{\cdot}76$ $= 1{\cdot}7$ s **(1)**	4	s and a must have the same sign $v^2 = u^2 + 2as$ $= 0 + 2 \times 9{\cdot}8 \times 4{\cdot}7$ $v = 9{\cdot}6$ $v = u + at$ $9{\cdot}6 = 0 + 9{\cdot}8t$ $t = 0{\cdot}979$ All formulae required to get final answer **(1)** Correct substitution into all **(1)** Answer of $0{\cdot}979$ **(1)** Watch for inappropriate intermediate rounding eg $t = 1$, treat as arithmetic error, max 3 marks Accept 2, $1{\cdot}74$, $1{\cdot}739$ but not $2{\cdot}0$ If $g = 9{\cdot}81$ or 10 then incorrect substitution, maximum 1 mark for formula NB No secs in physics!

Question			Answer	Max	Additional Guidance
			B $v = \frac{d}{t}$ **(1)** $8 \cdot 9 = \frac{d}{1 \cdot 7}$ **(1)** $d = 15\text{m}$ **(1)**	**3**	$s = ut + \frac{1}{2}at^2$ or $s = \frac{1}{2}(u+v)t$ **(1)** Or consistent with (a)(ii)(A) **<u>and</u>** (a)(i)(B) Accept 20, 15·1, 15·13 If t = 1·74 accept 15, 15·5, 15·49
	(b)		kinetic energy is less **(1)** (as θ increases) speed decreases **(1)**	**2**	This statement is required before any marks awarded. If there is wrong physics in the answer then award 0 marks Can be done by calculation but it must be clearly indicated which angle applies to which kinetic energy to access the second mark. Wrong substitution in calculation method – award 0 marks (wrong physics) Alternative: (total energy remains the same) The greater the angle the more energy used to lift the putt to a greater height before release **(1)** Less energy available to convert to E_k **(1)**

MARKS | DO NOT WRITE IN THIS MARGIN

2. A student sets up an experiment to investigate collisions between two trolleys on a long, horizontal track.



The mass of trolley X is 0·25 kg and the mass of trolley Y is 0·45 kg.

The effects of friction are negligible.

In one experiment, trolley X is moving at $1{\cdot}2\,\mathrm{m\,s^{-1}}$ to the right and trolley Y is moving at $0{\cdot}60\,\mathrm{m\,s^{-1}}$ to the left.

The trolleys collide and do not stick together. After the collision, trolley X rebounds with a velocity of $0{\cdot}80\,\mathrm{m\,s^{-1}}$ to the left.

(a) Determine the velocity of trolley Y after the collision. **3**

Space for working and answer

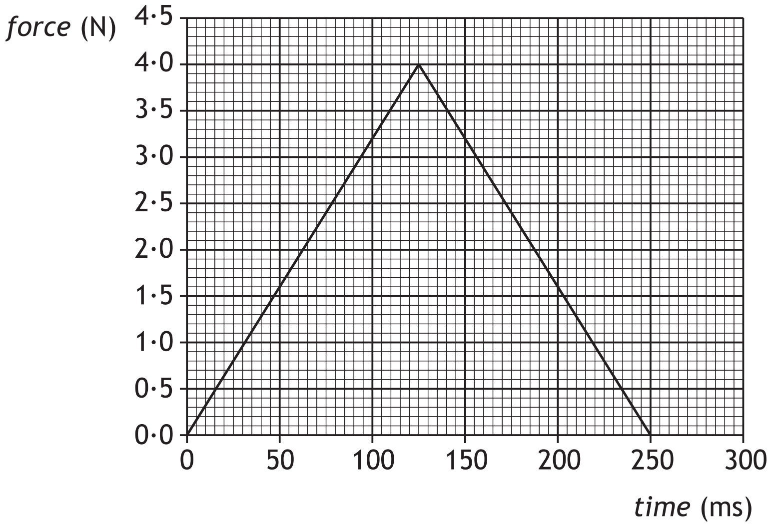
[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

2. (continued)

(b) The force sensor measures the force acting on trolley Y during the collision.

The laptop displays the following force-time graph for the collision.



(i) Determine the magnitude of the impulse on trolley Y. **3**

Space for working and answer

(ii) Determine the magnitude of the change in momentum of trolley X. **1**

MARKS DO NOT WRITE IN THIS MARGIN

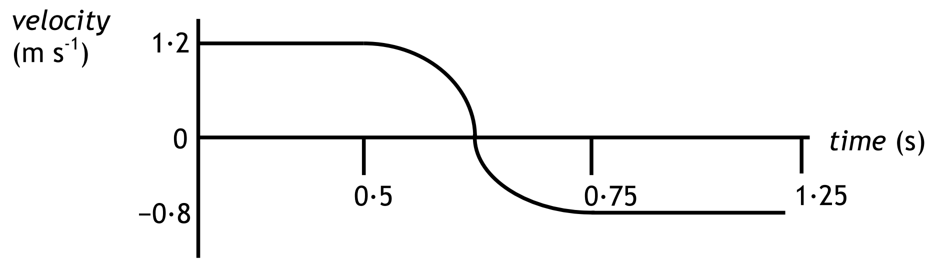
2. (b) (continued)

(iii) Sketch a velocity-time graph to show how the velocity of trolley X varies from 0·50 s before the collision to 0·50 s after the collision. **3**

Numerical values are required on both axes.
You may wish to use the square-ruled paper on *Page thirty-six*.

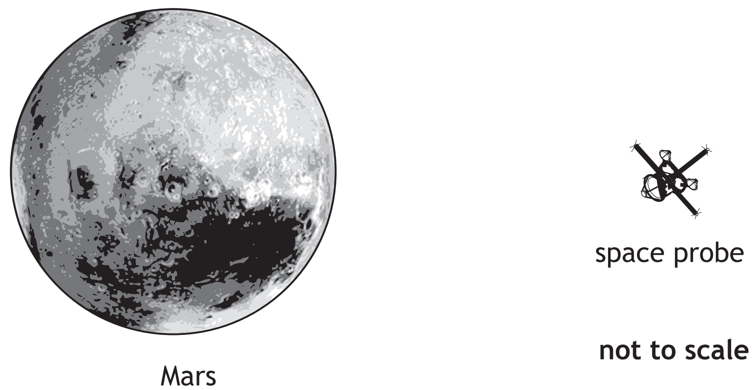
[Turn over

Question			Answer	Max Mark	Additional Guidance
2.	(a)		(Total momentum before = total momentum after) $m_x u_x + m_y u_y = m_x v_x + m_y v_y$ **(1)** $(0 \cdot 25 \times 1 \cdot 20) + (0 \cdot 45 \times -0 \cdot 60)$ $= (0 \cdot 25 \times -0 \cdot 80) + (0 \cdot 45 \times v_y)$ **(1)** $0 \cdot 30 - 0 \cdot 27 = -0 \cdot 20 + 0 \cdot 45 \times v_y$ $0 \cdot 45 \times v_y = 0 \cdot 23$ $v_y = 0 \cdot 51 \, \mathrm{m\,s^{-1}}$ **(1)** *(to the right)*	3	If sign convention not applied then max (1) for formula. Answer must be consistent with sign convention in substitution line. 0·5, 0·511, 0·5111 Where candidates calculate the momentum of each trolley individually both before and after, no marks are awarded unless correct addition (including sign convention) and equating takes place.
	(b)	(i)	*impulse = area under graph* $\left(= \frac{1}{2} b \times h\right)$ **(1)** $= \frac{1}{2} \times 0 \cdot 25 \times 4 \cdot 0$ **(1)** $= 0 \cdot 50 \text{ N s}$ **(1)** Accept 0·5, 0·500, 0·5000	3	Impulse = $mv - mu$ $= (0 \cdot 45 \times 0 \cdot 51) - (0 \cdot 45 \times -0 \cdot 60)$ $= 0 \cdot 50 \text{ N s}$ For alternative method accept: 0·5, 0·500, 0·4995 Accept $\mathrm{kg\,m\,s^{-1}}$
		(ii)	$0 \cdot 50 \text{ kg m s}^{-1}$ **(1)**	1	Or consistent with (i) Accept N s Accept 0·5

Question			Answer	Max Mark	Additional Guidance
		(iii)	 Constant velocity at correct values and signs before and after collision **(1)** Velocity change from initial to final in 0·25 s. **(1)** Shape of change of velocity correct ie initially gradual, increasing steepness then levelling out to constant velocity. **(1)**	**3**	The origin and at least one axis must be labelled with quantity or unit or both otherwise maximum 2 marks.

MARKS | DO NOT WRITE IN THIS MARGIN

3. A space probe of mass $5{\cdot}60 \times 10^{3}$ kg is in orbit at a height of $3{\cdot}70 \times 10^{6}$ m above the surface of Mars.



The mass of Mars is $6{\cdot}42 \times 10^{23}$ kg.
The radius of Mars is $3{\cdot}39 \times 10^{6}$ m.

(a) Calculate the gravitational force between the probe and Mars. **3**

Space for working and answer

(b) Calculate the gravitational field strength of Mars at this height. **3**

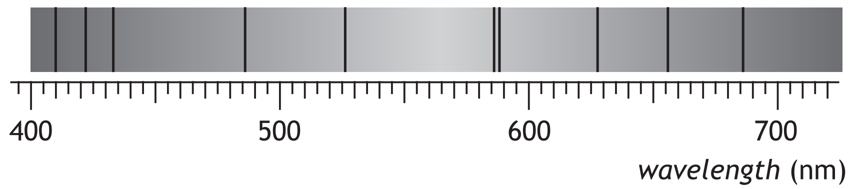
Space for working and answer

Question			Answer	Max Mark	Additional Guidance
3.	**(a)**		$F = \frac{GMm}{r^2}$ **(1)** $F = \frac{6\cdot67\times10^{-11}\times6\cdot42\times10^{23}\times5\cdot60\times10^{3}}{\left(3\cdot39\times10^{6}+3\cdot70\times10^{6}\right)^{2}}$ **(1)** $F = 4\cdot77\times10^{3}$ N **(1)**	**3**	Accept $4\cdot8$, $4\cdot770$, $4\cdot7704$
	(b)		$g = \frac{W}{m}$ **(1)** $g = \frac{4770}{5600}$ **(1)** $g = 0\cdot852$ N kg^{-1} **(1)**	**3**	Or consistent with (a) $F = ma$ is acceptable If candidate uses $g = \frac{GM}{r^2}$ and has already lost marks in (a) for not adding the radius to the height, do not penalise for a second time. (Gives $3\cdot13$) if r is consistent with (a). Accept m s^{-2}

MARKS DO NOT WRITE IN THIS MARGIN

4. Light from the Sun is used to produce a visible spectrum.

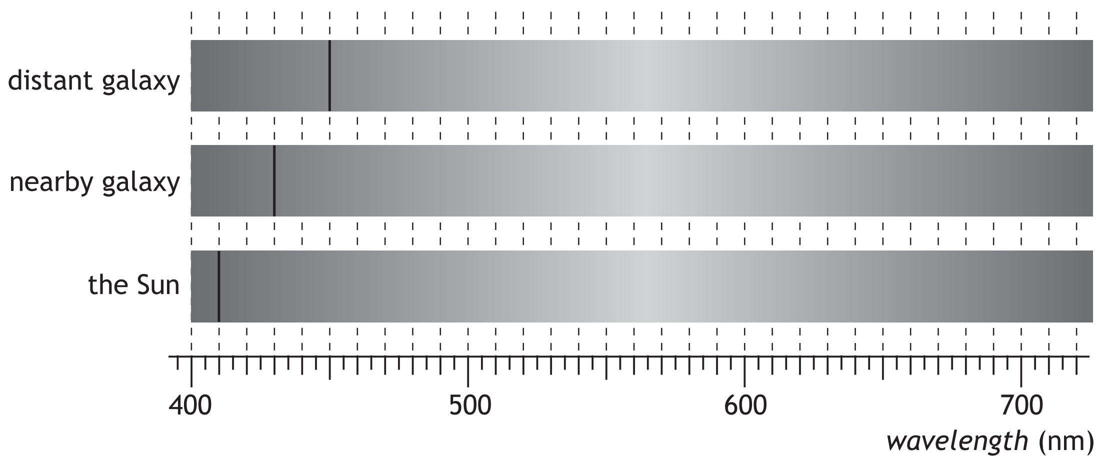
A student views this spectrum and observes a number of dark lines as shown.



(a) Explain how these dark lines in the spectrum of sunlight are produced. **2**

(b) One of the lines is due to hydrogen.

The position of this hydrogen line in the visible spectrum is shown for a distant galaxy, a nearby galaxy and the Sun.



(i) Explain why the position of the line is different in each of the spectra. **2**

MArKS DO NOT WRITE IN THIS MARGIN

4. (b) (continued)

(ii) Show that the redshift of the light from the distant galaxy is 0·098. **2**

Space for working and answer

(iii) Calculate the approximate distance to the distant galaxy. **5**

Space for working and answer

[Turn over

Question			Answer	Max Mark	Additional Guidance
4.	(a)		photons of particular/some/ certain energies/frequencies are absorbed **(1)** in its/the Sun's (upper/outer) atmosphere/outer layers **(1)**	2	1st mark stands alone Particular/some/certain frequencies/wavelengths of light/radiation are absorbed **(1)** 'the atmosphere' is too vague Accept gases or suitable named gases in place of atmosphere but not elements or atoms on their own.
	(b)	(i)	light is redshifted/ shifted towards red **(1)** (as) the galaxies are moving away (from the Sun) **(1)**	2	accept: the wavelength (λ) has increased/ frequency (f) has decreased /lines have been redshifted Not 'blueshift'/becomes red/shifted to red - this is wrong physics, award 0 marks. Or further galaxies have greater recessional velocity Or equivalent
		(ii)	$z = \frac{\lambda_{observed} - \lambda_{rest}}{\lambda_{rest}}$ **(1)** $= \frac{450\times10^{-9} - 410\times10^{-9}}{410\times10^{-9}}$ **(1)** $= 0{\cdot}098$	2	Must start with the appropriate relationship Accept $\frac{450-410}{410}$ Award maximum of 1 mark if final answer is not $0{\cdot}098$
		(iii)	$z = \frac{v}{c}$ **(1)** $0{\cdot}098 = \frac{v}{3{\cdot}00\times10^{8}}$ **(1)** $(v = 2{\cdot}94 \times 10^{7}\ \mathrm{m\ s^{-1}})$ $v = H_0 d$ **(1)** $2{\cdot}94 \times 10^{7} = 2{\cdot}3 \times 10^{-18} \times d$ **(1)** $d = 1{\cdot}3 \times 10^{25}\ \mathrm{m}$ **(1)** $(1{\cdot}4 \times 10^{9}\ \mathrm{ly})$	5	–anywhere Must use $0{\cdot}098$ otherwise incorrect substitution - max 2 marks –anywhere Accept 1×10^{25}, $1{\cdot}28 \times 10^{25}$, $1{\cdot}278 \times 10^{25}$ There is no need to convert to light years but if done must be correct otherwise max 4 marks.

MArKS | DO NOT WRITE IN THIS MARGIN

5. A quote from a well-known science fiction writer states:

"In the beginning there was nothing, which exploded."

Using your knowledge of physics, comment on the above statement. **3**

MArKS | DO NOT WRITE IN THIS MARGIN

6. (a) The Standard Model classifies *force mediating particles* as bosons. Name the boson associated with the electromagnetic force. **1**

(b) In July 2012 scientists at CERN announced that they had found a particle that behaved in the way that they expected the Higgs boson to behave. Within a year this particle was confirmed to be a Higgs boson.

This Higgs boson had a mass-energy equivalence of 126 GeV.
($1\ \text{eV} = 1{\cdot}6 \times 10^{-19}\ \text{J}$)

(i) Show that the mass of the Higgs boson is $2{\cdot}2 \times 10^{-25}$ kg. **3**

Space for working and answer

(ii) Compare the mass of the Higgs boson with the mass of a proton in terms of orders of magnitude. **2**

Space for working and answer

[Turn over

Question			Answer	Max Mark	Additional Guidance
6.	(a)		Photon	1	
	(b)	(i)	$126\text{ GeV} = 126 \times 10^9 \times (1{\cdot}6 \times 10^{-19})$ **(1)** $= 2{\cdot}0 \times 10^{-8}$ (J) $E = mc^2$ **(1)** $2{\cdot}0 \times 10^{-8} = m \times (3 \times 10^8)^2$ **(1)** $m = 2{\cdot}2 \times 10^{-25}$ (kg)	3	If candidate does not show this line, either separately or in the formula, then max 2 marks may be awarded. –anywhere Alternative: $E = mc^2$ **(1)** $126\times10^9 \times \left(1{\cdot}6\times10^{-19}\right) = m\times\left(3\times10^8\right)^2$ **(1)** $m = 2{\cdot}2 \times 10^{-25}$ (kg) Max 2 marks if final answer not given
		(ii)	$(2{\cdot}2 \times 10^{-25} / 1{\cdot}673 \times 10^{-27} =)130$ **(1)** (Higgs boson is) <u>2</u> orders of magnitude <u>bigger</u> **(1)**	2	**or** $10^{-25}/10^{-27} = 100$ **or** $2{\cdot}2 \times 10^{-25}/1{\cdot}67 \times 10^{-27} =$ **or** $2{\cdot}2 \times 10^{-25}/1{\cdot}7 \times 10^{-27} =$ **or** $2{\cdot}24 \times 10^{-25}/1{\cdot}673 \times 10^{-27} =$ etc Accept 100, 10^2, 132, 131·5, 134, 133·9, etc **(1)** If mass of neutron used treat as wrong physics - award 0 marks ‘2 bigger’ on its own is worth 2 marks

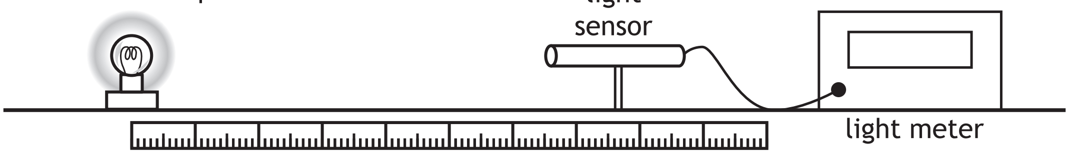
MArKS DO NOT WRITE IN THIS MARGIN

7. The use of analogies from everyday life can help better understanding of physics concepts. Throwing different balls at a coconut shy to dislodge a coconut is an analogy which can help understanding of the photoelectric effect.

Use your knowledge of physics to comment on this analogy. **3**

MArKS | DO NOT WRITE IN THIS MARGIN

8. A student investigates how irradiance I varies with distance d from a point source of light.



The distance between a small lamp and a light sensor is measured with a metre stick. The irradiance is measured with a light meter.

The apparatus is set up as shown in a darkened laboratory.

The following results are obtained.

.. (m)	0·20	0·30	0·40	0·50
I (W m^{-2})	134·0	60·5	33·6	21·8

(a) State what is meant by the term *irradiance*. **1**

(b) Use **all** the data to establish the relationship between irradiance I and distance d . **3**

MARKS | DO NOT WRITE IN THIS MARGIN

8. (continued)

(c) The lamp is now moved to a distance of 0·60 m from the light sensor.

Calculate the irradiance of light from the lamp at this distance. **3**

Space for working and answer

(d) Suggest one way in which the experiment could be improved.

You **must** justify your answer. **2**

(e) The student now replaces the lamp with a different small lamp.
The power output of this lamp is 24 W.

Calculate the irradiance of light from this lamp at a distance of 2·0 m. **4**

Space for working and answer

Question			Answer	Max Mark	Additional Guidance
8.	**(a)**		The power per unit area (incident on a surface)	**1**	Accept power per square metre (m^2)
	(b)		$134 \times 0{\cdot}2^2 = 5{\cdot}4$ $60{\cdot}5 \times 0{\cdot}3^2 = 5{\cdot}4$ $33{\cdot}6 \times 0{\cdot}4^2 = 5{\cdot}4$ $21{\cdot}8 \times 0{\cdot}5^2 = 5{\cdot}5$ **(2)** Statement of $I \times d^2$ = constant **(1)**	**3**	If only 3 sets of data used correctly then maximum 2 marks. If 2 sets of data used correctly then maximum 1 mark (for relationship) If only 1 set of data used award 0 marks. Must be clear how the candidate has used the data to obtain the relationship. Ignore inappropriate averaging in this case. Accept straight line graph proof A sketch graph is not acceptable. 1 mark for all 4 points plotted correctly and best fit line 1 mark for correct axes including scales and labels ie I and $1/d^2$ (ignore units) 1 mark for statement of $I \times d^2 =$ constant only if some or all data has been used $I \times d^2$ is equivalent to $I \alpha 1/d^2$ Accept $I_1 d_1^2 = I_2 d_2^2$
	(c)		$I \times d^2 = 5{\cdot}4$ **(1)** $I \times 0{\cdot}60^2 = 5{\cdot}4$ **(1)** $I = 15\ \text{W m}^{-2}$ **(1)**	**3**	Can use $I_1 d_1^2 = I_2 d_2^2$ Watch for a variation in answers due to data used.

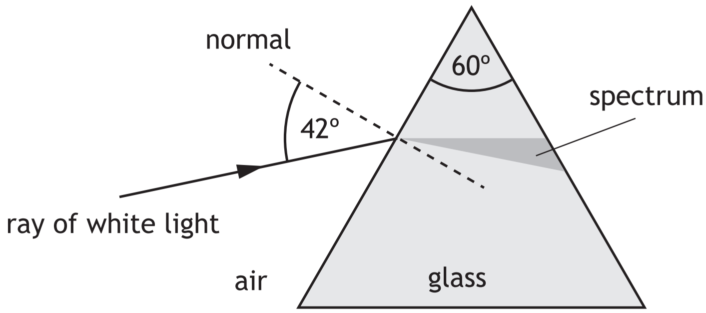
Question			Answer	Max Mark	Additional Guidance
	(d)		Smaller lamp **(1)** Will be more like a point source **(1)** **or** Black cloth on bench **(1)** to reduce reflections **(1)**	**2**	Accept Use a more precise instrument to reduce the (absolute) uncertainty. Must provide justification which is not wrong physics, otherwise 0 marks Do not accept 'repeat it' (since there is little variation in the calculated value of the constant/ spread of points from best fit line)
	(e)		$A = 4\pi r^2 = 4\pi \times 2^2 = 50{\cdot}265$ **(1)** $I = \frac{P}{A}$ **(1)** $I = 24/50{\cdot}265$ **(1)** $I = 0{\cdot}48 \text{ W m}^{-2}$ **(1)**	**4**	–anywhere Accept $0{\cdot}5$, $0{\cdot}477$, $0{\cdot}4775$

MArKS DO NOT WRITE IN THIS MARGIN

9. A student carries out two experiments to investigate the spectra produced from a ray of white light.

(a) In the first experiment, a ray of white light is incident on a glass prism as shown.

not to scale



(i) Explain why a spectrum is produced in the glass prism. **1**

(ii) The refractive index of the glass for red light is 1·54.

Calculate the speed of red light in the glass prism. **3**

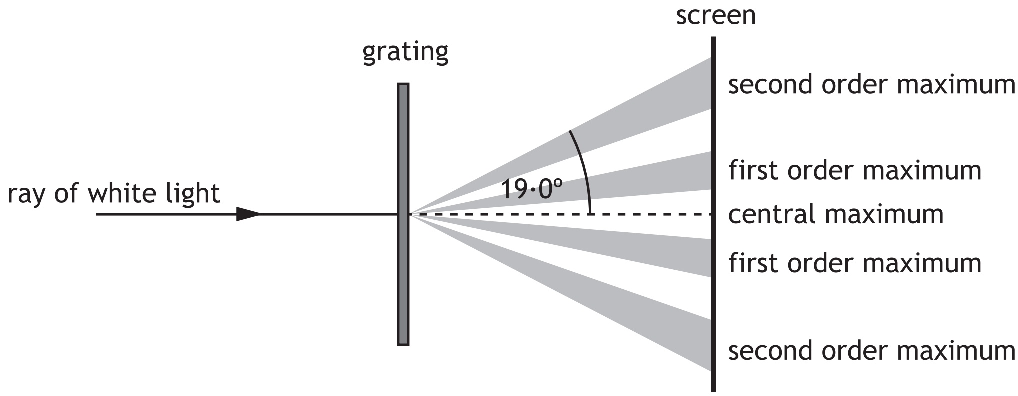
Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

9. (continued)

(b) In the second experiment, a ray of white light is incident on a grating.

not to scale



The angle between the central maximum and the second order maximum for red light is 19·0°.
The frequency of this red light is $4{\cdot}57 \times 10^{14}$ Hz.

(i) Calculate the distance between the slits on this grating. **5**

Space for working and answer

(ii) Explain why the angle to the second order maximum for blue light is different to that for red light. **3**

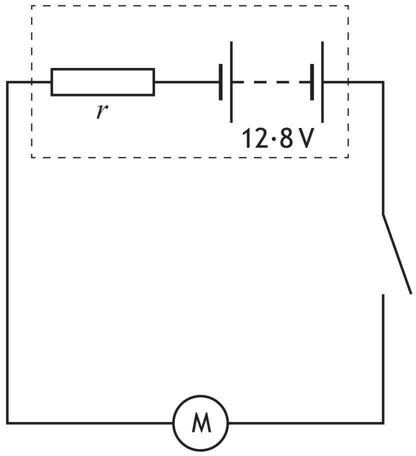
X757760123

Question			Answer	Max Mark	Additional Guidance
9.	(a)	(i)	• Different frequencies/ colours have different refractive indices **(1)** **or** • Different frequencies/ colours are refracted through different angles **(1)**	1	Do NOT accept "bending" on its own but ignore it if follows 'refraction' Do not accept 'different amounts'. Not wavelength or speed on its own but ignore if reference made to frequency or colour. A correct answer followed by 'diffract' or 'defract', *0 marks*
		(ii)	$n = \frac{v_1}{v_2}$ **(1)** $1 \cdot 54 = \frac{3 \cdot 00 \times 10^8}{v_2}$ **(1)** $v_2 = 1 \cdot 95 \times 10^8 \text{ m s}^{-1}$ **(1)**	3	Accept $1 \cdot 9$, $1 \cdot 948$, $1 \cdot 9481$ Example of inappropriate intermediate rounding: $n = \frac{\sin \theta_1}{\sin \theta_2}$ $1 \cdot 54 = \frac{\sin 42}{\sin \theta_2}$ $\theta_2 = 25 \cdot 75^\circ = 26^\circ$ $\frac{v_1}{v_2} = \frac{\sin \theta_1}{\sin \theta_2}$ $\frac{3 \cdot 00 \times 10^8}{v_2} = \frac{\sin 42}{\sin 26}$ $v_2 = 2 \cdot 0 \times 10^8 \text{ m s}^{-1}$ (max 2 marks)

Question			Answer	Max Mark	Additional Guidance
	(b)	(i)	$v = f\lambda$ **(1)** $3{\cdot}00 \times 10^{8} = 4{\cdot}57 \times 10^{14} \times \lambda$ **(1)** $\lambda = 656{\cdot}5 \times 10^{-9}$ $m\lambda = d\sin\theta$ **(1)** $2 \times 656{\cdot}5 \times 10^{-9} = d \times \sin19{\cdot}0$ **(1)** $d = 4{\cdot}03 \times 10^{-6}$ m **(1)**	5	–anywhere Inappropriate intermediate rounding eg 660, treat as arithmetic error max 4 marks –anywhere Accept 4·0, 4·033, 4·0327 If candidates go on to calculate 1/d then do not award the final mark for answer
		(ii)	• different colours have different λ **(1)** • $m\lambda = d\sin\theta$ **(1)** • (m and d are the same) • θ is different for different λ **(1)** **or** • different colours have different λ **(1)** • Path difference = $m\lambda$ **(1)** • (for the same m) • PD is different for different λ **(1)**	3	Any answer using different colours/wavelengths diffract/refracts different amounts as the explanation is wrong physics, award 0 marks Any answer using wrong physics, award 0 marks. $2\lambda = d\sin\theta$ is ok Path difference = 2λ is ok Can be done by recalculation but must include the first statement else maximum 2 marks.

MARKS DO NOT WRITE IN THIS MARGIN

10. A car battery is connected to an electric motor as shown.



The electric motor requires a large current to operate.

(a) The car battery has an e.m.f. of 12·8 V and an internal resistance r of $6{\cdot}0 \times 10^{-3}\,\Omega$. The motor has a resistance of $0{\cdot}050\,\Omega$.

(i) State what is meant by an *e.m.f. of 12·8 V*. **1**

(ii) Calculate the current in the circuit when the motor is operating. **3**

Space for working and answer

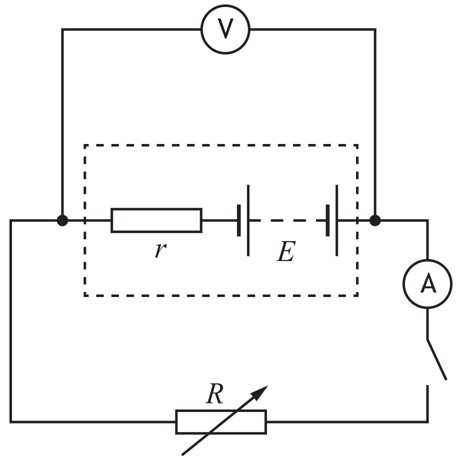
(iii) Suggest why the connecting wires used in this circuit have a large diameter. **1**

X757760125

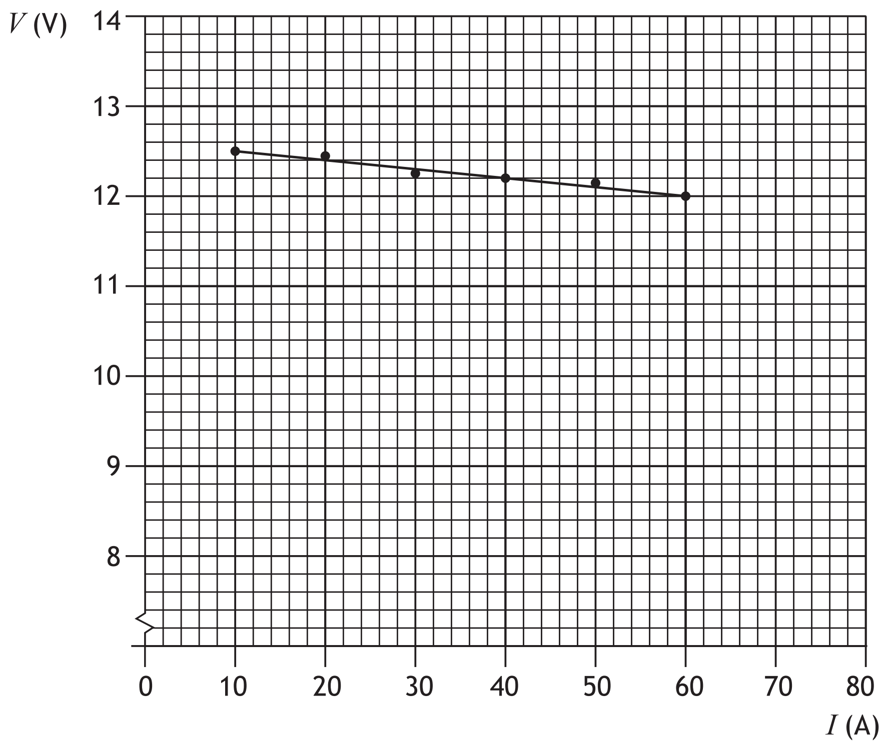
MArKS DO NOT WRITE IN THIS MARGIN

10. (continued)

(b) A technician sets up the following circuit with a different car battery connected to a variable resistor R.



Readings of current I and terminal potential difference V from this circuit are used to produce the following graph.



X757760126

MArKS DO NOT WRITE IN THIS MARGIN

10. (b) (continued)

Use information from the graph to determine:

(i) the e.m.f. of the battery; **1**

Space for working and answer

(ii) the internal resistance of the battery; **3**

Space for working and answer

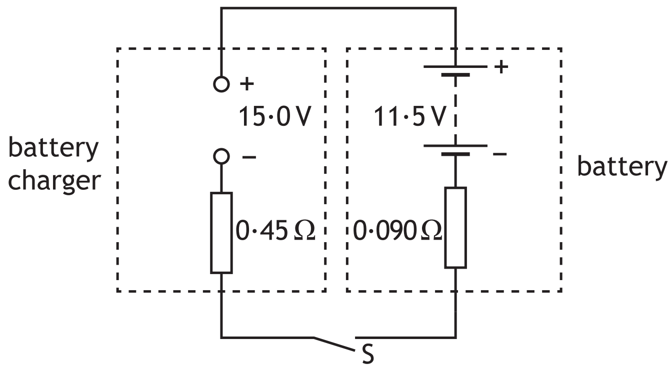
[Turn over

MArKS DO NOT WRITE IN THIS MARGIN

10. (b) (continued)

(iii) After being used for some time the e.m.f. of the battery decreases to 11·5 V and the internal resistance increases to 0·090 Ω.

The battery is connected to a battery charger of constant e.m.f. 15·0 V and internal resistance of 0·45 Ω as shown.



(A) Switch S is closed.

Calculate the initial charging current. **3**

Space for working and answer

(B) Explain why the charging current decreases as the battery charges. **2**

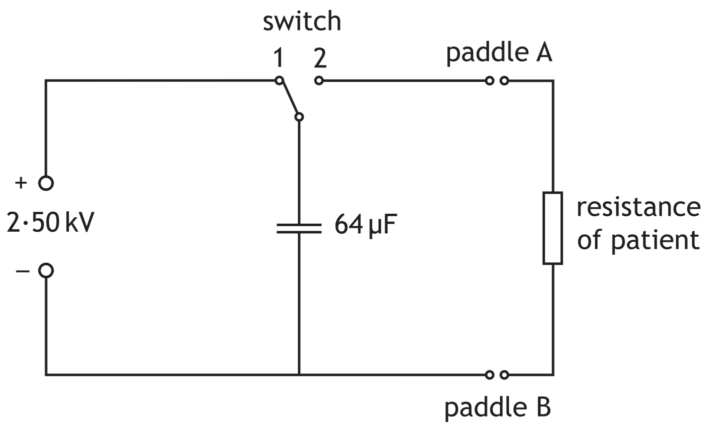
Question			Answer	Max Mark	Additional Guidance
10.	(a)	(i)	$12 \cdot 8$ J (of energy) <u>is gained by/supplied to</u> 1 coulomb (of charge passing through the battery)	1	
		(ii)	$E = V + Ir$ and $V = IR$ **(1)** $E = I(R + r)$ $12 \cdot 8 = I(0 \cdot 050 + 6 \cdot 0 \times 10^{-3})$ **(1)** $I = 230$ A **(1)**	3	Both required for 1 mark If candidates start with this expression, it gets the formula mark $R_{\text{Total}} = 0 \cdot 050 + 6 \cdot 0 \times 10^{-3}$ $= 0 \cdot 056\ (\Omega)$ $I = E/R_T$ **(1)** $= 12 \cdot 8/0 \cdot 056$ **(1)** $= 230$ A **(1)** accept $I = V/R$ if sub correct accept 200, 229, $228 \cdot 6$ Or consistent with (a) (i)
		(iii)	(Wire of large diameter) has a low resistance **(1)** **or** to <u>prevent</u> overheating **(1)** **or** to <u>prevent</u> wires melting **(1)**	1	Not: motor requires large current, on its own Not: The wires will melt, on its own. eg wires melt (no justification) 0 marks, <u>thin</u> wires could melt due to large current 1 mark
	(b)	(i)	$12 \cdot 6$ V	1	No tolerance
		(ii)	(gradient $= -r$) gradient= $(12 - 12 \cdot 5)/(60 - 10)$ **(1)** $= -0 \cdot 01$ (1) internal resistance $= 0 \cdot 01\ \Omega$ **(1)**	3	Gradient $= r$ is wrong physics, award 0 marks gradient formula or implied **(1)** calculating gradient **(1)** **or** $E = V + Ir$ **(1)** $12 \cdot 6 = 12 + 60r$ **(1)** $r = 0 \cdot 01\ \Omega$ **(1)** If using this method, they must use data from the line or points which lie on the line. Or consistent with (b) (i)

Question				Answer	Max Mark	Additional Guidance
		(iii)	(A)	$I = \frac{V}{R}$ **(1)** $= \frac{(15 - 11\cdot5)}{(0\cdot09 + 0\cdot45)}$ **(1)** $(0\cdot09 + 0\cdot45)$ $= 6\cdot5\ \text{A}$ **(1)**	3	Accept 6, 6·48, 6·481
			(B)	The e.m.f. of the battery increases **(1)** Difference between the two e.m.f.s decreases **(1)**	2	Independent marks Accept voltage or pd in place of emf or equivalent Apply ± rule

MARKS | DO NOT WRITE IN THIS MARGIN

11. A defibrillator is a device that provides a high energy electrical impulse to correct abnormal heart beats.

The diagram shows a simplified version of a defibrillator circuit.



The switch is set to position 1 and the capacitor charges.

(a) Show the charge on the capacitor when it is fully charged is 0·16 C. **2**

Space for working and answer

11. (continued)

MARKS | DO NOT WRITE IN THIS MARGIN

(b) Calculate the maximum energy stored by the capacitor. **3**

Space for working and answer

(c) To provide the electrical impulse required the capacitor is discharged through the person's chest using the paddles as shown

The initial discharge current through the person is 35·0 A.

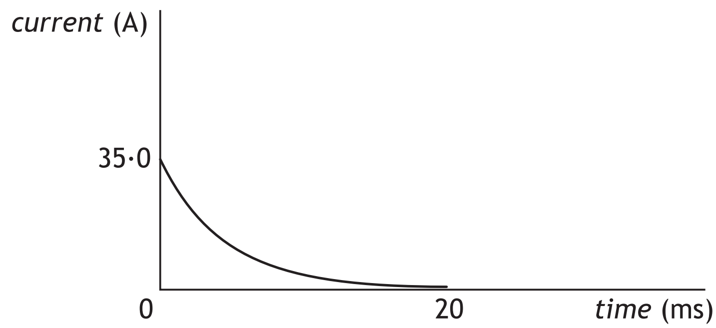
(i) Calculate the effective resistance of the part of the person's body between the paddles. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

11. (c) (continued)

(ii) The graph shows how the current between the paddles varies with time during the discharge of the capacitor.



The effective resistance of the person remains the same during this time.

Explain why the current decreases with time. **1**

(iii) The defibrillator is used on a different person with larger effective resistance. The capacitor is again charged to 2·50 kV.

On the graph in (c)(ii) add a line to show how the current in this person varies with time.

(An additional graph, if required, can be found on *Page thirty-eight*). **2**

Question			Answer	Max Mark	Additional Guidance
11.	(a)		$C = \frac{Q}{V}$ (1) $64\times10^{-6} = \frac{Q}{2\cdot50\times10^{3}}$ (1) $Q = 0\cdot16(C)$	2	Must start with formula Maximum 1 mark if final answer not shown Note: $C = \frac{Q}{V}$ $64\times10^{-3} = \frac{Q}{2\cdot50}$ $Q = 0\cdot16$ Is awarded a maximum of 1 mark for the formula, as knowledge of units has not been <u>shown</u>. It is acceptable to work back to find the value of capacitance.
	(b)		$E = \frac{1}{2}QV$ (1) $E = \frac{1}{2}\times0\cdot16\times2\cdot50\times10^{3}$ (1) $E = 200\text{J}$ (1)	3	Alternative methods: $E = \frac{1}{2}CV^{2}$ (1) $= \frac{1}{2}\times64\times10^{-6}\times\left(2\cdot50\times10^{3}\right)^{2}$ (1) $= 200$ J (1) **or** $E = \frac{1}{2}\frac{Q^{2}}{C}$ (1) $= \frac{1}{2}\frac{0\cdot16^{2}}{64\times10^{-6}}$ (1) = 200 J (1) Note: max 2 marks if not × 10^{-6}, unless value shown as $0\cdot064\times10^{-3}$, which is acceptable or answer quoted as 200×10^{6} μJ or similar. (treat as unit error)
	(c)	(i)	$v = IR$ (1) $2\cdot50\times10^{3} = 35\cdot0\times R$ (1) $R = 71\cdot4\Omega$ (1)	3	Accept 71, 71·43, 71·429
		(ii)	The voltage decreases (1)	1	

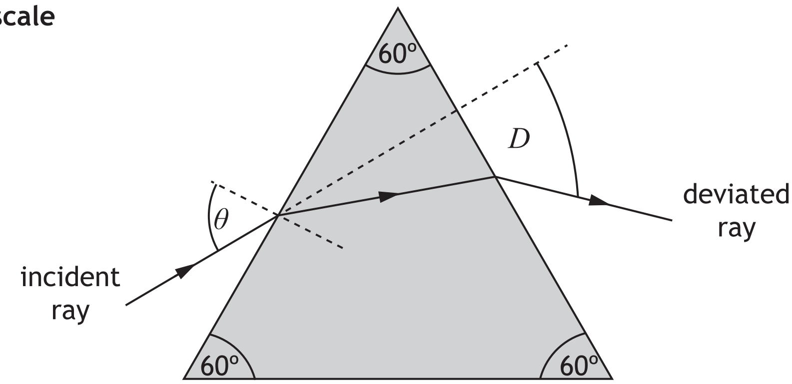
Question			Answer	Max Mark	Additional Guidance
		(iii)	Smaller initial current **(1)** Time to reach 0 A is longer **(1)**	**2**	Line must be a curve to award the second mark Line must tend towards the time axis to gain the second mark. Do not worry about areas under the lines being different.

MArKS DO NOT WRITE IN THIS MARGIN

12. A student carries out an investigation to determine the refractive index of a prism.

A ray of monochromatic light passes through the prism as shown.

not to scale



The angle of deviation D is the angle between the direction of the incident ray and the deviated ray.

The student varies the angle of incidence θ and measures the corresponding angles of deviation D.

The results are shown in the table.

Angle of incidence θ (°)	*Angle of deviation* D (°)
30·0	47·0
40·0	38·1
50·0	37·5
60·0	38·8
70·0	42·5

(a) Using the square-ruled paper on *Page thirty-five*, draw a graph of D against θ. **3**

(b) Using your graph state the two values of θ that produce an angle of deviation of 41·0°. **1**

(c) Using your graph give an estimate of the minimum angle of deviation D_m. **1**

* X 7 5 7 7 6 0 1 3 3 *

MArKS | DO NOT WRITE IN THIS MARGIN

12. (continued)

(d) The refractive index n of the prism can be determined using the relationship.

$$n \sin\left(\frac{A}{2}\right) = \sin\left(\frac{A + D_m}{2}\right)$$

where A is the angle at the top of the prism, and
D_m is the minimum angle of deviation.

Use this relationship and your answer to (c) to determine the refractive index of the prism. **2**

Space for working and answer

(e) Using the same apparatus, the student now wishes to determine more precisely the minimum angle of deviation.

Suggest two improvements to the experimental procedure that would achieve this. **2**

[END OF QUESTION PAPEr]

* X 7 5 7 7 6 0 1 3 4 *

Question			Answer	Max Mark	Additional Guidance
12.	**(a)**		Suitable scales with labels on axes (quantity and units) **(1)** [Allow for axes starting at zero or broken axes or an appropriate value eg 30°] Correct plotting of points **(1)** Smooth U shaped curve through these points. **(1)**	**3**	Accuracy of plotting should be easily checkable with the scale chosen. If the origin is shown the scale must either be continuous or the axis must be 'broken'. Otherwise maximum 2 marks. Do not penalise if candidates plot θ against D Graphs of sine of angles are incorrect for (a) 0 marks but can still gain marks for rest of question.
	(b)		36° and 66°	**1**	both required for 1 mark Must be consistent with (a) Allow ± half box tolerance
	(c)		37°	**1**	Must be consistent with (a) Allow ± half box tolerance
	(d)		Correct substitution into equation using D_m from answer to (c) **(1)** Correct value for n (1·5 if using D_m equal to 37°) **(1)**	**2**	Must be consistent with (c)
	(e)		Repeat measurements **(1)** More measurements around/ close to a minimum or smaller 'steps' in angle **(1)**	**2**	Not: take more measurements Repeat the experiment more times Extend the range

[END OF MARKING INSTRUCTIONS]

H

National
Qualifications
2016

X757/76/02

Physics
Section 1 — Questions

TUESDAY, 24 MAY

9:00 AM – 11:30 AM

Instructions for the completion of Section 1 are given on *Page 02* of your question and answer booklet X757/76/01.

Record your answers on the answer grid on *Page 03* of your question and answer booklet.

Reference may be made to the Data Sheet on *Page 02* of this booklet and to the Relationships Sheet X757/76/11.

Before leaving the examination room you must give your question and answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

X757760 2

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Speed of light in vacuum	c	$3{\cdot}00 \times 10^{8}\,\mathrm{m\,s^{-1}}$	Planck's constant	h	$6{\cdot}63 \times 10^{-34}\,\mathrm{J\,s}$
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}\,\mathrm{C}$	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}\,\mathrm{kg}$
Universal Constant of Gravitation	G	$6{\cdot}67 \times 10^{-11}\,\mathrm{m^3\,kg^{-1}\,s^{-2}}$	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}\,\mathrm{kg}$
Gravitational acceleration on Earth	g	$9{\cdot}8\,\mathrm{m\,s^{-2}}$	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}\,\mathrm{kg}$
Hubble's constant	H_0	$2{\cdot}3 \times 10^{-18}\,\mathrm{s^{-1}}$			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	*Refractive index*	*Substance*	*Refractive index*
Diamond	2·42	Water	1·33
Crown glass	1·50	Air	1·00

SPECTRAL LINES

Element	*Wavelength*/nm	*Colour*
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	*Wavelength*/nm	*Colour*
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	*Wavelength*/nm	*Colour*
Carbon dioxide	9550 10590	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	*Density*/$\mathrm{kg\,m^{-3}}$	*Melting Point*/K	*Boiling Point*/K
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853
Ice	$9{\cdot}20 \times 10^{2}$	273	. . . .
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377
Water	$1{\cdot}00 \times 10^{3}$	273	373
Air	1·29	. . . .	. . . .
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

SECTION 1 — 20 marks

Attempt ALL questions

1. A car accelerates uniformly from rest. The car travels a distance of 60 m in 6·0 s. The acceleration of the car is

A 0·83 m s^{-2}

B 3·3 m s^{-2}

C 5·0 m s^{-2}

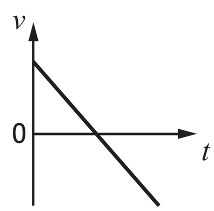
D 10 m s^{-2}

E 20 m s^{-2}.

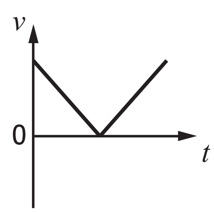
2. A ball is thrown vertically upwards and falls back to Earth.

Neglecting air resistance, which velocity-time graph represents its motion?

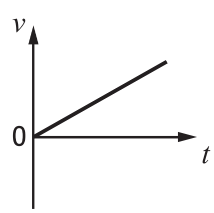
A



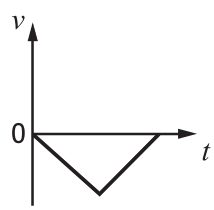
B



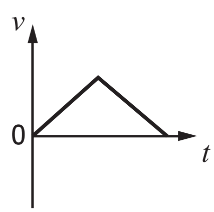
C



D

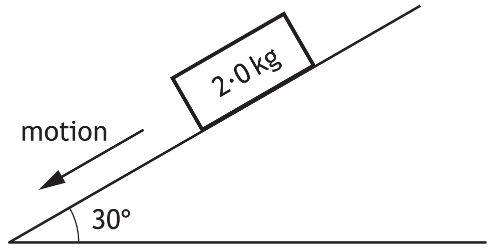


E



[Turn over

3. A block of wood slides with a constant velocity down a slope. The slope makes an angle of 30° with the horizontal as shown. The mass of the block is 2·0 kg.



The magnitude of the force of friction acting on the block is

A 1·0 N

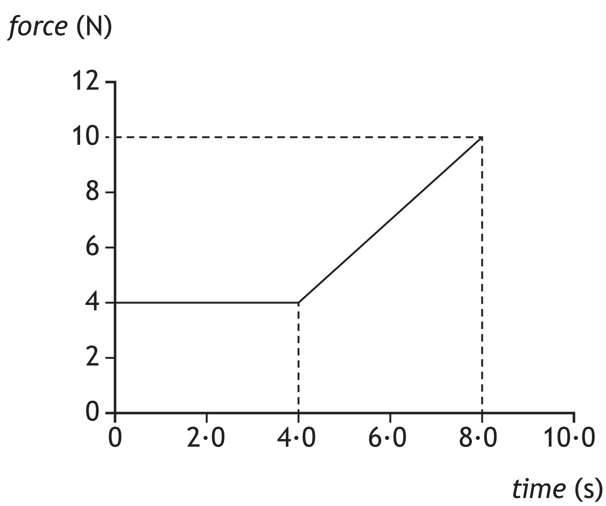
B 1·7 N

C 9·8 N

D 17·0 N

E 19·6 N.

4. The graph shows the force which acts on an object over a time interval of 8·0 seconds.



The momentum gained by the object during this 8·0 seconds is

A 12 kg m s^{-1}

B 32 kg m s^{-1}

C 44 kg m s^{-1}

D 52 kg m s^{-1}

E 72 kg m s^{-1}.

5. A planet orbits a star at a distance of $3{\cdot}0 \times 10^{9}$ m.

The star exerts a gravitational force of $1{\cdot}6 \times 10^{27}$ N on the planet.

The mass of the star is $6{\cdot}0 \times 10^{30}$ kg.

The mass of the planet is

A $2{\cdot}4 \times 10^{14}$ kg

B $1{\cdot}2 \times 10^{16}$ kg

C $3{\cdot}6 \times 10^{25}$ kg

D $1{\cdot}6 \times 10^{26}$ kg

E $2{\cdot}4 \times 10^{37}$ kg.

6. A car horn emits a sound with a constant frequency of 405 Hz.

The car is travelling away from a student at $28{\cdot}0\ \text{m s}^{-1}$.

The speed of sound in air is $335\ \text{m s}^{-1}$.

The frequency of the sound from the horn heard by the student is

A 371 Hz

B 374 Hz

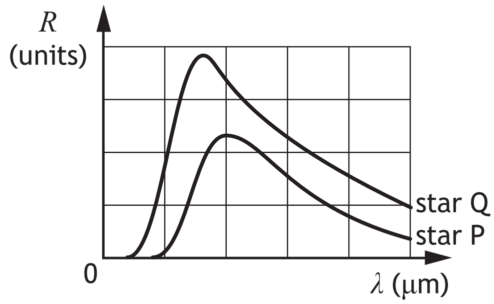
C 405 Hz

D 439 Hz

E 442 Hz.

[Turn over

7. The graphs show how the radiation per unit surface area, R, varies with the wavelength, λ, of the emitted radiation for two stars, P and Q.



A student makes the following conclusions based on the information in the graph.

I Star P is hotter than star Q.

II Star P emits more radiation per unit surface area than star Q.

III The peak intensity of the radiation from star Q is at a shorter wavelength than that from star P.

Which of these statements is/are correct?

A I only

B II only

C III only

D I and II only

E II and III only

8. One type of hadron consists of two down quarks and one up quark.

The charge on a down quark is $-\frac{1}{3}$.

The charge on an up quark is $+\frac{2}{3}$.

Which row in the table shows the charge and type for this hadron?

	charge	*type of hadron*
A	0	baryon
B	+1	baryon
C	−1	meson
D	0	meson
E	+1	meson

9. A student makes the following statements about sub-nuclear particles.

I The force mediating particles are bosons.

II Gluons are the mediating particles of the strong force.

III Photons are the mediating particles of the electromagnetic force.

Which of these statements is/are correct?

A I only

B II only

C I and II only

D II and III only

E I, II and III

10. The last two changes in a radioactive decay series are shown below.

A Bismuth nucleus emits a beta particle and its product, a Polonium nucleus, emits an alpha particle.

$$^{P}_{Q}\mathrm{Bi} \xrightarrow[\text{decay}]{\beta} {}^{R}_{S}\mathrm{Po} \xrightarrow[\text{decay}]{\alpha} {}^{208}_{82}\mathrm{Pb}$$

Which numbers are represented by P, Q, R and S?

	P	*Q*	*R*	*S*
A	210	83	208	81
B	210	83	210	84
C	211	85	207	86
D	212	83	212	84
E	212	85	212	84

[Turn over

11. The table below shows the threshold frequency of radiation for photoelectric emission for some metals.

Metal	*Threshold frequency* (Hz)
sodium	$4 \cdot 4 \times 10^{14}$
potassium	$5 \cdot 4 \times 10^{14}$
zinc	$6 \cdot 9 \times 10^{14}$

Radiation of frequency $6 \cdot 3 \times 10^{14}$ Hz is incident on the surface of each of the metals.

Photoelectric emission occurs from

A sodium only

B zinc only

C potassium only

D sodium and potassium only

E zinc and potassium only.

12. Radiation of frequency $9 \cdot 00 \times 10^{15}$ Hz is incident on a clean metal surface.

The maximum kinetic energy of a photoelectron ejected from this surface is $5 \cdot 70 \times 10^{-18}$ J.

The work function of the metal is

A $2 \cdot 67 \times 10^{-19}$ J

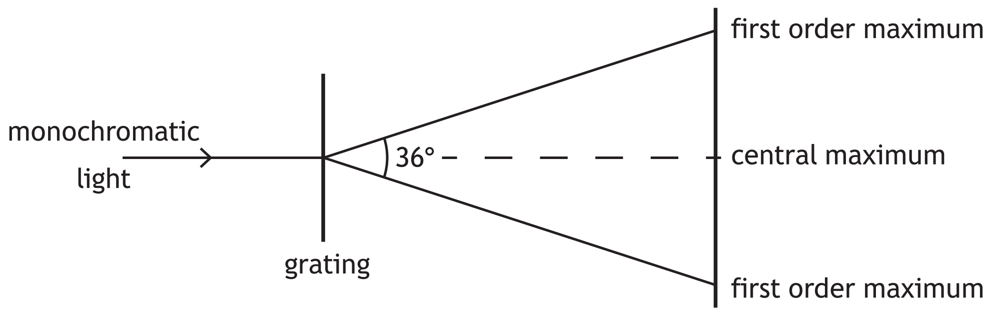
B $5 \cdot 97 \times 10^{-18}$ J

C $1 \cdot 17 \times 10^{-17}$ J

D $2 \cdot 07 \times 10^{-2}$ J

E $9 \cdot 60 \times 10^{-1}$ J.

13. A ray of monochromatic light is incident on a grating as shown.



The wavelength of the light is 633 nm.

The separation of the slits on the grating is

A $1{\cdot}96 \times 10^{-7}$ m

B $1{\cdot}08 \times 10^{-6}$ m

C $2{\cdot}05 \times 10^{-6}$ m

D $2{\cdot}15 \times 10^{-6}$ m

E $4{\cdot}10 \times 10^{-6}$ m.

14. Light travels from **glass** into **air**.

Which row in the table shows what happens to the speed, frequency and wavelength of the light as it travels from glass into air?

	Speed	*Frequency*	*Wavelength*
A	decreases	stays constant	decreases
B	decreases	increases	stays constant
C	stays constant	increases	increases
D	increases	increases	stays constant
E	increases	stays constant	increases

15. The irradiance of light from a point source is $32\,\text{W m}^{-2}$ at a distance of 4·0 m from the source.

The irradiance of the light at a distance of 16 m from the source is

A $0{\cdot}125\,\text{W m}^{-2}$

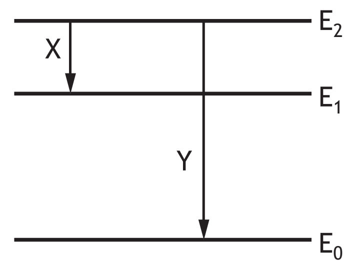
B $0{\cdot}50\,\text{W m}^{-2}$

C $2{\cdot}0\,\text{W m}^{-2}$

D $8{\cdot}0\,\text{W m}^{-2}$

E $128\,\text{W m}^{-2}$.

16. Part of the energy level diagram for an atom is shown



X and Y represent two possible electron transitions.

A student makes the following statements about transitions X and Y.

I Transition Y produces photons of higher frequency than transition X

II Transition X produces photons of longer wavelength than transition Y

III When an electron is in the energy level E_0, the atom is ionised.

Which of the statements is/are correct?

A I only

B I and II only

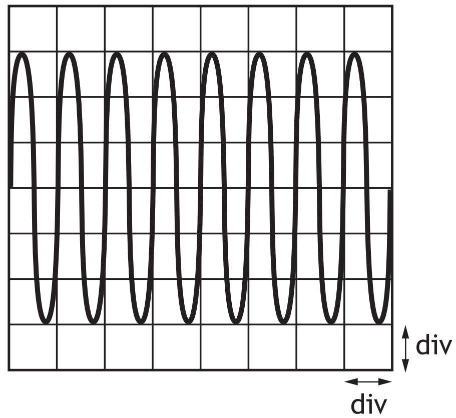
C I and III only

D II and III only

E I, II and III

17. The output of a signal generator is connected to the input of an oscilloscope.

The trace produced on the screen of the oscilloscope is shown.



The timebase control of the oscilloscope is set at 2 ms/div.

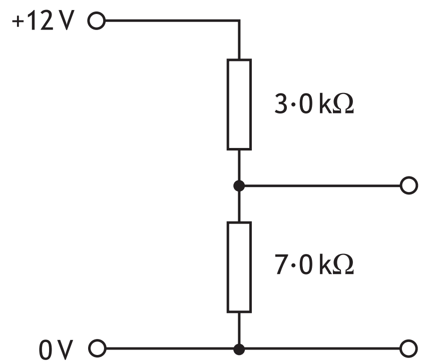
The Y-gain control of the oscilloscope is set at 4 mV/div.

Which row in the table shows the frequency and peak voltage of the output of the signal generator?

	frequency (Hz)	*peak voltage* (mV)
A	0·5	12
B	0·5	6
C	250	6
D	500	12
E	500	24

[Turn over

18. A potential divider circuit is set up as shown.



The potential difference across the 7·0 kΩ resistor is

A 3·6 V

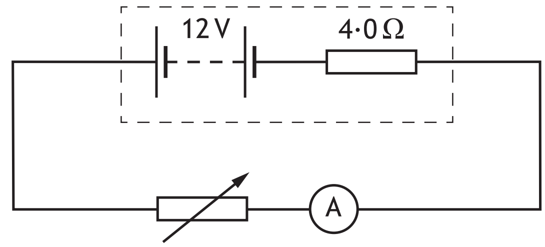
B 4·0 V

C 5·1 V

D 8·4 V

E 9·0 V.

19. A circuit is set up as shown.



The resistance of the variable resistor is increased and corresponding readings on the ammeter are recorded.

Resistance (Ω)	2·0	4·0	6·0	8·0
Current (A)	2·0	1·5	1·2	1·0

These results show that as the resistance of the variable resistor increases the power dissipated in the variable resistor

A increases

B decreases

C remains constant

D decreases and then increases

E increases and then decreases.

20. A 20 μF capacitor is connected to a 12 V d.c. supply.

The maximum charge stored on the capacitor is

A $1{\cdot}4 \times 10^{-3}$ C

B $2{\cdot}4 \times 10^{-4}$ C

C $1{\cdot}2 \times 10^{-4}$ C

D $1{\cdot}7 \times 10^{-6}$ C

E $6{\cdot}0 \times 10^{-7}$ C.

[END OF SECTION 1. NOW ATTEMPT THE QUESTIONS IN SECTION 2 OF YOUR QUESTION AND ANSWER BOOKLET]

Marking Instructions for each question

Section 1

Question	Answer	Max Mark
1.	B	1
2.	A	1
3.	C	1
4.	C	1
5.	C	1
6.	B	1
7.	C	1
8.	A	1
9.	E	1
10.	D	1
11.	D	1
12.	A	1
13.	C	1
14.	E	1
15.	C	1
16.	B	1
17.	D	1
18.	D	1
19.	E	1
20.	B	1

FOR OFFICIAL USE

H

National Qualifications 2016

Mark

X757/76/01

Physics Section 1 — Answer Grid and Section 2

TUESDAY, 24 MAY

9:00 AM – 11:30 AM

* X 7 5 7 7 6 0 1 *

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth

Day Month Year

Scottish candidate number

Total marks — 130

SECTION 1 — 20 marks

Attempt ALL questions.

Instructions for the completion of Section 1 are given on *Page 02*.

SECTION 2 — 110 marks

Attempt ALL questions.

Reference may be made to the Data Sheet on *Page 02* of the question paper X757/76/02 and to the Relationships Sheet X757/76/11.

Care should be taken to give an appropriate number of significant figures in the final answers to calculations.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. You should score through your rough work when you have written your final copy.

Use **blue** or **black** ink.

Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

SQA ©

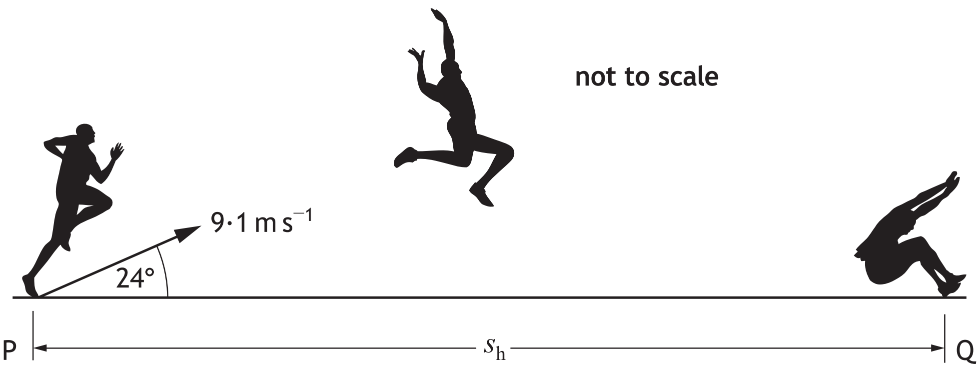
* X 7 5 7 7 6 0 1 0 1 *

MARKS DO NOT WRITE IN THIS MARGIN

SECTION 2 — 110 marks

Attempt ALL questions

1.



An athlete takes part in a long jump competition. The athlete takes off from point P with an initial velocity of $9{\cdot}1\ \text{m s}^{-1}$ at an angle of 24° to the horizontal and lands at point Q.

(a) Calculate:

(i) the vertical component of the initial velocity of the athlete; **1**

Space for working and answer

(ii) the horizontal component of the initial velocity of the athlete. **1**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

1. (continued)

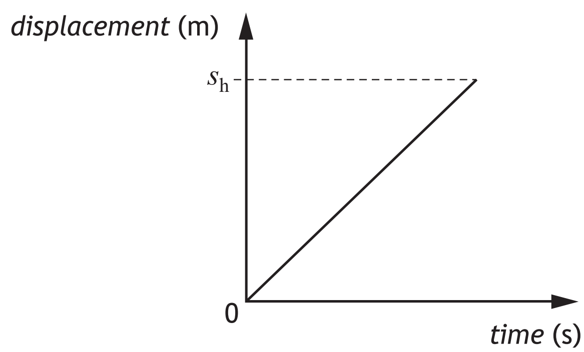
(b) Show that the time taken for the athlete to travel from P to Q is 0·76 s. **2**

Space for working and answer

(c) Calculate the horizontal displacement s_h between points P and Q. **3**

Space for working and answer

(d) The graph shows how the horizontal displacement of the athlete varies with time for this jump when air resistance is ignored.



Add a line to the graph to show how the horizontal displacement of the athlete varies with time when air resistance is taken into account. **2**

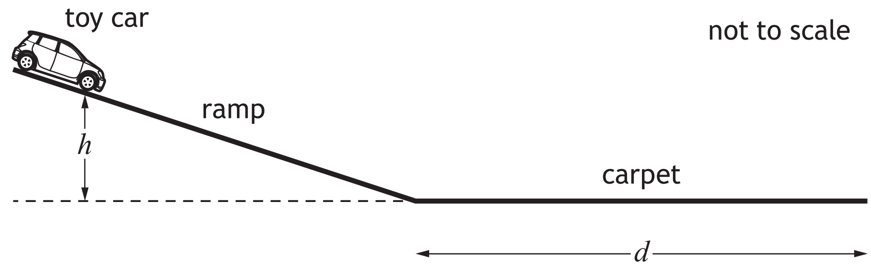
(An additional graph, if required can be found on *Page 38*)

Section 2

Question			Answer	Max Mark	Additional Guidance
1.	(a)	(i)	$u_v = 9{\cdot}1 \sin 24°$ $u_v = 3{\cdot}7$ m s^{-1} (1)	1	Sig figs: Accept 4, 3·70, 3·701 **OR** Accept m/s
		(ii)	$u_h = 9{\cdot}1 \cos 24°$ $u_h = 8{\cdot}3$ m s^{-1} (1)	1	Sig figs: Accept 8, 8·31, 8·313
	(b)		$v = u + at$ (1) $0 = 3{\cdot}7 + (-9{\cdot}8)t$ $t = 0{\cdot}378$ (s) (total) $t = 0{\cdot}378 \times 2$ (1) (total) $t = 0{\cdot}76$ s **OR** $v = u + at$ (1) $-3{\cdot}7 = 3{\cdot}7 + (-9{\cdot}8) \times t$ (1) (total) $t = 0{\cdot}76$ s	2	SHOW question. Sign convention must be correct. Accept $0 = 3{\cdot}7 - 9{\cdot}8t$ If final line not shown then a maximum of 1 mark can be awarded. Guidance on alternatives $s = ut + \frac{1}{2}at^2$ (1) $0 = 3{\cdot}7t + \frac{1}{2}(-9{\cdot}8)t^2$ (1) (total) $t = 0{\cdot}76$ s
	(c)		$s = v_h \times t$ (1) $s = 8{\cdot}3 \times 0{\cdot}76$ (1) $s = 6{\cdot}3$ m (1)	3	Or consistent with (a)(ii) Sig figs: Accept 6, 6·31, 6·308 Accept $s = \frac{1}{2}(u+v)t$ Accept $s = ut + \frac{1}{2}at^2$ Accept $s = ut$ v_h= 8·31 m s^{-1} gives s = 6·32 m is acceptable
	(d)		Smaller displacement (1) curve with decreasing gradient (1)	2	Ignore any change in time Any part of the curve drawn above the original line - award 0 marks These marks are independent.

MARKS | DO NOT WRITE IN THIS MARGIN

2. A student uses the apparatus shown to investigate the force of friction between the wheels of a toy car and a carpet.



The toy car is released from rest, from a height h. It then travels down the ramp and along the carpet before coming to rest. The student measures the distance d that the car travels along the carpet.

The student repeats the procedure several times and records the following measurements and uncertainties.

Mass of car, m: (0·20 ± 0·01) kg

Height, h: (0·40 ± 0·005) m

Distance, d: 1·31 m 1·40 m 1·38 m 1·41 m 1·35 m

(a) (i) Calculate the mean distance d travelled by the car. **1**

Space for working and answer

(ii) Calculate the approximate random uncertainty in this value. **2**

Space for working and answer

X757760108

MARKS | DO NOT WRITE IN THIS MARGIN

2. (continued)

(b) Determine which of the quantities; mass m, height h or mean distance d, has the largest percentage uncertainty.

You must justify your answer by calculation. **4**

Space for working and answer

(c) (i) Calculate the potential energy of the toy car at height h.

An uncertainty in this value is not required. **3**

Space for working and answer

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

2. (c) (continued)

(ii) Calculate the average force of friction acting between the toy car and carpet, as the car comes to rest.

An uncertainty in this value is not required. **3**

Space for working and answer

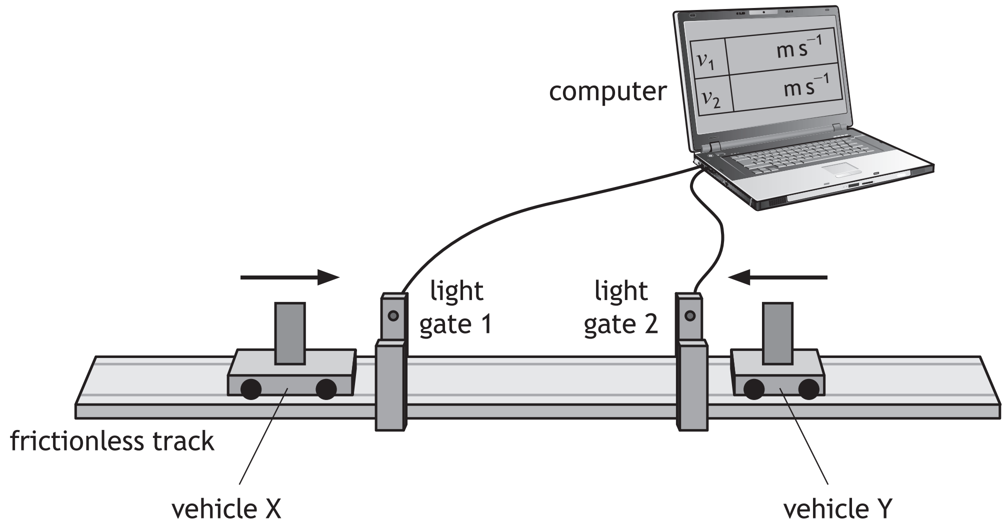
(iii) State one assumption you have made in (c) (ii). **1**

Question			Answer	Max Mark	Additional Guidance
2.	(a)	(i)	$\bar{d} = \dfrac{1\cdot31+1\cdot40+1\cdot38+1\cdot41+1\cdot35}{5}$ $\bar{d} = 1\cdot37$ m (1)	1	Sig figs: Accept 1·4, 1·370
		(ii)	$\Delta\bar{d} = \dfrac{1\cdot41-1\cdot31}{5}$ (1) $\Delta\bar{d} = 0\cdot02$ m (1)	2	Sig figs: Accept 0·020 Accept $(1\cdot37 \pm 0\cdot02)$m
	(b)		$\%\Delta m = \dfrac{0\cdot01}{0\cdot20}\times100 = 5\%$ (1) $\%\Delta h = \dfrac{0\cdot005}{0\cdot40}\times100 = 1\cdot3\%$ (1) $\%\Delta\bar{d} = \dfrac{0\cdot02}{1\cdot37}\times100 = 1\cdot5\%$ (1) Mass (has largest percentage uncertainty). (1)	4	Or consistent with (a)(i) and (a)(ii). Each correct calculation <u>with correct substitution</u> is awarded 1 mark Each calculation is independent but must have all three calculations <u>shown</u> to access the final mark for the conclusion. Accept percentage sign missing. Wrong substitution – maximum of 2 marks. Sig figs: for $\%\Delta m$ Accept 5·0, 5·00 for $\%\Delta h$ Accept 1, 1·25, 1·250 for $\%\Delta\bar{d}$ Accept 1, 1·46, 1·460
	(c)	(i)	$E_p = mgh$ (1) $E_p = 0\cdot20\times9\cdot8\times0\cdot40$ (1) $E_p = 0\cdot78$ J (1)	3	Sig figs: Accept 0·8, 0·784 Treat −9·8 as wrong substitution unless h is also negative.

Question			Answer	Max Mark	Additional Guidance
2.	(c)	(ii)	$E_w = Fd$ (1) $0{\cdot}78 = F \times 1{\cdot}37$ (1) $F = 0{\cdot}57$ N (1)	**3**	Or consistent with (a)(i) and (c)(i) Sig figs: Accept 0·6, 0·569, 0·5693 Candidates can arrive at this answer by alternative methods eg equating loss in E_P to gain in E_K etc. If alternative methods used, can also accept 0·572, 0·5723 1 for ALL equations 1 for ALL substitutions 1 for correct answer
		(iii)	All E_p converted to E_k All E_p converted to E_W Air resistance is negligible Ramp is frictionless Bearings in the wheels are frictionless The carpet is horizontal No energy/heat loss <u>on the ramp</u> etc	**1**	Only one correct statement required Note the ± rule applies Energy is conserved on its own **OR** No energy/ heat loss on its own – 0 marks

MARKS DO NOT WRITE IN THIS MARGIN

3. The following apparatus is set up to investigate the law of conservation of linear momentum.



In one experiment, vehicle X is travelling to the right along the track and vehicle Y is travelling to the left along the track.

The vehicles collide and stick together.

The computer displays the speeds of each vehicle before the collision.

The following data are recorded:

Mass of vehicle X = 0·85 kg
Mass of vehicle Y = 0·25 kg
Speed of vehicle X before the collision = 0·55 m s^{-1}
Speed of vehicle Y before the collision = 0·30 m s^{-1}

(a) State the law of conservation of linear momentum. **1**

(b) Calculate the velocity of the vehicles immediately after the collision. **3**

Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

3. (continued)

(c) Show by calculation that the collision is inelastic. 4

Space for working and answer

[Turn over

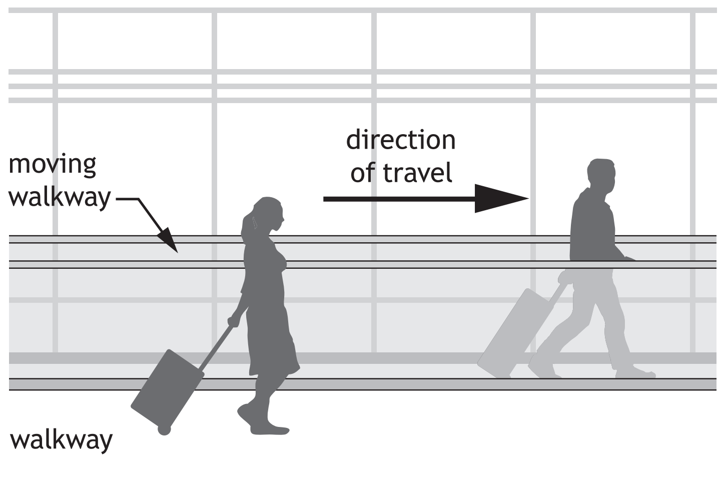
Question			Answer	Max Mark	Additional Guidance
3.	(a)		<u>Total</u> momentum before (a collision) is equal to the <u>total</u> momentum after (a collision) in the absence of external forces (1)	**1**	Not: TMB = TMA An isolated system is equivalent to the absence of external forces
	(b)		$m_1u_1 + m_2u_2 = (m_1 + u_2)v$ (1) $(0\cdot85\times0\cdot55)+(0\cdot25\times-0\cdot3)$ $=(0\cdot25+0\cdot85)v$ (1) $v = 0\cdot36\ \mathrm{m\ s^{-1}}$ (1)	**3**	Sign of the answer must be consistent with the substitution of + and – velocities. Sig figs: Accept 0·4, 0·357, 0·3568 If candidate then goes on to state a direction which is not consistent with their substitution then maximum two marks can be awarded. Where candidates calculate the momentum of each trolley individually both before and after, no marks are awarded unless correct addition (including sign convention) <u>and</u> equating takes place.
	(c)		$E_k = ½mv^2$ ANYWHERE (1) Before $E_k = ½m_Xv_X{}^2 + ½m_Yv_Y{}^2$ $= (½ \times 0\cdot85 \times 0\cdot55^2)$ $+ (½ \times 0\cdot25 \times 0\cdot3^2)$ $= 0\cdot14$ (J) (1) After $E_k = ½mv^2$ $= ½ \times 1\cdot1 \times 0\cdot36^2 = 0\cdot071$ (J) (1) <u>Kinetic</u> energy is lost. (Therefore inelastic.) (1)	**4**	Or consistent with (b) 1 mark for both substitutions If candidate answers 0·49 in (b), this gives 0·13 J for E_K after. $E_K before \neq E_K after$ is insufficient

MARKS DO NOT WRITE IN THIS MARGIN

4. Two physics students are in an airport building on their way to visit CERN.

(a) The first student steps onto a moving walkway, which is travelling at $0{\cdot}83\,\mathrm{m\,s^{-1}}$ relative to the building. This student walks along the walkway at a speed of $1{\cdot}20\,\mathrm{m\,s^{-1}}$ relative to the walkway.

The second student walks alongside the walkway at a speed of $1{\cdot}80\,\mathrm{m\,s^{-1}}$ relative to the building.



Determine the speed of the first student relative to the second student. **2**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

4. (continued)

(b) On the plane, the students discuss the possibility of travelling at relativistic speeds.

(i) The students consider the plane travelling at $0 \cdot 8c$ relative to a stationary observer. The plane emits a beam of light towards the observer.

State the speed of the emitted light as measured by the observer.

Justify your answer. **2**

(ii) According to the manufacturer, the length of the plane is 71 m.

Calculate the length of the plane travelling at $0 \cdot 8c$ as measured by the stationary observer. **3**

Space for working and answer

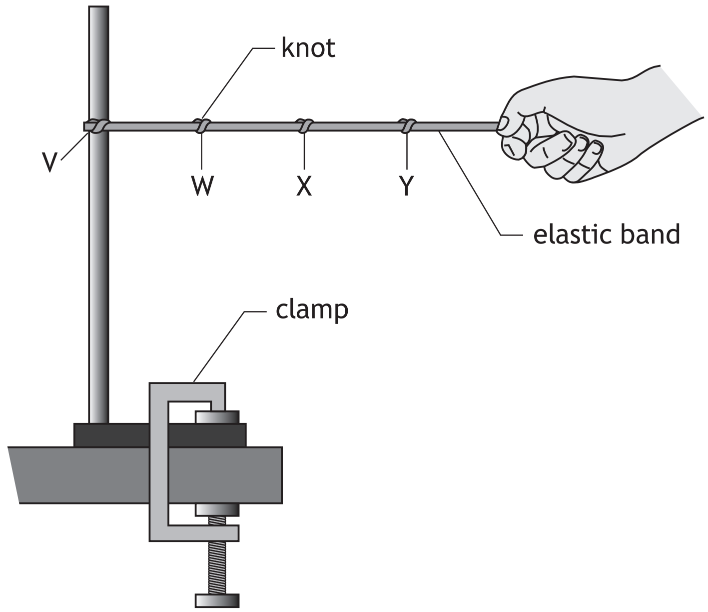
(iii) One of the students states that the clocks on board the plane will run slower when the plane is travelling at relativistic speeds.

Explain whether or not this statement is correct. **1**

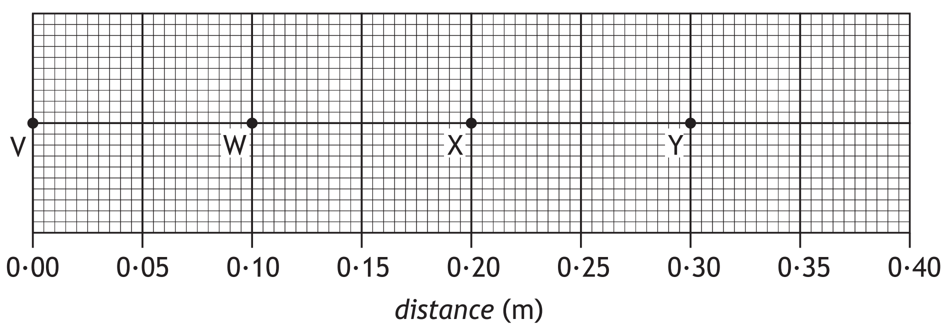
[Turn over

Question			Answer	Max Mark	Additional Guidance
4.	(a)		$(0{\cdot}83 + 1{\cdot}20) - 1{\cdot}80$ (1) $0{\cdot}23\ \text{m s}^{-1}$ (1)	2	
	(b)	(i)	$3 \times 10^8\ \text{m s}^{-1}$ or c (1) Speed of light is the same for all observers / all (inertial) frames of reference or equivalent (1)	2	Look for this statement first - if incorrect then 0 marks. $3 \times 10^8\ \text{m s}^{-1}$ or c on its own is worth 1 mark If the numerical value for speed is given, then unit is required- otherwise 0 marks Any wrong physics in justification then maximum 1 mark for the statement
		(ii)	$l' = l\sqrt{1-\left(\frac{v}{c}\right)^2}$ (1) $l = 71\sqrt{1-0{\cdot}8^2}$ (1) $l = 43\ \text{m}$ (1)	3	Sig figs: Accept 40, 42·6, 42·60
		(iii)	Correct - from the perspective of the stationary observer there will be time dilation Incorrect - from the perspective of the students they are in the same frame of reference as the clock Not possible to say/could be both correct and incorrect - frame of reference has not been defined	1	The response must involve a statement referring to, or implying, a frame of reference

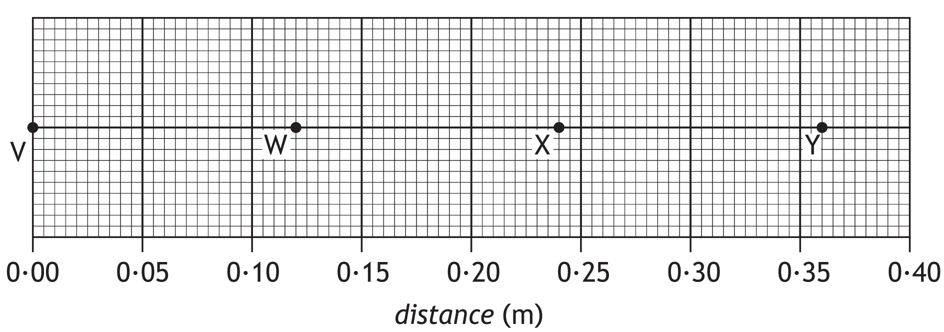
5. (a) A student is using an elastic band to model the expansion of the Universe.



One end of the band is fixed in a clamp stand at V. Knots are tied in the band to represent galaxies. The knots are at regular intervals of 0·10 m, at points W, X and Y as shown.



The other end of the elastic band is pulled slowly for 2·5 seconds, so that the band stretches. The knots are now in the positions shown below.



MARKS DO NOT WRITE IN THIS MARGIN

5. (a) (continued)

(i) Complete the table to show the average speeds of the knots X and Y. **2**

Knot	*Average speed* ($m\,s^{-1}$)
W	0·008
X	
Y	

Space for working

(ii) Explain why this model is a good simulation of the expansion of the Universe. **1**

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

5. (continued)

(b) When viewed from the Earth, the continuous emission spectrum from the Sun has a number of dark lines. One of these lines is at a wavelength of 656 nm.

In the spectrum of light from a distant galaxy, the corresponding dark line is observed at 667 nm.

Calculate the redshift of the light from the distant galaxy. **3**

Space for working and answer

Question			Answer	Max Mark	Additional Guidance
5.	(a)	(i)	$\Delta X = 0{\cdot}04$ (m) $X = 0{\cdot}016$ (m s^{-1}) (1) $\Delta Y = 0{\cdot}06$ (m) $Y = 0{\cdot}024$ (m s^{-1}) (1)	2	If values are not entered in the table, then X and Y must be identified <u>and</u> units required.
		(ii)	More distant <u>galaxies</u> are moving <u>away</u> at a greater velocity/ have a greater recessional velocity Or equivalent	1	The (average) speed (of the knots) is (directly) <u>proportional</u> to the distance (from V) Any reference to planets or stars alone - 0 marks
	(b)		$z = \dfrac{\lambda_{observed} - \lambda_{rest}}{\lambda_{rest}}$ (1) $z = \dfrac{667\times10^{-9} - 656\times10^{-9}}{656\times10^{-9}}$ (1) $z = 0{\cdot}0168$ (1)	3	Sig figs: Accept 0·017, 0·01677, 0·016768 Accept $z = \dfrac{667-656}{656}$

MARKS DO NOT WRITE IN THIS MARGIN

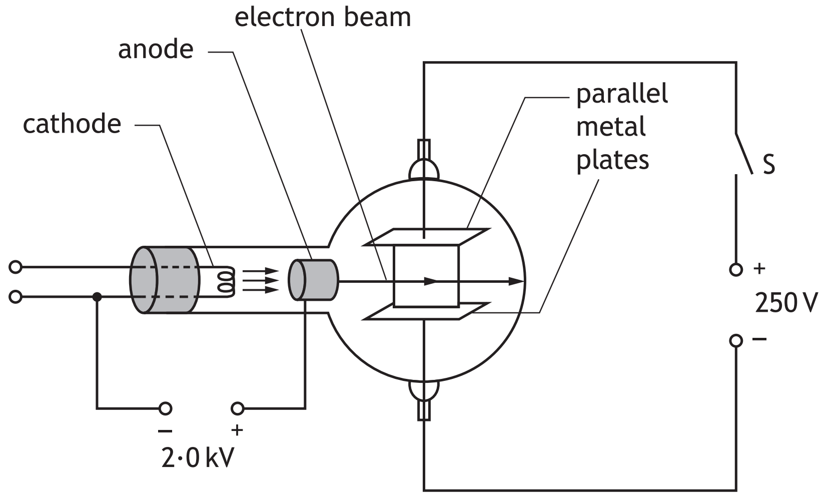
6. A website states "*Atoms are like tiny solar systems with electrons orbiting a nucleus like the planets orbit the Sun*".

Use your knowledge of physics to comment on this statement. **3**

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

7. An experiment is set up to investigate the behaviour of electrons in electric fields.



(a) Electrons are accelerated from rest between the cathode and the anode by a potential difference of 2·0 kV.

Calculate the kinetic energy gained by each electron as it reaches the anode. **3**

Space for working and answer

(b) The electrons then pass between the two parallel metal plates.

The electron beam current is 8·0 mA.

Determine the number of electrons passing between the metal plates in one minute. **4**

Space for working and answer

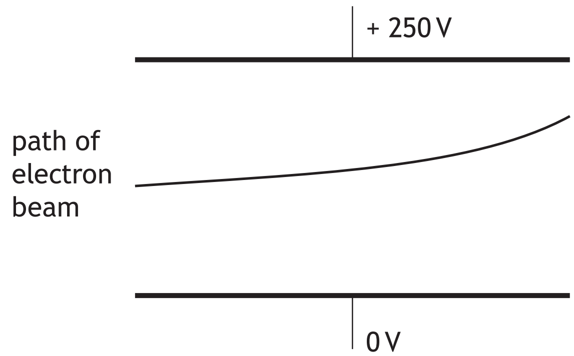
MARKS DO NOT WRITE IN THIS MARGIN

7. (continued)

(c) The switch S is now closed.

The potential difference between the metal plates is 250 V.

The path of the electron beam between the metal plates is shown.



Complete the diagram to show the electric field pattern between the two metal plates. **1**

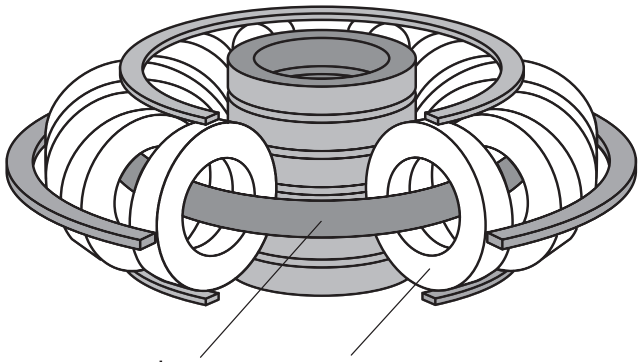
(An additional diagram, if required, can be found on *Page 38*.)

[Turn over

Question			Answer	Max Mark	Additional Guidance
7.	(a)		$W = QV$ (1) $= 1 \cdot 6 \times 10^{-19} \times 2000$ (1) $= 3 \cdot 2 \times 10^{-16}$ J (1)	3	Sig figs: Accept 3×10^{-16}, $3 \cdot 20 \times 10^{-16}$, $3 \cdot 200 \times 10^{-16}$, Ignore negative sign for charge.
	(b)		$Q = It$ (1) $= 0 \cdot 008 \times 60$ (1) $= 0 \cdot 48\ (C)$ (1) $number = \dfrac{0 \cdot 48}{1 \cdot 6 \times 10^{-19}}$ $= 3 \cdot 0 \times 10^{18}$ (1)	4	Sig figs: Accept 3×10^{18} If the response stops at 0·48 then a correct unit is required. Candidates can arrive at this answer by alternative methods eg P=IV and E=Pt **OR** Q=It to calculate the time for 1 electron.
	(c)		Straight lines with arrows pointing downwards.	1	spacing should be approximately equal (ignore end effect) Field lines must start and finish on the plates Lines at right angles to the plates

MARKS DO NOT WRITE IN THIS MARGIN

8. The diagram shows part of an experimental fusion reactor.



The following statement represents a reaction that takes place inside the reactor.

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$$

The masses of the particles involved in the reaction are shown in the table.

Particle	*Mass* (kg)
$^{2}_{1}H$	$3{\cdot}3436 \times 10^{-27}$
$^{3}_{1}H$	$5{\cdot}0083 \times 10^{-27}$
$^{4}_{2}He$	$6{\cdot}6465 \times 10^{-27}$
$^{1}_{0}n$	$1{\cdot}6749 \times 10^{-27}$

(a) Explain why energy is released in this reaction. **1**

(b) Calculate the energy released in this reaction. **4**

Space for working and answer

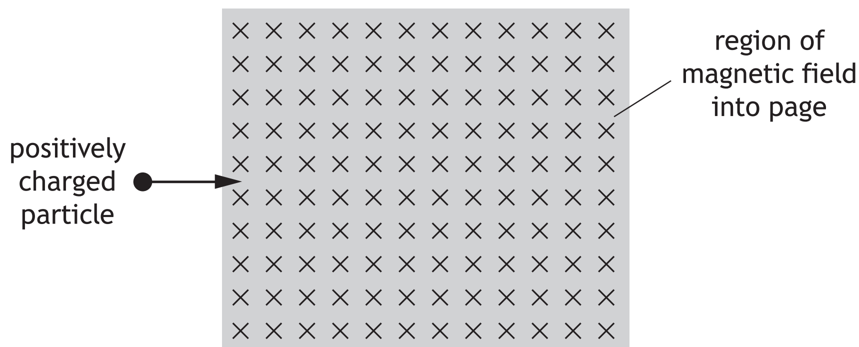
MARKS DO NOT WRITE IN THIS MARGIN

8. (continued)

(c) Magnetic fields are used to contain the plasma inside the fusion reactor.

Explain why it is necessary to use a magnetic field to contain the plasma. **1**

(d) The plasma consists of charged particles. A positively charged particle enters a region of the magnetic field as shown.



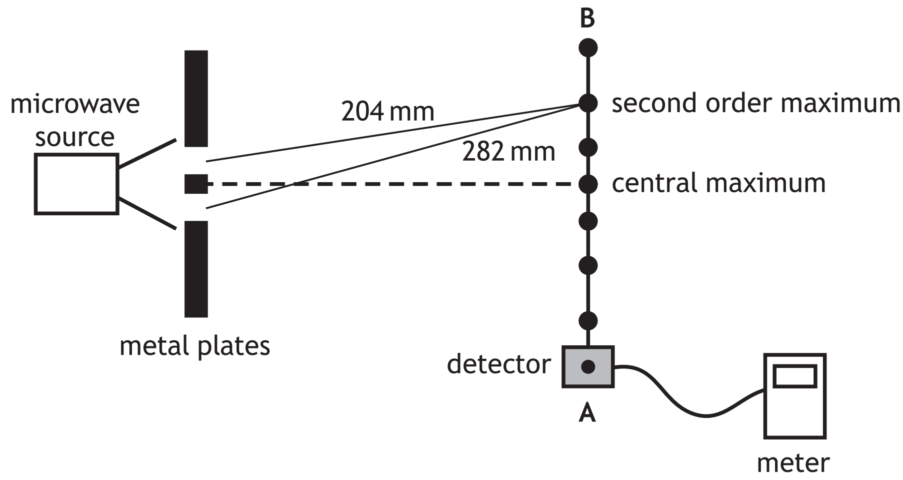
Determine the direction of the force exerted by the magnetic field on the positively charged particle as it enters the field. **1**

[Turn over

Question			Answer	Max Mark	Additional Guidance
8.	(a)		mass is converted into energy	**1**	There must be a link between mass and energy. Mass is lost on its own - 0 marks Mass defect is wrong physics - 0 marks Energy is released or equivalent is not sufficient.
	(b)		$m_{before} = 3 \cdot 3436 \times 10^{-27} + 5 \cdot 0083 \times 10^{-27}$ $= 8 \cdot 3519 \times 10^{-27}$ (kg) $m_{after} = 6 \cdot 6465 \times 10^{-27} + 1 \cdot 6749 \times 10^{-27}$ $= 8 \cdot 3214 \times 10^{-27}$ (kg) $\Delta m = 3 \cdot 0500 \times 10^{-29}$ (kg) (1) $E = mc^2$ (1) $= 3 \cdot 0500 \times 10^{-29} \times (3 \cdot 00 \times 10^8)^2$ (1) $= 2 \cdot 75 \times 10^{-12}$ J (1)	**4**	$E = mc^2$ anywhere - 1 mark. If mass before and after not used to 5 significant figures from table then stop marking - maximum 1 mark for formula Arithmetic mistake can be carried forward Truncation error in mass before and/or mass after– maximum 1 mark for formula Sig figs: 2·7, 2·745, 2·7450 If finding $E = mc^2$ for each particle, then $E = mc^2$ (1) All substitutions (1) Subtraction (1) Final answer (1)
	(c)		Plasma would cool down if it came too close to the sides (and reaction would stop)	**1**	(Reaction requires very high temperature), so plasma would melt the sides of the reactor **OR** High temperature plasma could damage/ destroy the container
	(d)		Up the page	**1**	Accept up and upwards Arrow drawn pointing up the page is acceptable If upwards arrow is drawn on the original diagram, it must be on the left hand edge The path of the particle on its own is not acceptable

MARKS DO NOT WRITE IN THIS MARGIN

9. A student carries out an experiment to measure the wavelength of microwave radiation. Microwaves pass through two gaps between metal plates as shown.



As the detector is moved from A to B, a series of maxima and minima are detected.

(a) The microwaves passing through the gaps are coherent.

State what is meant by the term *coherent*. **1**

(b) Explain, in terms of waves, how a maximum is produced. **1**

(c) The measurements of the distance from each gap to the second order maximum are shown in the diagram above.

Calculate the wavelength of the microwaves. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

9. (continued)

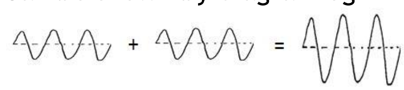
(d) The distance separating the two gaps is now increased.

State what happens to the path difference to the second order maximum.

Justify your answer. **2**

[Turn over

X757760125

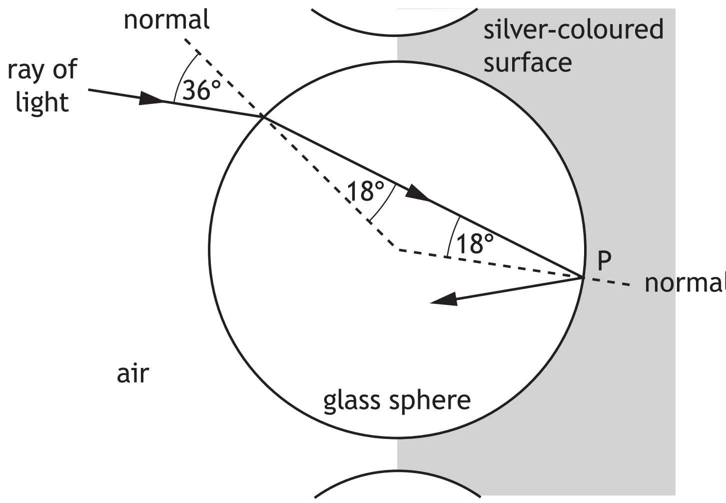
Question			Answer	Max Mark	Additional Guidance
9.	(a)		The waves from the two sources have a constant phase relationship (and have the same frequency, wavelength, and velocity).	**1**	"In phase" is not sufficient
	(b)		Waves <u>meet</u> in phase OR Crest <u>meets</u> crest OR Trough <u>meets</u> trough OR Path difference = mλ	**1**	Accept peak for crest Can be shown by diagram eg  Diagram must imply addition of two waves in phase
	(c)		Path Difference $= m\lambda$ (1) $0{\cdot}282 - 0{\cdot}204 = 2 \times \lambda$ (1) $\lambda = 0{\cdot}0390\text{m}$ (1) (39 mm)	**3**	Sig figs: 0·039 m 0·03900 m 0·039000 m Not: 0·04 m
	(d)		The path difference stays the same **OR** The path difference is still 2λ (1) because the wavelength has not changed (1)	**2**	Look for this statement first - if incorrect then 0 marks. The path difference stays the same **OR** The path difference is still 2λ on its own - 1 mark Any wrong physics in justification then maximum 1 mark (for the statement)

MARKS DO NOT WRITE IN THIS MARGIN

10. Retroflective materials reflect light to enhance the visibility of clothing.

One type of retroflective material is made from small glass spheres partially embedded in a silver-coloured surface that reflects light.

A ray of monochromatic light follows the path shown as it enters one of the glass spheres.



(a) Calculate the refractive index of the glass for this light. **3**

Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

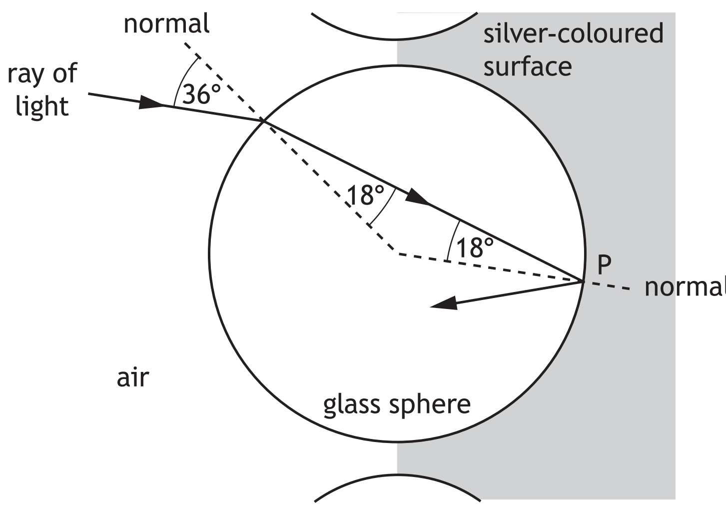
10. (continued)

(b) Calculate the critical angle for this light in the glass. **3**

Space for working and answer

(c) The light is reflected at point P.

Complete the diagram below to show the path of the ray as it passes through the sphere and emerges into the air. **1**



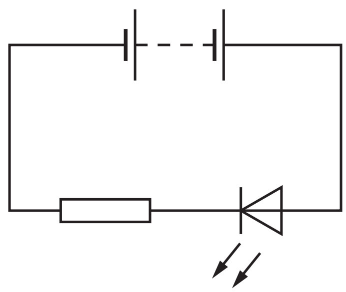
(An additional diagram, if required, can be found on *Page 38*.)

[Turn over

Question			Answer	Max Mark	Additional Guidance
10.	(a)		$n = \sin i/\sin r$ (1) $= \sin 36/\sin 18$ (1) $= 1{\cdot}9$ (1)	**3**	Sig figs: Accept 2, 1·90, 1·902
	(b)		$\sin\theta_C = 1/n$ (1) $= 1/1{\cdot}9$ (1) $= 0{\cdot}5263$ $\theta_C = 32^o$ (1)	**3**	Or consistent with 10(a).
	(c)		Completed diagram, showing light emerging (approximately) parallel to the incident ray	**1**	The normal is not required

MARKS DO NOT WRITE IN THIS MARGIN

11. A student is describing how the following circuit works.



The student states:

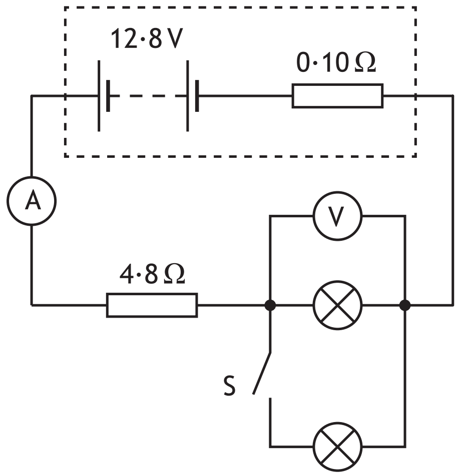
"The electricity comes out of the battery with energy and flows through the resistor using up some of the energy, it then goes through the LED and the rest of the energy is changed into light waves."

Use your knowledge of physics to comment on this statement. **3**

MARKS DO NOT WRITE IN THIS MARGIN

12. A technician sets up a circuit as shown, using a car battery and two identical lamps.

The battery has an e.m.f. of 12·8 V and an internal resistance of 0·10 Ω.



(a) Switch S is open. The reading on the ammeter is 1·80 A.

(i) Determine the reading on the voltmeter. **4**

Space for working and answer

(ii) Switch S is now closed.

State the effect this has on the reading on the voltmeter.

Justify your answer. **3**

* X 7 5 7 7 6 0 1 2 9 *

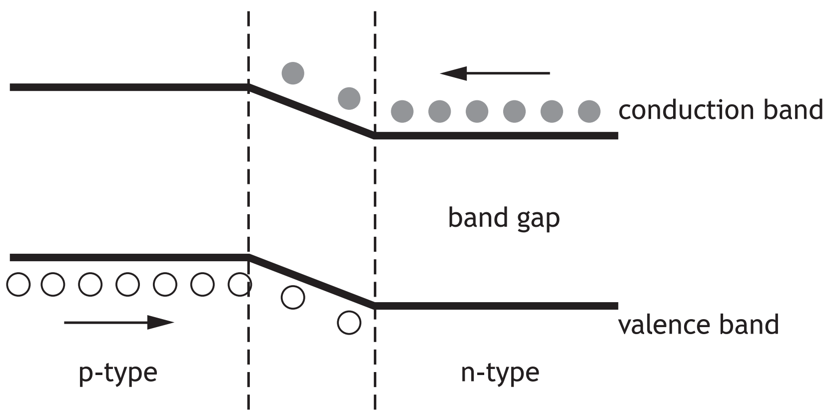
12. (continued)

MARKS DO NOT WRITE IN THIS MARGIN

(b) Some cars use LEDs in place of filament lamps.

An LED is made from semiconductor material that has been doped with impurities to create a p-n junction.

The diagram represents the band structure of an LED.



(i) A voltage is applied across an LED so that it is forward biased and emits light.

Using **band theory,** explain how the LED emits light. **3**

12. (b) (continued)

MARKS | DO NOT WRITE IN THIS MARGIN

(ii) The energy gap between the valence band and conduction band is known as the band gap.

The band gap for the LED is $3{\cdot}03 \times 10^{-19}$ J

(A) Calculate the wavelength of the light emitted by the LED. **4**

Space for working and answer

(B) Determine the colour of the light emitted by the LED. **1**

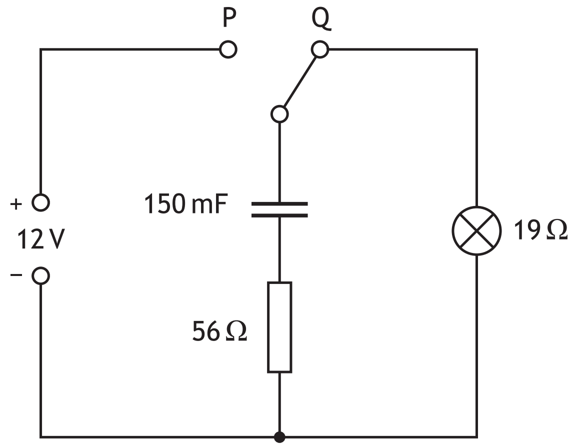
[Turn over

Question			Answer	Max Mark	Additional Guidance
12.	(a)	(i)	$V = IR$ (1) $V = 1 \cdot 80\,(4 \cdot 8 + 0 \cdot 10)$ (1) V = 8·82 (V) (1) Voltmeter reading $(= 12{\cdot}8 - 8{\cdot}82)$ $= 4{\cdot}0$ V (1)	**4**	$lost\ volts = Ir$ $lost\ volts = 1 \cdot 80 \times 0 \cdot 10$ $lost\ volts = 0 \cdot 18$ V $V = IR$ $V = 1 \cdot 80 \times 4 \cdot 8$ $V = 8 \cdot 64$ V $V = 12 \cdot 8 - 0 \cdot 18 - 8 \cdot 64$ $V = 4 \cdot 0$ V **OR** $E = V + Ir$ $12 \cdot 8 = V + (1 \cdot 80 \times 0 \cdot 10)$ $V = 12 \cdot 62$ V $V = IR$ $V = 1 \cdot 80 \times 4 \cdot 8$ $V = 8 \cdot 64$ V $V = 12 \cdot 62 - 8 \cdot 64$ $V = 4 \cdot 0$ V 1 for all equations 1 for all substitutions 1 for all correct intermediate values 1 for final answer Sig figs: Accept 4, 3·98, 3·980
		(ii)	(Reading on voltmeter)/(voltage across lamp) decreases (1) (total) resistance decreases/ current increases. (1) lost volts increases/V_{tpd} decreases/p.d. across 4·8 Ω increases/share of p.d. across parallel branch decreases (1)	**3**	Look for this statement first - if incorrect then 0 marks. 'Reading on voltmeter decreases' on its own is worth 1 mark Any wrong physics in justification then maximum 1 mark for the statement Last 2 marks are independent of each other Can be justified by calculation (R_{lamp} is 2·2 Ω, I = 2·1 A, gives V = 2·3 V)

Question			Answer	Max Mark	Additional Guidance
12.	(b)	(i)	(Voltage applied causes) electrons to move towards conduction band of p-type/ away from n-type (towards the junction) (1) Electrons move/ drop from conduction band to valence band (1) Photon emitted (when electron drops) (1)	3	Look for reference to either conduction or valence band first. Otherwise 0 marks. Bands must be named correctly in first two marking point eg not valency and not conductive Any answer using recombination of holes and electrons **on its own**, with no reference to band theory, is worth 0 marks. Must be directional Any wrong physics eg holes move up (from valence band to conduction band)- 0 marks This mark is dependent upon having at least one of the first two statements
		(ii) (A)	$E = hf$ $3{\cdot}03\times10^{-19} = 6{\cdot}63\times10^{-34}\times f$ (1) $f = 4{\cdot}57\times10^{14}$ (Hz) $v = f\lambda$ (1) for both equations $3\times10^{8} = 4{\cdot}57\times10^{14}\times\lambda$ (1) $\lambda = 6{\cdot}56\times10^{-7}$ m (1)	4	Alternative: $E = \frac{hc}{\lambda}$ (1) Correct substitution (2) (1 for E and h; 1 for c) Final value of λ (1) Sig figs: Accept $6\cdot6\times10^{-7}$, $6\cdot564\times10^{-7}$, $6\cdot5644\times10^{-7}$
		(ii) (B)	Red (1)	1	or consistent with (A) If wavelength stated in this part, then colour must be consistent with this value

MARKS DO NOT WRITE IN THIS MARGIN

13. A technician sets up a circuit as shown.



The power supply has negligible internal resistance.

(a) The capacitor is initially uncharged.

The switch is moved to position P and the capacitor charges.

(i) State the potential difference across the capacitor when it is fully charged. **1**

(ii) Calculate the maximum energy stored by the capacitor. **3**

Space for working and answer

13. (continued)

MARKS DO NOT WRITE IN THIS MARGIN

(b) The switch is now moved back to position Q.

Determine the maximum discharge current in the circuit. **3**

Space for working and answer

(c) The technician replaces the 150 mF capacitor with a capacitor of capacitance 47 mF.

The switch is moved to position P and the capacitor is fully charged.

The switch is now moved to position Q.

State the effect that this change has on the time the lamp stays lit.

You must justify your answer. **2**

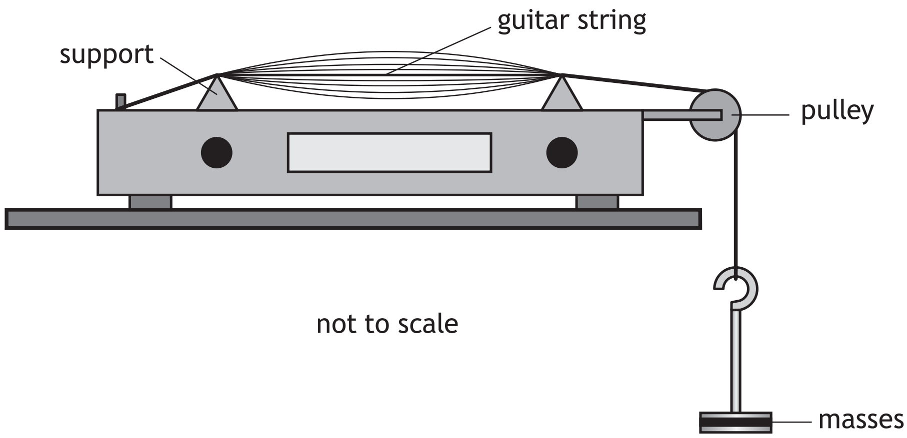
[Turn over for next question

Question			Answer	Max Mark	Additional Guidance
13.	(a)	(i)	12 V	1	Accept 12·0 V
		(ii)	$E = ½ C V^2$ (1) $E = ½ \times 150 \times 10^{-3} \times 12^2$ (1) $E = 11$ J (1)	3	Or consistent with a(i) Sig figs: 10 J 10·8 J 10·80 J $Q = CV$ and $E = \frac{1}{2}QV$ **OR** $Q = CV$ and $E = \frac{1}{2}\frac{Q^2}{C}$ (1) Both substitutions (1) Final answer (1)
	(b)		($R_T = 56 + 19 = 75$ (Ω)) $I = \frac{V}{R}$ (1) $I = \frac{12}{75}$ (1) $I = 0{\cdot}16$ A (1)	3	Or consistent with a(i) Candidates can arrive at this answer by alternative methods. Sig figs: 0·2 A 0·160 A 0·1600 A
	(c)		(Lamp stays lit for a) shorter time (1) (as smaller capacitance results in) less energy stored / less charge stored (1)	2	Look for this first Must provide relevant justification which is not wrong physics. If wrong physics - 0 marks. E is less because $E = ½\, C\, V^2$ is acceptable. If candidate says the current stays the same, they must identify it is the <u>initial</u> current.

MARKS | DO NOT WRITE IN THIS MARGIN

14. A student investigates the factors affecting the frequency of sound produced by a vibrating guitar string.

The guitar string is stretched over two supports and is made to vibrate as shown.



The frequency *f* of the sound produced by the vibrating string is given by the relationship

$$f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$$

where T is the tension in the string
L is the distance between the supports
. is the mass per unit length of the string.

(a) The tension in the string is 49·0 N and the mass per unit length of the string is $4{\cdot}00 \times 10^{-4}\,\text{kg m}^{-1}$.

The distance between the supports is 0·550 m.

Calculate the frequency f of the sound produced. **2**

Space for working and answer

* X 7 5 7 7 6 0 1 3 4 *

MARKS DO NOT WRITE IN THIS MARGIN

14. (continued)

(b) The guitar string in part (a) is replaced by a different guitar string.

A student varies the tension T and measures the frequency f of the sound produced by the new guitar string.

The student records the following information.

T (N)	$\sqrt{T}$ ($N^{1/2}$)	f (Hz)
10	3·2	162
15	3·9	190
20	4·5	220
25	5·0	254
30	5·5	273

(i) Using the square-ruled paper on *Page 36*, draw a graph of f against $\sqrt{T}$ **3**

(ii) Use your graph to determine the frequency of the sound produced when the tension in the guitar string is 22 N. **1**

[END OF QUESTION PAPER]

Question			Answer	Max Mark	Additional Guidance
14.	(a)		$f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$ $= \frac{1}{2 \times 0 \cdot 550}\sqrt{\frac{49 \cdot 0}{4 \cdot 00 \times 10^{-4}}}$ (1) $= 318\ \text{Hz}$ (1)	2	Substitution (1) Answer (1) Sig figs: Accept 320, 318·2, 318·18
	(b)	(i)	Suitable scales with labels on axes (quantity and units) (1) [Allow for axes starting at zero or broken axes or an appropriate value] Points plotted correctly (1) Best-fit straight line (1)	3	If the origin is shown the scale must either be continuous or the axis must be 'broken'. Otherwise maximum 2 marks. If an invalid scale is used on either axis eg values from the table are used as the scale points - 0 marks Do not penalise if candidates plot $\sqrt{T}$ against f Graphs of T and f are incorrect for (b)(i) - 0 marks, but can still gain marks for b(ii).
		(ii)	230 Hz	1	Must be consistent with the candidate's graph in (b)(i) ($\sqrt{22} = 4 \cdot 7$ gives) 230 Hz Correct value of $\sqrt{T}$ must be used If f against T is drawn in b(i), then this mark can still be accessed. If values from table are used as the scale points - 0 marks

[END OF MARKING INSTRUCTIONS]

H

National Qualifications 2017

X757/76/02

Physics
Section 1 — Questions

WEDNESDAY, 17 MAY

9:00 AM – 11:30 AM

Instructions for the completion of Section 1 are given on *Page 02* of your question and answer booklet X757/76/01.

Record your answers on the answer grid on *Page 03* of your question and answer booklet.

Reference may be made to the Data Sheet on *Page 02* of this booklet and to the Relationships Sheet X757/76/11.

Before leaving the examination room you must give your question and answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

X757760 2

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Speed of light in vacuum	c	$3{\cdot}00 \times 10^{8}\ \mathrm{m\,s^{-1}}$	Planck's constant	h	$6{\cdot}63 \times 10^{-34}\ \mathrm{J\,s}$
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}\ \mathrm{C}$	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}\ \mathrm{kg}$
Universal Constant of Gravitation	G	$6{\cdot}67 \times 10^{-11}\ \mathrm{m^3\,kg^{-1}\,s^{-2}}$	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}\ \mathrm{kg}$
Gravitational acceleration on Earth	g	$9{\cdot}8\ \mathrm{m\,s^{-2}}$	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}\ \mathrm{kg}$
Hubble's constant	H_0	$2{\cdot}3 \times 10^{-18}\ \mathrm{s^{-1}}$			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	*Refractive index*	*Substance*	*Refractive index*
Diamond	2·42	Water	1·33
Crown glass	1·50	Air	1·00

SPECTRAL LINES

Element	*Wavelength/nm*	*Colour*
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	*Wavelength/nm*	*Colour*
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	*Wavelength/nm*	*Colour*
Carbon dioxide	9550 } 10590	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

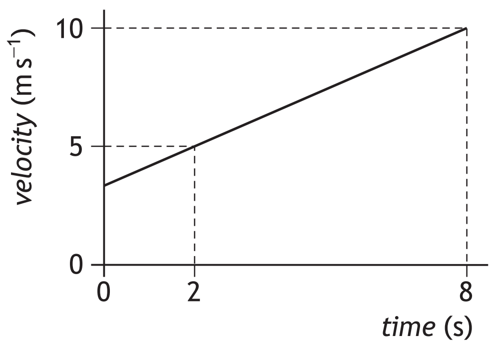
Substance	*Density/kg m^{-3}*	*Melting Point/K*	*Boiling Point/K*
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853
Ice	$9{\cdot}20 \times 10^{2}$	273	....
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377
Water	$1{\cdot}00 \times 10^{3}$	273	373
Air	1·29	....	....
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

SECTION 1 — 20 marks

Attempt ALL questions

1. The graph shows how the velocity of an object varies with time.



The acceleration of the object is

A $0{\cdot}83\ \text{m s}^{-2}$

B $1{\cdot}2\ \text{m s}^{-2}$

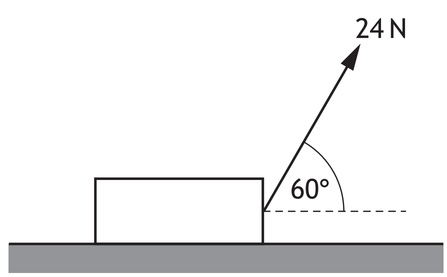
C $2{\cdot}5\ \text{m s}^{-2}$

D $5{\cdot}0\ \text{m s}^{-2}$

E $6{\cdot}0\ \text{m s}^{-2}$.

2. A block is resting on a horizontal surface.

A force of 24 N is now applied as shown and the block slides along the surface.



The mass of the block is 20 kg.

The acceleration of the block is $0{\cdot}20\ \text{m s}^{-2}$.

The force of friction acting on the block is

A 4·0 N

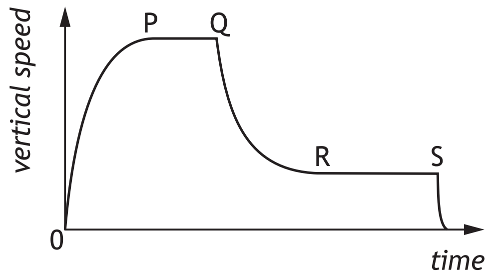
B 8·0 N

C 12 N

D 16 N

E 25 N.

3. The graph shows how the vertical speed of a skydiver varies with time.



A student uses information from the graph to make the following statements.

I The acceleration of the skydiver is greatest between P and Q.

II The air resistance acting on the skydiver between Q and R is less than the weight of the skydiver.

III The forces acting on the skydiver are balanced between R and S.

Which of these statements is/are correct?

A I only

B II only

C III only

D I and II only

E I , II and III

4. A spacecraft is travelling at a constant speed of $2{\cdot}75 \times 10^8\,\mathrm{m\,s^{-1}}$ relative to a planet.

A technician on the spacecraft measures the length of the spacecraft as 125 m.

An observer on the planet measures the length of the spacecraft as

A 36 m

B 50 m

C 124 m

D 314 m

E 433 m.

5. A galaxy has a recessional velocity of $0{\cdot}30c$.

Hubble's Law predicts that the distance between Earth and this galaxy is

A $1{\cdot}3 \times 10^{17}$ m

B $3{\cdot}9 \times 10^{25}$ m

C $1{\cdot}3 \times 10^{26}$ m

D $1{\cdot}4 \times 10^{41}$ m

E $4{\cdot}5 \times 10^{42}$ m.

6. Measurements of the expansion rate of the Universe lead to the conclusion that the rate of expansion is increasing.

Present theory proposes that this is due to

A redshift

B dark matter

C dark energy

D the gravitational force

E cosmic microwave background radiation.

7. A student makes the following statements about the radiation emitted by stellar objects.

I Stellar objects emit radiation over a wide range of frequencies.

II The peak wavelength of radiation is longer for hotter objects than for cooler objects.

III At all frequencies, hotter objects emit more radiation per unit surface area per unit time than cooler objects.

Which of these statements is/are correct?

A I only

B III only

C I and II only

D I and III only

E I, II and III

[Turn over

8. The following statement represents a nuclear reaction.

$^{256}_{103}\text{Lr} \rightarrow \text{Z} + ^{4}_{2}\text{He}$

Nucleus Z is

A $^{252}_{101}\text{Md}$

B $^{252}_{101}\text{No}$

C $^{256}_{101}\text{Md}$

D $^{260}_{105}\text{Db}$

E $^{252}_{103}\text{Lr}$.

9. Radiation is incident on a clean zinc plate causing photoelectrons to be emitted.

The source of radiation is replaced with one emitting radiation of a higher frequency.

The irradiance of the radiation incident on the plate remains unchanged.

Which row in the table shows the effect of this change on the maximum kinetic energy of a photoelectron and the number of photoelectrons emitted per second?

	Maximum kinetic energy of a photoelectron	*Number of photoelectrons emitted per second*
A	no change	no change
B	no change	increases
C	increases	no change
D	increases	decreases
E	decreases	increases

10. Ultraviolet radiation of frequency $7{\cdot}70 \times 10^{14}$ Hz is incident on the surface of a metal.

Photoelectrons are emitted from the surface of the metal.

The maximum kinetic energy of an emitted photoelectron is $2{\cdot}67 \times 10^{-19}$ J.

The work function of the metal is

A $1{\cdot}07 \times 10^{-19}$ J

B $2{\cdot}44 \times 10^{-19}$ J

C $2{\cdot}67 \times 10^{-19}$ J

D $5{\cdot}11 \times 10^{-19}$ J

E $7{\cdot}78 \times 10^{-19}$ J.

11. A student makes the following statements about waves from coherent sources.

I Waves from coherent sources have the same velocity.

II Waves from coherent sources have the same wavelength.

III Waves from coherent sources have a constant phase relationship.

Which of these statements is/are correct?

A I only

B II only

C I and II only

D I and III only

E I, II and III

[Turn over

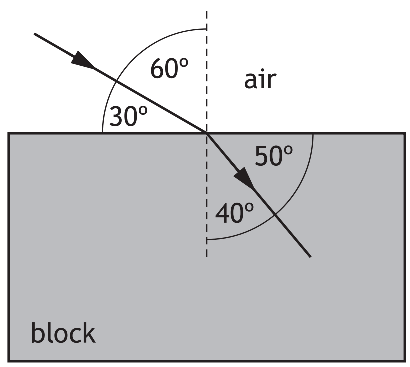
12. A ray of red light passes from a liquid to a transparent solid.

The solid and the liquid have the same refractive index for this light.

Which row in the table shows what happens to the speed and wavelength of the light as it passes from the liquid into the solid?

	Speed	*Wavelength*
A	decreases	decreases
B	decreases	increases
C	no change	increases
D	increases	no change
E	no change	no change

13. A ray of blue light passes from air into a transparent block as shown.



The speed of this light in the block is

A $1{\cdot}80 \times 10^{8}\,\mathrm{m\,s^{-1}}$

B $1{\cdot}96 \times 10^{8}\,\mathrm{m\,s^{-1}}$

C $2{\cdot}00 \times 10^{8}\,\mathrm{m\,s^{-1}}$

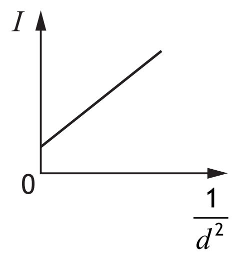
D $2{\cdot}23 \times 10^{8}\,\mathrm{m\,s^{-1}}$

E $2{\cdot}65 \times 10^{8}\,\mathrm{m\,s^{-1}}$.

14. A student carries out an experiment to investigate how irradiance varies with distance.

A small lamp is placed at a distance d away from a light meter. The irradiance I at this distance is displayed on the meter. This measurement is repeated for a range of different distances.

The student uses these results to produce the graph shown.



The graph indicates that there is a systematic uncertainty in this experiment.

Which of the following would be most likely to reduce the systematic uncertainty in this experiment?

A Repeating the readings and calculating mean values.

B Replacing the small lamp with a larger lamp.

C Decreasing the brightness of the lamp.

D Repeating the experiment in a darkened room.

E Increasing the range of distances.

15. A point source of light is 8·00 m away from a surface. The irradiance, due to the point source, at the surface is 50·0 mW m^{-2}. The point source is now moved to a distance of 12·0 m from the surface.

The irradiance, due to the point source, at the surface is now

A 22·2 mW m^{-2}

B 26·0 mW m^{-2}

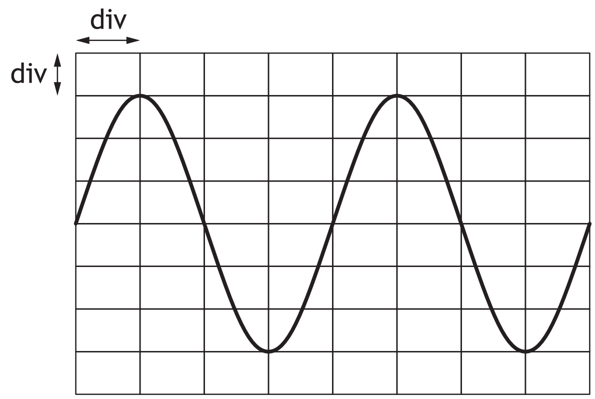
C 33·3 mW m^{-2}

D 75·0 mW m^{-2}

E 267 mW m^{-2}.

[Turn over

16. The output from an a.c. power supply is connected to an oscilloscope. The trace seen on the oscilloscope screen is shown.



The Y-gain setting on the oscilloscope is 1·0 V/div.

The r.m.s. voltage of the power supply is

A 2·1 V

B 3·0 V

C 4·0 V

D 4·2 V

E 6·0 V.

17. A 20 μF capacitor is connected to a 12 V d.c. supply.

The maximum charge stored on the capacitor is

A $1{\cdot}4 \times 10^{-3}$ C

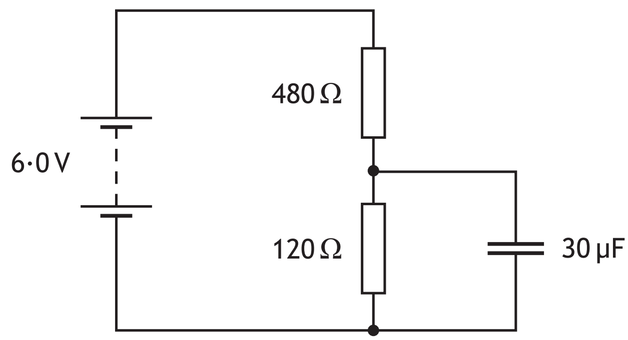
B $2{\cdot}4 \times 10^{-4}$ C

C $1{\cdot}4 \times 10^{-4}$ C

D $1{\cdot}7 \times 10^{-6}$ C

E $6{\cdot}0 \times 10^{-7}$ C.

18. A circuit containing a capacitor is set up as shown.



The supply has negligible internal resistance.

The maximum energy stored in the capacitor is

A $5{\cdot}4 \times 10^{-4}$ J

B $3{\cdot}5 \times 10^{-4}$ J

C $1{\cdot}4 \times 10^{-4}$ J

D $3{\cdot}4 \times 10^{-5}$ J

E $2{\cdot}2 \times 10^{-5}$ J.

19. A student makes the following statements about conductors, insulators and semiconductors.

I In conductors, the conduction band is completely filled with electrons.

II In insulators, the gap between the valence band and the conduction band is large.

III In semiconductors, increasing the temperature increases the conductivity.

Which of these statements is/are correct?

A I only

B II only

C III only

D I and II only

E II and III only

[Turn over for next question

20. Astronomers use the following relationship to determine the distance, d, to a star.

$$F = \frac{L}{4\pi d^2}$$

For a particular star the following measurements are recorded:

apparent brightness, $F = 4{\cdot}4 \times 10^{-10}$ W m^{-2}

luminosity, $L = 6{\cdot}1 \times 10^{30}$ W

Based on this information, the distance to this star is

A $3{\cdot}3 \times 10^{19}$ m

B $1{\cdot}5 \times 10^{21}$ m

C $3{\cdot}7 \times 10^{36}$ m

D $1{\cdot}1 \times 10^{39}$ m

E $3{\cdot}9 \times 10^{39}$ m.

[END OF SECTION 1. NOW ATTEMPT THE QUESTIONS IN SECTION 2 OF YOUR QUESTION AND ANSWER BOOKLET]

Marking instructions for each question

Section 1

Question	Answer	Max mark
1.	A	**1**
2.	B	**1**
3.	C	**1**
4.	B	**1**
5.	B	**1**
6.	C	**1**
7.	D	**1**
8.	A	**1**
9.	D	**1**
10.	B	**1**
11.	E	**1**
12.	E	**1**
13.	D	**1**
14.	D	**1**
15.	A	**1**
16.	A	**1**
17.	B	**1**
18.	E	**1**
19.	E	**1**
20.	A	**1**

FOR OFFICIAL USE

H

National Qualifications 2017

Mark

X757/76/01

Physics
Section 1 — Answer Grid and Section 2

WEDNESDAY, 17 MAY

9:00 AM – 11:30 AM

* X 7 5 7 7 6 0 1 *

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth

Day Month Year

Scottish candidate number

Total marks — 130

SECTION 1 — 20 marks

Attempt ALL questions.

Instructions for the completion of Section 1 are given on *Page 02*.

SECTION 2 — 110 marks

Attempt ALL questions.

Reference may be made to the Data Sheet on *Page 02* of the question paper X757/76/02 and to the Relationship Sheet X757/76/11.

Care should be taken to give an appropriate number of significant figures in the final answers to calculations.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. You should score through your rough work when you have written your final copy.

Use **blue** or **black** ink.

Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

* X 7 5 7 7 6 0 1 0 1 *

MARKS DO NOT WRITE IN THIS MARGIN

SECTION 2 — 110 marks

Attempt ALL questions

1. A student is on a stationary train.

The train now accelerates along a straight level track.

The student uses an app on a phone to measure the acceleration of the train.

(a) The train accelerates uniformly at $0{\cdot}32\,\mathrm{m\,s^{-2}}$ for 25 seconds.

(i) State what is meant by *an acceleration of $0{\cdot}32\,\mathrm{m\,s^{-2}}$*. **1**

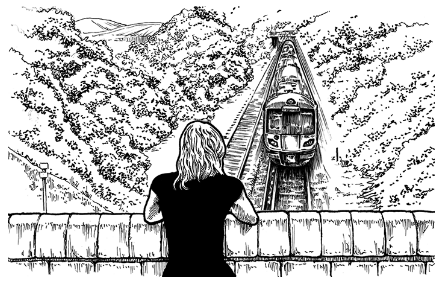
(ii) Calculate the distance travelled by the train in the 25 seconds. **3**

Space for working and answer

1. (continued)

MARKS DO NOT WRITE IN THIS MARGIN

(b) Later in the journey, the train is travelling at a constant speed as it approaches a bridge.



A horn on the train emits sound of frequency 270 Hz.

The frequency of the sound heard by a person standing on the bridge is 290 Hz.

The speed of sound in air is 340 m s^{-1}.

(i) Calculate the speed of the train. **3**

Space for working and answer

(ii) The train continues to sound its horn as it passes under the bridge.

Explain why the frequency of the sound heard by the person standing on the bridge decreases as the train passes under the bridge and then moves away.

You may wish to use a diagram. **1**

Section 2

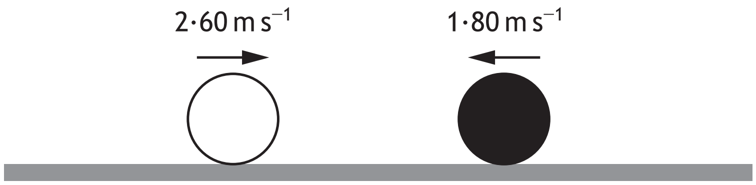
Question			Answer	Max mark	Additional guidance
1.	(a)	(i)	The velocity increases by $0{\cdot}32\ \mathrm{m\,s^{-1}}$ each/per second	1	Accept: Speed increases by … Rate of change of velocity/speed is … Train gets faster by … Velocity/speed changes by …
		(ii)	$s = ut + \frac{1}{2}at^2$ (1) $s = ((0 \times 25)) + (0{\cdot}5 \times 0{\cdot}32 \times 25^2)$ (1) $s = 100\ \mathrm{m}$ (1)	3	Accept: $v = u + at$ $v = (0) + 0{\cdot}32 \times 25$ $v = 8(\mathrm{ms^{-1}})$ $v^2 = u^2 + 2as$ $8^2 = (0^2) + (2 \times 0{\cdot}32 \times s)$ $s = 100\ \mathrm{m}$ OR $s = \frac{1}{2}(u+v)t$ or $s = \bar{v}\,t$ $s = \frac{1}{2}((0) + 8) \times 25$ $s = 100\ \mathrm{m}$ Note: 1 mark for **ALL** equations 1 mark for **ALL** substitutions 1 mark for **correct answer**
	(b)	(i)	$f_o = f_s\left(\frac{v}{v \pm v_s}\right)$ (1) $290 = 270\left(\frac{340}{340 - v_s}\right)$ (1) $v_s = 23\,\mathrm{ms^{-1}}$ (1)	3	$f_o = f_s\left(\frac{v}{v - v_s}\right)$ is also acceptable Accept 20, 23·4, 23·45
		(ii)	Statement that there are fewer wavefronts per second. **OR** The wavefronts are further apart **OR** The wavelength increases **OR** diagram showing wavefronts closer together ahead of the train and further apart behind it. or any similar response	1	In a diagram, there must be an implication of direction of travel. Do Not Accept Any answer that implies that the frequency/wavelength of the horn itself is changing.

MARKS DO NOT WRITE IN THIS MARGIN

2. A white snooker ball and a black snooker ball travel towards each other in a straight line.

The white ball and the black ball each have a mass of 0·180 kg.

Just before the balls collide head-on, the white ball is travelling at $2{\cdot}60\,\mathrm{m\,s^{-1}}$ to the right and the black ball is travelling at $1{\cdot}80\,\mathrm{m\,s^{-1}}$ to the left.



After the collision, the black ball rebounds with a velocity of $2{\cdot}38\,\mathrm{m\,s^{-1}}$ to the right.

(a) (i) Determine the velocity of the white ball immediately after the collision. **3**

Space for working and answer

(ii) The collision between the balls is inelastic.

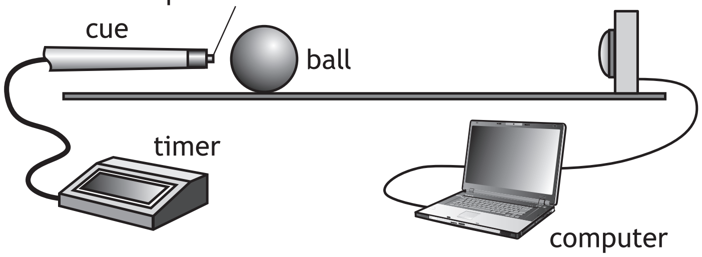
State what is meant by an *inelastic collision*. **1**

X757760108

2. (continued)

MARKS DO NOT WRITE IN THIS MARGIN

(b) A student carries out an experiment to measure the average force exerted by a cue on a ball.



The cue hits the stationary ball.

The timer records the time the cue is in contact with the ball.

The computer displays the speed of the ball.

The results are shown.

Time of contact between the cue and the ball = $(0{\cdot}040 \pm 0{\cdot}001)$ s

Speed of the ball immediately after contact = $(0{\cdot}84 \pm 0{\cdot}01)$ m s^{-1}

Mass of the ball = $(0{\cdot}180 \pm 0{\cdot}001)$ kg

(i) Calculate the average force exerted on the ball by the cue. An uncertainty in this value is not required. **3**

Space for working and answer

(ii) Determine the percentage uncertainty in the value for the average force on the ball. **2**

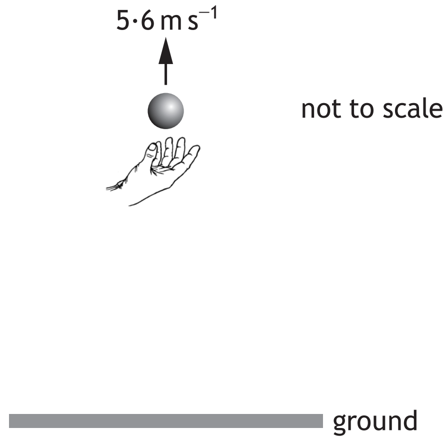
Space for working and answer

Question			Answer	Max mark	Additional guidance
2.	(a)	(i)	(total momentum before = total momentum after) $m_x u_x + m_y u_y = m_x v_x + m_y v_y$ (1) $(0 \cdot 180 \times 2 \cdot 60) + (0 \cdot 180 \times -1 \cdot 80)$ $= (0 \cdot 180 v_x + 0 \cdot 180 \times 2 \cdot 38)$ (1) $0 \cdot 468 - 0 \cdot 324 = 0 \cdot 180 v_x + 0 \cdot 4284$ $v_x = -1 \cdot 58 \text{ m s}^{-1}$ (1) (Accept '1·58 ms^{-1} to the left' or an indication of direction eg arrow left)	3	1 mark for equating the momentums before and after. 1 mark for the substitutions. 1 mark for answer including unit. Signs must be consistent. Allow cancellation of masses throughout the relationship. Accept $v_x = -1 \cdot 58 \text{ m s}^{-1}$ to the left as "loose" use of direction. Sig fig 1·6, 1·580, 1·5800
		(ii)	**kinetic** energy is lost/greater before the collision than after.	1	Do not accept: E_k before $\neq E_k$ after. E_k is not conserved.
	(b)	(i)	$Ft = mv - mu$ (1) $F \times 0 \cdot 040 = (0 \cdot 180 \times 0 \cdot 84) - (0 \cdot 180 \times 0)$ (1) $F = 3 \cdot 8 \text{N}$ (1)	3	Accept: $a = \frac{v-u}{t}$ $a = \frac{0 \cdot 84(-0)}{0 \cdot 040}$ $a = 21 (\text{m s}^{-2})$ $F = ma$ $F = 0 \cdot 180 \times 21$ $F = 3 \cdot 8 \text{ N}$ Sig figs 4, 3·78, 3·780 Note: 1 mark for **ALL** equations 1 mark for **ALL** substitutions 1 mark for **correct answer** Ignore any uncertainty calculations within this question.
		(ii)	$\left(\frac{0 \cdot 01}{0 \cdot 84} \times 100 = 1 \cdot 2\right)$ $\left(\frac{0 \cdot 001}{0 \cdot 180} \times 100 = 0 \cdot 56\right)$ $\frac{0 \cdot 001}{0 \cdot 040} \times 100 \ (=2 \cdot 5)$ (1) (Uncertainty in F is) $2 \cdot 5\%$ (1)	2	1 mark for correct or implied working for % uncertainty in t. 1 mark for indicating 2·5% as the largest. Must have % in final answer – equivalent to 'unit'. Accept: 3%

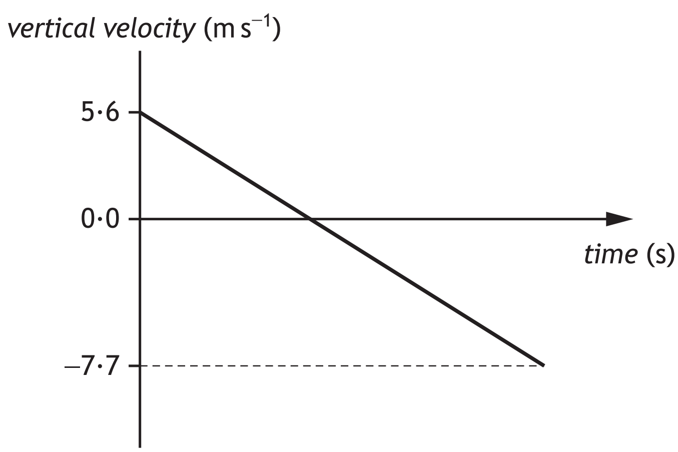
MARKS DO NOT WRITE IN THIS MARGIN

3. A ball is thrown vertically upwards.

The ball is above the ground when released.



The graph shows how the vertical velocity of the ball varies with time from the instant it is released until just before it hits the ground.



The effects of air resistance can be ignored.

(a) (i) Calculate the time taken for the ball to reach its maximum height. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

3. (a) (continued)

(ii) Calculate the distance the ball falls from its maximum height to the ground. **3**

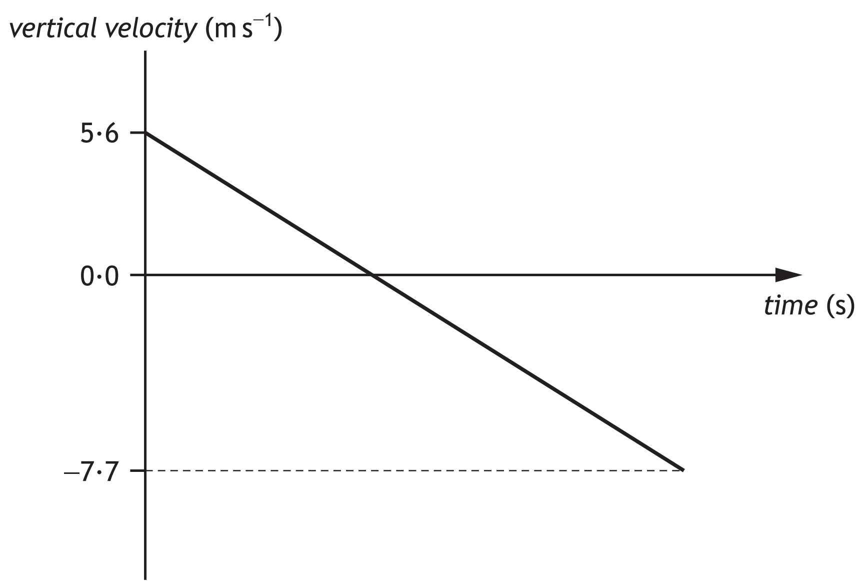
Space for working and answer

(b) The ball is now thrown vertically upwards from the same height with a greater initial vertical velocity.

Add a line to the graph below to show how the vertical velocity of the ball varies with time from the instant it is released until just before it hits the ground.

The effects of air resistance can be ignored.

Additional numerical values on the axes are not required. **3**



(An additional graph, if required, can be found on *Page 39*.)

Question			Answer	Max mark	Additional guidance
3.	(a)	(i)	$v = u + at$ 1 $0 = 5 \cdot 6 + (-9 \cdot 8)t$ 1 $t = 0 \cdot 57$ s 1	**3**	u and a must have opposite signs Accept $0 = 5 \cdot 6 - 9 \cdot 8t$ Accept 0·6, 0·571, 0·5714 Alternative method: $v^2 = u^2 + 2as$ $0^2 = 5 \cdot 6^2 + 2 \times (-9 \cdot 8) \times s$ $s = 1 \cdot 6$ (m) $s = \frac{1}{2}(u+v)t$ $1 \cdot 6 = \left(\frac{5 \cdot 6 + 0}{2}\right)t$ $t = 0 \cdot 57$ s If an alternative method is used, 1 mark for **ALL** equations 1 mark for **ALL** substitutions 1 mark for **correct answer** **If candidate answers question in terms of an object falling from the max height and reaching a velocity of 5·6ms^{-1}, then a suitable justification MUST be given to allow access to 2nd and 3rd marks.** **A negative value for time is wrong physics - max 1 mark.**

Question			Answer		Max mark	Additional guidance
3.	(a)	(ii)	$v^2 = u^2 + 2as$ $(-7\cdot7)^2 = 0^2 + 2\times(-9\cdot8)s$ $s = -3\cdot0\,\text{m}$ (Distance = 3·0 m)	1 1 1	3	v and a must have the same sign and calculated value of s must agree with sign convention used. Accept 3, 3·03, 3·025 Alternative method: $mgh = \frac{1}{2}mv^2$ $gh = \frac{1}{2}v^2$ $9\cdot8\times h = \frac{1}{2}\times7\cdot7^2$ $h = 3\cdot0\text{ m}$ If an alternative method is used, 1 mark for **ALL** equations 1 mark for **ALL** substitutions 1 mark for **correct answer**
	(b)		Starting point greater than 5·6 Final point beyond -7·7 Acceptably parallel line	1 1 1	3	Independent marks Must be one continuous acceptably straight line for third mark.

MARKS | DO NOT WRITE IN THIS MARGIN

4. Some motorways have variable speed limits, with overhead information boards displaying the maximum speed allowed. This system is designed to keep the traffic flowing and to avoid congestion.

In this system, the flow of traffic is observed and the maximum speed to be displayed is determined using

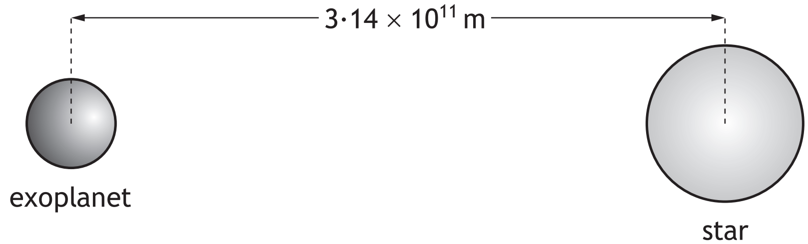
$$speed = frequency \times wavelength$$

Use your knowledge of physics to comment on this system for determining the maximum speed to be displayed. **3**

MARKS DO NOT WRITE IN THIS MARGIN

5. Planets outside our solar system are called exoplanets.

An exoplanet of mass $5{\cdot}69 \times 10^{27}$ kg orbits a star of mass $3{\cdot}83 \times 10^{30}$ kg.



not to scale

(a) (i) Compare the mass of the star with the mass of the exoplanet in terms of orders of magnitude. **2**

Space for working and answer

(ii) The distance between the exoplanet and the star is $3{\cdot}14 \times 10^{11}$ m.

Calculate the gravitational force between the star and the exoplanet. **3**

Space for working and answer

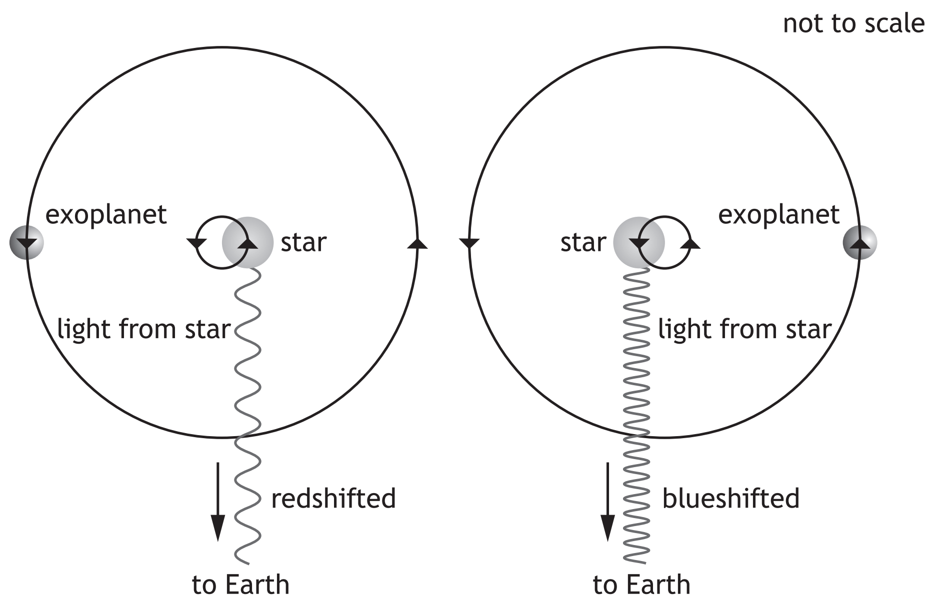
X757760114

MARKS DO NOT WRITE IN THIS MARGIN

5. (continued)

(b) The gravitational force between the star and the exoplanet causes the star to follow a circular path as the exoplanet orbits the star. Small differences in the wavelength of the light from the star are observed on Earth.

Light from the star is redshifted when the star moves away from the Earth and blueshifted when the star moves towards the Earth.



(i) Calculate the redshift of light from the star observed on Earth when the star is moving away from the Earth at $6{\cdot}60 \times 10^{3}\,\mathrm{m\,s^{-1}}$. **3**

Space for working and answer

(ii) For an exoplanet of greater mass at the same distance from the star, suggest whether the radius of the circular path followed by the star would be greater than, less than, or the same as that for an exoplanet of smaller mass. **1**

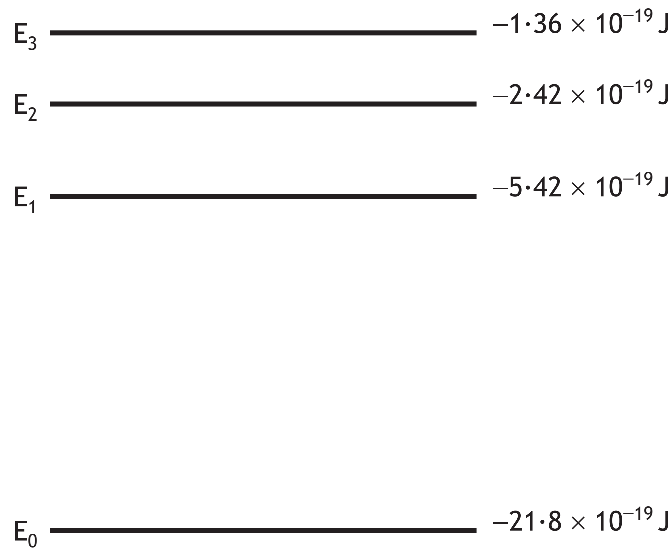
* X 7 5 7 7 6 0 1 1 5 *

Question			Answer	Max mark	Additional guidance
5.	(a)	(i)	$\left(\dfrac{3\cdot83\times10^{30}}{5\cdot69\times10^{27}}\right)=673$ 1 (Star is) 3 (orders of magnitude) <u>greater</u> 1 **OR** <u>Exoplanet</u> is 3 (orders of magnitude) <u>smaller</u>	**2**	Sig figs: accept 670, 673·1, 673·11 Or $\left(\dfrac{10^{30}}{10^{27}}\right)=1000$ or 10^3 Or $(30\text{-}27)=3$ **1** '3 greater' on its own is worth 2 marks. Care should be taken where candidates answer by the reciprocal method - 2 marks are still available. $\left(\dfrac{5\cdot69\times10^{27}}{3\cdot83\times10^{30}}\right)=1\cdot49\times10^{-3}$ **1** Comparison statement **1** 'Greater' on its own - 0 marks
		(ii)	$F=G\dfrac{m_1m_2}{r^2}$ 1 $F=6\cdot67\times10^{-11}\dfrac{5\cdot69\times10^{27}\times3\cdot83\times10^{30}}{\left(3\cdot14\times10^{11}\right)^2}$ 1 $F=1\cdot47\times10^{25}\text{ N}$ 1	**3**	Sig figs: Accept 1·5, 1·474, 1·4743
	(b)	(i)	$z=\dfrac{v}{c}$ 1 $z=\dfrac{6\cdot60\times10^{3}}{3\cdot00\times10^{8}}$ 1 $z=2\cdot20\times10^{-5}$ 1	**3**	Sig figs: Accept 2·2, 2·200, 2·2000
		(ii)	Greater (than)	**1**	Accept any word synonymous with 'greater'. Any correct suggestion followed by wrong physics 0 marks.

MARKS DO NOT WRITE IN THIS MARGIN

6. The visible spectrum of light emitted by a star is observed to contain a number of dark lines. The dark lines occur because certain wavelengths of light are absorbed when light passes through atoms in the star's outer atmosphere.

The diagram shows some of the energy levels for a hydrogen atom.



(a) For the energy levels shown in the diagram, identify the electron transition that would lead to the absorption of a photon with the highest frequency. **1**

(b) An electron makes the transition from energy level E_1 to E_3.

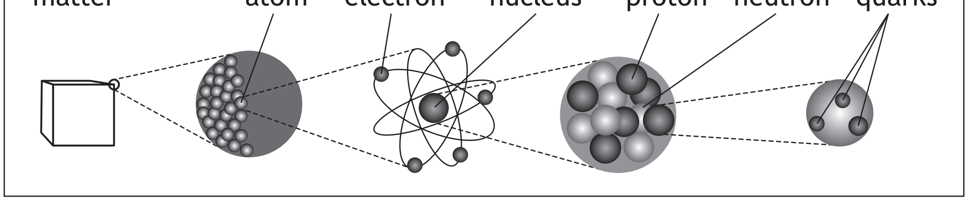
Determine the frequency of the photon absorbed. **3**

Space for working and answer

Question			Answer	Max mark	Additional guidance
6.	(a)		E_0 to E_3 $E_0 \rightarrow E_3$ Between E_0 and E_3	1	Could be shown by an arrow on the diagram showing the correct upwards transition. Direction must be correct. Do not accept: E_0 - E_3 Between E_3 and E_0
	(b)		$E_2 - E_1 = hf$ 1 $-1{\cdot}36\times10^{-19} - \left(-5{\cdot}42\times10^{-19}\right)$ $= 6{\cdot}63\times10^{-34}\times f$ 1 $f = 6{\cdot}12\times10^{14}$ Hz 1	3	Sig figs: Accept 6·1 , 6·124, 6·1237 Accept: $(\Delta)E = hf$ or $E_3 - E_1 = hf$ for formula mark $5{\cdot}42\times10^{-19} - 1{\cdot}36\times10^{-19}$ $= 6{\cdot}63\times10^{-34}\times f$ for substitution mark Note: Correct $\Delta E = 4{\cdot}06\times10^{-19} (J)$ $1{\cdot}36\times10^{-19} - 5{\cdot}42\times10^{-19}$ **for ΔE, maximum 1 mark for a correct formula.**

MARKS DO NOT WRITE IN THIS MARGIN

7. The following diagram gives information on the Standard Model of fundamental particles.



(a) Explain why the proton and the neutron are **not** fundamental particles. **1**

(b) An extract from a data book contains the following information about three types of sigma (.) particles. Sigma particles are made up of three quarks.

Particle	*Symbol*	*Quark Content*	*Charge*	*Mean lifetime* (s)
sigma plus	Σ^+	up up strange	$+1e$	$8{\cdot}0 \times 10^{-11}$
neutral sigma	Σ^0	up down strange	0	$7{\cdot}4 \times 10^{-20}$
sigma minus	Σ^-	down down strange	$-1e$	$1{\cdot}5 \times 10^{-10}$

(i) A student makes the following statement.

All baryons are hadrons, but not all hadrons are baryons.

Explain why this statement is correct. **2**

(ii) The charge on an up quark is $+\frac{2}{3}e$.

Determine the charge on a strange quark. **1**

Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

7. (continued)

(c) (i) State the name of the force that holds the quarks together in the sigma (Σ) particle. **1**

(ii) State the name of the boson associated with this force. **1**

(d) Sigma minus (Σ^-) particles have a mean lifetime of $1{\cdot}5 \times 10^{-10}$ s in their frame of reference.

Σ^- are produced in a particle accelerator and travel at a speed of $0{\cdot}9c$ relative to a stationary observer.

Calculate the mean lifetime of the Σ^- particle as measured by this observer. **3**

Space for working and answer

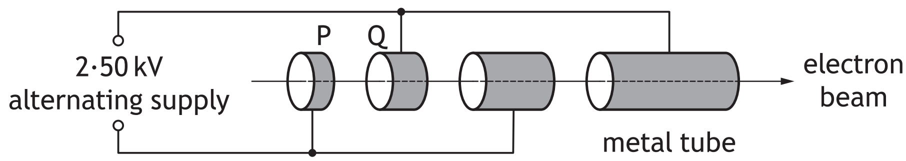
Question			Answer	Max mark	Additional guidance
7.	(a)		They are composed of other particles/quarks, (fundamental particles are not).	**1**	Accept they are composite particles.
	(b)	(i)	Baryons are (hadrons as they are) composed of (three) quarks. 1 Mesons/some hadrons are made from a quark - anti-quark pair so are not baryons. 1	**2**	For first mark, a correct statement that baryons consist of quarks. For second mark, a correct statement that there are other hadrons that have a different quark-count from baryons. Accept two quarks in place of quark-anti-quark pair.
		(ii)	- 1/3(e)	**1**	
	(c)	(i)	strong (nuclear force)	**1**	
		(ii)	gluon	**1**	**Or** consistent with (c)(i). A carry forward mark is only accessible if one of the four fundamental forces is identified in (c)(i).
	(d)		$t' = \dfrac{t}{\sqrt{1-\left(\dfrac{v}{c}\right)^2}}$ 1 $t' = \dfrac{1\cdot 5\times 10^{-10}}{\sqrt{1-\dfrac{(0\cdot 9c)^2}{c^2}}}$ 1 $t' = 3\cdot 4 \times 10^{-10}$ s 1	**3**	Accept: 3, 3·44, 3·441 Accept: $\dfrac{1\cdot 5\times 10^{-10}}{\sqrt{1-0\cdot 9^2}}$

MARKS DO NOT WRITE IN THIS MARGIN

8. X-ray machines are used in hospitals.

An X-ray machine contains a linear accelerator that is used to accelerate electrons towards a metal target.

The linear accelerator consists of hollow metal tubes placed in a vacuum.



Electrons are accelerated across the gaps between the tubes by an alternating supply.

(a) (i) Calculate the work done on an electron as it accelerates from P to Q. **3**

Space for working and answer

(ii) Explain why an alternating supply is used in the linear accelerator. **1**

X757760120

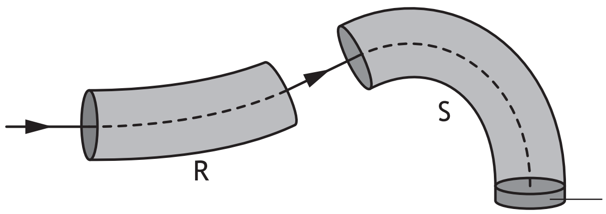
MARKS DO NOT WRITE IN THIS MARGIN

8. (continued)

(b) The electron beam is then passed into a "slalom magnet" beam guide. The function of the beam guide is to direct the electrons towards a metal target.

Inside the beam guides R and S, two different magnetic fields act on the electrons.

Electrons strike the metal target to produce high energy photons of radiation.



(i) Determine the direction of the magnetic field inside beam guide R. **1**

(ii) State **two** differences between the magnetic fields inside beam guides R and S. **2**

(c) Calculate the minimum speed of an electron that will produce a photon of energy $4{\cdot}16 \times 10^{-17}$ J. **3**

Space for working and answer

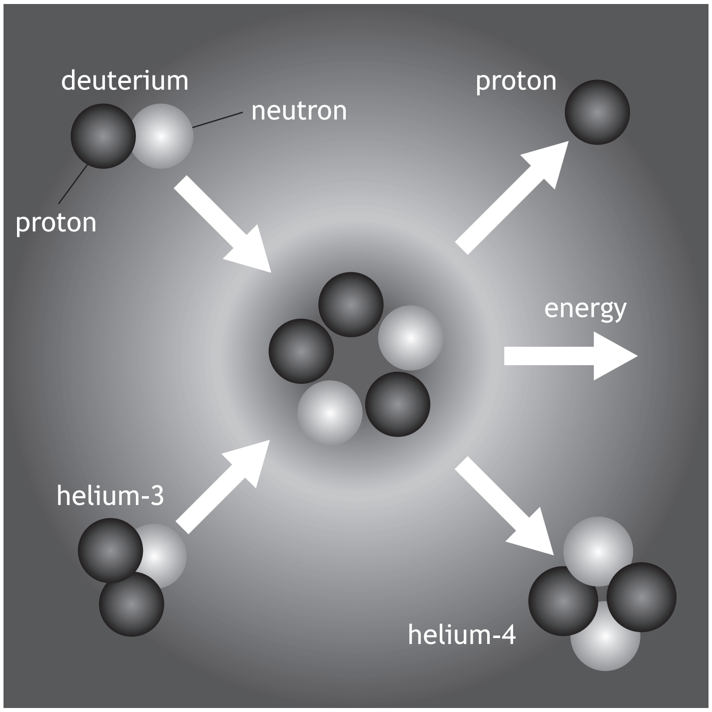
* X 7 5 7 7 6 0 1 2 1 *

Question			Answer	Max mark	Additional guidance
8.	(a)	(i)	W or $E_W = QV$ 1 $= 1{\cdot}60 \times 10^{-19} \times 2{\cdot}50 \times 10^3$ 1 $= 4{\cdot}00 \times 10^{-16}$ J 1	3	Suspend significant figure rule and accept 4×10^{-16} J. Ignore negative sign for charge.
		(ii)	Particle (always) accelerates in the same direction/forwards **OR** Force on particle/electron is always in same direction **OR** Ensure the direction of the electric field is correct when particle/ electron passes between (alternate) gaps	1	Candidate must make some implication of 'same direction'.
	(b)	(i)	Out of page	1	Do not accept: 'upwards' on its own, **OR** 'out of the page' with other comments such ad 'circular' 'clockwise'.
		(ii)	(Magnetic fields are in) <u>opposite</u> directions 1 (Magnetic field in) S is <u>stronger</u> than (field in) R 1	2	Independent marks Or consistent with (b)(i) for first mark as long as a <u>linear</u> field is described. Accept statement referring to direction of (magnetic field in) S alone ONLY if (b)(i) has been answered. Do not accept: 'different directions' 'force in S is opposite to force in R' alone.
	(c)		$E_K = \frac{1}{2}mv^2$ 1 $4{\cdot}16 \times 10^{-17} = \frac{1}{2} \times 9{\cdot}11 \text{ x } 10^{-31} \times v^2$ 1 $v = 9{\cdot}56 \times 10^6$ ms^{-1} 1	3	Accept: 9·6, 9·557, 9·5566

MARKS | DO NOT WRITE IN THIS MARGIN

9. A diagram from a 'How Things Work' website contains information about a nuclear fusion reaction.

Reaction of helium-3 with deuterium



(a) State what is meant by the term *nuclear fusion*. **1**

MARKS DO NOT WRITE IN THIS MARGIN

9. (continued)

(b) The following statement represents this fusion reaction.

$$^{3}_{2}He + ^{2}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{1}p$$

The mass of the particles involved in the reaction are shown in the table.

Particle	*Mass* (kg)
$^{3}_{2}He$	$5{\cdot}008 \times 10^{-27}$
$^{2}_{1}H$	$3{\cdot}344 \times 10^{-27}$
$^{4}_{2}He$	$6{\cdot}646 \times 10^{-27}$
$^{1}_{1}p$	$1{\cdot}673 \times 10^{-27}$

(i) Explain why energy is released in this reaction. **1**

(ii) Determine the energy released in this reaction. **4**

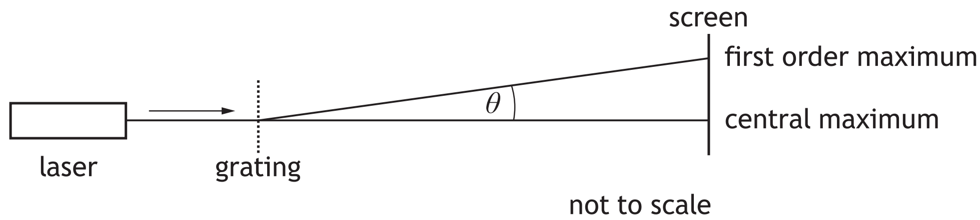
Space for working and answer

Question			Answer	Max mark	Additional guidance
9.	(a)		(Two) small nuclei combine to form a larger nucleus	**1**	Accept: ‘light’ and ‘heavy’. Accept: ‘fuse’, ‘join’ Do not accept: Atoms/molecules/particles/ isotopes/elements. Do not accept: ‘react’ in place of ‘combine’ or equivalent of ‘combining’.
	(b)	(i)	(Some) mass (is lost and) <u>converted</u> to energy	**1**	There must be an indication of mass being converted (or an equivalent term) to energy e.g. transformed, becomes, changed to etc… Do not accept: transferred… Mass is lost on its own – 0 marks. Mass defect is wrong physics – 0 marks.

Question			Answer	Max mark	Additional guidance
9.	(b)	(ii)	Mass before: $5{\cdot}008 \times 10^{-27} + 3{\cdot}344 \times 10^{-27}$ $= 8{\cdot}352 \times 10^{-27}$ Mass after: $6{\cdot}646 \times 10^{-27} + 1{\cdot}673 \times 10^{-27}$ $= 8{\cdot}319 \times 10^{-27}$ Mass "lost": $0{\cdot}033 \times 10^{-27}$ (kg) 1 $E = mc^2$ 1 $E = 0{\cdot}033 \times 10^{-27} \times (3{\cdot}00 \times 10^8)^2$ 1 $E = 2{\cdot}97 \times 10^{-12}$ J 1	**4**	$E = mc^2$ anywhere, 1 mark. Accept: 3·0, 2·970, 2·9700 Do not accept 3. Check for correct substitutions of values in calculation of mass "lost". If values are incorrect, maximum 1 mark for formula, even if final answer is correct. If mass before and after not used to 4 significant figures from table then stop marking - maximum 1 mark for formula. Ignore inappropriate reference to mass defect. Arithmetic mistake can be carried forward. Truncation error in mass before and/or mass after – maximum 1 mark for formula. If finding $E = mc^2$ for each particle, then $E = mc^2$ **1** All substitutions **1** Subtraction **1** Final answer **1**

MARKS DO NOT WRITE IN THIS MARGIN

10. An experiment is carried out to determine the wavelength of light from a laser.



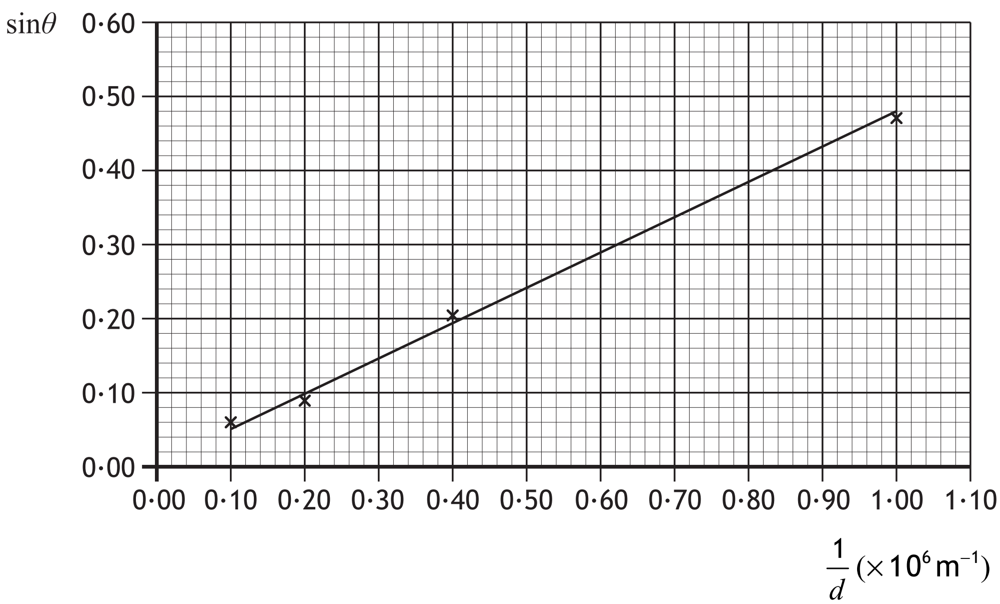
(a) Explain, in terms of waves, how a maximum is formed. **1**

(b) The experiment is carried out with four gratings.

The separation of the slits d is different for each grating.

The angle between the central maximum and the first order maximum θ, produced by each grating, is measured.

The results are used to produce a graph of $\sin\theta$ against $\frac{1}{d}$.



MARKS DO NOT WRITE IN THIS MARGIN

10. (b) (continued)

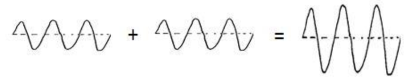
(i) Determine the wavelength of the light from the laser used in this experiment. **3**

Space for working and answer

(ii) Determine the angle θ produced when a grating with a spacing d of $2{\cdot}0 \times 10^{-6}$ m is used with this laser. **3**

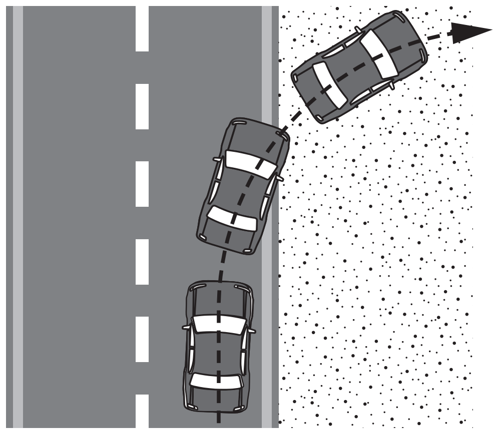
Space for working and answer

(c) Suggest **two** improvements that could be made to the experiment to improve reliability. **2**

Question			Answer	Max mark	Additional guidance
10.	(a)		Waves meet in phase OR Crest meets crest OR Trough meets trough OR Path difference = $m\lambda$	**1**	Accept 'peak' for 'crest'. Can be shown by diagram:  Do not accept 'join' or 'merge' alone.
	(b)	(i)	statement that λ = gradient or link λ to the gradient 1 subs to calculate gradient 1 $\lambda = 4{\cdot}8 \times 10^{-7}\text{m}$ 1	**3**	Acceptable range using the 'gradient' method, 4·7 to $5{\cdot}0\times10^{-7}$ m, but intermediate steps still need to be checked. If any of the plotted points on the graph ('x') are used, then maximum 1 for formula. $m\lambda = d \sin\theta$ 1 Accept : $\lambda = d\sin\theta$ in this case Subs of values **from line** 1 $\lambda = 4{\cdot}8 \times 10^{-7}\,\text{m}$ 1
		(ii)	($d = 2 \times 10^{-6}$ gives:) $\frac{1}{d} = 0{\cdot}50 \times 10^{6}$ 1 $\sin\theta = 0{\cdot}24$ from graph 1 $\theta = 14^{\circ}$ 1	**3**	Sig figs: Accept 10, 13·9, 13·89 Alternative method - $m\lambda = d\sin\theta$ 1 Accept: $\lambda = d\sin\theta$ in this case $1 \times 4{\cdot}8 \times 10^{-7} = 2{\cdot}0 \times 10^{-6} \times \sin\theta$ 1 $\theta = 14°$ 1 Or consistent with (b)(i).
	(c)		Any two correct answers from: Repeat measurements Use additional gratings Move screen further away Use second order maxima to determine θ Measure angle from first order to first order	**2**	Independent marks For the first point opposite, it must be clear that the candidate is implying that the measurements are being repeated. Do not accept: 'repeat the experiment' 'different sizes of slits/gratings' 'darkened room' Any additional improvements stated (beyond two) that reduce reliability, then ± rule applies.

MARKS DO NOT WRITE IN THIS MARGIN

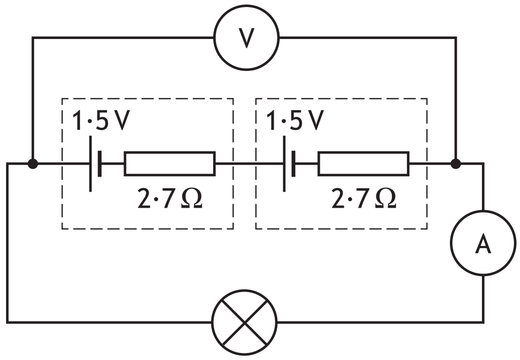
11. The use of analogies from everyday life can help better understanding of physics concepts. A car moving from a smooth surface to a rough surface, eg from a road to sand, can be used as an analogy for the refraction of light.



Use your knowledge of physics to comment on this analogy. **3**

MARKS DO NOT WRITE IN THIS MARGIN

12. A lamp is connected to a battery containing two cells as shown.



The e.m.f. of each cell is 1·5 V and the internal resistance of each cell is 2·7 Ω.

The reading on the ammeter is 64 mA.

(a) State what is meant by *an e.m.f. of 1·5 V*. **1**

(b) (i) Show that the lost volts in the battery is 0·35 V. **2**

Space for working and answer

(ii) Determine the reading on the voltmeter. **1**

Space for working and answer

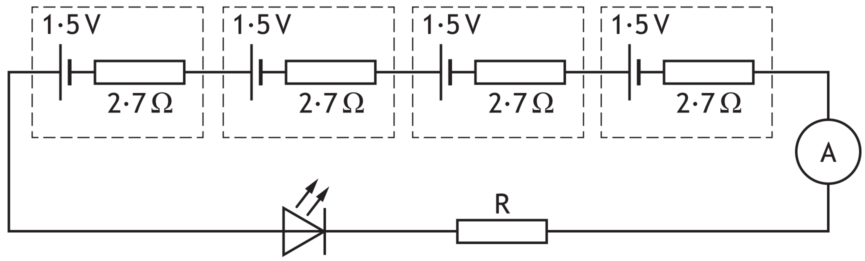
(iii) Calculate the power dissipated by the lamp. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

12. (continued)

(c) In a different circuit, an LED is connected to a battery containing four cells.



The potential difference across the LED is 3·6 V when the current is 26 mA.

Determine the resistance of resistor R. 4

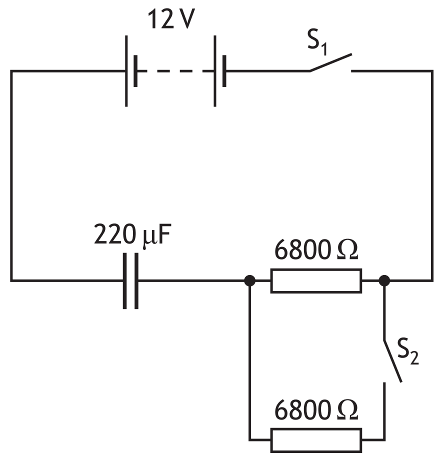
Space for working and answer

Question			Answer	Max mark	Additional guidance
12.	(a)		$1\cdot5$ J (of energy) is <u>supplied to/gained by</u> each coulomb (of charge passing through the cell).	**1**	Accept 'given to'… Accept 'battery'/'source'.
	(b)	(i)	lost volts = Ir 1 lost volts = $64 \times 10^{-3} \times (2 \times 2\cdot7)$ 1 lost volts = $0\cdot35$ V	**2**	**"SHOW" question.** Must start with a correct formula. Accept $V = IR$ Accept $5\cdot4$ as substitution for 'r' Accept working out lost volts for one cell, then doubling.
		(ii)	$V = 2\cdot7\ V$	**1**	Must use $0\cdot35\ V$ Do not accept 3V on its own, but if 3V is clearly shown as a rounded value - 1 mark.
		(iii)	$P = IV$ 1 $P = 64 \times 10^{-3} \times 2\cdot7$ 1 $P = 0\cdot17\ W$ 1	**3**	Or consistent with (b)(ii) Sig figs: Accept $0\cdot2$, $0\cdot173$, $0\cdot1728$

Question			Answer	Max mark	Additional guidance
12.	(c)		$V = E - Ir$ $V = 6{\cdot}0 - (26 \times 10^{-3} \times (4 \times 2{\cdot}7))$ 1 $V = 5{\cdot}7192\ (V)$ $R = \dfrac{V_R}{I}$ (both formulae) 1 $R = \dfrac{5{\cdot}7192 - 3{\cdot}6}{26 \times 10^{-3}}$ 1 $R = 82\ \Omega$ 1	4	1 mark for quoting **both** formulae - explicitly or implied. Sig figs: Accept 80, 81·5, 81·51 Alternative methods: $R_T = \dfrac{V}{I}$ $R_T = \dfrac{6{\cdot}0}{26 \times 10^{-3}} = 230{\cdot}8(\Omega)$ $R_{LED} = \dfrac{V}{I}$ $R_{LED} = \dfrac{3{\cdot}6}{26 \times 10^{-3}} = 138{\cdot}5(\Omega)$ $R = 230{\cdot}8 - (138{\cdot}5 + 10{\cdot}8)$ $R = 82\ \Omega$ $V = Ir$ $V = 26 \times 10^{-3} \times (2{\cdot}7 \times 4)$ $V = 0{\cdot}2808\ (V)$ $V_R = 6{\cdot}0 - 3{\cdot}6 - 0{\cdot}2808$ $V_R = 2{\cdot}1192\ (V)$ $R = \dfrac{V_R}{I}$ $R = \dfrac{2{\cdot}1192}{26 \times 10^{-3}}$ $R = 82\ \Omega$ 1 mark for all formulae 1 mark for all substitutions 1 mark for all correct intermediate values 1 mark for final answer

13. An uncharged 220 μF capacitor is connected in a circuit as shown.

MARKS DO NOT WRITE IN THIS MARGIN



The 12 V battery has negligible internal resistance.

(a) Switch S_1 is closed and the capacitor charges in a time of 7·5 s.

Calculate the initial charging current. **3**

Space for working and answer

(b) Switch S_1 is opened.

The capacitor is discharged.

Switch S_2 is now closed and then switch S_1 is closed.

Explain why the time for the capacitor to fully charge is less than in part (a). **2**

X 7 5 7 7 6 0 1 3 1

Question			Answer	Max mark	Additional guidance
13.	(a)		$V = IR$ 1 $12 = I \times 6800$ 1 $I = 1{\cdot}8 \times 10^{-3}\ A$ 1	**3**	Sig figs: Accept 2, 1·76, 1·765
	(b)		The (circuit/total) resistance is less 1 Initial charging current is greater 1	**2**	Independent marks. Accept: Average current is greater OR The current at any given time is greater. 'Current greater' on its own is not sufficient for 2^{nd} mark.

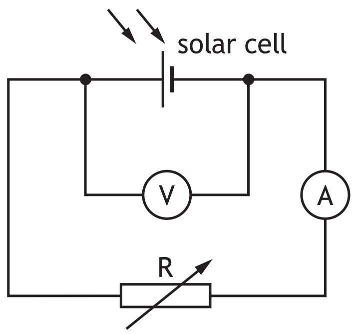
MARKS | DO NOT WRITE IN THIS MARGIN

14. Solar cells are made by joining n-type and p-type semiconductor materials. A layer is formed at the junction between the materials.

(a) A potential difference is produced when photons enter the layer between the p-type and n-type materials.

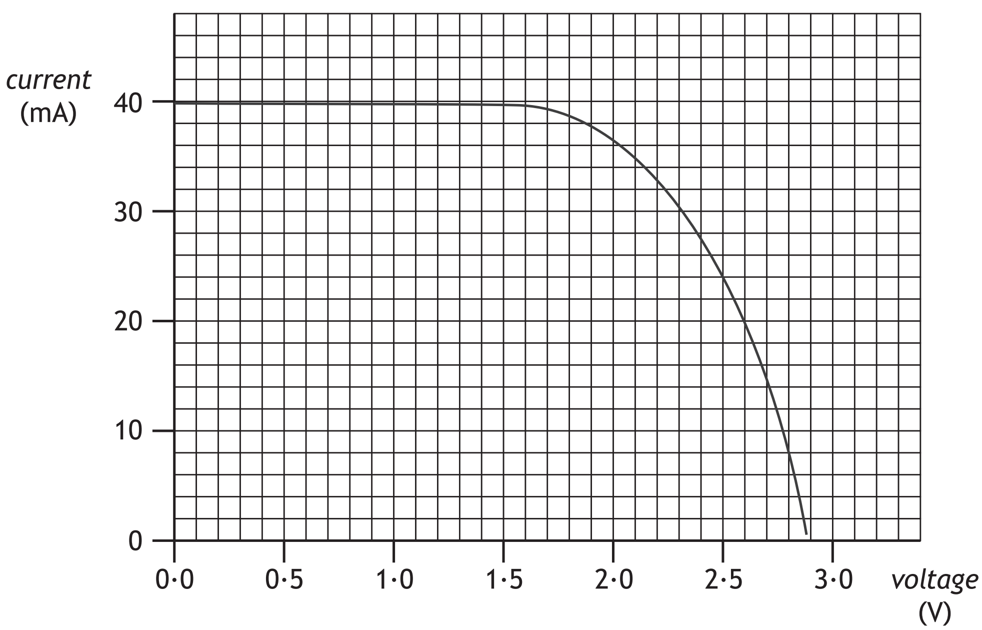
State the name of this effect. **1**

(b) A student carries out an experiment using a solar cell connected to a variable resistor R as shown.



A lamp is placed above the solar cell and switched on.

The variable resistor is altered and readings of current and voltage are taken. These readings are used to produce the following graph.



* X 7 5 7 7 6 0 1 3 2 *

14. (b) (continued)

(i) Solar cells have a maximum power output for a particular irradiance of light.

In this experiment, the maximum power output occurs when the voltage is 2·1 V.

Use information from the graph to estimate a value for the maximum power output from the solar cell. **3**

Space for working and answer

(ii) The lamp is now moved closer to the solar cell.

Explain, in terms of photons, why the maximum output power from the solar cell increases. **1**

Question			Answer	Max mark	Additional guidance
14.	(a)		Photovoltaic (effect)	**1**	
	(b)	(i)	$I = 35\ mA$ (from graph) 1 $P = IV$ 1 $(P = 0{\cdot}035 \times 2{\cdot}1)$ $P = 0{\cdot}074\ W$ 1	**3**	$P = IV$ anywhere, 1 mark. Sig figs: Accept 0·07, 0·0735 Accept a value for I between 34·5 and 35 mA inclusive. $I = 34{\cdot}5\ mA$ gives $P = 0{\cdot}073\ W$ Sig figs for above: Accept 0·07, 0·0725, 0·07245
		(ii)	Greater number of photons (strike the solar cell) per second	**1**	The answer has to imply a 'rate'. Any correct statement followed by wrong physics, 0 marks.

MARKS DO NOT WRITE IN THIS MARGIN

15. A wire of length L and cross-sectional area A is shown.

The resistance R of the wire is given by the relationship

$$R = \frac{\rho L}{A}$$

where ρ is the resistivity of the wire in Ω m.

(a) The resistivity of aluminium is $2{\cdot}8 \times 10^{-8}$ Ω m.

Calculate the resistance of an aluminium wire of length 0·82 m and cross-sectional area $4{\cdot}0 \times 10^{-6}$ m^2. **2**

Space for working and answer

15. (continued)

MARKS DO NOT WRITE IN THIS MARGIN

(b) A student carries out an investigation to determine the resistivity of a cylindrical metal wire of cross-sectional area $4{\cdot}52 \times 10^{-6}\,m^2$.

$4{\cdot}52 \times 10^{-6}\,m^2$

The student varies the length L of the wire and measures the corresponding resistance R of the wire.

The results are shown in the table.

Length of wire L (m)	*Resistance of wire* R ($\times 10^{-3}\,\Omega$)
1·5	5·6
2·0	7·5
2·5	9·4
3·0	11·2
3·5	13·2

(i) Using the square-ruled paper on *Page 36*, draw a graph of R against L. **3**

(ii) Calculate the gradient of your graph. **2**

Space for working and answer

(iii) Determine the resistivity of the metal wire. **3**

Space for working and answer

[END OF QUESTION PAPER]

* X 7 5 7 7 6 0 1 3 5 *

Question			Answer	Max mark	Additional guidance
15.	(a)		$R=\frac{\rho L}{A}$ $R=\frac{2\cdot8\times10^{-8}\times0\cdot82}{4\cdot0\times10^{-6}}$ 1 $R=5\cdot7\times10^{-3}\Omega$ 1	**2**	Sig figs: Accept 6×10^{-3} , $5\cdot74\times10^{-3}$, $5\cdot740\times10^{-3}$
	(b)	(i)	Suitable scales with labels on axes (quantity and unit) 1 [Allow for axes starting at zero or broken axes or starting at an appropriate value] Correct plotting of points 1 Best fit line 1	**3**	The scale must correctly extend over the range of the points plotted. The resistance scale must include ($\times10^{-3}$) or show correct converted values, otherwise maximum 2 marks. If an invalid scale is used on either axis eg values for resistance from the table are used as major grid line values - 0 marks. Accuracy of plotting should be easily checkable with scale chosen. If the origin on an axis is shown, the scale must either be continuous or the axis must be 'broken'. Otherwise maximum 2 marks. Do not penalise if candidates plot *L* against *R*.

Question			Answer	Max mark	Additional guidance
15.	(b)	(ii)	Choosing 2 points on <u>their</u> line 1 Calculate gradient : accept value between $3{\cdot}7 \times 10^{-3}$ and $4{\cdot}0 \times 10^{-3}$ ($\Omega\,\mathrm{m}^{-1}$) 1 (min 1 sig fig, max 4 sig figs)	**2**	**<u>Must</u>** be consistent with graph drawn for (b)(i). Candidates are asked to calculate the gradient of **<u>their graph</u>.** Calculated value must be consistent with the points selected. Data points x=3·0 and 3·5 give an acceptable gradient of $4{\cdot}0\times10^{-3}$. If the scale points <u>do not</u> lie on the line drawn outwith ± ½ box tolerance, the scale points cannot be used to calculate the gradient. If ($\times10^{-3}$) is not included in the final answer, maximum 1 mark unless this being omitted is consistent with the graph drawn in (b)(i). Unit is not required, but must be correct if stated and be consistent with graph drawn, otherwise maximum 1 mark.

Question			Answer		Max mark	Additional guidance
15.	(b)	(iii)	$\rho = gradient \times A$ $\rho = 3 \cdot 7 \times 10^{-3} \times 4 \cdot 52 \times 10^{-6}$ $\rho = 1 \cdot 7 \times 10^{-8}\ \Omega\text{m}$	1 1 1	**3**	Or consistent with (b)(ii). $gradient = 3 \cdot 7 \times 10^{-3}$ leads to $\rho = 1 \cdot 672 \times 10^{-8}\ \Omega\text{m}$ $gradient = 4 \cdot 0 \times 10^{-3}$ leads to $\rho = 1 \cdot 808 \times 10^{-8}\ \Omega\text{m}$ If the candidate has drawn a straight line through the origin (tolerance within ± 1 full box), then any point on the line can be used to calculate the resistivity. If the candidate has used a point on their line and uses continuous scales from zero, but has not extended their line back through the origin, then use the ruler tool to confirm that their line passes through the origin within tolerance. If the line drawn (or extrapolated line 'created' on Assessor) does NOT pass through the origin within ± 1 full box tolerance, the gradient of the line must be used and not one single point selected, otherwise 0 marks. If candidate has chosen an appropriate point on their line, 1 mark for selection of point 1 mark for correct substitution 1 mark for final answer. If ($\times 10^{-3}$) is missing from substitution, then maximum 1 mark if not corrected in the unit given with the final answer. If the candidate uses a broken scale on either axis, or does not start their scale at zero, they must use the gradient in their calculation of ρ, otherwise 0 marks. If candidate has plotted L against R, the formula becomes $\rho = \frac{1}{gradient} \times A$, otherwise 0 marks.

[END OF MARKING INSTRUCTIONS]

H

National Qualifications 2018

X757/76/02

Physics Section 1 — Questions

TUESDAY, 8 MAY

9:00 AM – 11:30 AM

Instructions for the completion of Section 1 are given on *page 02* of your question and answer booklet X757/76/01.

Record your answers on the answer grid on *page 03* of your question and answer booklet.

Reference may be made to the Data Sheet on *page 02* of this booklet and to the Relationships Sheet X757/76/11.

Before leaving the examination room you must give your question and answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

X757760 2

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Speed of light in vacuum	c	$3{\cdot}00 \times 10^{8}$ m s^{-1}	Planck's constant	h	$6{\cdot}63 \times 10^{-34}$ J s
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}$ C	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}$ kg
Universal Constant of Gravitation	G	$6{\cdot}67 \times 10^{-11}$ m^{3} kg^{-1} s^{-2}	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}$ kg
Gravitational acceleration on Earth	g	$9{\cdot}8$ m s^{-2}	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}$ kg
Hubble's constant	H_0	$2{\cdot}3 \times 10^{-18}$ s^{-1}			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	*Refractive index*	*Substance*	*Refractive index*
Diamond	2·42	Water	1·33
Crown glass	1·50	Air	1·00

SPECTRAL LINES

Element	*Wavelength*/nm	*Colour*
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	*Wavelength*/nm	*Colour*
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	*Wavelength*/nm	*Colour*
Carbon dioxide	9550, 10590	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	*Density*/kg m^{-3}	*Melting Point*/K	*Boiling Point*/K
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853
Ice	$9{\cdot}20 \times 10^{2}$	273	....
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377
Water	$1{\cdot}00 \times 10^{3}$	273	373
Air	1·29	....	....
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

SECTION 1 — 20 marks

Attempt ALL questions

1. A car is moving at a speed of $2\cdot0\,\mathrm{m\,s^{-1}}$.

The car now accelerates at $4\cdot0\,\mathrm{m\,s^{-2}}$ until it reaches a speed of $14\,\mathrm{m\,s^{-1}}$.

The distance travelled by the car during this acceleration is

A 1·5 m

B 18 m

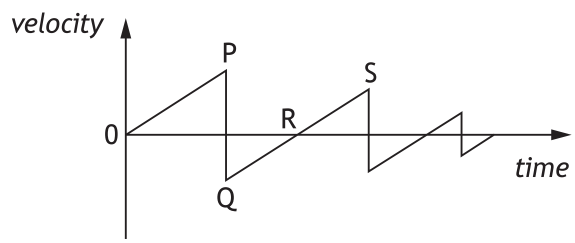
C 24 m

D 25 m

E 48 m.

2. A ball is dropped from rest and allowed to bounce several times.

The graph shows how the velocity of the ball varies with time.



A student makes the following statements about the ball.

I The ball hits the ground at P.

II The ball is moving upwards between Q and R.

III The ball is moving upwards between R and S.

Which of these statements is/are correct?

A I only

B II only

C III only

D I and II only

E I and III only

[Turn over

3. A block of mass 6·0 kg and a block of mass 8·0 kg are connected by a string.

A force of 32 N is applied to the blocks as shown.

A frictional force of 4·0 N acts on **each** block.

The acceleration of the 6·0 kg block is

A $1·7\,m\,s^{-2}$

B $2·0\,m\,s^{-2}$

C $2·3\,m\,s^{-2}$

D $2·9\,m\,s^{-2}$

E $5·3\,m\,s^{-2}$.

4. A person stands on a weighing machine in a lift. When the lift is at rest, the reading on the weighing machine is 700 N.

The lift now descends and its speed increases at a constant rate.

The reading on the weighing machine

A is a constant value higher than 700 N

B is a constant value lower than 700 N

C continually increases from 700 N

D continually decreases from 700 N

E remains constant at 700 N.

5. Enceladus is a moon of Saturn. The mass of Enceladus is $1·08 \times 10^{20}$ kg.

The mass of Saturn is $5·68 \times 10^{26}$ kg.

The gravitational force of attraction between Enceladus and Saturn is $7·24 \times 10^{19}$ N.

The orbital radius of Enceladus around Saturn is

A $2·38 \times 10^{8}$ m

B $9·11 \times 10^{13}$ m

C $5·65 \times 10^{16}$ m

D $8·30 \times 10^{27}$ m

E $3·19 \times 10^{33}$ m.

6. A spacecraft is travelling at 0·10c relative to a star.

An observer on the spacecraft measures the speed of light emitted by the star to be

A 0·90c

B 0·99c

C 1·00c

D 1·01c

E 1·10c.

7. A spacecraft is travelling at a speed of 0·200c relative to the Earth.

The spacecraft emits a signal for 20·0 seconds as measured in the frame of reference of the spacecraft.

An observer on Earth measures the duration of the signal as

A 19·2 s

B 19·6 s

C 20·0 s

D 20·4 s

E 20·8 s.

8. How many types of quark are there?

A 8

B 6

C 4

D 3

E 2

9. An electron is a

A boson

B hadron

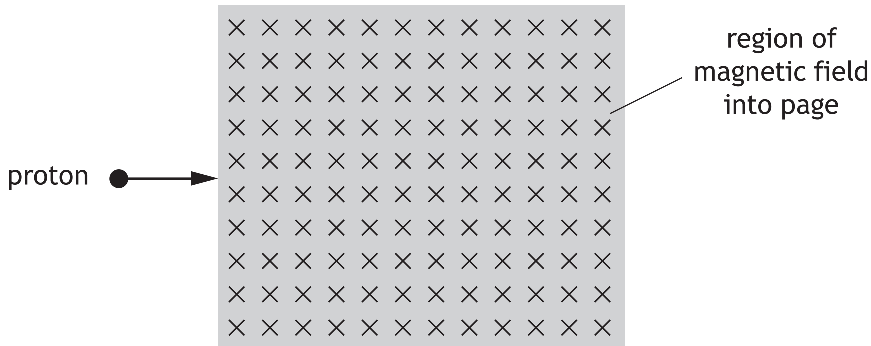
C baryon

D meson

E lepton.

[Turn over

10. A proton enters a region of magnetic field as shown.



On entering the magnetic field the proton

A deflects into the page

B deflects out of the page

C deflects towards the top of the page

D deflects towards the bottom of the page

E is not deflected.

11. A nuclear fission reaction is represented by the following statement.

$${}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{141}_{56}Ba + X + 3\,{}^{1}_{0}n$$

The nucleus represented by X is

A ${}^{96}_{40}Zr$

B ${}^{92}_{36}Kr$

C ${}^{97}_{40}Zr$

D ${}^{93}_{36}Kr$

E ${}^{94}_{40}Zr$.

12. The irradiance on a surface 0·50 m from a point source of light is I.

The irradiance on a surface 1·5 m from this source is

A 0·11I

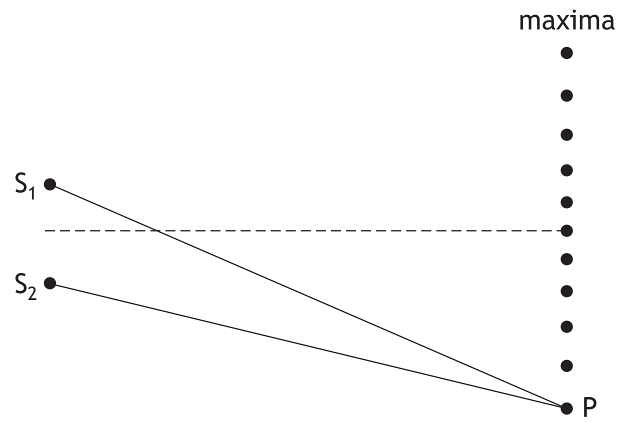
B 0·33I

C 1·5I

D 3·0I

E 9·0I.

13. Waves from two coherent sources, S_1 and S_2, produce an interference pattern. Maxima are detected at the positions shown below.



The path difference $S_1P - S_2P$ is 154 mm.

The wavelength of the waves is

A 15·4 mm

B 25·7 mm

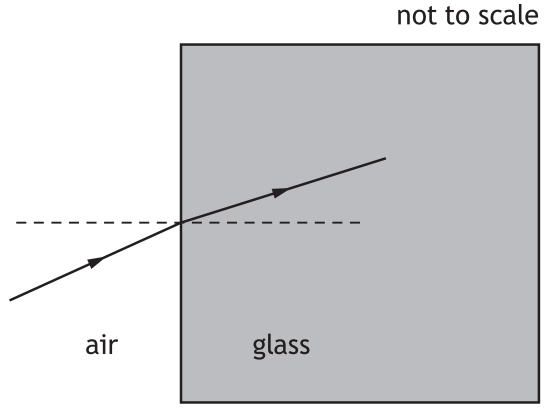
C 28·0 mm

D 30·8 mm

E 34·2 mm.

[Turn over

14. A ray of monochromatic light passes from air into a block of glass as shown.



The wavelength of this light in air is $6{\cdot}30 \times 10^{-7}$ m.

The refractive index of the glass for this light is 1·50.

The frequency of this light in the glass is

A $2{\cdot}10 \times 10^{-15}$ Hz

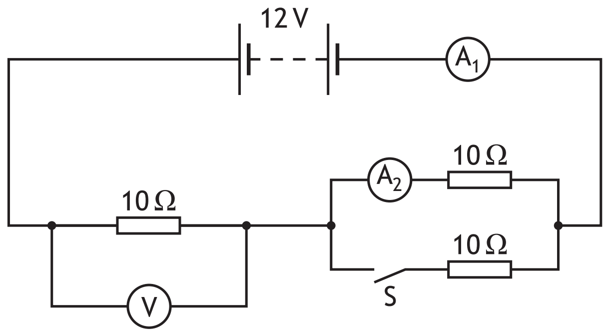
B $1{\cdot}26 \times 10^{2}$ Hz

C $1{\cdot}89 \times 10^{2}$ Hz

D $4{\cdot}76 \times 10^{14}$ Hz

E $7{\cdot}14 \times 10^{14}$ Hz.

15. A circuit is set up as shown.



The battery has negligible internal resistance.

A student makes the following statements about the readings on the meters in this circuit.

I When switch S is open the reading on the voltmeter will be 6·0 V.

II When switch S is open the reading on A_2 will be 0·60 A.

III When switch S is closed the reading on A_1 will be 0·80 A.

Which of these statements is/are correct?

A I only

B II only

C I and II only

D II and III only

E I, II and III

16. The power dissipated in a 120 Ω resistor is 4·8 W.

The current in the resistor is

A 0·020 A

B 0·040 A

C 0·20 A

D 5·0 A

E 25 A.

[Turn over

17. A $24 \cdot 0\,\mu F$ capacitor is charged until the potential difference across it is 125 V.

The charge stored on the capacitor is

A $5 \cdot 21 \times 10^{6}$ C

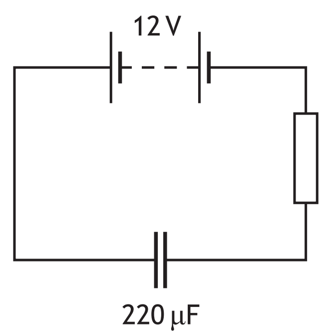
B $7 \cdot 75 \times 10^{-2}$ C

C $1 \cdot 50 \times 10^{-3}$ C

D $3 \cdot 00 \times 10^{-3}$ C

E $1 \cdot 92 \times 10^{-7}$ C.

18. A circuit is set up as shown.



When the capacitor is fully charged the energy stored in the capacitor is

A $1 \cdot 6 \times 10^{-5}$ J

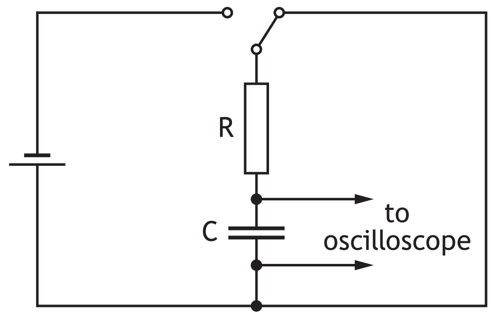
B $1 \cdot 3 \times 10^{-3}$ J

C $2 \cdot 6 \times 10^{-3}$ J

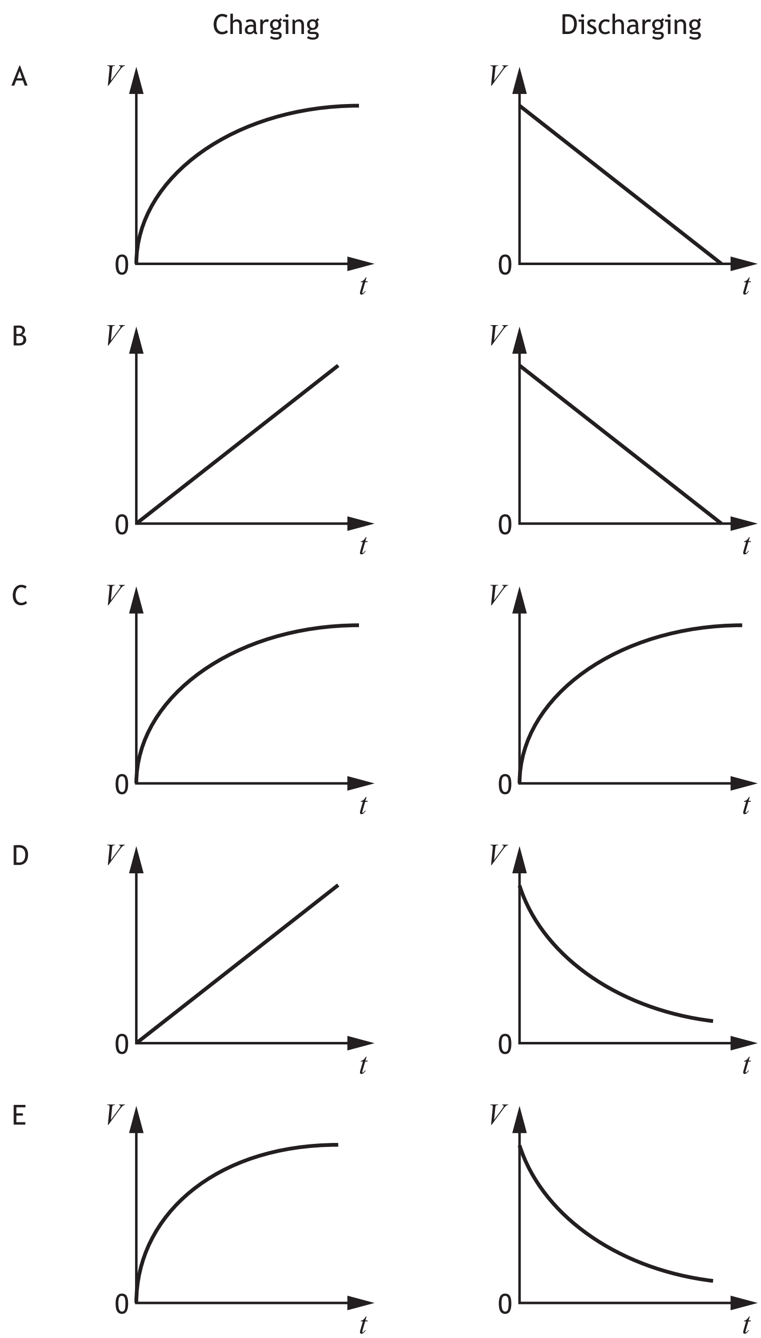
D $1 \cdot 6 \times 10^{-2}$ J

E $1 \cdot 6 \times 10^{4}$ J.

19. The circuit shown is used to charge and then discharge a capacitor C.



Which pair of graphs shows how the potential difference V across the capacitor varies with time t during charging and discharging?



20. A student carries out an experiment to determine the specific heat capacity c of a solid.

The relationship used to calculate c is

$$c = \frac{E}{m\Delta T}$$

The recorded measurements and their percentage uncertainties are shown.

energy supplied, $E = 5000\text{ J} \pm 1\%$

mass of solid, $m = 0{\cdot}20\text{ kg} \pm 2\%$

change in temperature, $\Delta T = 4{\cdot}5\text{ °C} \pm 5\%$

A good estimate of the percentage uncertainty in the calculated value of c is

A 8%

B 7%

C 5%

D 3%

E 1%.

[END OF SECTION 1. NOW ATTEMPT THE QUESTIONS IN SECTION 2 OF YOUR QUESTION AND ANSWER BOOKLET]

Marking instructions for each question

Section 1

Question	Answer	Mark
1.	C	1
2.	D	1
3.	A	1
4.	B	1
5.	A	1
6.	C	1
7.	D	1
8.	B	1
9.	E	1
10.	C	1
11.	B	1
12.	A	1
13.	D	1
14.	D	1
15.	E	1
16.	C	1
17.	D	1
18.	D	1
19.	E	1
20.	C	1

FOR OFFICIAL USE

H

National Qualifications 2018

Mark

X757/76/01

Physics
Section 1 — Answer Grid and Section 2

TUESDAY, 8 MAY

9:00 AM – 11:30 AM

* X 7 5 7 7 6 0 1 *

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth

Day Month Year

Scottish candidate number

Total marks — 130

SECTION 1 — 20 marks

Attempt ALL questions.

Instructions for the completion of Section 1 are given on *page 02*.

SECTION 2 — 110 marks

Attempt ALL questions.

Reference may be made to the Data Sheet on *page 02* of the question paper X757/76/02 and to the Relationships Sheet X757/76/11.

Care should be taken to give an appropriate number of significant figures in the final answers to calculations.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. You should score through your rough work when you have written your final copy.

Use **blue** or **black** ink.

Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

* X 7 5 7 7 6 0 1 0 1 *

MARKS DO NOT WRITE IN THIS MARGIN

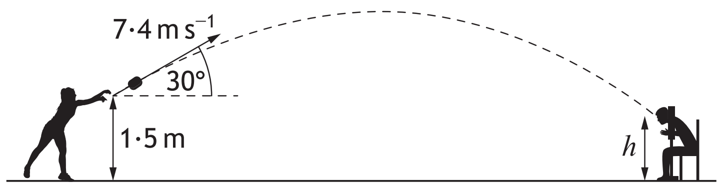
SECTION 2 — 110 marks

Attempt ALL questions

1. During a school funfair, a student throws a wet sponge at a teacher. The sponge is thrown with an initial velocity of $7 \cdot 4\,\mathrm{m\,s^{-1}}$ at an angle of 30° to the horizontal.

The sponge leaves the student's hand at a height of $1 \cdot 5\,\mathrm{m}$ above the ground.

not to scale



The sponge hits the teacher.

The effects of air resistance can be ignored.

(a) (i) Calculate:

(A) the horizontal component of the initial velocity of the sponge; **1**

Space for working and answer

(B) the vertical component of the initial velocity of the sponge. **1**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

1. (a) (continued)

(ii) Calculate the time taken for the sponge to reach its maximum height. 3

Space for working and answer

(iii) The sponge takes a further 0·45 s to travel from its maximum height until it hits the teacher.

Determine the height h above the ground at which the sponge hits the teacher. 4

Space for working and answer

(b) The student throwing the sponge makes the following statement.

"If the sponge is thrown with a higher speed at the same angle from the same height then it would take a shorter time to hit the teacher in the same place."

Explain why the student's statement is incorrect. 2

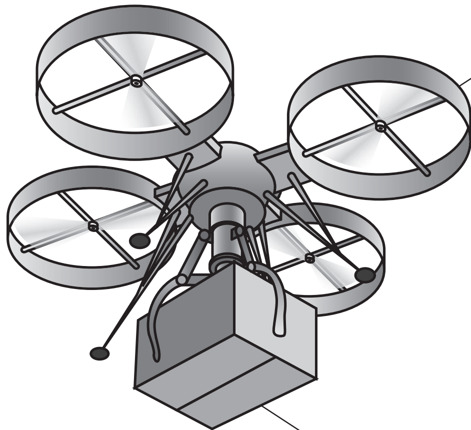
Section 2

Question			Answer	Max mark	Additional guidance
1.	(a)	(i) (A)	$u_h = 7 \cdot 4 \cos 30$ $u_h = 6 \cdot 4\ \text{m s}^{-1}$ **(1)**	**1**	Accept: 6, 6·41, 6·409
		(i) (B)	$u_v = 7 \cdot 4 \sin 30$ $u_v = 3 \cdot 7\ \text{m s}^{-1}$ **(1)**	**1**	Accept: 4, 3·70, 3·700
		(ii)	$v = u + at$ **(1)** $0 = 3 \cdot 7 + (-9 \cdot 8)t$ **(1)** $t = 0 \cdot 38$ s **(1)**	**3**	**OR** consistent with (a)(i)(B) u and a must have opposite signs Accept: 0·4, 0·378, 0·3776
		(iii)	$s = ut + \frac{1}{2}at^2$ **(1)** $s = (3 \cdot 7 \times 0 \cdot 83) + (0 \cdot 5 \times -9 \cdot 8 \times 0 \cdot 83^2)$ **(1)** $h = 1 \cdot 5 + \left((3 \cdot 7 \times 0 \cdot 83) \times \left(0 \cdot 5 \times -9 \cdot 8 \times 0 \cdot 83^2\right)\right)$ **(1)** $h = 1 \cdot 2$ m **(1)**	**4**	**OR** consistent with (a)(i)(B) and (a)(ii) Accept: 1, 1·20, 1·195 For alternative methods 1 mark for **ALL** relationships 1 mark for **ALL** substitutions 1 mark for addition relative to 1·5m 1 mark for **final answer** $s = \frac{1}{2}(u+v)t$ $s = \frac{1}{2} \times (3 \cdot 7 + 0) \times 0 \cdot 38$ $s = ut + \frac{1}{2}at^2$ $s = (0 \times 0 \cdot 45) + (0 \cdot 5 \times -9 \cdot 8 \times 0 \cdot 45^2)$ $h_{max} = 1 \cdot 5 + \left(\frac{1}{2} \times (3 \cdot 7 + 0) \times 0 \cdot 38\right)$ $h_{max} = 2 \cdot 203$ (m) $h = 2 \cdot 203 + (0 \cdot 5 \times -9 \cdot 8 \times 0 \cdot 45^2)$ $h = 1 \cdot 2$ m Accept 1, 1·21, 1·211 for this method.

Question			Answer	Max mark	Additional guidance
1.	(b)		(Initial) vertical/horizontal speed is greater. **(1)** Sponge is higher than the teacher when it has travelled the same horizontal distance. **OR** Sponge has travelled further horizontally when it is at the same height as the teacher. **(1)**	**2**	Look for this statement first - if incorrect or missing then 0 marks.

MARKS DO NOT WRITE IN THIS MARGIN

2. An internet shopping company is planning to use drones to deliver packages.



(a) During a test the drone is hovering at a constant height above the ground.

The mass of the drone is 5·50 kg.

The mass of the package is 1·25 kg.

(i) Determine the upward force produced by the drone. **3**

Space for working and answer

X757760108

MARKS DO NOT WRITE IN THIS MARGIN

2. (a) (continued)

(ii) The package is now lowered using a motor and a cable.

A battery supplies 12 V across the motor. The resistance of the motor is $9{\cdot}6\,\Omega$.

Calculate the power dissipated by the motor. **3**

Space for working and answer

(iii) While the package is being lowered the cable breaks.

The upward force produced by the drone remains constant.

Describe the vertical motion of the drone immediately after the cable breaks. **2**

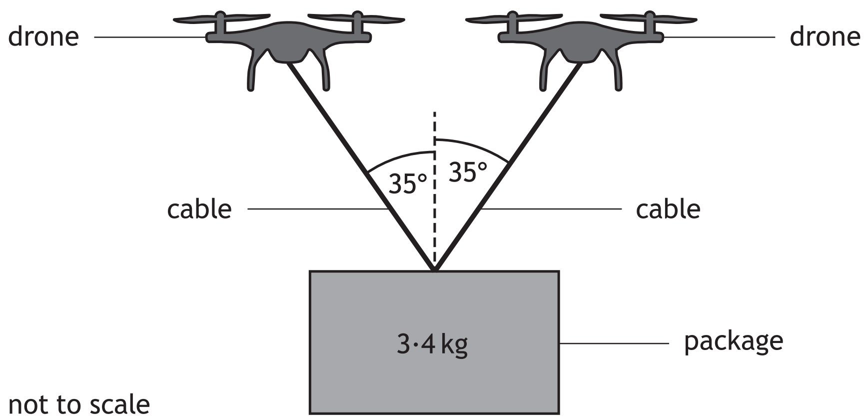
Justify your answer.

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

2. (continued)

(b) To carry a package with a greater mass two drones are used as shown.



The drones are hovering at a constant height above the ground.

The mass of the package suspended from the two drones is 3·4 kg.

Determine the tension in each cable. **4**

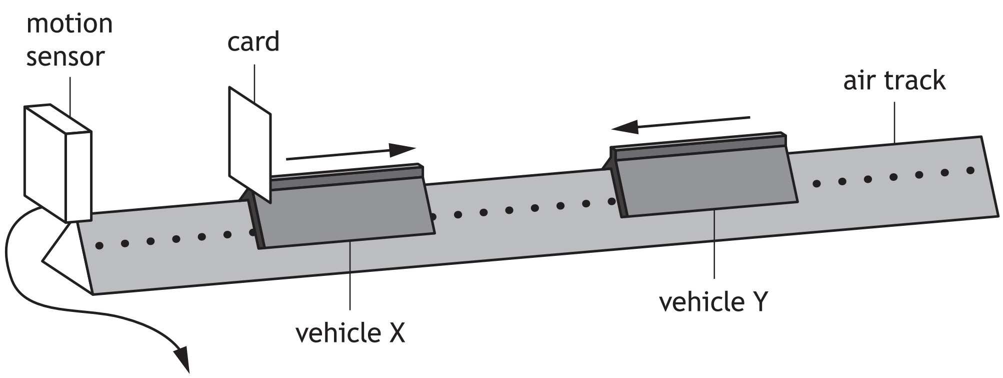
Space for working and answer

Question			Answer	Max mark	Additional guidance
2.	(a)	(i)	$W = mg$ **(1)** $W = (5\cdot50 + 1\cdot25) \times 9\cdot8$ **(1)** $W = 66$ N **(1)**	**3**	Accept: 70, 66·2, 66·15 In <u>this</u> question, ignore negative signs in both the substitution and final answer for weight. Do not accept: $F = ma$
	(ii)		$P = \frac{V^2}{R}$ **(1)** $P = \frac{12^2}{9\cdot6}$ **(1)** $P = 15$ W **(1)**	**3**	Accept: 20, 15·0, 15·00 For alternative methods 1 mark for **ALL** relationships 1 mark for **ALL** substitutions 1 mark for **final answer**
		(iii)	Drone <u>accelerates upwards</u> **(1)** Upward force is greater than weight **OR** (Upward force remains constant but) weight decreases therefore forces are no longer balanced. **OR** (Upward force remains constant but) weight decreases therefore there is an unbalanced force (upwards). **(1)**	**2**	Look for correct statement of effect first – if incorrect or missing then 0 marks. Accept free-body diagram to aid description of relative size and direction of forces acting on the drone.

Question			Answer	Max mark	Additional guidance
2.	(b)		$W = mg$ $W = 3 \cdot 4 \times 9 \cdot 8$ $W = 33 \cdot 32$ (N) **(1)** Each cord supports 33·32/2 = 16·66 (N) **(1)** $F \cos 35 = 16 \cdot 66$ **(1)** $F = 20$ N **(1)**	4	Accept: 20·3, 20·34 Accept: $F \sin 55 = 16 \cdot 66$ $F = 20$ N Alternative methods: Each cord supports 3·4/2 = 1·7 (kg) **(1)** $W = mg$ $W = 1 \cdot 7 \times 9 \cdot 8$ $W = 16 \cdot 66$ (N) **(1)** $F \cos 35 = 16 \cdot 66$ **(1)** $F = 20$ N **(1)** **OR** $W = mg$ $W = 3 \cdot 4 \times 9 \cdot 8$ $W = 33 \cdot 32$ (N) **(1)** $F \cos 35 = 33 \cdot 32$ **(1)** Tension in each cord = 40·6762093/2 = 20 N **(1)**

DO NOT WRITE IN THIS MARGIN

3. A student sets up an experiment to investigate a collision between two vehicles on a frictionless air track.

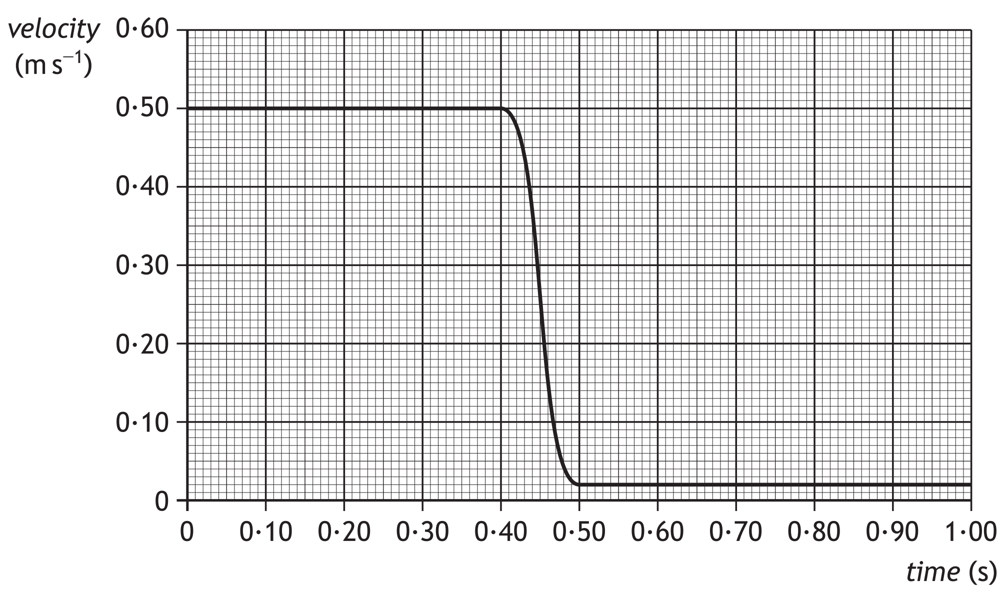


Vehicle X of mass 0·75 kg is travelling to the right along the track.

Vehicle Y of mass 0·50 kg is travelling to the left along the track with a speed of 0·30 m s^{-1}.

The vehicles collide and move off separately.

A computer displays a graph showing the velocity of vehicle X from just before the collision to just after the collision.



X 7 5 7 7 6 0 1 1 2

MARKS DO NOT WRITE IN THIS MARGIN

3. (continued)

(a) Show that the velocity of vehicle Y after the collision is $0{\cdot}42\,\mathrm{m\,s^{-1}}$. **2**

Space for working and answer

(b) Determine the impulse on vehicle Y during the collision. **3**

Space for working and answer

[Turn over

X757760113

MARKS DO NOT WRITE IN THIS MARGIN

3. (continued)

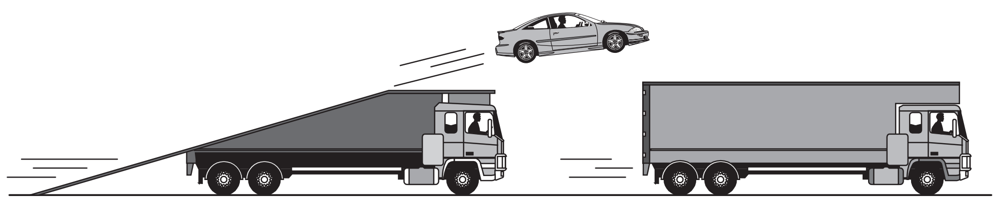
(c) Explain how the student would determine whether the collision was elastic or inelastic. **2**

Question			Answer	Max mark	Additional guidance
3.	(a)		(Total momentum before = Total momentum after) $p = mv$ OR **(1)** $(m_x u_x + m_y u_y) = (m_x v_x + m_y v_y)$ $(0 \cdot 75 \times 0 \cdot 50) + (0 \cdot 50 \times -0 \cdot 30) = (0 \cdot 75 \times 0 \cdot 02) + (0 \cdot 50 v_y)$ **(1)** $v_y = 0 \cdot 42$ m s^{-1}	2	**"SHOW" question** If sign convention is not applied then max 1 mark for formula.
	(b)		$Ft = mv - mu$ **(1)** $Ft = (0 \cdot 50 \times 0 \cdot 42) - (0 \cdot 50 \times -0 \cdot 30)$ **(1)** $Ft = 0 \cdot 36$ N s **(1)**	3	Accept: 0·4 Accept: $\text{Impulse} = mv - mu$ v and u must have opposite sign. Accept: kg m s^{-1}
	(c)		Calculate the <u>total</u> kinetic energy before and (<u>total</u> kinetic energy) after. **(1)** If E_k before is equal to E_k after the collision, is elastic. **OR** If E_k before is greater than E_k after, the collision is inelastic. **(1)**	2	Look for a statement relating to calculating/finding the <u>total</u> E_k before and after first, otherwise 0 marks. There must be an indication of total kinetic energy or equivalent term. Accept: If kinetic energy is not the same, collision is inelastic. Can show by calculation but would still require a statement for the second mark. Do not Accept: If kinetic energy is gained, collision is inelastic. If candidate says energy is lost then max 1 mark.

MARKS DO NOT WRITE IN THIS MARGIN

4. A stunt is being carried out during the making of a film.

A car is to be driven up a ramp on a moving lorry by a stunt driver, who will attempt to land the car safely on the roof of a second moving lorry. The car is to stop on the roof of the second lorry while this lorry is still moving.



Using your knowledge of physics, comment on the challenges involved in carrying out the stunt successfully. 3

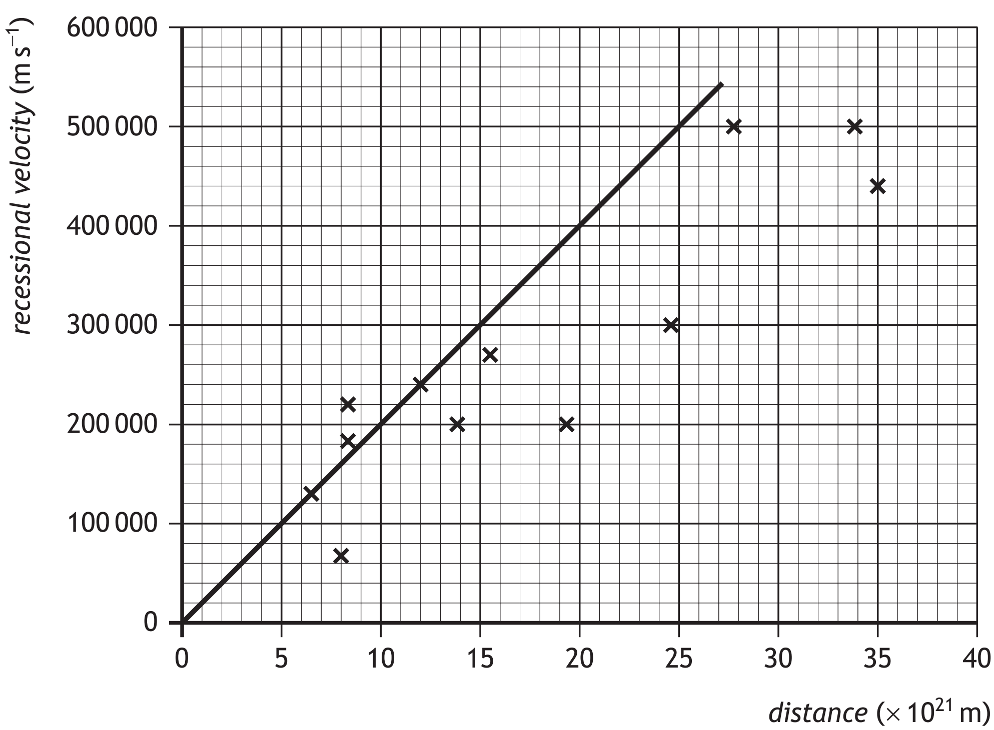
[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

5. Hubble's Law states that the universe is expanding. The expanding universe is one piece of evidence that supports the Big Bang theory.

(a) State one other piece of evidence that supports the Big Bang theory. **1**

(b) A student plots some of the original data from the 1929 paper by Edwin Hubble and adds the line shown in order to determine a value for the Hubble constant H_0.



The student calculates the gradient of their line and obtains a value for the Hubble constant of $2{\cdot}0 \times 10^{-17}\ s^{-1}$.

The age of the universe can be calculated using the relationship

$$\text{age of universe} = \frac{1}{H_0}$$

MARKS DO NOT WRITE IN THIS MARGIN

5. (b) (continued)

(i) Calculate the age of the universe, in years, obtained when using the student's value for the Hubble constant. **2**

Space for working and answer

(ii) The current estimate for the age of the universe is $13{\cdot}8 \times 10^9$ years.

(A) State why the value obtained in (b)(i) is different from the current estimate for the age of the universe. **1**

(B) Suggest a change that the student could make to their graph to obtain a value closer to the current estimate for the age of the universe. **1**

(c) It has been discovered that the rate of expansion of the universe is increasing.

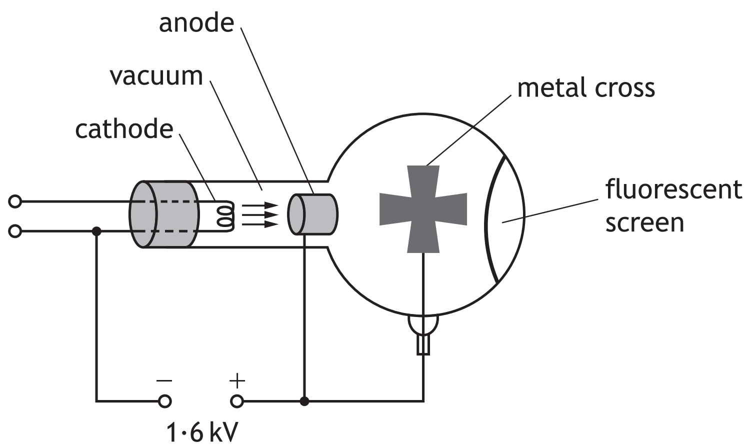
State what physicists think is responsible for this increase. **1**

Question			Answer	Max mark	Additional guidance
5.	(a)		Cosmic Microwave Background Radiation **OR** Olber's Paradox **OR** Abundance of Hydrogen and Helium in the Universe	**1**	Present temperature of the universe 2·7K (Blackbody radiation graph) Accept: Abundance of Light elements in the Universe Do not accept: the abbreviation "CMBR" on its own. Do not accept any further evidence based on redshift alone.
	(b)	(i)	$\left(\text{Age} = \frac{1}{H_0}\right)$ $\text{Age} = \frac{1}{2 \cdot 0 \times 10^{-17}}$ **(1)** $\left(\text{Age} = 5 \cdot 0 \times 10^{16}\ (\text{s})\right)$ $\text{Age} = 1 \cdot 6 \times 10^{9}$ (years) **(1)**	**2**	Accept: 2, 1·58, 1·584 Accept: 2, 1·59, 1·585 (365 days has been used – this does not need to be shown explicitly.) Years in brackets as question asks for age "in years".

Question			Answer	Max mark	Additional guidance
5.	(ii)	(A)	(Student's) value for H_0 is incorrect/too large/not accurate (enough). **OR** Incorrect line (of best fit) drawn. **OR** The (student's) gradient (which is H_0) is too large. **OR** New/more data is available/more accurate. **OR** Not enough data at large distances.	**1**	Accept: H_0 varies/decreases as age of the universe increases Do not accept: H_0 is different
		(B)	The student could draw the (correct) line of best fit. **OR** Student could use a larger sample/all of the 1929 Hubble data.	**1**	Accept: The student could use current data. Do not accept "different line of best fit" alone.
	(c)		Dark energy	**1**	

MARKS DO NOT WRITE IN THIS MARGIN

6. An experiment is set up to demonstrate a simple particle accelerator.



(a) Electrons are accelerated from rest between the cathode and the anode by a potential difference of 1·6 kV.

(i) Show that the work done in accelerating an electron from rest is $2{\cdot}6 \times 10^{-16}$ J. **2**

Space for working and answer

(ii) Calculate the speed of the electron as it reaches the anode. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

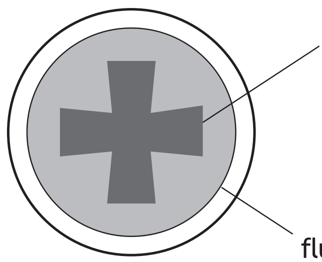
6. (continued)

(b) As the electrons travel through the vacuum towards the fluorescent screen they spread out.

In the path of the electrons there is a metal cross, which is connected to the positive terminal of the supply. The electrons that hit the cross are stopped by the metal.

Electrons that get past the metal cross hit a fluorescent screen at the far side of the tube.

When electrons hit the fluorescent screen, the screen glows.



The potential difference between the anode and the cathode is now increased to 2·2 kV. This changes what is observed on the screen.

Suggest one change that is observed. **2**

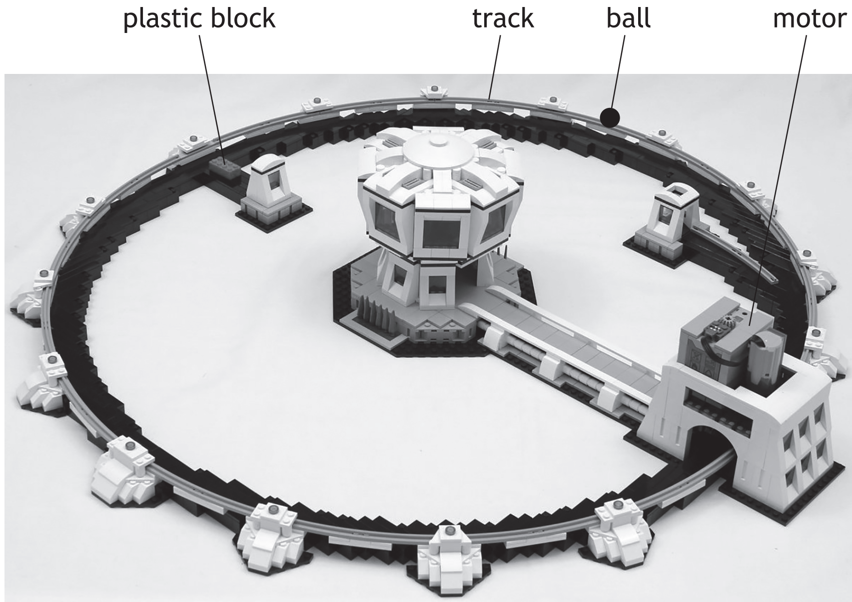
You must justify your answer.

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

6. (continued)

(c) A student builds a model of a particle accelerator. The model accelerates a small ball on a circular track. A battery-operated motor accelerates the ball each time it passes the motor. To cause a collision a plastic block is pushed onto the track. The ball then hits the block.



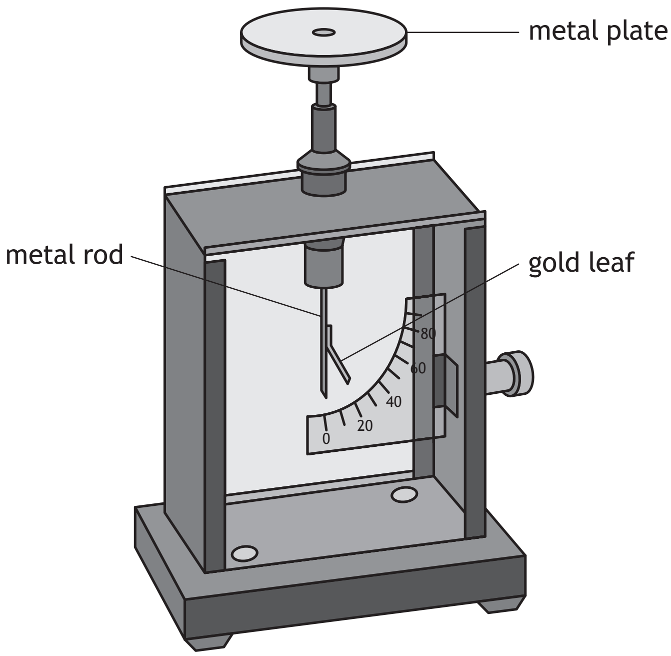
Using your knowledge of physics comment on the model compared to a real particle accelerator, such as the large hadron collider at CERN. **3**

Question			Answer	Max mark	Additional guidance
6.	(a)	(i)	$W = QV$ **(1)** $W = 1{\cdot}60\times10^{-19}\times1600$ **(1)** $W = 2{\cdot}6\times10^{-16}$ J	2	**"SHOW" question**
		(ii)	$E_K = \frac{1}{2}mv^2$ **(1)** $2{\cdot}6\times10^{-16} = \frac{1}{2}\times9{\cdot}11\times10^{-31}\times v^2$ **(1)** $v = 2{\cdot}4\times10^7$ m s^{-1} **(1)**	3	Accept: 2, 2·39, 2·389
	(b)		Screen will be brighter/increase glow. **(1)** Electrons will gain more energy/move faster. **OR** Increase in number of electrons <u>per second</u>. **(1)**	2	Look for correct statement of effect first - if incorrect or missing then 0 marks. Accept: Circle of brightness on fluorescent screen is reduced. (1) Greater force of attraction on the electrons due to the cross. (1) **OR** Cross on screen is sharper. (1) Greater force of attraction on the electrons due to the cross. (1) 'increase in current' alone is insufficient for the justification. Any correct statement followed by wrong physics, 0 marks. Any correct statement followed by no justification, 0 marks.

MARKS DO NOT WRITE IN THIS MARGIN

7. A student uses a gold-leaf electroscope to investigate the photoelectric effect. A deflection of the gold leaf on the electroscope shows that the metal plate is charged.

The student charges the metal plate on the electroscope and the gold leaf is deflected.



gold-leaf electroscope

(a) Ultraviolet light is shone onto the negatively charged metal plate. The gold-leaf electroscope does not discharge. This indicates that photoelectrons are not ejected from the surface of the metal.

Suggest one reason why photoelectrons are not ejected from the surface of the metal. **1**

MARKS DO NOT WRITE IN THIS MARGIN

7. (continued)

(b) The student adjusts the experiment so that the gold-leaf electroscope now discharges when ultraviolet light is shone onto the plate.

The work function for the metal plate is $6 \cdot 94 \times 10^{-19}$ J.

(i) State what is meant by a *work function of* $6 \cdot 94 \times 10^{-19}$ *J*. **1**

(ii) The irradiance of the ultraviolet light on the metal plate is reduced by increasing the distance between the gold-leaf electroscope and the ultraviolet light source.

State what effect, if any, this has on the maximum kinetic energy of the photoelectrons ejected from the surface of the metal. **2**

Justify your answer.

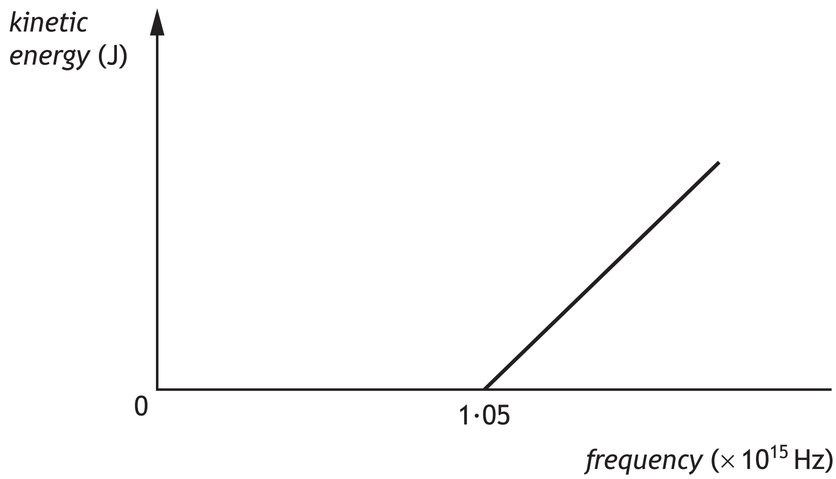
[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

7. (continued)

(c) The graph shows how the kinetic energy of the photoelectrons ejected from the metal plate varies as the frequency of the incident radiation increases.

The threshold frequency for the metal plate is $1{\cdot}05 \times 10^{15}$ Hz.



The metal plate is now replaced with a different metal plate made of aluminium.

The aluminium has a threshold frequency of $0{\cdot}99 \times 10^{15}$ Hz.

Add a line to the graph to show how the kinetic energy of the photoelectrons ejected from the aluminium plate varies as the frequency of the incident radiation increases. **2**

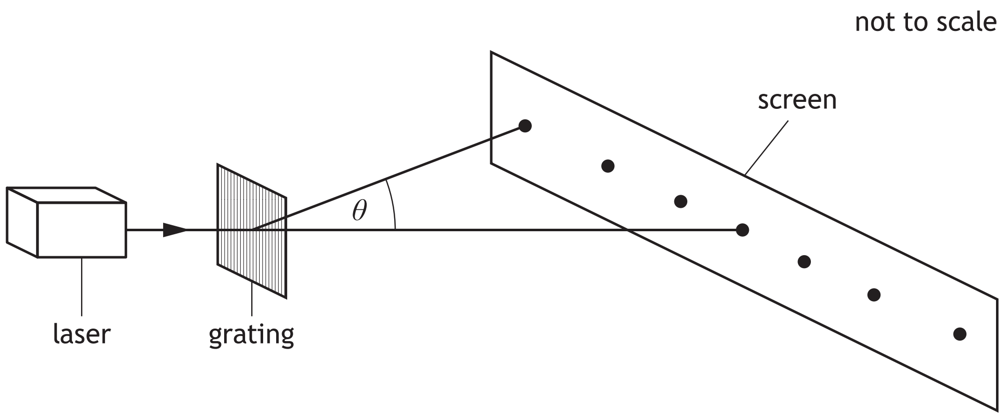
(An additional graph, if required, can be found on *page 45*.)

(d) Explain why the photoelectric effect provides evidence for the particle nature of light. **1**

Question			Answer	Max mark	Additional guidance
7.	(a)		Frequency of <u>UV/photons/light</u> is not high enough. **OR** Frequency of <u>UV/photons/light</u> is less than threshold frequency. **OR** Energy of <u>photons</u> (of UV light) is not high enough. **OR** Energy of <u>photons</u> (of UV light) is less than work function. **OR** May not be a 'clean plate'.	1	Do not accept "gold" for metal plate.
	(b)	(i)	$6{\cdot}94 \times 10^{-19}$ joules of energy is the <u>minimum</u> energy required for (photo) electrons to be emitted/ejected/ photoemission (of electrons).	1	Do not accept "to cause photoelectric effect" alone.
		(ii)	No change (to the kinetic energy). **(1)** As the irradiance does not affect the energy of the photons/ $E = hf$ is unchanged. **(1)**	2	Look for this first – if incorrect or missing then 0 marks.
	(c)		Lower starting frequency. **(1)** Same gradient. **(1)**	2	**Independent marks** Do not accept: Additional line starting at origin.
	(d)		Each photon contains a fixed/discrete amount of energy. **OR** Each photon removes one electron.	1	Some indication of quantisation of energy. If light was a wave then the photoelectric effect would occur regardless of the frequency of the light, it would just take longer for electrons to absorb the energy required to be ejected.

MARKS DO NOT WRITE IN THIS MARGIN

8. A student investigates interference of light by directing laser light of wavelength 630 nm onto a grating as shown.



(a) A pattern of bright spots is observed on a screen.

(i) Explain, in terms of waves, how bright spots are produced on the screen. **1**

(ii) The grating has 250 lines per millimetre.

Calculate the angle θ between the central maximum and the third order maximum. **3**

Space for working and answer

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

8. (a) (continued)

(iii) The grating is now replaced by one which has 600 lines per millimetre.

State the effect of this change on the pattern observed. **2**

Justify your answer.

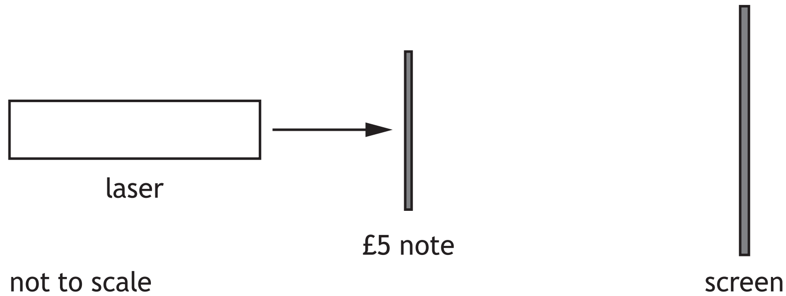
(iv) The interference pattern is produced by coherent light.

State what is meant by the term *coherent*. **1**

MARKS DO NOT WRITE IN THIS MARGIN

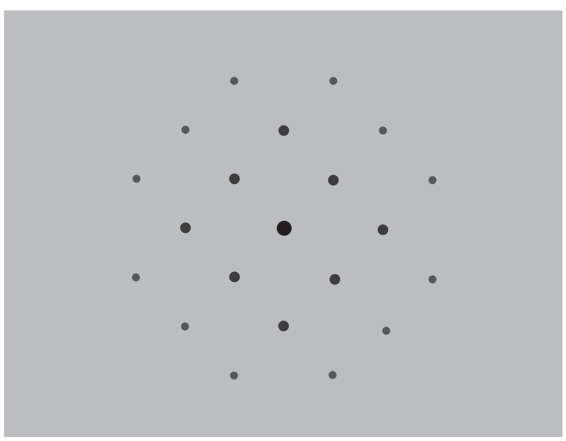
8. (continued)

(b) The student now shines light from the laser onto a £5 note.



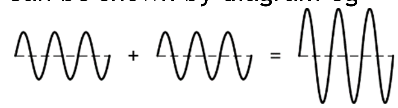
When it is shone through the transparent section of the note the student observes a pattern of bright spots on the screen.

The diagram below shows the pattern that the student observes on the screen.



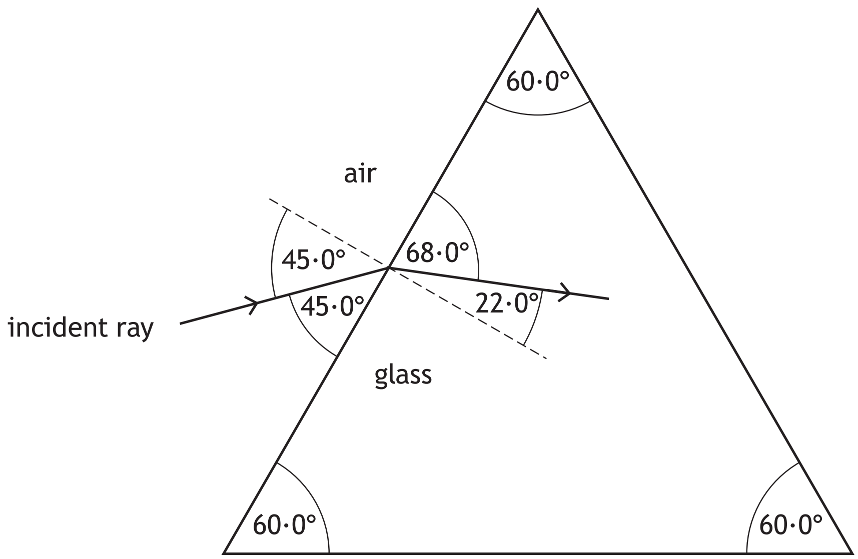
Suggest a reason for the difference in the pattern produced using the £5 note and the pattern produced using the grating. **1**

[Turn over

Question			Answer	Max mark	Additional guidance
8.	(a)	(i)	Waves <u>meet</u> in phase. **OR** Crest <u>meets</u> crest. **OR** Trough <u>meets</u> trough. **OR** Path difference = mλ	1	Accept: peak for crest. Can be shown by diagram eg  Diagram must imply addition of two waves in phase. Do not accept: 'join' or 'merge' alone.
		(ii)	$m\lambda = d\sin\theta$ **(1)** $3\times630\times10^{-9} = \dfrac{1}{250\ 000}\sin\theta$ **(1)** $\theta = 28^{\circ}$ **(1)**	3	Accept: 30°, $28{\cdot}2^{\circ}$, $28{\cdot}20^{\circ}$ Note: d = 4×10^{-6} m Alternative substitution: $m\lambda = d\sin\theta$ **(1)** $3\times630\times10^{-9} = \dfrac{1\times10^{-3}}{250}\sin\theta$ **(1)** $\theta = 28^{\circ}$ **(1)**
		(iii)	Spots will be further apart. **OR** Angle θ is greater. **(1)** Slit separation d of new grating is smaller than the previous grating. **(1)**	2	Look for correct statement of effect first - if incorrect or missing then 0 marks. Accept: fewer/less spots on the screen. Justification can be done by calculation. If calculation is carried out using m = 3, candidate will obtain an invalid answer. This implies fewer/less spots (five) on the screen.
		(iv)	(The waves from the laser have a) constant phase relationship (and have the same frequency, wavelength, and velocity).	1	"In phase" is not sufficient.
	(b)		(Polymer) note has vertical and horizontal or crossed lines/grid/grating.	1	Accept: crosshatch, mesh Accept: diagram to aid description There are vertical and horizontal spots so there are vertical and horizontal lines or a grid of lines.

MARKS DO NOT WRITE IN THIS MARGIN

9. A ray of monochromatic light is incident on a glass prism as shown.



(a) Show that the refractive index of the glass for this ray of light is 1·89. **2**

Space for working and answer

(b) (i) State what is meant by the term *critical angle*. **1**

MARKS DO NOT WRITE IN THIS MARGIN

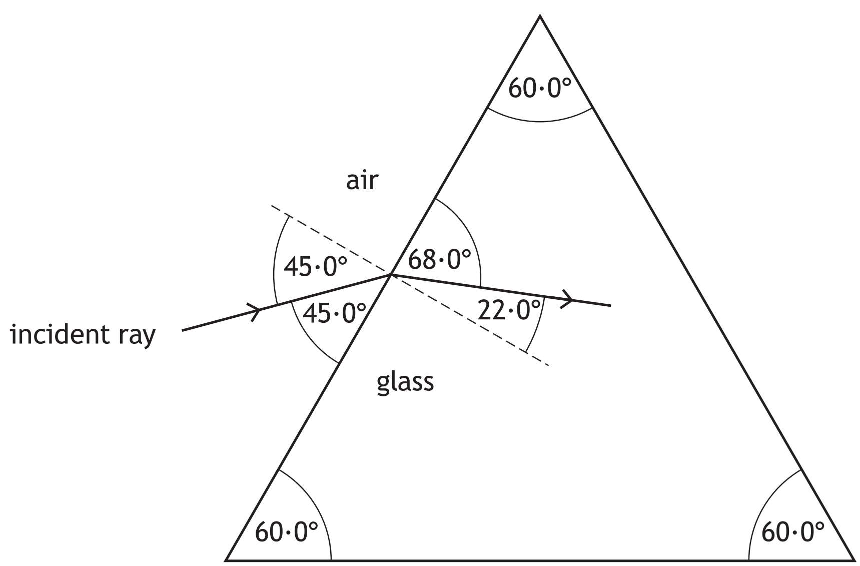
9. (b) (continued)

(ii) Calculate the critical angle for this light in the prism. **3**

Space for working and answer

(iii) Complete the diagram below to show the path of the ray as it passes through the prism and emerges into the air.

Mark on the diagram the values of all relevant angles. **4**



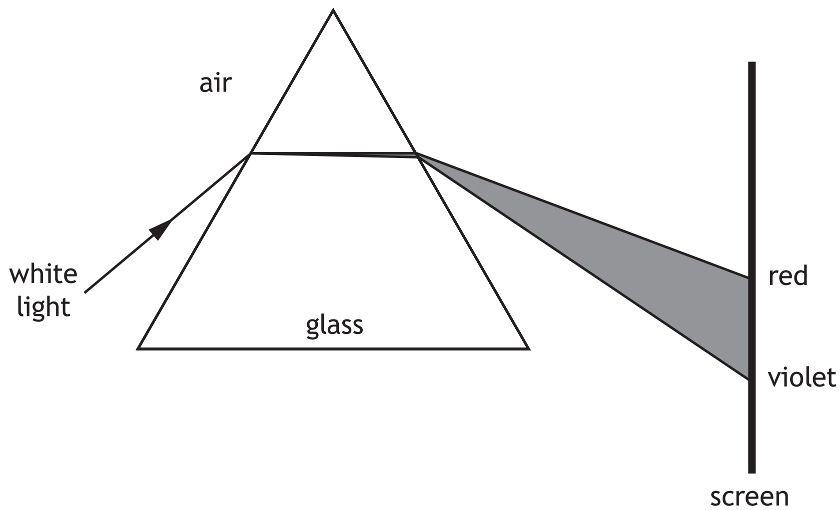
(An additional diagram, if required, can be found on *page 45*.)

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

9. (continued)

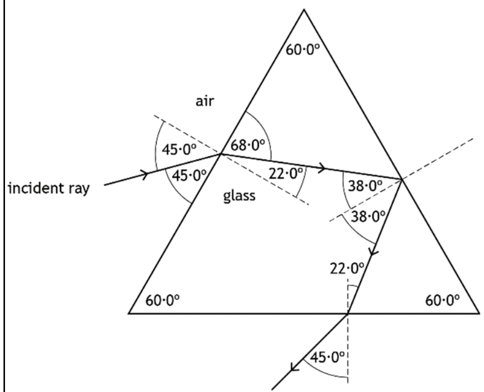
(c) A ray of white light is shone through the prism and a spectrum is observed as shown.



The prism is now replaced with another prism made from a different type of glass with a lower refractive index.

Describe one difference in the spectrum produced by this prism compared to the spectrum produced by the first prism. **1**

Question			Answer	Max mark	Additional guidance
9.	(a)		$n = \frac{\sin\theta_1}{\sin\theta_2}$ **(1)** $n = \frac{\sin 45\cdot 0}{\sin 22\cdot 0}$ **(1)** $n = 1\cdot 89$	2	**"SHOW" question** Accept: $\frac{n_2}{n_1} = \frac{\sin\theta_1}{\sin\theta_2}$ **(1)** $\frac{n_2}{1} = \frac{\sin 45\cdot 0}{\sin 22\cdot 0}$ **(1)** $n = 1\cdot 89$
	(b)	(i)	The angle of incidence such that the angle of refraction is 90°.	1	Accept a description of the incident ray as an alternative to the word 'incidence'. Do not accept: The minimum angle of incidence that causes total internal reflection.
		(ii)	$\sin\theta_C = \frac{1}{n}$ **(1)** $\sin\theta_C = \frac{1}{1\cdot 89}$ **(1)** $\theta_C = 31\cdot 9^\circ$ **(1)**	3	Accept: 32°, 31·94°, 31·945°

Question			Answer	Max mark	Additional guidance
9.	(b)	(iii)	 Total Internal Reflection **(1)** 38° **(1)** Refraction away from the normal on exit **(1)** 22° and 45° **(1)**	4	**OR** consistent with part (ii) If arithmetic error for finding one of the angles – maximum 3 marks. First two marks are independent. To access last two marks TIR must be shown. Reflection at any angle Either incidence or reflection angle labelled. Refraction at any angle Both angles required. Notes: Only penalise missing degree unit once in whole question. Decimal points not required Candidate may calculate exit angle, therefore 45·1° is acceptable
	(c)		Less deviation in spectrum position **OR** Less dispersion.	1	Accept: Spectrum position higher on screen Smaller spread/width of spectrum Brighter spectrum Do not accept: smaller spectrum alone

MARKS DO NOT WRITE IN THIS MARGIN

10. In a laboratory experiment, light from a hydrogen discharge lamp is used to produce a line emission spectrum. The line spectrum for hydrogen has four lines in the visible region as shown.

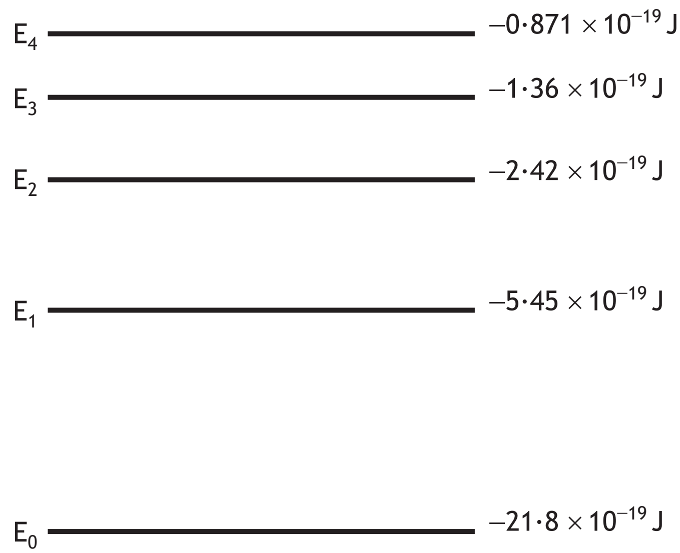
(a) The production of the line spectrum can be explained using the Bohr model of the atom.

State **two** features of the *Bohr model* of the atom. **2**

[Turn over

10. (continued)

(b) Some of the energy levels of the hydrogen atom are shown.



One of the spectral lines is due to electron transitions from E_3 to E_1.

Determine the frequency of the photon emitted when an electron makes this transition. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

10. (continued)

(c) In the laboratory, a line in the hydrogen spectrum is observed at a wavelength of 656 nm.

When the spectrum of light from a distant galaxy is viewed, this hydrogen line is now observed at a wavelength of 661 nm.

Determine the recessional velocity of the distant galaxy. **5**

Space for working and answer

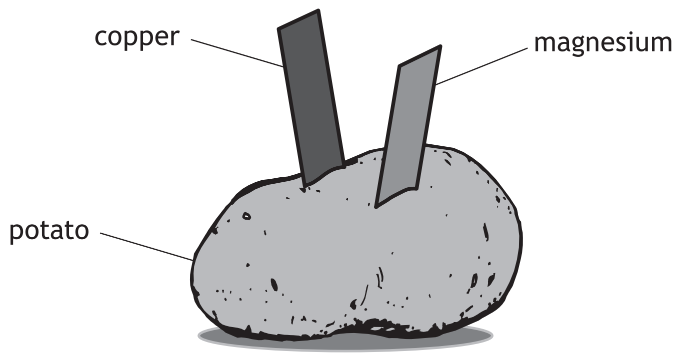
[Turn over

Question			Answer	Max mark	Additional guidance
10.	(a)		A (central) positively charged nucleus. (Negatively charged) electrons in (discrete) energy levels/shells (orbiting the nucleus, not radiating energy.) When an electron moves from one state to another, the energy lost or gained is done so ONLY in very specific amounts of energy. Each line in a spectrum is produced when an electron moves from one energy level/orbit/shell to another.	2	Any two correct answers **Independent marks** Accept: A clearly labelled diagram A (central) nucleus containing protons (and neutrons). Some indication of quantisation of energy Do not accept: Atom is mainly empty space. Nucleus is small compared to size of the atom. Any statement referring to photons and photon frequency is a consequence, not a feature.
	(b)		$E_2 - E_1 = hf$ **(1)** $-1{\cdot}36\times10^{-19} - (-5{\cdot}45\times10^{-19}) = 6{\cdot}63\times10^{-34}\times f$ **(1)** $f = 6{\cdot}17\times10^{14}$ Hz **(1)**	3	Accept: 6·2, 6·169, 6·1689 Accept: $(\Delta)E = hf$ or $E_3 - E_1 = hf$ for formula mark anywhere Accept: $5{\cdot}45\times10^{-19} - 1{\cdot}36\times10^{-19}$ $= 6{\cdot}63\times10^{-34}\times f$ for substitution mark Note: Correct ΔE = $4{\cdot}09\times10^{-19}$ (J) If $1{\cdot}36\times10^{-19} - 5{\cdot}45\times10^{-19}$ is shown for ΔE, maximum 1 mark for a correct formula.

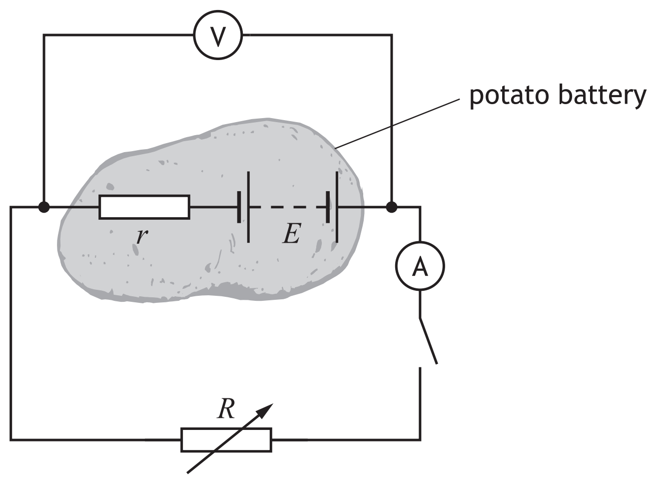
Question			Answer	Max mark	Additional guidance
10.	(c)		$z = \dfrac{\lambda_o - \lambda_r}{\lambda_r}$ **(1)** $z = \dfrac{661 - 656}{656}$ **(1)** $\left(z = 7 \cdot 62195122 \times 10^{-3}\right)$ $z = \dfrac{v}{c}$ **(1)** $7 \cdot 62195122 \times 10^{-3} = \dfrac{v}{3 \cdot 00 \times 10^{8}}$ **(1)** $v = 2 \cdot 29 \times 10^{6}$ m s^{-1} **(1)**	5	Accept: 2·3, 2·287, 2·2866 $z = \dfrac{\lambda_o - \lambda_r}{\lambda_r}$ anywhere, 1 mark $z = \dfrac{v}{c}$ anywhere, 1 mark Substitution of $3{\cdot}00 \times 10^{8}$ **(1)** Alternative method: $\dfrac{v}{c} = \dfrac{\lambda_o - \lambda_r}{\lambda_r}$ $\dfrac{v}{3 \cdot 00 \times 10^{8}} = \dfrac{661 - 656}{656}$ $v = 2 \cdot 29 \times 10^{6}$ m s^{-1} Equating formula, **(2)** Substitution of wavelengths, **(1)** Substitution of $3{\cdot}00 \times 10^{8}$ **(1)** Final answer **(1)**

MARKS DO NOT WRITE IN THIS MARGIN

11. A student constructs a battery using a potato, a strip of copper and a strip of magnesium.



The student then sets up the following circuit with the potato battery connected to a variable resistor R, in order that the electromotive force (e.m.f.) and internal resistance of the battery may be determined.

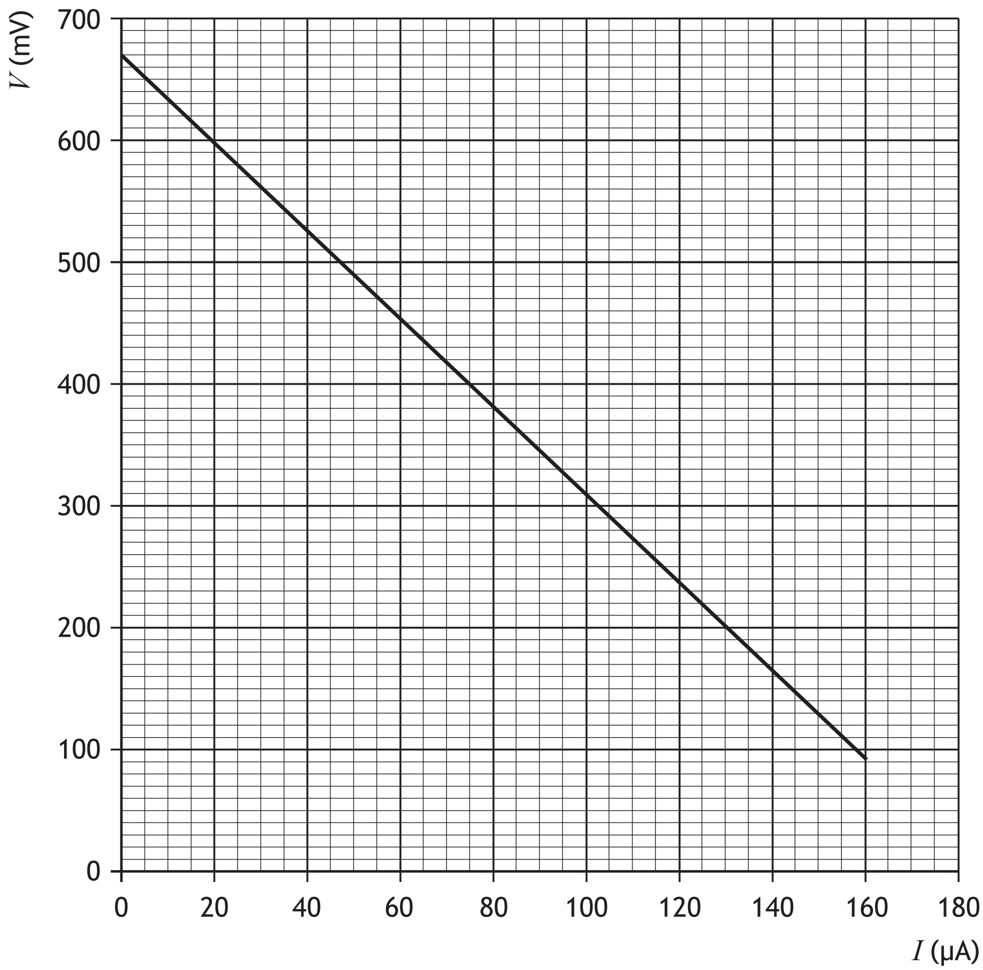


(a) State what is meant by the term *electromotive force* (*e.m.f.*). **1**

11. (continued)

MARKS DO NOT WRITE IN THIS MARGIN

(b) The student uses readings of current I and terminal potential difference V from this circuit to produce the graph shown.



Determine the internal resistance of the potato battery. **3**

Space for working and answer

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

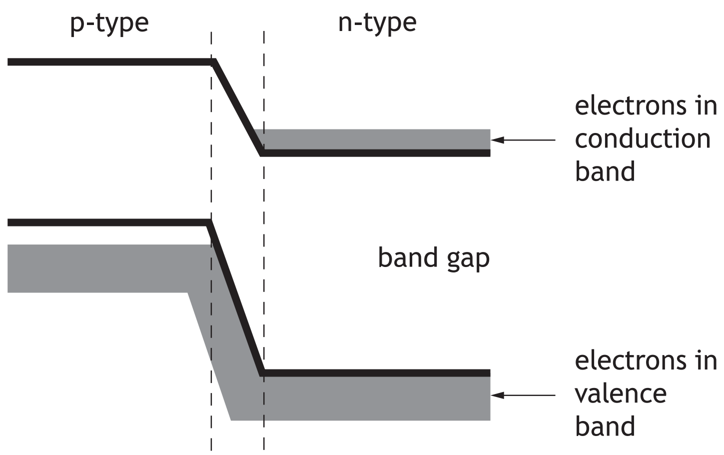
11. (continued)

(c) The student connects a red LED and a blue LED, in turn, to the battery.

The LEDs are forward biased when connected.

The student observes that the battery will operate the red LED but not the blue LED.

The diagram represents the band structure of the blue LED.



LEDs emit light when electrons fall from the conduction band into the valence band of the p-type semiconductor.

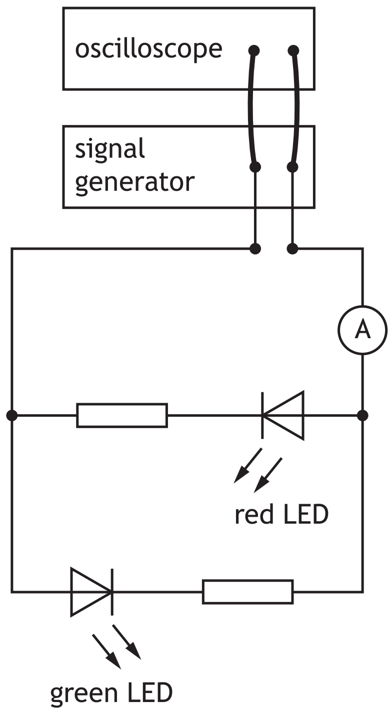
Explain, using **band theory**, why the blue LED will not operate with this battery. **1**

Question			Answer	Max mark	Additional guidance
11.	(a)		The number of joules/energy gained by/supplied to 1 coulomb (of charge passing through the cell).	**1**	Accept unit charge for 1 coulomb.
	(b)		$\text{gradient} = \frac{(290\times10^{-3} - 470\times10^{-3})}{(105\times10^{-6} - 55\times10^{-6})}$ **(1)** $\text{gradient} = -3600$ **(1)** $(\text{gradient} = -r)$ $r = 3600\ \Omega$ **(1)**	**3**	Accept: 4000 Gradient = r is wrong physics, award 0 marks. subs into gradient formula **(1)** calculating gradient **(1)** Alternative method: $E = V + Ir$ (1) $670\times10^{-3} = 400\times10^{-3} + 75\times10^{-6}r$ (1) $r = 3600\ \Omega$ (1)
	(c)		The electrons do not gain enough energy to move into/towards the conduction band of the p-type.	**1**	Electrons in conduction band (of the n-type) do not gain enough energy to move into/towards the p-type.

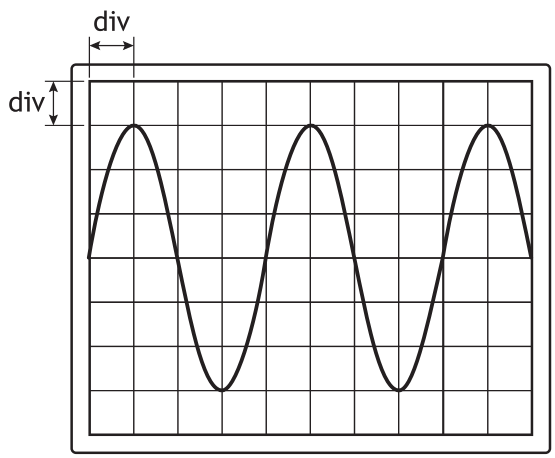
DO NOT WRITE IN THIS MARGIN

12. A student carries out a series of experiments to investigate alternating current.

(a) A signal generator is connected to an oscilloscope and a circuit as shown.



The output of the signal generator is displayed on the oscilloscope.



The Y-gain setting on the oscilloscope is 1·0 V/div.

The timebase setting on the oscilloscope is 0·5 s/div.

MARKS DO NOT WRITE IN THIS MARGIN

12. (a) (continued)

(i) Determine the peak voltage of the output of the signal generator. **1**

Space for working and answer

(ii) Determine the frequency of the output of the signal generator. **3**

Space for working and answer

(iii) The student observes that the red LED is only lit when the ammeter gives a positive reading and the green LED is only lit when the ammeter gives a negative reading.

Explain these observations. **2**

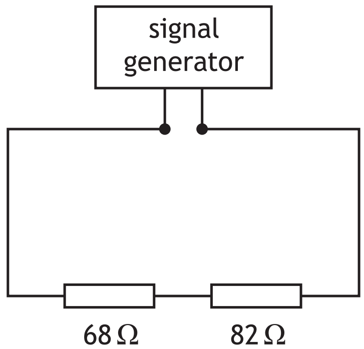
MARKS DO NOT WRITE IN THIS MARGIN

12. (continued)

(b) The signal generator is now connected in a circuit as shown.

The settings on the signal generator are unchanged.

The signal generator has negligible internal resistance.



Determine the r.m.s. voltage across the 82 Ω resistor. **5**

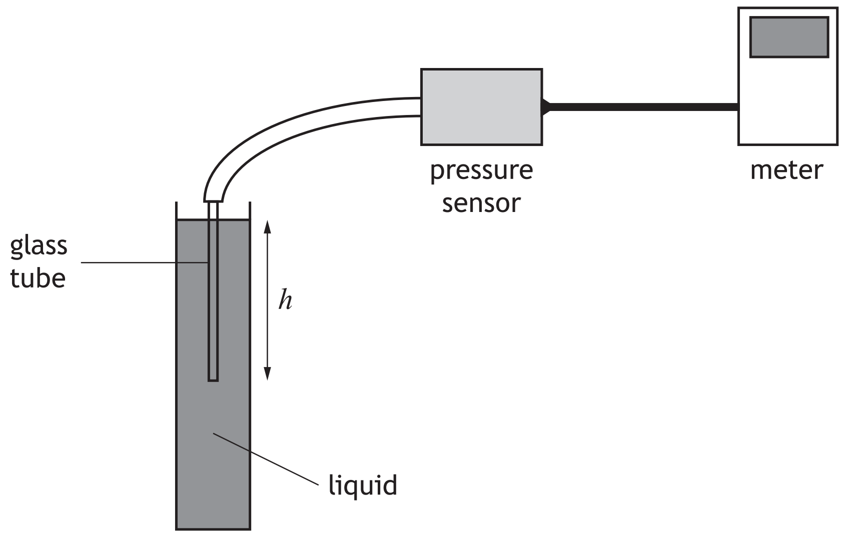
Space for working and answer

Question			Answer	Max mark	Additional guidance
12.	(a)	(i)	$(3\times1\cdot0=)\ 3\cdot0\ \text{V}$ **(1)**	1	Accept: 3, 3·00, 3·000
		(ii)	$f=\frac{1}{T}$ **(1)** $f=\frac{1}{2}$ **(1)** $f=0\cdot5\ \text{Hz}$ **(1)**	3	Accept: 0·50, 0·500
		(iii)	The LEDs will light when they are forward biased. **(1)** The change in polarity of voltage changes the biasing. **(1)**	2	**Independent marks** LEDs will only conduct in one direction (1) Identifying current/voltage has changed direction (1) Do not accept 'different direction' alone. One LED conducts during one half of the cycle the other LED conducts during the other half of the cycle.
	(b)		$V_2=\left(\frac{R_2}{R_1+R_2}\right)V_S$ **(1)** $V_2=\left(\frac{82}{68+82}\right)\times3\cdot0$ **(1)** $V_2=1\cdot64\ (\text{V})$ $V_{peak}=\sqrt{2}V_{rms}$ **(1)** $1\cdot64=\sqrt{2}V_{rms}$ **(1)** $V_{rms}=1\cdot2\ \text{V}$ **(1)**	5	**OR** consistent with (a)(i) Accept: 1, 1·16, 1·160 Alternative Methods: $V_{peak}=\sqrt{2}V_{rms}$ **(1)** $3\cdot0=\sqrt{2}V_{rms}$ **(1)** $V_{rms}=2\cdot12132034\ (\text{V})$ $V_2=\left(\frac{R_2}{R_1+R_2}\right)V_S$ **(1)** $V_2=\left(\frac{82}{68+82}\right)\times2\cdot12132034$ **(1)** $V_2=1\cdot2\ \text{V}$ **(1)**

Question			Answer	Max mark	Additional guidance
12.	(b)		continued		**OR** $V_{peak} = \sqrt{2}V_{rms}$ **(1)** $3 \cdot 0 = \sqrt{2}V_{rms}$ **(1)** $V_{rms} = 2 \cdot 12132034$ (V) $V = IR$ $2 \cdot 12132034 = I \times (68 + 82)$ $I = 0 \cdot 0141421356$ (A) $V = IR$ $V = 0 \cdot 0141421356 \times 82$ $V = 1 \cdot 2$ V $V = IR$ **twice** **(1)** Both substitutions into $V = IR$ **(1)** Final answer **(1)** **OR** $V = IR$ $3 \cdot 0 = I \times (68 + 82)$ $I = 0 \cdot 02$ (A) $V = IR$ $V = 0 \cdot 02 \times 82$ $V = 1 \cdot 64$ (V) $V_{peak} = \sqrt{2}V_{rms}$ **(1)** $1 \cdot 64 = \sqrt{2}V_{rms}$ **(1)** $V_{rms} = 1 \cdot 2$ V $V = IR$ **twice** **(1)** Both substitutions into $V = IR$ **(1)** Final answer **(1)**

MARKS DO NOT WRITE IN THIS MARGIN

13. A student sets up an experiment to investigate the pressure due to a liquid as shown.



The pressure due to a liquid is given by the relationship

$$p = \rho g h$$

where p is the pressure due to the liquid in pascals (Pa),

g is the gravitational field strength in N kg^{-1},

ρ is the density of the liquid in kg m^{-3},

and h is the depth in the liquid in m.

(a) The student initially carries out the investigation using water.

The density of water is $1{\cdot}00 \times 10^3$ kg m^{-3}.

Calculate the pressure due to the water at a depth of 0·35 m. **2**

Space for working and answer

13. (continued)

(b) The student repeats the experiment with a different liquid.

The pressure meter is set to zero before the glass tube is lowered into the liquid.

The student takes measurements of the pressure at various depths below the surface of the liquid.

The student records the following information.

Depth, h (m)	Pressure, p (kPa)
0·10	1·2
0·20	2·5
0·30	3·6
0·40	4·9
0·50	6·2

(i) Using the square-ruled paper on *page 43*, draw a graph of p against h. **3**

(Additional graph paper, if required, can be found on *page 44*.)

(ii) Calculate the gradient of your graph. **2**

Space for working and answer

(iii) Determine the density of this liquid. **2**

Space for working and answer

[END OF QUESTION PAPER]

* X 7 5 7 7 6 0 1 4 2 *

Question			Answer	Max mark	Additional guidance
13.	(a)		$p = 1 \cdot 00 \times 10^3 \times 9 \cdot 8 \times 0 \cdot 35$ **(1)** $p = 3 \cdot 4 \times 10^3$ Pa **(1)**	2	Accept: 3, 3·43, 3·430
	(b)	(i)	Suitable scales with labels on axes (quantity and units) **(1)** Correct plotting of points **(1)** Appropriate line of best fit **(1)**	3	Allow for axes starting at zero or broken axes or at an appropriate value. Accuracy of plotting should be easily checkable with the scale chosen. If the origin is shown the scale must either be continuous or the axis must be 'broken'. Otherwise maximum 2 marks. Do not penalise if the candidate plots h against p.
		(ii)	$m = \frac{y_2 - y_1}{x_2 - x_1}$ $m = \frac{4 \cdot 9 \times 10^3 - 1 \cdot 2 \times 10^3}{0 \cdot 40 - 0 \cdot 10}$ **(1)** = 12 000 (Pa m^{-1}) **(1)**	2	**Must** be consistent with graph drawn for (b)(i). Candidates are asked to calculate the gradient of **their graph**. Tolerance required depending upon best fit line drawn by the candidate. Accept: $m = \frac{y_2 - y_1}{x_2 - x_1}$ $m = \frac{4 \cdot 9 - 1 \cdot 2}{0 \cdot 40 - 0 \cdot 10}$ **(1)** = 12 (kPa m^{-1}) **(1)**

Question			Answer	Max mark	Additional guidance
13.		(iii)	*(gradient =* ρg *)* 12 000 = ρg **(1)** ρ = 1·2 × 10^{3} kg m^{-3} **(1)**	**2**	**OR** consistent with (b)(ii) If m = 12 in (b)(ii) 12 = ρg **(1)** ρ = 1·2 × 10^{3} kg m^{-3} **(1)** If candidate arrives at this answer then they **have** taken into consideration the prefix (kPa). If the candidate has drawn a straight line through the origin (tolerance within ± 1 full division), then any point on the line, within ± ½ division tolerance, can be used to calculate the density using $p = \rho g h$. If the candidate has used a point on their line and uses continuous scales from zero, but has not extended their line back through the origin, then use the ruler tool to confirm that their line passes through the origin within tolerance. If the line drawn (or extrapolated line 'created' on Assessor) does NOT pass through the origin within ± 1 full division tolerance, the gradient of the line must be used and not one single point selected, otherwise 0 marks.

Question			Answer	Max mark	Additional guidance
13.		(iii)	continued		If candidate has chosen an appropriate point on their line, 1 mark for correct substitution 1 mark for final answer. If the candidate uses a broken scale on either axis, or does not start their scale at zero, they must use the gradient in their calculation of ρ, otherwise 0 marks. If candidate has plotted h against p, the formula becomes $\rho g = \frac{1}{gradient}$, otherwise 0 marks for the 'gradient' method. The method by selecting a valid point is can still be used, and the criteria above apply.

[END OF MARKING INSTRUCTIONS]

H

National
Qualifications
SPECIMEN ONLY

S857/76/12

Physics
Paper 1 — Multiple choice

Date — Not applicable

Duration — 45 minutes

Total marks — 25

Attempt ALL questions.

You may use a calculator.

Instructions for the completion of Paper 1 are given on *page 02* of your answer booklet S857/76/02.

Record your answers on the answer grid on *page 03* of your answer booklet.

Reference may be made to the data sheet on *page 02* of this question paper and to the relationships sheet S857/76/22.

Space for rough work is provided at the end of this booklet.

Before leaving the examination room you must give your answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

* S 8 5 7 7 6 1 2 *

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	Symbol	Value	Quantity	Symbol	Value
Speed of light in vacuum	c	$3{\cdot}00 \times 10^{8}$ m s^{-1}	Planck's constant	h	$6{\cdot}63 \times 10^{-34}$ J s
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}$ C	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}$ kg
Universal Constant of Gravitation	G	$6{\cdot}67 \times 10^{-11}$ m^3 kg^{-1} s^{-2}	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}$ kg
Gravitational acceleration on Earth	g	$9{\cdot}8$ m s^{-2}	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}$ kg
Hubble's constant	H_0	$2{\cdot}3 \times 10^{-18}$ s^{-1}			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	Refractive index	Substance	Refractive index
Diamond	2·42	Water	1·33
Crown glass	1·50	Air	1·00

SPECTRAL LINES

Element	Wavelength / nm	Colour	Element	Wavelength / nm	Colour
Hydrogen	656	Red	Cadmium	644	Red
	486	Blue-green		509	Green
	434	Blue-violet		480	Blue
	410	Violet	Lasers		
	397	Ultraviolet			
	389	Ultraviolet	Element	Wavelength / nm	Colour
			Carbon dioxide	9550	Infrared
Sodium	589	Yellow		10 590	
			Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

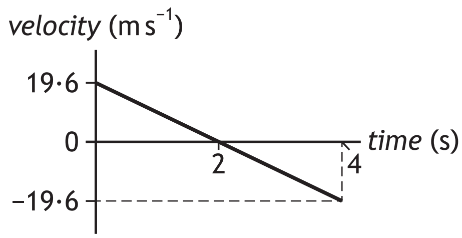
Substance	Density / kg m^{-3}	Melting point / K	Boiling point / K
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853
Ice	$9{\cdot}20 \times 10^{2}$	273	....
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377
Water	$1{\cdot}00 \times 10^{3}$	273	373
Air	1·29	....	....
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

Total marks — 25

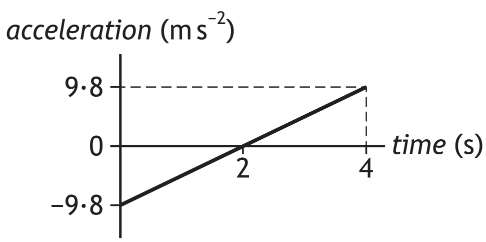
Attempt ALL questions

1. The following velocity-time graph represents the vertical motion of a ball.

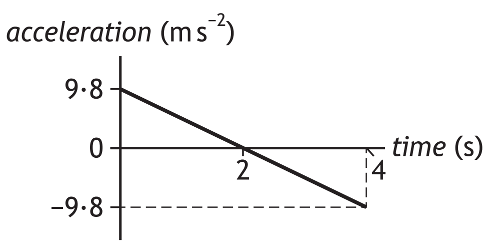


Which of the following acceleration-time graphs represents the same motion?

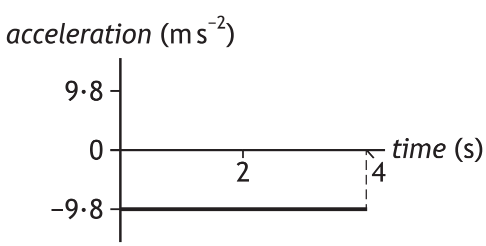
A



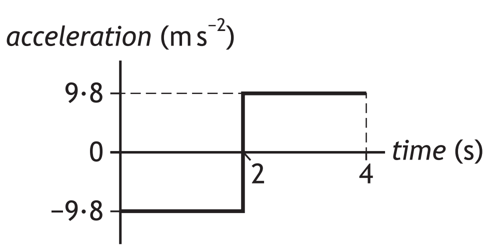
B



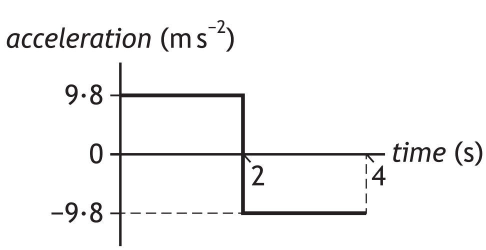
C



D



E



2. A train accelerates uniformly from $5 \cdot 0\,\mathrm{m\,s^{-1}}$ to $12 \cdot 0\,\mathrm{m\,s^{-1}}$ while travelling a distance of 119 m along a straight track.

The acceleration of the train is

A $0 \cdot 50\,\mathrm{m\,s^{-2}}$

B $0 \cdot 70\,\mathrm{m\,s^{-2}}$

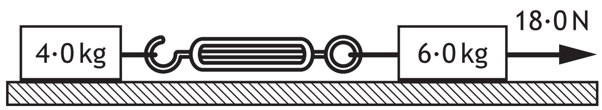
C $1 \cdot 2\,\mathrm{m\,s^{-2}}$

D $7 \cdot 0\,\mathrm{m\,s^{-2}}$

E $14\,\mathrm{m\,s^{-2}}$.

3. Two blocks are linked by a newton balance of negligible mass.

The blocks are placed on a level, frictionless surface. A force of 18·0 N is applied to the blocks as shown.



The reading on the newton balance is

A 3·6 N

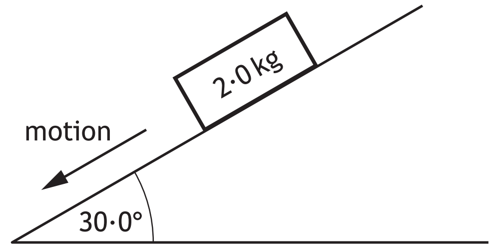
B 7·2 N

C 9·0 N

D 10·8 N

E 18·0 N.

4. A block of wood slides with a constant velocity down a slope. The slope makes an angle of 30·0° with the horizontal as shown. The mass of the block is 2·0 kg.



The magnitude of the force of friction acting on the block is

A 1·0 N

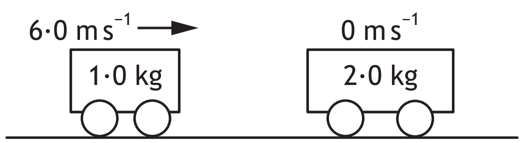
B 1·7 N

C 9·8 N

D 17 N

E 19·6 N.

5. The diagram shows the masses and velocities of two trolleys just before they collide on a level bench.



After the collision, the trolleys move along the bench joined together.

The kinetic energy lost in this collision is

A 0 J

B 6·0 J

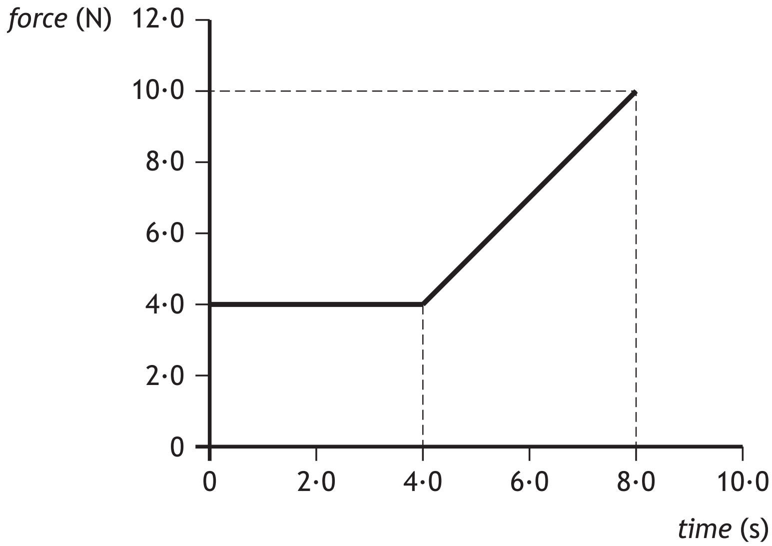
C 12 J

D 18 J

E 24 J.

[Turn over

6. The graph shows the force that acts on an object over a time interval of 8·0 seconds.



The momentum gained by the object during the 8·0 seconds is

A 12 kg m s^{-1}

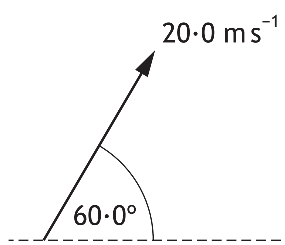
B 32 kg m s^{-1}

C 44 kg m s^{-1}

D 52 kg m s^{-1}

E 80 kg m s^{-1}.

7. A javelin is thrown at an angle of 60·0° to the horizontal with a speed of 20·0 m s^{-1}.



The javelin is in flight for 3·50 s.

The effects of air resistance can be ignored.

The horizontal distance travelled by the javelin is

A 15·3 m

B 35·0 m

C 60·6 m

D 70·0 m

E 121 m.

8. Two small asteroids are 12 m apart.

The masses of the asteroids are $2·0 \times 10^3$ kg and $0·050 \times 10^3$ kg.

The gravitational force acting between the asteroids is

A $1·2 \times 10^{-9}$ N

B $4·6 \times 10^{-8}$ N

C $5·6 \times 10^{-7}$ N

D $1·9 \times 10^{-6}$ N

E $6·8 \times 10^{3}$ N.

9. A spaceship on a launch pad is measured to have a length L.

This spaceship has a speed of $2·5 \times 10^8$ m s^{-1} as it passes a planet.

Which row in the table describes the length of the spaceship as measured by the pilot in the spaceship and an observer on the planet?

	Length measured by pilot in the spaceship	*Length measured by observer on the planet*
A	L	greater than L
B	L	L
C	L	less than L
D	greater than L	L
E	less than L	less than L

[Turn over

10. The siren on an ambulance is emitting sound with a constant frequency of 900 Hz. The ambulance is travelling at a constant speed of $25\,\text{m}\,\text{s}^{-1}$ as it approaches and passes a stationary observer. The speed of sound in air is $340\,\text{m}\,\text{s}^{-1}$.

Which row in the table shows the frequency of the sound heard by the observer as the ambulance approaches and as it moves away from the observer?

	Frequency as ambulance approaches (Hz)	*Frequency as ambulance moves away* (Hz)
A	900	838
B	971	838
C	838	900
D	971	900
E	838	971

11. Cosmic microwave background radiation and Olbers' paradox provide evidence for

A the photoelectric effect

B the Bohr model of the atom

C the theory of special relativity

D the Big Bang theory

E Newton's Law of Universal Gravitation.

12. A student makes the following statements about particles in electric fields.

I A neutron experiences a force in an electric field.

II When an alpha particle is moved in an electric field work is done.

III An electric field applied to a conductor causes the free electrons in the conductor to move.

Which of the statements is/are correct?

A II only

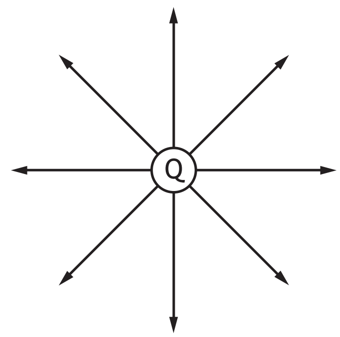
B III only

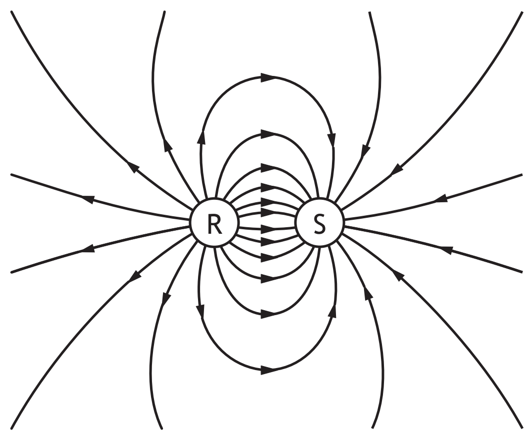
C I and II only

D II and III only

E I, II and III

13. The electric field patterns around charged particles Q, R and S are shown.





Which row in the table shows the charges on particles Q, R and S?

	Charge on Q	*Charge on R*	*Charge on S*
A	negative	negative	positive
B	positive	positive	negative
C	negative	positive	negative
D	negative	negative	negative
E	positive	positive	positive

[Turn over

14. A student makes the following statements about an electron.

I An electron is a boson.

II An electron is a lepton.

III An electron is a fermion.

Which of these statements is/are correct?

A I only

B II only

C III only

D I and II only

E II and III only

15. The last two changes in a radioactive decay series are shown below.

A Bismuth nucleus emits a beta particle and its product, a Polonium nucleus, emits an alpha particle.

$$^{P}_{Q}\mathrm{Bi} \xrightarrow[\text{decay}]{\beta} {}^{R}_{S}\mathrm{Po} \xrightarrow[\text{decay}]{\alpha} {}^{208}_{82}\mathrm{Pb}$$

Which numbers are represented by P, Q, R and S?

	P	*Q*	*R*	*S*
A	210	83	208	81
B	210	83	210	84
C	211	85	207	86
D	212	83	212	84
E	212	85	212	84

16. Light from a point source is incident on a screen. The screen is 3·0 m from the source. The irradiance at the screen is $8{\cdot}0\,W\,m^{-2}$.

The light source is now moved to a distance of 12 m from the screen.

The irradiance at the screen is now

A $0{\cdot}50\,W\,m^{-2}$

B $2{\cdot}0\,W\,m^{-2}$

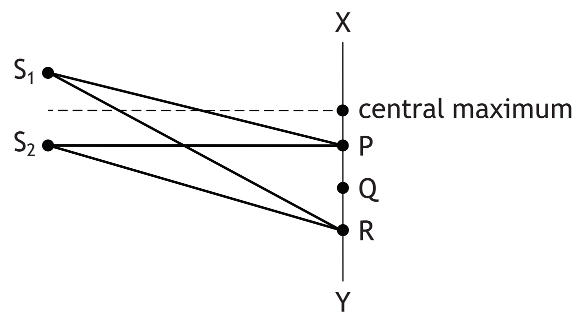
C $4{\cdot}0\,W\,m^{-2}$

D $6{\cdot}0\,W\,m^{-2}$

E $8{\cdot}0\,W\,m^{-2}$.

17. S_1 and S_2 are sources of coherent waves.

An interference pattern is obtained between X and Y.



The first order maximum occurs at P, where $S_1P = 200$ mm and $S_2P = 180$ mm.

For the third order maximum, at R, the path difference ($S_1R - S_2R$) is

A 20 mm

B 30 mm

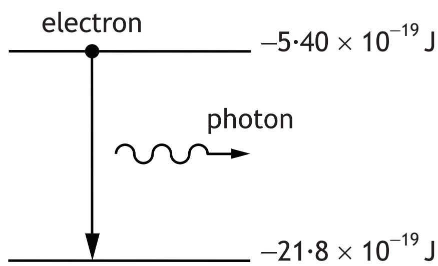
C 40 mm

D 50 mm

E 60 mm.

[Turn over

18. In an atom, a photon is emitted when an electron makes a transition from a higher energy level to a lower energy level as shown.



The wavelength of the radiation emitted due to an electron transition between the two energy levels shown is

A $7{\cdot}31 \times 10^{-8}$ m

B $9{\cdot}12 \times 10^{-8}$ m

C $1{\cdot}21 \times 10^{-7}$ m

D $8{\cdot}23 \times 10^{6}$ m

E $2{\cdot}47 \times 10^{15}$ m.

19. A ray of red light travels from air into water.

Which row in the table describes the change, if any, in speed and frequency of a ray of red light as it travels from air into water?

	Speed	*Frequency*
A	stays constant	decreases
B	increases	increases
C	increases	stays constant
D	decreases	stays constant
E	decreases	decreases

20. The rms voltage of the mains supply is 230 V.

The approximate value of the peak voltage is

A 115 V

B 163 V

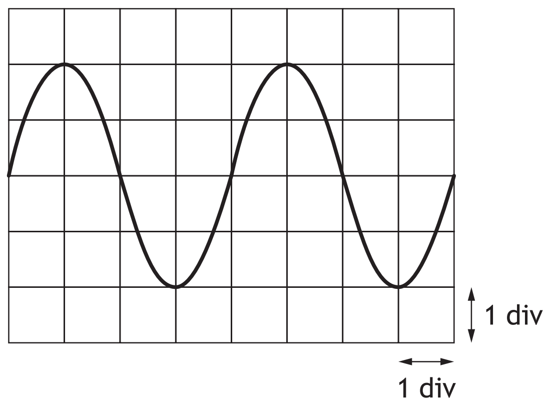
C 325 V

D 460 V

E 651 V.

21. An oscilloscope is connected to the output terminals of a signal generator.

The trace displayed on the screen is shown.



The timebase of the oscilloscope is set at 30 ms/div.

The frequency of the output signal from the signal generator is

A $4{\cdot}2 \times 10^{-3}$ Hz

B $8{\cdot}3 \times 10^{-3}$ Hz

C 0·12 Hz

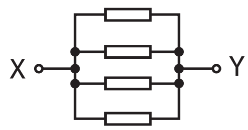
D 4·2 Hz

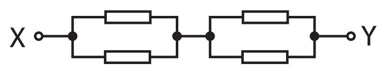
E 8·3 Hz.

[Turn over

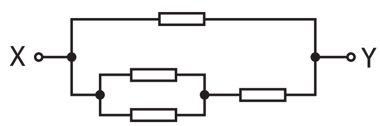
22. In the diagrams below, each resistor has the same resistance.

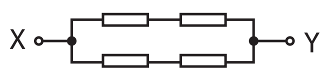
Which combination has the least value of the effective resistance between the terminals X and Y?

A 

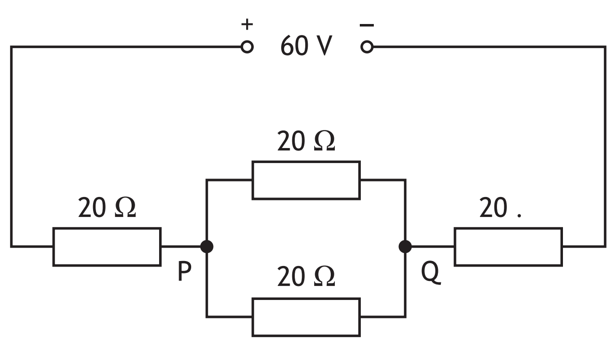
B 

C 

D 

E 

23. Four resistors each of resistance 20 Ω are connected to a 60 V supply of negligible internal resistance as shown.



The potential difference across PQ is

A 12 V

B 15 V

C 20 V

D 24 V

E 30 V.

24. The EMF of a battery is

A the total energy supplied by the battery

B the voltage lost due to the internal resistance of the battery

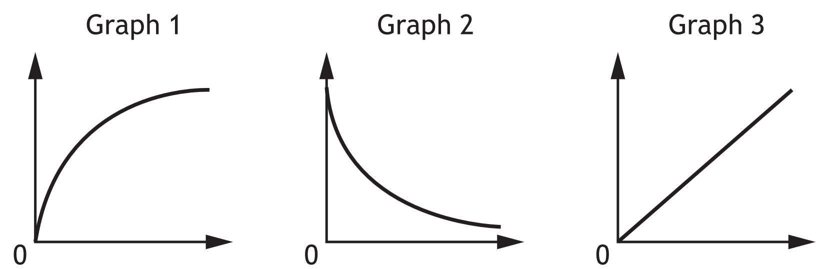
C the total charge that passes through the battery

D the number of coulombs of charge passing through the battery per second

E the energy supplied to each coulomb of charge passing through the battery.

25. A student carries out three experiments to investigate the charging of a capacitor using a DC supply.

The graphs obtained from the experiments are shown.



The axes of the graphs have not been labelled.

Which row in the table shows the labels for the axes of the graphs?

	Graph 1	*Graph 2*	*Graph 3*
A	voltage and time	charge and voltage	current and time
B	current and time	voltage and time	charge and voltage
C	current and time	charge and voltage	voltage and time
D	voltage and time	current and time	charge and voltage
E	charge and voltage	current and time	voltage and time

[END OF SPECIMEN QUESTION PAPER]

Marking instructions for each question

Question	Answer	Max mark
1.	C	1
2.	A	1
3.	B	1
4.	C	1
5.	C	1
6.	C	1
7.	B	1
8.	B	1
9.	C	1
10.	B	1
11.	D	1
12.	D	1
13.	B	1
14.	E	1
15.	D	1
16.	A	1
17.	E	1
18.	C	1
19.	D	1
20.	C	1
21.	E	1
22.	A	1
23.	A	1
24.	E	1
25.	D	1

[END OF SPECIMEN MARKING INSTRUCTIONS]

FOR OFFICIAL USE

H

National
Qualifications
SPECIMEN ONLY

Mark

S857/76/01

Physics
Paper 2

Date — Not applicable

Duration — 2 hours 15 minutes

* S 8 5 7 7 6 0 1 *

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth

Day Month Year

Scottish candidate number

Total marks — 130

Attempt ALL questions.

You may use a calculator.

Reference may be made to the data sheet on *page 02* of this booklet and to the relationships sheet S857/76/11.

Care should be taken to give an appropriate number of significant figures in the final answers to calculations.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. Score through your rough work when you have written your final copy.

Use **blue** or **black** ink.

Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

* S 8 5 7 7 6 0 1 0 1 *

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Speed of light in vacuum	c	$3{\cdot}00 \times 10^{8}$ m s^{-1}	Planck's constant	h	$6{\cdot}63 \times 10^{-34}$ J s
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}$ C	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}$ kg
Universal Constant of Gravitation	G	$6{\cdot}67 \times 10^{-11}$ m^{3} kg^{-1} s^{-2}	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}$ kg
Gravitational acceleration on Earth	g	$9{\cdot}8$ m s^{-2}	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}$ kg
Hubble's constant	H_0	$2{\cdot}3 \times 10^{-18}$ s^{-1}			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	*Refractive index*	*Substance*	*Refractive index*
Diamond	2·42	Water	1·33
Crown glass	1·50	Air	1·00

SPECTRAL LINES

Element	*Wavelength*/nm	*Colour*
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	*Wavelength*/nm	*Colour*
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	*Wavelength*/nm	*Colour*
Carbon dioxide	9550 10 590	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	*Density*/kg m^{-3}	*Melting point*/K	*Boiling point*/K
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853
Ice	$9{\cdot}20 \times 10^{2}$	273	. . . .
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377
Water	$1{\cdot}00 \times 10^{3}$	273	373
Air	1·29	. . . .	. . . .
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

S857760102

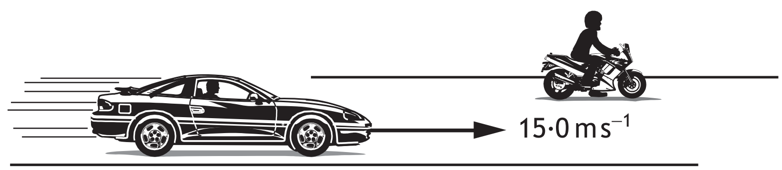
Total marks — 130

Attempt ALL questions

MARKS DO NOT WRITE IN THIS MARGIN

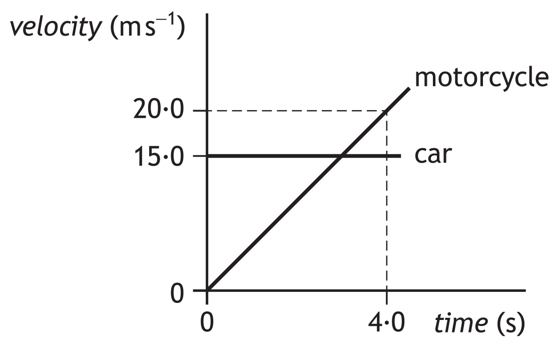
1. A car is travelling at a constant speed of $15 \cdot 0 \, m \, s^{-1}$ along a straight, level road.

It passes a motorcycle, which is stationary at the roadside.



At the instant the car passes, the motorcycle starts to move in the same direction as the car.

The graph shows the motion of each vehicle from the instant the car passes the motorcycle.



(a) Calculate the initial acceleration of the motorcycle. **3**

Space for working and answer

(b) Determine the distance between the car and motorcycle at $4 \cdot 0 \, s$. **4**

Space for working and answer

1. (continued)

MARKS DO NOT WRITE IN THIS MARGIN

(c) The total mass of the motorcycle and rider is 290 kg. At a time of 2·0 s the driving force on the motorcycle is 1800 N.

(i) Determine the frictional force acting on the motorcycle at this time. **4**

Space for working and answer

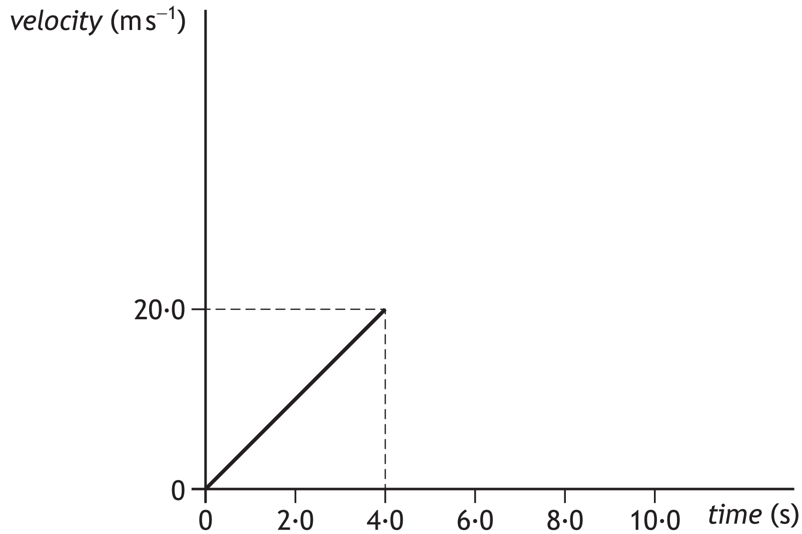
(ii) Explain why the driving force must be increased with time to maintain a constant acceleration. **2**

MARKS DO NOT WRITE IN THIS MARGIN

1. (continued)

(d) The driving force on the motorcycle reaches its maximum value at 5·0 s and then remains constant.

The velocity-time graph for the motorcycle during the first 4·0 s is shown below.



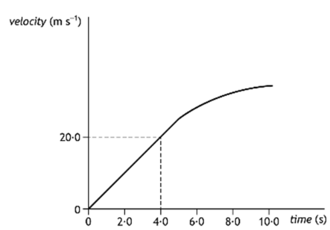
Extend the graph to show how the velocity of the motorcycle varies between 4·0 s and 10·0 s.

Additional numerical values on the velocity axis are **not** required. **1**

(An additional graph, if required, can be found on *page 42*.)

[Turn over

Marking instructions for each question

Question			Expected response	Max mark	Additional guidance
1.	(a)		$v = u + at$ **(1)** $20{\cdot}0 = 0 + a \times 4{\cdot}0$ **(1)** $a = 5{\cdot}0\ \text{m s}^{-2}$ **(1)**	3	Accept 5, 5·00, 5·000
	(b)		motorcycle $s = area\ under\ graph$ **(1)** $s = \frac{1}{2} \times 4{\cdot}0 \times 20{\cdot}0$ **(1)** car $s = area\ under\ graph$ $s = 4{\cdot}0 \times 15{\cdot}0$ **(1)** $s_{between} = (4{\cdot}0 \times 15{\cdot}0) - (\frac{1}{2} \times 4{\cdot}0 \times 20{\cdot}0)$ $s_{between} = 20\ \text{m}$ **(1)**	4	Accept 20·0, 20·00 Alternative method motorcycle $s = ut + \frac{1}{2}at^2$ $s = \frac{1}{2} \times 5{\cdot}0 \times 4{\cdot}0^2$ car $d = \bar{v}t$ $d = 15 \times 4{\cdot}0$ 1 mark for both relationships 1 mark for each substitution 1 mark for final answer
	(c)	(i)	$F = ma$ **(1)** $F = 290 \times 5{\cdot}0$ **(1)** $F = F_{Driving} - F_{Friction}$ $(290 \times 5{\cdot}0) = 1800 - F_{Friction}$ **(1)** $F_{Friction} = 350\ \text{N}$ **(1)**	4	Or consistent with (a) Accept 400, 350·0, 350·00
		(ii)	Frictional force /friction/drag/air resistance increases with speed **(1)** Driving force must be increased to ensure a constant unbalanced force **(1)**	2	
	(d)		 graph curves (gradually, away from velocity axis) after 5 s	1	Line can level out, but not curve downwards.

MARKS DO NOT WRITE IN THIS MARGIN

2. When a car brakes kinetic energy is turned into heat and sound.

In order to make cars more efficient some manufacturers have developed kinetic energy recovery systems (KERS). These systems store some of the energy that would otherwise be lost as heat and sound.

Estimate the maximum energy that could be stored in such a system when a car brakes.

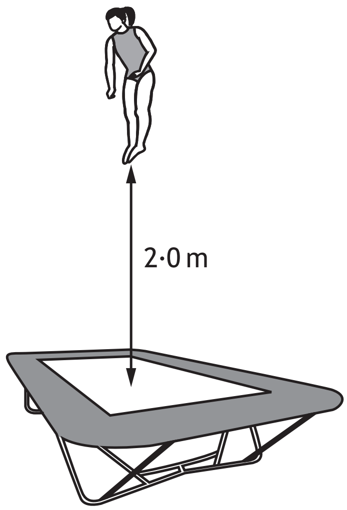
Cleary show your working for the calculation and any estimates you have made. **4**

Space for working and answer

Question			Expected response	Max mark	Additional guidance
2.			Estimate of car mass (500 kg < mass < 3000 kg) **(1)** Estimate of car speed (20 m s^{-1} < speed < 70 m s^{-1}) **(1)** $E_k = \frac{1}{2}mv^2$ **(1)** Final answer **(1)**	4	Both estimates must be within the given tolerances in order to access the final 1 mark.

MARKS DO NOT WRITE IN THIS MARGIN

3. (a) A gymnast of mass 42 kg is practising on a trampoline.



(i) At maximum height the gymnast's feet are 2·0 m above the trampoline.

Show that the speed of the gymnast, as they land on the trampoline, is 6·3 m s^{-1}. **2**

Space for working and answer

(ii) The gymnast rebounds with a speed of 5·3 m s^{-1}.

Calculate the magnitude of the change in momentum of the gymnast. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

3. (a) (continued)

(iii) The gymnast was in contact with the trampoline for 0·50 s.

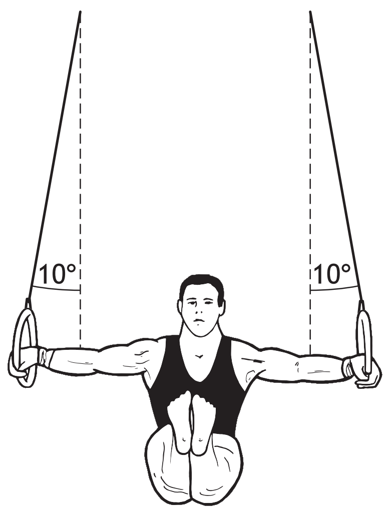
Calculate the magnitude of the average force exerted by the trampoline on the gymnast. **3**

Space for working and answer

3. (continued) **MARKS** DO NOT WRITE IN THIS MARGIN

(b) Another gymnast is practising on a piece of equipment called the rings. The gymnast grips two wooden rings suspended above the gym floor by strong vertical ropes as shown.

The gymnast now stretches out their arms until each rope makes an angle of 10° with the vertical as shown.



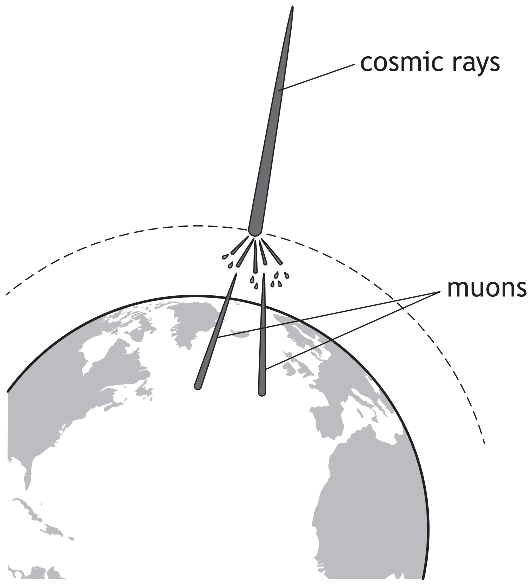
Explain why the tension in each rope increases as the gymnast stretches out their arms. **2**

[Turn over

Question			Expected response	Max mark	Additional guidance
3.	(a)	(i)	$v^2 = u^2 + 2as$ **(1)** $v^2 = 0 + 2 \times 9{\cdot}8 \times 2{\cdot}0$ **(1)** $v = 6{\cdot}3\ \text{m s}^{-1}$ OR $(m)gh = \frac{1}{2}(m)v^2$ **(1)** $(42) \times 9{\cdot}8 \times 2{\cdot}0 = \frac{1}{2}(42)v^2$ **(1)** $v = 6{\cdot}3\ \text{m s}^{-1}$	**2**	SHOW question. A maximum of 1 mark is available if the final line is not shown.
		(ii)	$\Delta p = mv - mu$ **(1)** $\Delta p = (42 \times (5{\cdot}3)) - (42 \times (-6{\cdot}3))$ **(1)** $\Delta p = 490\ \text{kg m s}^{-1}$ **(1)**	**3**	Accept 500, 487, 487·2 Accept alternative direction convention.
		(iii)	$Ft = mv - mu$ **(1)** $F \times 0{\cdot}50 = 490$ **(1)** $F = 980\ \text{N}$ **(1)**	**3**	Or consistent with (a)(ii) Accept 1000, 980·0
	(b)		Tension (in rope) now has a horizontal component **(1)** Vertical component of tension (in rope) is unchanged **(1)**	**2**	Independent marks Statements must refer to forces on rope.

MARKS DO NOT WRITE IN THIS MARGIN

4. Muons are sub-atomic particles produced when cosmic rays enter the atmosphere about 10 km above the surface of the Earth.



Muons have a mean lifetime of $2{\cdot}2 \times 10^{-6}$ s in their frame of reference. Muons are travelling at $0{\cdot}995c$ relative to an observer on Earth.

(a) Show that the mean distance travelled by the muons in their frame of reference is 660 m. **2**

Space for working and answer

(b) Calculate the mean lifetime of the muons measured by an observer on Earth.

Space for working and answer **3**

MARKS DO NOT WRITE IN THIS MARGIN

4. (continued)

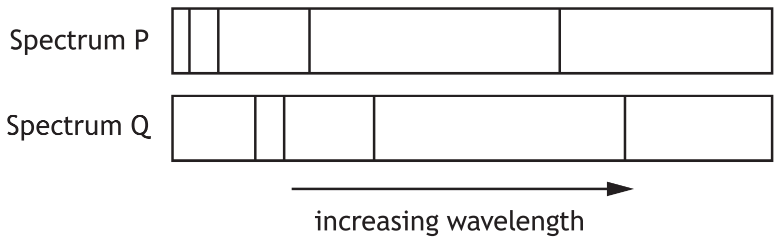
(c) Explain why a greater number of muons are detected on the surface of the Earth than would be expected if relativistic effects were not taken into account. **1**

[Turn over

Question			Expected response	Max mark	Additional guidance
4.	(a)		$d = \bar{v}t$ **(1)** $d = (3{\cdot}00 \times 10^8 \times 0{\cdot}995) \times 2{\cdot}2 \times 10^{-6}$ **(1)** $d = 660$ m	2	SHOW question. A maximum of 1 mark is available if the final line is not shown.
	(b)		$t' = \dfrac{t}{\sqrt{1-\left(\dfrac{v}{c}\right)^2}}$ **(1)** $t' = \dfrac{2{\cdot}2\times10^{-6}}{\sqrt{1-\left(\dfrac{0{\cdot}995}{1}\right)^2}}$ **(1)** $t' = 2{\cdot}2\times10^{-5}$ s **(1)**	3	Accept 2, 2·20, 2·203
	(c)		The mean lifetime of the muon is greater for an observer in Earth's frame of reference OR The mean distance travelled by a muon is shorter in the muon's frame of reference	1	

MARKS DO NOT WRITE IN THIS MARGIN

5. (a) The diagram below represents part of the emission spectrum for the element hydrogen.



Spectrum P is from a laboratory source.

Spectrum Q shows the equivalent lines from a distant galaxy as observed on the Earth.

(i) Explain why the lines on spectrum Q are in a different position to those on spectrum P. **2**

(ii) One of the lines in spectrum P has a wavelength of 656 nm. The equivalent line in spectrum Q is measured to have a wavelength of 676 nm.

Determine the recessional velocity of the galaxy. **5**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

5. (continued)

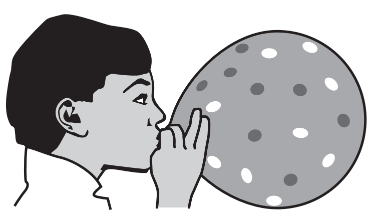
(b) The recessional velocity of another distant galaxy is $1 \cdot 2 \times 10^7\ \text{m s}^{-1}$.

Calculate the approximate distance to this galaxy. **3**

Space for working and answer

(c) A student explains the expansion of the Universe using an 'expanding balloon model'.

The student draws 'galaxies' on a balloon and then inflates it.



Using your knowledge of physics, comment on this model. **3**

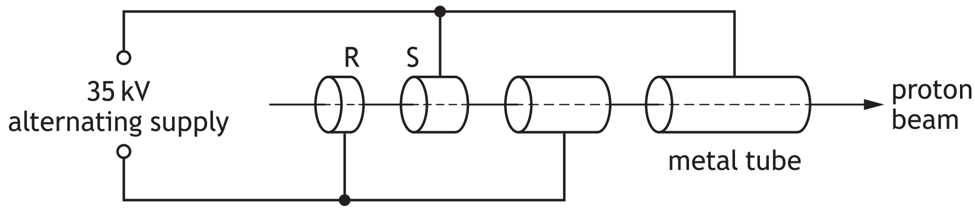
S857760113

Question			Expected response	Max mark	Additional guidance
5.	(a)	(i)	The galaxy is moving away from Earth **(1)** The apparent wavelengths of the lines of the hydrogen spectrum from the galaxy have increased **(1)** OR The apparent frequencies of the lines of the hydrogen spectrum from the galaxy are less than the corresponding frequencies from the laboratory source OR The frequency of the light from the galaxy has shifted towards the red end of the spectrum OR Observed light from the galaxy shows redshift	**2**	
		(ii)	$z=\frac{(\lambda_{obs}-\lambda_{rest})}{\lambda_{rest}}$ **(1)** $z=\frac{(676\times10^{-9}-656\times10^{-9})}{656\times10^{-9}}$ **(1)** $z=\frac{v}{c}$ **(1)** $\frac{(676\times10^{-9}-656\times10^{-9})}{656\times10^{-9}}=\frac{v}{3\cdot00\times10^{8}}$ **(1)** $v=9\cdot15\times10^{6}\ \text{m s}^{-1}$ **(1)**	**5**	Accept 9·1,9·146,9·1463
	(b)		$v=H_0d$ **(1)** $1\cdot2\times10^{7}=2\cdot3\times10^{-18}\times d$ **(1)** $d=5\cdot2\times10^{24}\ \text{m}$ **(1)**	**3**	Accept 5, 5·22, 5·217

MARKS DO NOT WRITE IN THIS MARGIN

6. A linear accelerator is used to accelerate protons.

The accelerator consists of hollow metal tubes placed in a vacuum.



The diagram shows the path of the protons through the accelerator.

Protons are accelerated across the gaps between the tubes by a potential difference of 35 kV.

(a) The protons are travelling at $1{\cdot}2 \times 10^6\ \mathrm{m\,s^{-1}}$ at point R.

(i) Show that the work done on a proton as it accelerates from R to S is $5{\cdot}6 \times 10^{-15}$ J. **2**

Space for working and answer

(ii) Determine the speed of the proton as it reaches S. **5**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

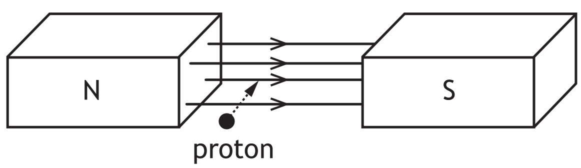
6. (continued)

(b) (i) Explain why an alternating supply is used in the linear accelerator. **1**

(ii) Suggest one reason why the lengths of the tubes increase along the accelerator. **1**

(c) In the Large Hadron Collider (LHC) beams of hadrons travel in opposite directions inside a circular accelerator and then collide. The accelerating particles are guided along the collider using strong magnetic fields.

The diagram shows a proton entering a magnetic field.



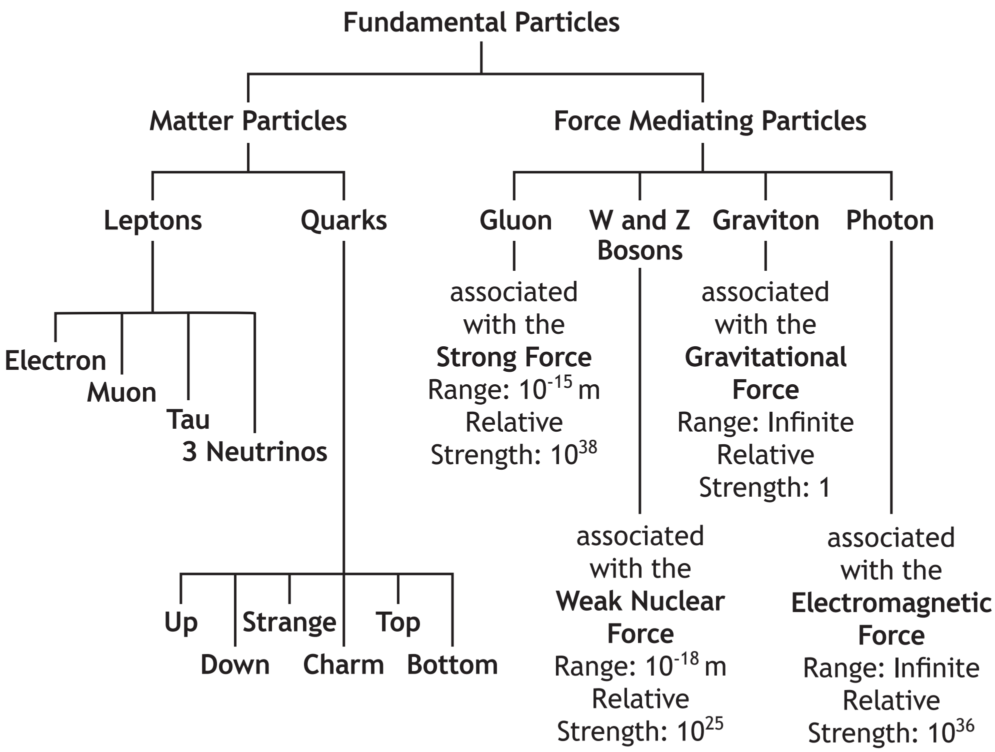
In which direction is this proton initially deflected? **1**

[Turn over

Question			Expected response	Max mark	Additional guidance
6.	(a)	(i)	$W = QV$ **(1)** $W = 1{\cdot}60 \times 10^{-19} \times 3{\cdot}5 \times 10^{4}$ **(1)** $W = 5{\cdot}6 \times 10^{-15}$ J	2	SHOW question. A maximum of 1 mark is available if the final line is not shown.
		(ii)	E_k at R $E_k = \frac{1}{2}mv^2$ **(1)** $E_k = 0{\cdot}5 \times 1{\cdot}673 \times 10^{-27} \times (1{\cdot}2 \times 10^{6})^2$ **(1)** E_k at S $E_k = \frac{1}{2}mv^2$ $\lfloor 0{\cdot}5 \times 1{\cdot}673 \times 10^{-27} \times (1{\cdot}2 \times 10^{6})^2 \rfloor$ $+5{\cdot}6 \times 10^{-15}$ $= 0{\cdot}5 \times 1{\cdot}673 \times 10^{-27} \times v^2$ addition **(1)** substitution **(1)** $v = 2{\cdot}9 \times 10^{6}$ m s^{-1} **(1)**	5	Accept 3,2·85,2·852
	(b)	(i)	To ensure the (accelerating) force is in the same direction OR To ensure the protons accelerate in the same direction OR To ensure that the direction of the electric field is correct when the proton passes through a tube	1	
	(b)	(ii)	Alternating voltage has a constant frequency (rather than a frequency that changes) OR As speed of proton increases, they travel further in the same time	1	
	(c)		Downwards	1	

MARKS DO NOT WRITE IN THIS MARGIN

7. The following diagram gives information about the Standard Model of fundamental particles and interactions.



Use information from the diagram and your knowledge of the Standard Model to answer the following questions.

(a) Explain why particles such as leptons and quarks are known as *fundamental particles*. **1**

(b) A particle called the sigma plus (Σ^+) has a charge of $+1e$. It contains two different types of quark. It has two up quarks each having a charge of $+\frac{2}{3}e$ and one strange quark.

Determine the charge on the strange quark. **1**

MARKS DO NOT WRITE IN THIS MARGIN

7. **(continued)**

(c) Explain why the gluon cannot be the force mediating particle for the gravitational force. **2**

(d) Compare the relative strength of the strong force with the weak nuclear force in terms of orders of magnitude. **1**

(e) A neutron decays into a proton, an electron and an antineutrino.

The equation for this decay is

$$ {}^{1}_{0}\text{n} \rightarrow {}^{1}_{1}\text{p} + {}^{0}_{-1}\text{e} + \bar{\nu}_e $$

State the name of this type of decay. **1**

[Turn over

Question			Expected response	Max mark	Additional guidance
7.	(a)		Fundamental particles cannot be subdivided	**1**	
	(b)		$-\frac{1}{3}e$	**1**	
	(c)		The strong force (associated with the gluon) has a short range. **(1)** The gravitational force (requires a force mediating particle that) has infinite range. **(1)**	**2**	
	(d)		(The strong force is) 13 (orders of magnitude) greater (than the weak force)	**1**	
	(e)		beta decay	**1**	

MARKS DO NOT WRITE IN THIS MARGIN

8. The following statement represents a fusion reaction.

$$4\,{}^{1}_{1}H \rightarrow {}^{4}_{2}He + 2\,{}^{0}_{1}e^{+}$$

The masses of the particles involved in the reaction are shown in the table.

Particle	*Mass* (kg)
${}^{1}_{1}H$	$1{\cdot}673 \times 10^{-27}$
${}^{4}_{2}He$	$6{\cdot}646 \times 10^{-27}$
${}^{0}_{1}e^{+}$	negligible

(a) Calculate the energy released in this reaction. **4**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

8. (continued)

(b) Calculate the energy released when 0·20 kg of hydrogen is converted to helium by this reaction. **3**

Space for working and answer

(c) Fusion reactors are being developed that use this type of reaction as an energy source.

Explain why this type of fusion reaction is hard to sustain in these reactors. **1**

[Turn over

S857760119

Question			Expected response	Max mark	Additional guidance
8.	(a)		mass loss $m = (4 \times 1{\cdot}673 \times 10^{-27}) - 6{\cdot}646 \times 10^{-27}$ **(1)** $E = mc^2$ **(1)** $E = ((4 \times 1{\cdot}673 \times 10^{-27}) - (6{\cdot}646 \times 10^{-27})) \times (3{\cdot}00 \times 10^8)^2$ **(1)** $E = 4{\cdot}14 \times 10^{-12}$ J **(1)**	**4**	Accept 4·1, 4·140, 4·1400
	(b)		0·20 kg hydrogen has $\dfrac{0{\cdot}20}{1{\cdot}673 \times 10^{-27}}$ $(= 1{\cdot}195 \times 10^{26}$ atoms) **(1)** provides $\dfrac{1{\cdot}195 \times 10^{26}}{4} = 0{\cdot}2989 \times 10^{26}$ reactions **(1)** releases $0{\cdot}2989 \times 10^{26} \times 4{\cdot}14 \times 10^{-12}$ $= 1{\cdot}2 \times 10^{14}$ J **(1)**	**3**	Accept 1, 1·24,1·237 Multiplying the number of hydrogen nuclei by the energy for each reaction is wrong physics.
	(c)		The particles involved in fusion reactions must be at a high temperature	**1**	

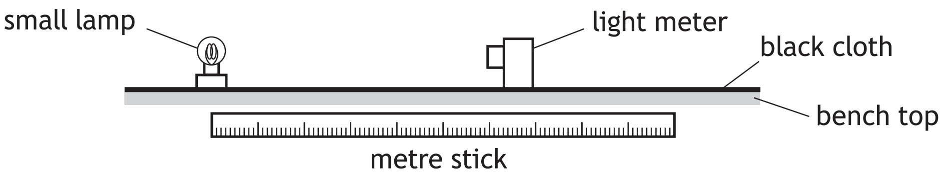
MARKS DO NOT WRITE IN THIS MARGIN

9. A student carries out an experiment to investigate how irradiance on a surface varies with distance from a small lamp.

Irradiance is measured using a light meter.

The distance between the small lamp and the light meter is measured with a metre stick.

The apparatus is set up in a darkened laboratory as shown.



The following results are obtained.

Distance from source (m)	0·200	0·300	0·400	0·500
Irradiance (units)	672	302	170	110

(a) State what is meant by the term *irradiance*. **1**

(b) Use **all** the data to find the relationship between irradiance I and distance d from the source.

You may wish to use the square-ruled paper on *page 37*. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

9. (continued)

(c) Suggest the purpose of the black cloth placed on top of the bench in the experimental setup. **1**

(d) The small lamp is replaced by a laser.

Light from the laser is shone onto the light meter.

A reading is taken from the light meter when the distance between the light meter and the laser is 0·200 m.

The distance is now increased to 0·500 m.

The reading on the light meter does not change.

Suggest why the reading on the light meter does not change. **1**

[Turn over

<table>
<tr><th colspan="3">Question</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>9.</td><td>(a)</td><td></td><td>Irradiance is the power incident per unit area</td><td>1</td><td></td></tr>
<tr><td></td><td>(b)</td><td></td><td>Graphical method

Correct quantities on axes
(I and $1/d^2$) (1)

Accuracy of plotting and line of best fit (1)

Statement of relationship (1)

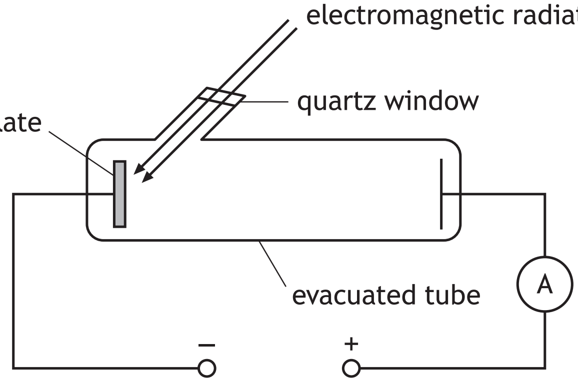
Do not award statement mark if less than three points plotted accurately.</td><td>3</td><td>ALTERNATIVE METHOD

<table><tr><td>d</td><td>0·200</td><td>0·300</td><td>0·400</td><td>0·500</td></tr><tr><td>I</td><td>672</td><td>302</td><td>170</td><td>110</td></tr><tr><td>Id^2</td><td>26·9</td><td>27·2</td><td>27·2</td><td>27·5</td></tr></table>
AND
Within the limits of experimental uncertainty, Id^2 is constant and so $I \alpha 1/d^2$.

Award 3 marks where all four calculated values in the table are correct and the final statement is correct.
Award 2 marks where all four calculated values in the table are correct and the final statement is incorrect or omitted.
Award 2 marks where three calculations in the table are correct and the final statement is correct.
Award 1 mark where three calculations in the table are correct and the final statement is incorrect or omitted.
Award 0 marks where fewer than three calculations are correct (a relationship cannot be stated from only two values or fewer).</td></tr>
<tr><td></td><td>(c)</td><td></td><td>(Black cloth) prevents reflections</td><td>1</td><td></td></tr>
<tr><td></td><td>(d)</td><td></td><td>The laser is not a point source
OR
Light from the laser does not conform to the inverse square law
OR
Laser beam does not spread out</td><td>1</td><td></td></tr>
</table>

MARKS DO NOT WRITE IN THIS MARGIN

10. A metal plate emits electrons when certain wavelengths of electromagnetic radiation are incident on it.



The work function of the metal is $2{\cdot}24 \times 10^{-19}$ J.

(a) Electrons are released when electromagnetic radiation of wavelength 525 nm is incident on the surface of the metal plate.

(i) Show that the energy of each photon of the incident radiation is $3{\cdot}79 \times 10^{-19}$ J. **4**

Space for working and answer

(ii) Determine the maximum kinetic energy of an electron released from the surface of the metal plate. **1**

Space for working and answer

S857760122

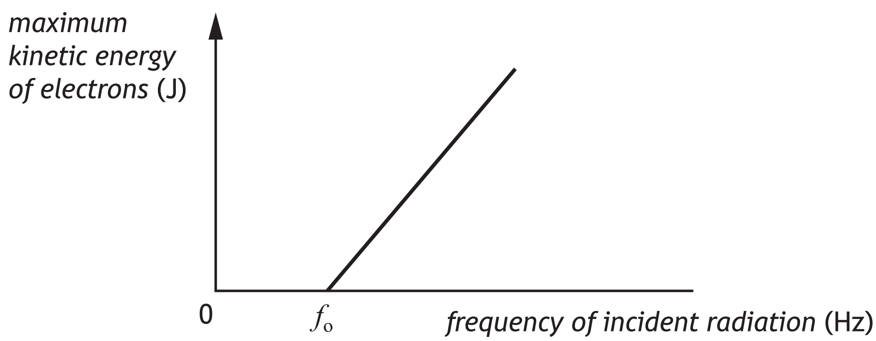
MARKS DO NOT WRITE IN THIS MARGIN

10. (continued)

(b) The frequency of the incident radiation in now varied through a range of values.

The maximum kinetic energy of electrons leaving the metal plate is determined for each frequency.

A graph of this maximum kinetic energy against frequency is shown.



(i) Explain why no electrons leave the metal plate when the frequency of the incident radiation is below f_0. **1**

(ii) Calculate the frequency f_0. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

10. (continued)

(c) The use of analogies from everyday life can help better understanding of physics concepts. Throwing different balls at a coconut shy to dislodge a coconut is an analogy that can help understanding of the photoelectric effect .

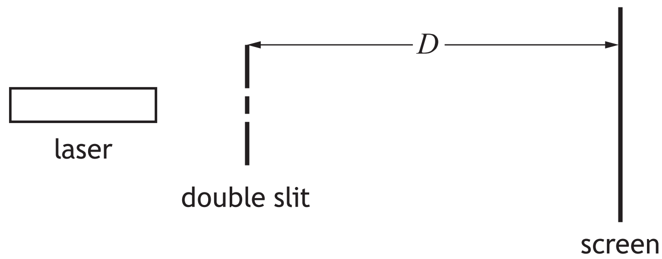
Use your knowledge of physics to comment on this analogy. **3**

Question			Expected response	Max mark	Additional guidance
10.	(a)	(i)	$v = f\lambda$ **(1)** $3{\cdot}00\times10^{8} = f\times525\times10^{-9}$ **(1)** $E = hf$ **(1)** $E = 6{\cdot}63\times10^{-34}\times\left(\dfrac{3{\cdot}00\times10^{8}}{525\times10^{-9}}\right)$ **(1)** $E = 3{\cdot}79\times10^{-19}$ J	**4**	SHOW question. A maximum of 3 marks is available if the final line is not shown.
		(ii)	$(E_k = 3{\cdot}79\times10^{-19} - 2{\cdot}24\times10^{-19})$ $E_k = 1{\cdot}55\times10^{-19}$ J	**1**	
	(b)	(i)	Photons with frequency below f_0 do not have enough energy to release electrons	**1**	
		(ii)	$E = hf_0$ **(1)** $2{\cdot}24\times10^{-19} = (6{\cdot}63\times10^{-34})\times f_0$ **(1)** $f_0 = 3{\cdot}38\times10^{14}$ Hz **(1)**	**3**	Accept 3·4, 3·379, 3·3786

MARKS DO NOT WRITE IN THIS MARGIN

11. A helium-neon laser produces a beam of monochromatic light.

A student directs this laser beam onto a double slit arrangement as shown in the diagram.



A pattern of bright red fringes is observed on the screen.

(a) Explain, in terms of waves, why bright red fringes are produced. **1**

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

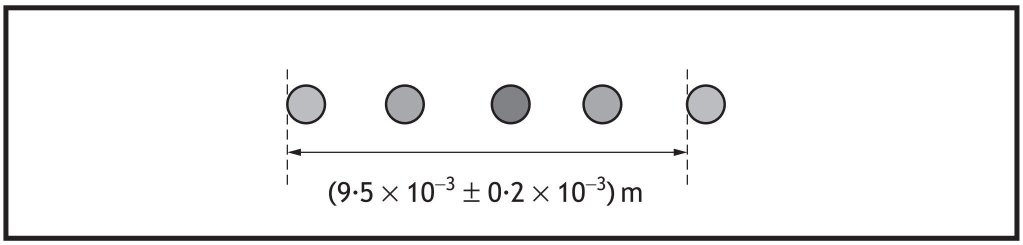
11. (continued)

(b) The average separation Δx between adjacent fringes is given by the relationship

$$\Delta x = \frac{\lambda D}{d}$$

where: λ is the wavelength of the light
D is the distance between the double slit and the screen
d is the distance between the two slits

The diagram shows the value measured by the student of the distance between a series of fringes and the uncertainty in this measurement.



The student measures the distance D between the double slit and the screen as (0·750 ± 0·001) m.

(i) Calculate the best estimate of the distance between the two slits.

An uncertainty in the calculated value is not required. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

11. (b) (continued)

(ii) The student wishes to determine more precisely the value of the distance between the two slits d.

Show, by calculation, which of the student's measurements should be taken more precisely in order to achieve this.

You must indicate clearly which measurement you have identified. **3**

Space for working and answer

(c) The helium-neon laser is replaced by a laser emitting green light. No other changes are made to the experimental set-up.

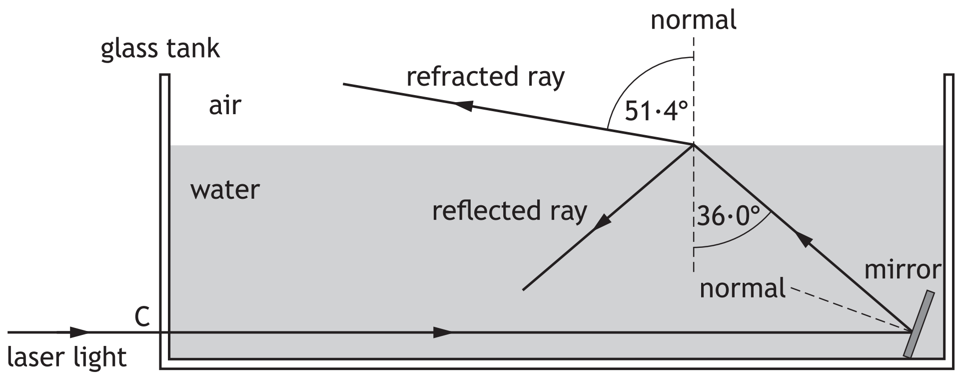
Explain the effect this change has on the separation of the fringes observed on the screen. **2**

[Turn over

Question			Expected response	Max mark	Additional guidance
11.	(a)		Bright fringes are produced by waves meeting in phase/crest to crest/trough to trough	**1**	
	(b)	(i)	$\Delta x = \frac{\lambda D}{d}$ $\frac{9 \cdot 5 \times 10^{-3}}{4} = \frac{633 \times 10^{-9} \times 0 \cdot 750}{d}$ division by 4 **(1)** substitutions **(1)** $d = 2 \cdot 0 \times 10^{-4}$ m **(1)**	**3**	Accept 2,2·00,1·999 The mark for dividing by 4 is independent
		(ii)	$\%uncertainty \Delta x = \frac{0 \cdot 2 \times 10^{-3} \times 100}{9 \cdot 5 \times 10^{-3}} = 2 \cdot 1\%$ **(1)** $\%uncertainty D = \frac{0 \cdot 001 \times 100}{0 \cdot 750} = 0 \cdot 13\%$ **(1)** Improve precision in measurement of Δx **(1)**	**3**	
	(c)		Green light has a shorter wavelength **(1)** Fringes are closer together **(1)**	**2**	

MARKS | DO NOT WRITE IN THIS MARGIN

12. A technician investigates the path of laser light as it passes through a glass tank filled with water. The light enters the glass tank along the normal at **C** then reflects off a mirror submerged in the water.



(a) Show that the refractive index of water for this laser light is 1·33. **2**

Space for working and answer

(b) The mirror is now adjusted until the light strikes the surface of the water at the critical angle.

(i) State what is meant by the *critical angle*. **1**

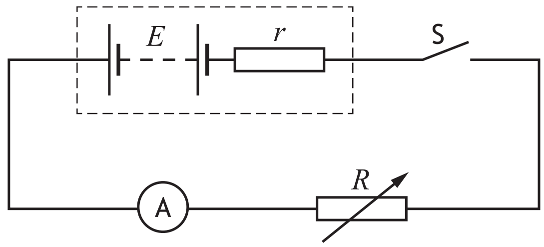
(ii) Calculate the critical angle for this light in the water. **3**

Space for working and answer

* S 8 5 7 7 6 0 1 2 8 *

Question			Expected response	Max mark	Additional guidance
12.	(a)		$n = \frac{\sin\theta_1}{\sin\theta_2}$ **(1)** $n = \frac{\sin(51 \cdot 4)}{\sin(36 \cdot 0)}$ **(1)** $n = 1 \cdot 33$	**2**	SHOW question. A maximum of 1 mark is available if the final line is not shown.
	(b)	(i)	(Critical angle is) the angle of incidence that produces an angle of refraction of 90°	**1**	
		(ii)	$\sin\theta_c = \frac{1}{n}$ **(1)** $\sin\theta_c = \frac{1}{1 \cdot 33}$ **(1)** $\theta_c = 48 \cdot 8^\circ$ **(1)**	**3**	Accept 49, 48·75, 48·753

13. The following circuit is used to determine the internal resistance r of a battery of EMF E.

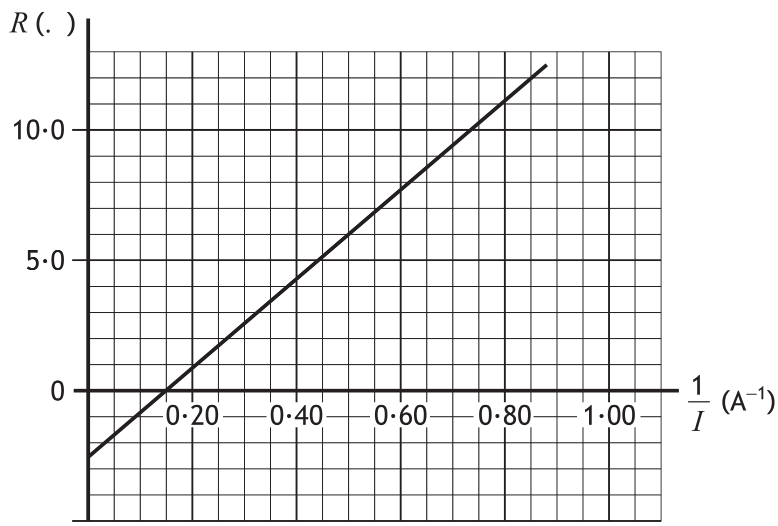


The variable resistor provides known values of resistance R.

For each value of resistance R the switch S is closed and the current I is noted.

For each current, the value of $\frac{1}{I}$ is calculated.

In one such experiment, the following graph of R against $\frac{1}{I}$ is obtained.



Conservation of energy applied to the complete circuit gives the following relationship.

$$R = \frac{E}{I} - r$$

This relationship is in the form of the equation of a straight line

$$y = mx + c$$

where m is the gradient and c is the y-intercept.

MARKS DO NOT WRITE IN THIS MARGIN

13. **(continued)**

(a) Use information from the graph to determine:

(i) the internal resistance of the battery **1**

(ii) the EMF of the battery. **2**

Space for working and answer

(b) The battery is accidentally short-circuited.

Calculate the current in the battery when this happens. **3**

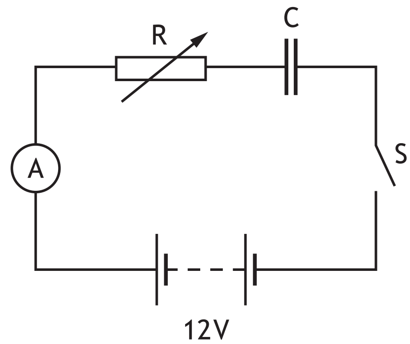
Space for working and answer

Question			Expected response	Max mark	Additional guidance
13.	(a)	(i)	2·5 Ω	**1**	
		(ii)	$E=\dfrac{y_2-y_1}{x_2-x_1}$ $E=\dfrac{11-0}{0\cdot80-0\cdot15}$ substitution of two points on line **(1)** $E=17\ \text{V}$ **(1)**	**2**	Or consistent with data points chosen
	(b)		$V=IR$ **(1)** $17=I\times2\cdot5$ **(1)** $I=6\cdot8\ \text{A}$ **(1)**	**3**	Or consistent with (a)(i) and (a)(ii)

MARKS DO NOT WRITE IN THIS MARGIN

14. A 220 μF capacitor is charged using the circuit shown.

The 12 V battery has negligible internal resistance.



The capacitor is initially uncharged.

The switch S is closed. The charging current is kept constant at $3{\cdot}0 \times 10^{-5}$ A by adjusting the resistance of variable resistor R.

(a) Calculate the resistance of the variable resistor R just after the switch is closed. **3**

Space for working and answer

(b) (i) Calculate the charge on the capacitor 25 s after switch S is closed. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

14. (b) (continued)

(ii) Calculate the potential difference across R at this time. **4**

Space for working and answer

S857760132

Question			Expected response	Max mark	Additional guidance
14.	(a)		$V = IR$ **(1)** $12 = 3{\cdot}0\times10^{-5}\times R$ **(1)** $R = 4{\cdot}0\times10^{5}\ \Omega$ **(1)**	**3**	Accept 4, 4·00, 4·000
	(b)	(i)	$Q = It$ **(1)** $Q = 3{\cdot}0\times10^{-5}\times25$ **(1)** $Q = 7{\cdot}5\times10^{-4}$ C **(1)**	**3**	Accept 8, 7·50, 7·500
		(ii)	$C = \dfrac{Q}{V}$ **(1)** $220\times10^{-6} = \dfrac{7{\cdot}5\times10^{-4}}{V}$ **(1)** $V = 3{\cdot}4$ (V) **(1)** Therefore voltage across resistor is $12 - 3{\cdot}4 = 8{\cdot}6$ V **(1)**	**4**	Or consistent with (b)(i) Accept 9, 8·59, 8·591

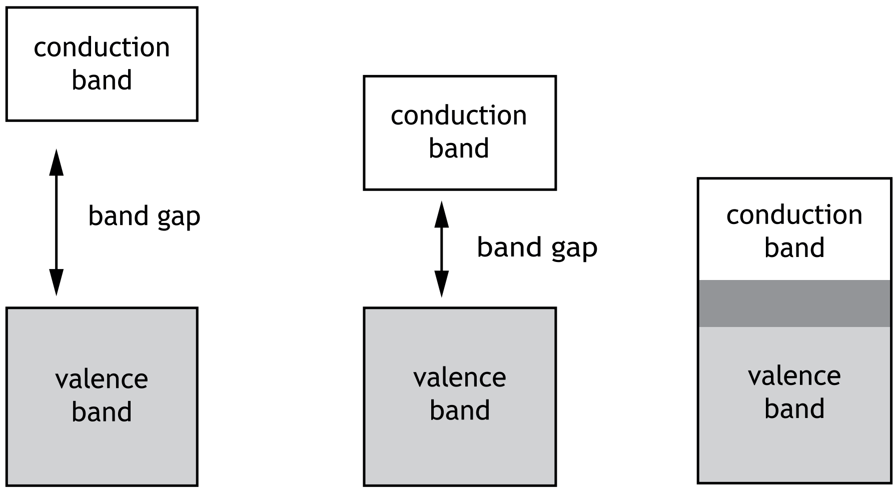
MARKS DO NOT WRITE IN THIS MARGIN

15. The electrical conductivity of solids can be explained using band theory.

The diagrams below show the distributions of the valence and conduction bands of materials classified as conductors, insulators and semiconductors.

Shaded areas represent bands occupied by electrons.

The band gap is also indicated.



Material 1 **Material 2** **Material 3**

(a) State which material is a semiconductor. **1**

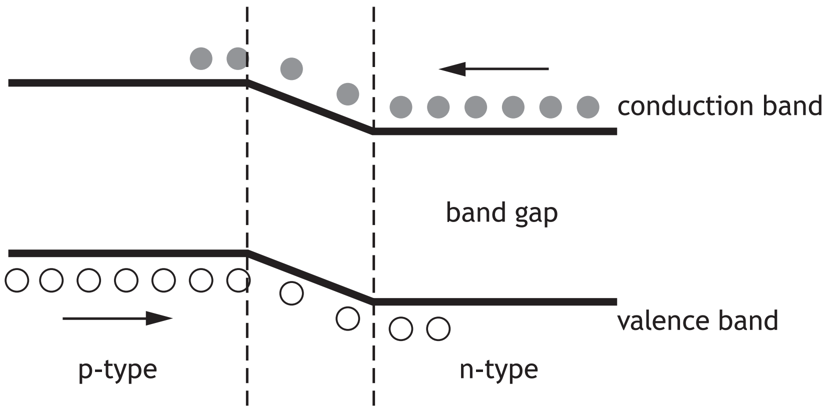
[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

15. (continued)

(b) An LED is made from semiconductor material that has been doped with impurities to create a p-n junction.

The diagram represents the band structure of an LED.



A voltage is applied across an LED so that it is forward biased and emits light.

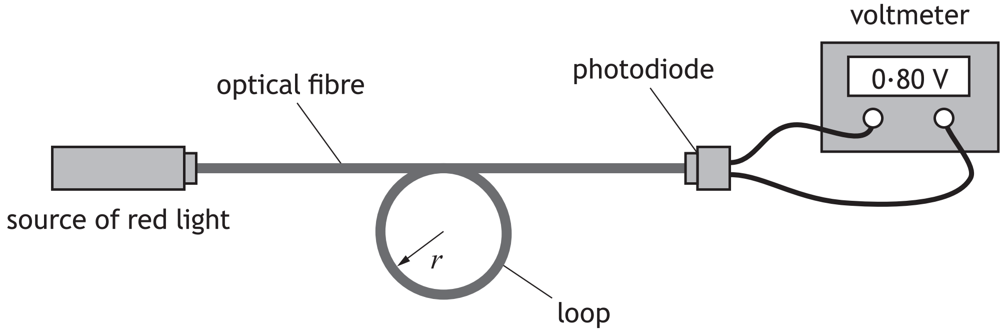
Using **band theory**, explain how the LED emits light. **3**

Question			Expected response	Max mark	Additional guidance
15.	(a)		Material 2	**1**	
	(b)		(Voltage applied causes) electrons to move towards conduction band of p-type **(1)** Electrons move/drop from conduction band to valence band **(1)** Photon emitted (when electron drops) **(1)**	**3**	If candidate does not refer to either conduction band or valence band, award 0 marks. Bands must be named correctly in first two marking points ie not valency or conductive. Award 0 marks for any answer using recombination of holes and electrons **on its own**, with no reference to band theory. The final mark is dependent upon having at least one of the first two statements correct.

MARKS DO NOT WRITE IN THIS MARGIN

16. A group of students carries out an experiment to investigate the transmission of light through an optical fibre.

Red light is transmitted through a loop of optical fibre and detected by a photodiode connected to a voltmeter as shown.



The photodiode produces a voltage proportional to the irradiance of light incident on it.

The students vary the radius, r, of the loop of the optical fibre and measure the voltage produced by the photodiode.

The results are shown in the table.

Radius of loop (mm)	*Voltage* (V)
5	0·48
10	0·68
15	0·76
20	0·79
30	0·80
40	0·80

(a) Using the square-ruled paper provided on *page 38*, draw a graph of these results. **3**

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

16. (continued)

(b) For use in communication systems, the amount of light transmitted through a loop of optical fibre must be at least 75% of the value of the fibre with no loop.

With no loop in this fibre the reading on the voltmeter is 0·80 V.

Use your graph to estimate the minimum radius of loop when using this fibre in communication systems. **1**

(c) Using the same apparatus, the students now wish to determine a better estimate of the true value of minimum radius of loop when using this fibre in communication systems.

Suggest **two** improvements to the experimental procedure that would achieve this. **2**

[END OF SPECIMEN QUESTION PAPER]

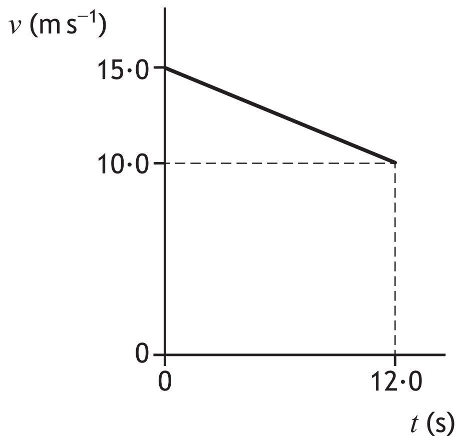
Question			Expected response	Max mark	Additional guidance
16.	(a)		Suitable scales with labels on axes (quantity and unit) **(1)** Points plotted accurately **(1)** Acceptable line(curve) of best fit **(1)**	**3**	
	(b)		7·5 mm ±1mm	**1**	Or consistent with graph drawn
	(c)		Repeat measurements **(1)** Smaller steps/divisions/intervals in radius (around the 75% value or equivalent) **(1)**	**2**	

[END OF SPECIMEN MARKING INSTRUCTIONS]

Total mark — 25

Attempt ALL questions

1. The graph shows how the speed v of a car varies with time t.



The average speed of the car during the 12·0 s is

A $1{\cdot}25\ \text{m s}^{-1}$

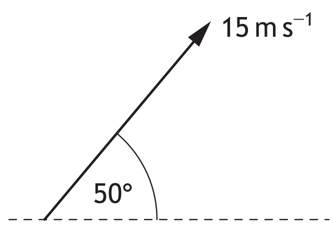
B $2{\cdot}08\ \text{m s}^{-1}$

C $2{\cdot}50\ \text{m s}^{-1}$

D $7{\cdot}50\ \text{m s}^{-1}$

E $12{\cdot}5\ \text{m s}^{-1}$.

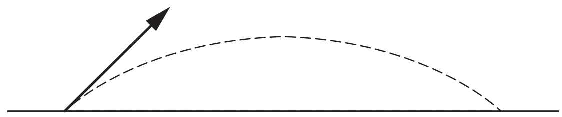
2. A stone is thrown at 50° to the horizontal with a speed of $15\ \text{m s}^{-1}$.



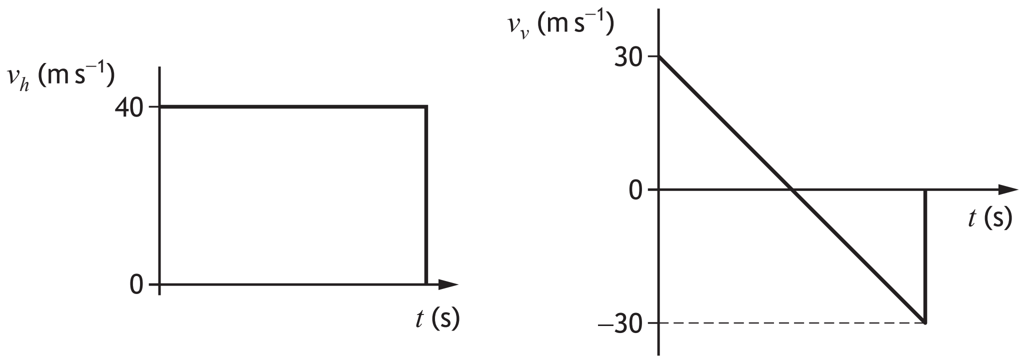
Which row in the table gives the horizontal component and the vertical component of the initial velocity of the stone?

	Horizontal component (m s^{-1})	Vertical component (m s^{-1})
A	15 sin 50	15 cos 50
B	15 cos 50	15 sin 50
C	15 cos 50	15 sin 40
D	15 cos 40	15 sin 50
E	15 sin 50	15 cos 40

3. A golfer strikes a golf ball, which then moves off at an angle to the ground. The ball follows the path shown.



The graphs show how the horizontal component of the velocity v_h and the vertical component of the velocity v_v of the ball vary with time t.



The speed of the ball just before it hits the ground is

A 10 m s^{-1}

B 30 m s^{-1}

C 40 m s^{-1}

D 50 m s^{-1}

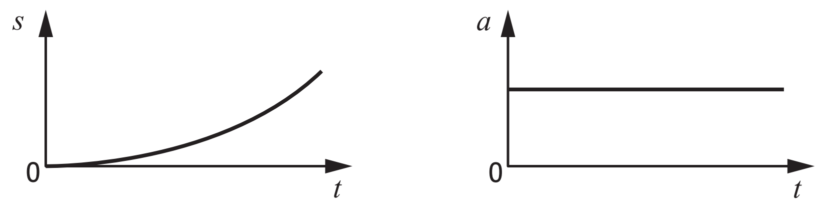
E 70 m s^{-1}.

4. A car accelerates from rest along a straight level road.

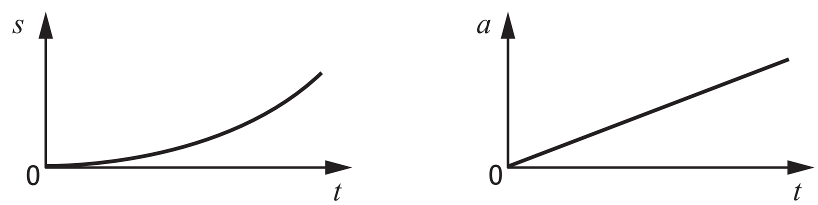
The acceleration of the car is constant.

Which pair of displacement-time (s-t) and acceleration-time (a-t) graphs represent the motion of the car?

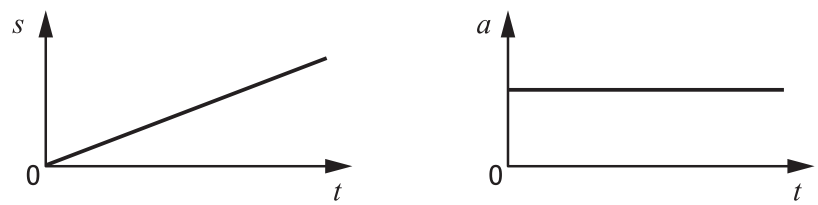
A



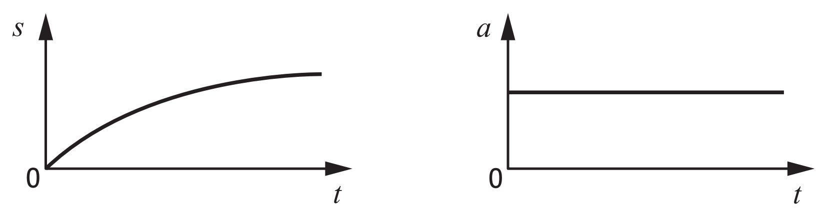
B



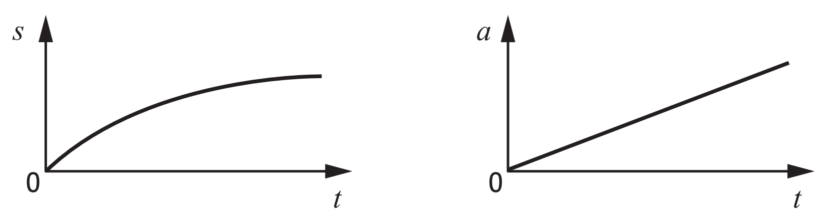
C



D

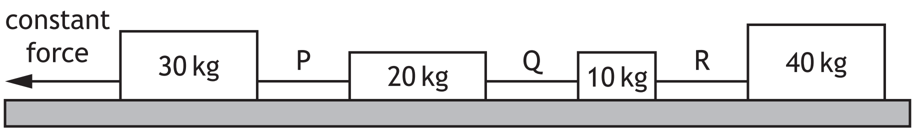


E



[Turn over

5. Four masses on a horizontal, frictionless surface are linked together by strings P, Q and R. A constant force is applied as shown.



The tension in the strings is

A greatest in P and least in Q

B greatest in P and least in R

C greatest in R and least in Q

D greatest in R and least in P

E the same in P, Q and R.

6. A student makes the following statements about an elastic collision.

I Total momentum is conserved.

II Total kinetic energy is conserved.

III Total energy is conserved.

Which of these statements is/are correct?

A I only

B II only

C I and II only

D I and III only

E I, II and III

7. The terminal velocity v_t of a skydiver is given by the relationship

$$v_t = \sqrt{\frac{2mg}{\rho A C_d}}$$

where

m is the mass of the skydiver in kg

g is the gravitational field strength in N kg^{-1}

C_d is the drag coefficient

ρ is the density of air in kg m^{-3}

A is the area of the skydiver in m^2.

When in freefall, a skydiver of mass 95 kg has a drag coefficient of 1·0 and a terminal velocity of 44 m s^{-1}.

The gravitational field strength is 9·8 N kg^{-1} and the density of air is 1·21 kg m^{-3}.

The area of the skydiver is

A 0·59 m^2

B 0·79 m^2

C 0·89 m^2

D 4·2 m^2

E 35 m^2.

8. A spacecraft is travelling at a constant speed relative to a nearby planet.

A technician on the spacecraft measures the length of the spacecraft as 275 m.

An observer on the planet measures the length of the spacecraft as 125 m.

The speed of the spacecraft relative to the observer on the nearby planet is

A $1{\cdot}54 \times 10^4$ m s^{-1}

B $2{\cdot}22 \times 10^8$ m s^{-1}

C $2{\cdot}67 \times 10^8$ m s^{-1}

D $3{\cdot}00 \times 10^8$ m s^{-1}

E $7{\cdot}14 \times 10^{16}$ m s^{-1}.

[Turn over

9. The redshift of a distant galaxy is 0·014.

According to Hubble's law, the distance of the galaxy from Earth is

A $9{\cdot}66 \times 10^{-12}$ m

B $1{\cdot}83 \times 10^{24}$ m

C $1{\cdot}30 \times 10^{26}$ m

D $9{\cdot}32 \times 10^{27}$ m

E $6{\cdot}33 \times 10^{39}$ m.

10. A student makes the following statements about the Universe.

I The force due to gravity acts against the expansion of the Universe.

II Measurements show the rate of expansion of the Universe is increasing.

III The mass of a galaxy can be estimated by the orbital speed of the stars within the galaxy.

Which of these statements is/are correct?

A I only

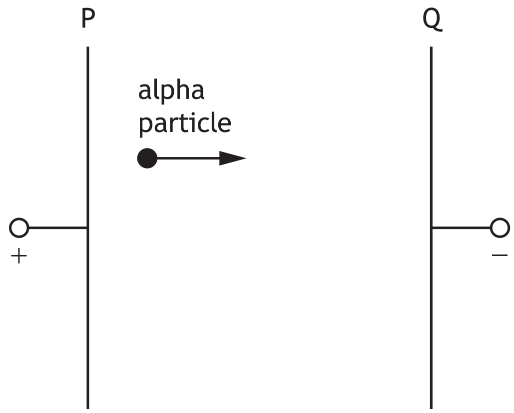
B II only

C III only

D I and II only

E I, II and III

11. An alpha particle is accelerated in an electric field between metal plates P and Q.



The charge on the alpha particle is $3{\cdot}2 \times 10^{-19}$ C.

The kinetic energy gained by the alpha particle while travelling from plate P to plate Q is $8{\cdot}0 \times 10^{-16}$ J.

The potential difference across plates P and Q is

A $2{\cdot}6 \times 10^{-34}$ V

B $2{\cdot}0 \times 10^{-4}$ V

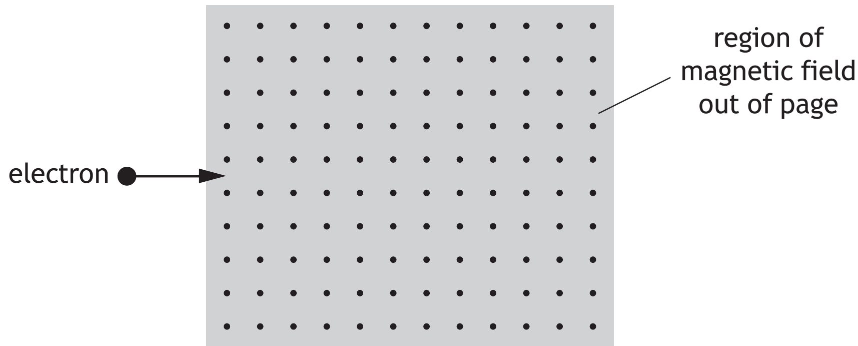
C $4{\cdot}0 \times 10^{-4}$ V

D $2{\cdot}5 \times 10^{3}$ V

E $5{\cdot}0 \times 10^{3}$ V.

[Turn over

12. An electron enters a region of uniform magnetic field as shown.



The direction of the magnetic force on the electron immediately after entering the field is

A towards the top of the page

B towards the bottom of the page

C towards the right of the page

D into the page

E out of the page.

13. A student makes the following statements about the Standard Model.

I Every particle has an antiparticle.

II Alpha decay is evidence for the existence of the neutrino.

III The W-boson is associated with the strong nuclear force.

Which of these statements is/are correct?

A I only

B II only

C III only

D I and II only

E I and III only

14. A nucleus represented by $^{223}_{87}\mathrm{Fr}$ decays by beta emission.

The symbol representing the nucleus formed as a result of this decay is

A $^{224}_{87}\mathrm{Fr}$

B $^{222}_{87}\mathrm{Fr}$

C $^{223}_{88}\mathrm{Ra}$

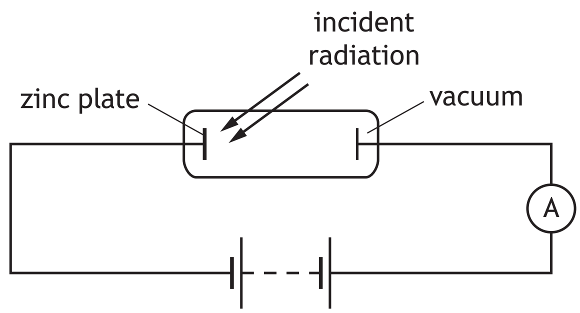
D $^{223}_{86}\mathrm{Rn}$

E $^{224}_{88}\mathrm{Ra}$.

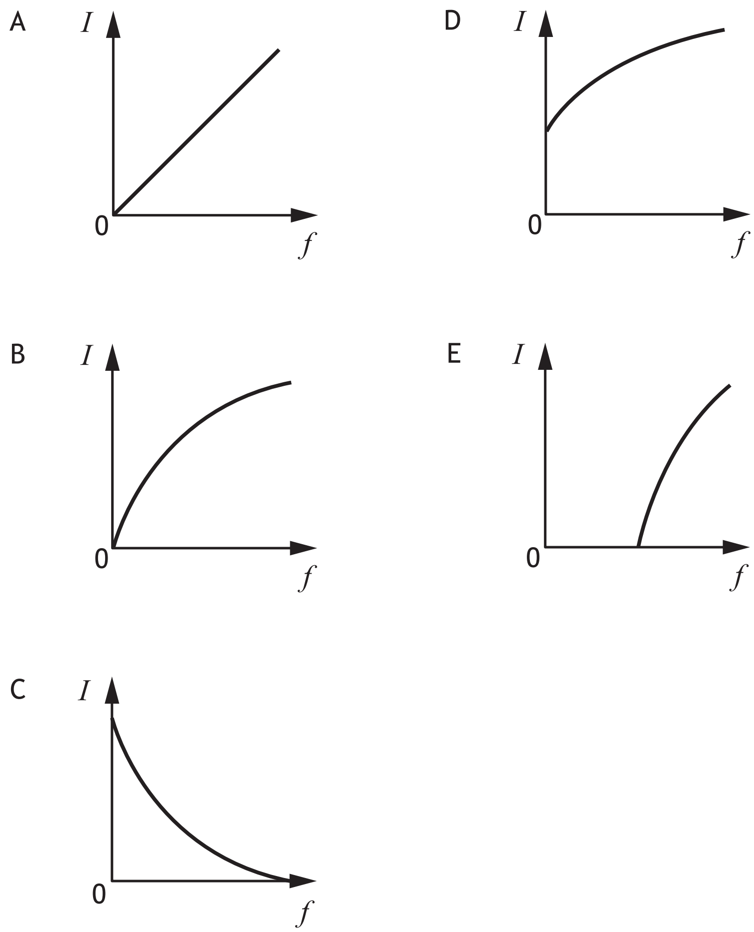
[Turn over

15. The diagram shows an experiment set up to investigate the photoelectric effect.

The frequency of the incident radiation is varied and the current in the circuit is measured.



Which graph shows the relationship between the current I in the circuit and the frequency f of the incident radiation?



16. A photon of energy $6{\cdot}40 \times 10^{-19}$ J is incident on a metal plate.

This causes photoemission to take place.

The work function of the metal is $4{\cdot}20 \times 10^{-19}$ J.

The maximum speed of the photoelectron is

A $1{\cdot}19 \times 10^{6}\,\mathrm{m\,s^{-1}}$

B $9{\cdot}60 \times 10^{5}\,\mathrm{m\,s^{-1}}$

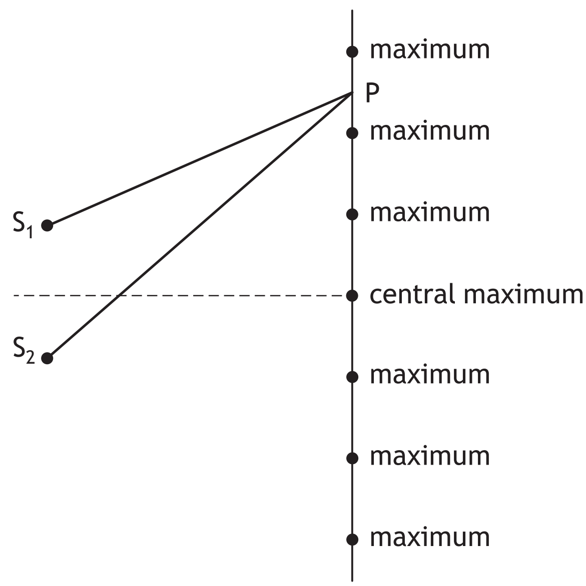
C $6{\cdot}95 \times 10^{5}\,\mathrm{m\,s^{-1}}$

D $6{\cdot}79 \times 10^{5}\,\mathrm{m\,s^{-1}}$

E $4{\cdot}91 \times 10^{5}\,\mathrm{m\,s^{-1}}$.

17. Waves from two coherent sources, S_1 and S_2, produce an interference pattern.

Maxima are detected at the positions shown.



The wavelength of the waves is 28 mm.

For the third **minimum** at P the path difference ($S_2P - S_1P$) is

A 42 mm

B 56 mm

C 70 mm

D 84 mm

E 98 mm.

[Turn over

18. A ray of monochromatic light passes from air into water.

The wavelength of this light in air is 589 nm.

The speed of this light in water is

A $2{\cdot}56 \times 10^{2}\,\mathrm{m\,s^{-1}}$

B $4{\cdot}52 \times 10^{2}\,\mathrm{m\,s^{-1}}$

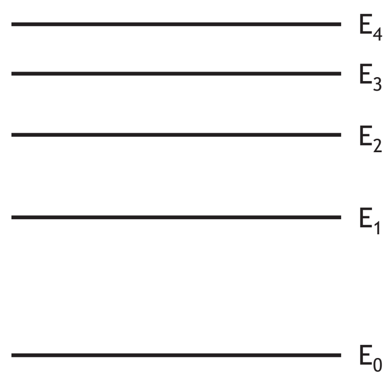
C $2{\cdot}26 \times 10^{8}\,\mathrm{m\,s^{-1}}$

D $3{\cdot}00 \times 10^{8}\,\mathrm{m\,s^{-1}}$

E $3{\cdot}99 \times 10^{8}\,\mathrm{m\,s^{-1}}$.

19. When light passes through the outer layers of the Sun certain frequencies of light are absorbed by hydrogen atoms, producing dark lines in the spectrum.

The diagram represents some of the energy levels for a hydrogen atom.



The number of absorption lines in the spectrum caused by the transition of electrons between these energy levels is

A 4

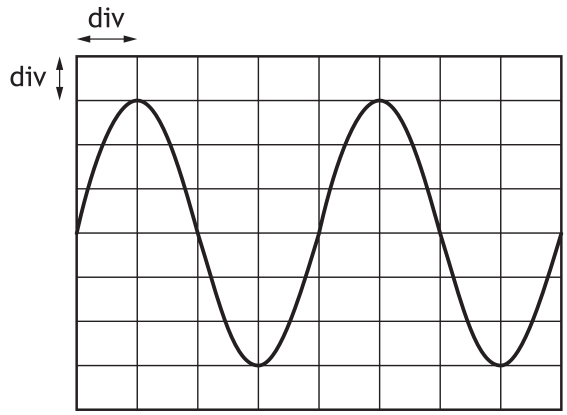
B 6

C 9

D 10

E 20.

20. The output from an AC power supply is connected to an oscilloscope. The trace seen on the oscilloscope screen is shown.



The Y-gain setting on the oscilloscope is 1·0 V/div.

The rms voltage of the power supply is

A 2·1 V

B 3·0 V

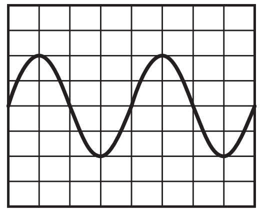
C 4·0 V

D 4·2 V

E 6·0 V.

[Turn over

21. The output from a signal generator is connected to an oscilloscope. The trace observed on the oscilloscope screen is as shown in the diagram.



The frequency of the signal from the signal generator is now doubled.

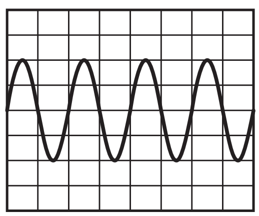
The amplitude of the signal is unchanged.

The Y-gain setting on the oscilloscope is unchanged.

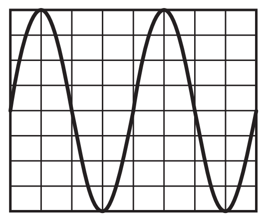
The timebase setting on the oscilloscope is changed from 1·0 ms/division to 0·5 ms/division.

Which of the following diagrams shows the trace that is now observed on the oscilloscope screen?

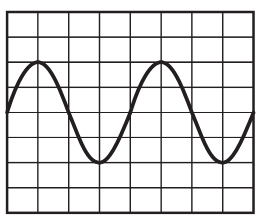
A



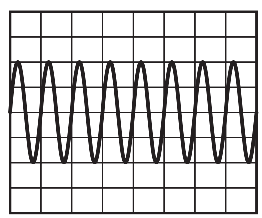
D



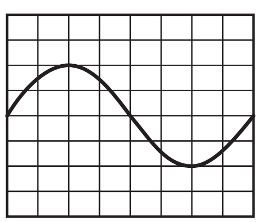
B



E



C



22. A student sets up a circuit and measures the voltage across and the current in a resistor.

The measurements and their uncertainties are

$$\text{voltage} = (10{\cdot}0 \pm 0{\cdot}1)\,\text{V}$$
$$\text{current} = (0{\cdot}50 \pm 0{\cdot}01)\,\text{A}$$

The approximate absolute uncertainty in the calculated value of the resistance of the resistor is

A $\pm 0{\cdot}11\,\Omega$

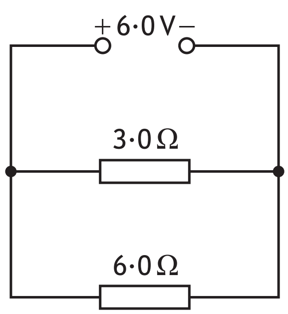
B $\pm 0{\cdot}2\,\Omega$

C $\pm 0{\cdot}4\,\Omega$

D $\pm 1\,\Omega$

E $\pm 2\,\Omega$.

23. A circuit is set up as shown.



The power supply has negligible internal resistance.

The power dissipated in the $3{\cdot}0\,\Omega$ resistor is

A $3{\cdot}0\,\text{W}$

B $6{\cdot}0\,\text{W}$

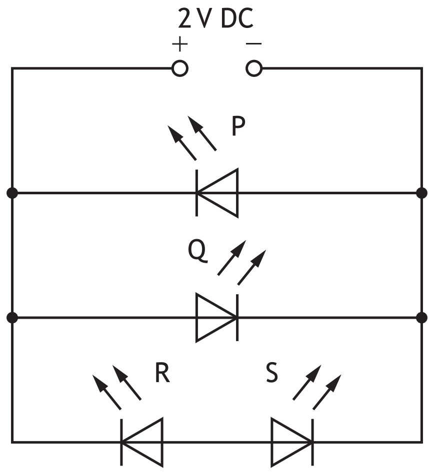
C $9{\cdot}0\,\text{W}$

D $12\,\text{W}$

E $18\,\text{W}$.

[Turn over

24. A student connects four identical light emitting diodes (LEDs) to a 2 V DC supply as shown.



Which of the LEDs P, Q, R, and S will light?

A P only

B Q only

C P and Q only

D P and R only

E Q and S only.

25. A student makes the following statements about uncertainties.

I All measurements of physical quantities are liable to uncertainties.

II Random uncertainties occur when a measurement is repeated and slight variations occur.

III Systematic uncertainties in a quantity occur when measurements are either all smaller or all larger than the true value of the quantity.

Which of these statements is/are correct?

A I only

B I and II only

C I and III only

D II and III only

E I, II and III

[END OF QUESTION PAPER]

Marking instructions for each question

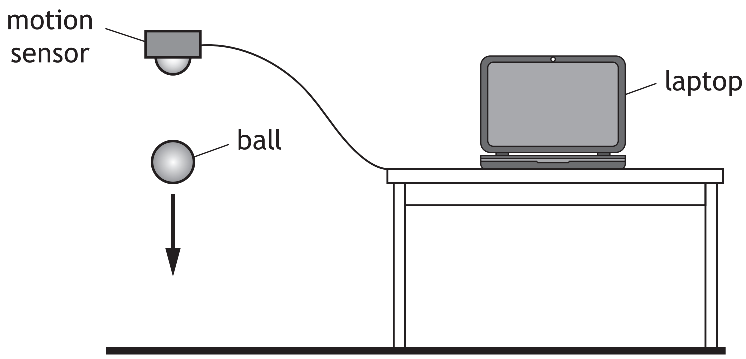
Question	Answer	Mark
1.	E	1
2.	B	1
3.	D	1
4.	A	1
5.	B	1
6.	E	1
7.	B	1
8.	C	1
9.	B	1
10.	E	1
11.	D	1
12.	A	1
13.	A	1
14.	C	1
15.	E	1
16.	C	1
17.	C	1
18.	C	1
19.	D	1
20.	A	1
21.	B	1
22.	C	1
23.	D	1
24.	B	1
25.	E	1

[END OF MARKING INSTRUCTIONS]

Total marks — 130

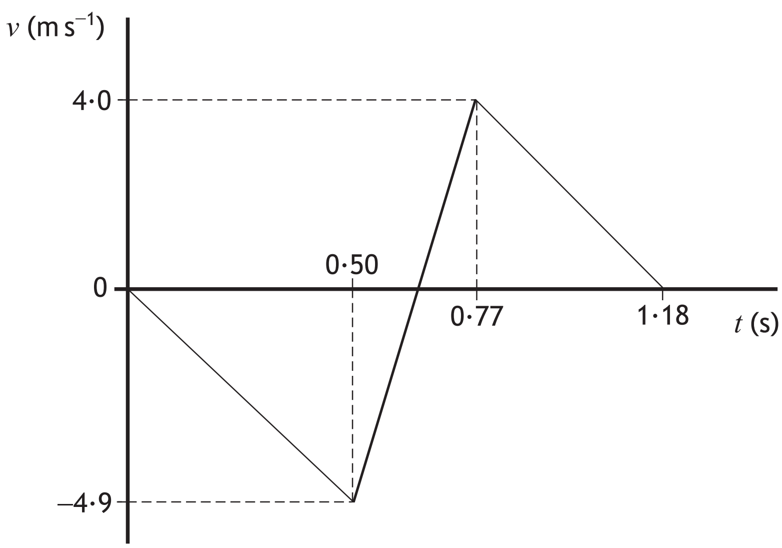
Attempt ALL questions

1. A student carries out an experiment with a tennis ball and a motion sensor connected to a laptop.



The ball is released from rest below the sensor.

The graph shows how the vertical velocity v of the ball varies with time t, from the moment the ball is released until it rebounds to its new maximum height.



MARKS DO NOT WRITE IN THIS MARGIN

1. **(continued)**

(a) Using information from the graph

(i) show that the initial acceleration of the ball is $-9 \cdot 8\ \mathrm{m\,s^{-2}}$ **2**

Space for working and answer

(ii) determine the height from which the ball is released. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

1. (continued)

(b) The mass of the ball is 57·0 g.

(i) Determine the magnitude of the change in momentum of the ball during the bounce. **3**

Space for working and answer

(ii) Determine the magnitude of the average force exerted by the ball on the ground during the bounce. **3**

Space for working and answer

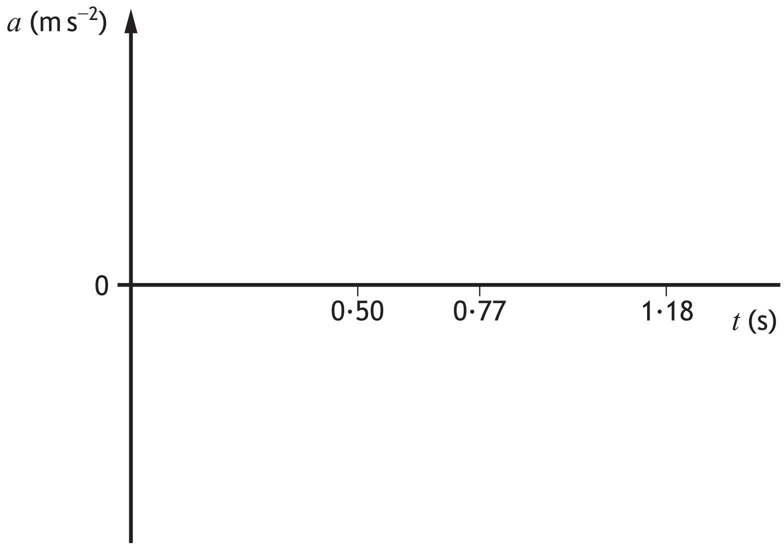
MARKS DO NOT WRITE IN THIS MARGIN

1. (continued)

(c) Complete the sketch graph of acceleration a against time t for the ball, between 0 s and 1·18 s after it is released.

Numerical values are **not** required on the acceleration axis. **2**

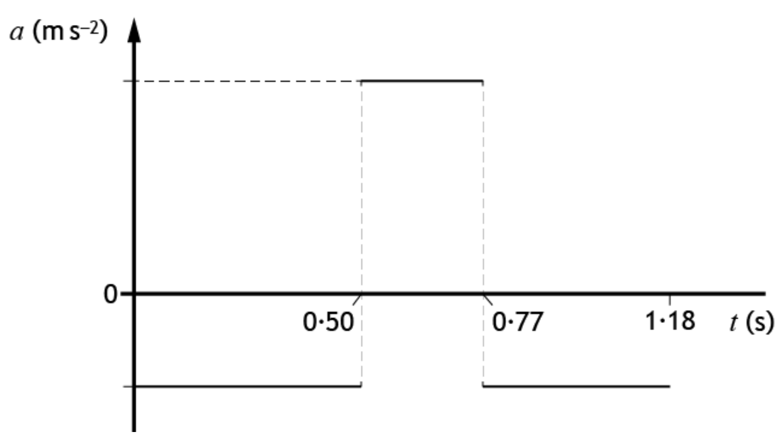
(An additional graph, if required, can be found on *page 44*)



[Turn over

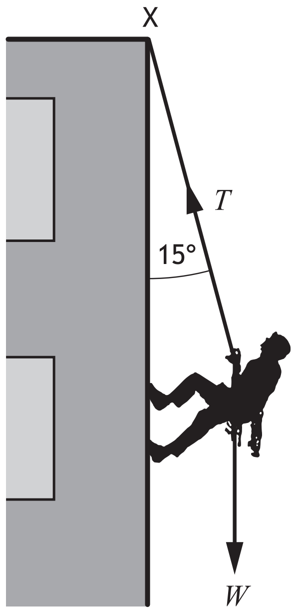
Question			Expected response	Max mark	Additional guidance
1.	(a)	(i)	$v = u + at$ **(1)** $-4 \cdot 9 = 0 + a \times 0 \cdot 50$ **(1)** $a = -9 \cdot 8\ \mathrm{m\,s^{-2}}$	2	**SHOW QUESTION.** Do not accept: $a = \frac{v}{t}$ Must show substitution for u and must use the sign convention given in the question. Alternative method: $a = \frac{\Delta v}{t}$ $= \frac{-4 \cdot 9}{0 \cdot 50}$ $= -9 \cdot 8\ \mathrm{m\,s^{-2}}$ Accept methods starting with $a = gradient$ **OR** $a = \frac{\Delta v}{\Delta t}$ **OR** $a = \frac{y_2 - y_1}{x_2 - x_1}$

Question			Expected response	Max mark	Additional guidance
		(ii)	$s=ut+\frac{1}{2}at^2$ **(1)** $=0\times0{\cdot}50+\frac{1}{2}\times(-)9{\cdot}8\times(0{\cdot}50)^2$ **(1)** $=(-)1{\cdot}2\text{ m}$ **(1)**	3	Accept: $1, 1{\cdot}23, 1{\cdot}225$ Sign convention must be consistent for all methods. Alternative methods: v and a must have same sign $v^2=u^2+2as$ $((-)4{\cdot}9)^2=0^2+2\times(-)9{\cdot}8\times s$ $s=(-)1{\cdot}2\text{ m}$ $s=\frac{1}{2}(u+v)t$ $s=\frac{1}{2}(0+(-)4{\cdot}90)\times0{\cdot}50$ $s=(-)1{\cdot}2\text{ m}$ *s= area under the graph* $s=\frac{1}{2}\times0{\cdot}5\times(-)4{\cdot}9$ $s=(-)1{\cdot}2\text{ m}$
	(b)	(i)	$\Delta mv = mv - mu$ **(1)** $=(0{\cdot}0570\times4{\cdot}0)-(0\times0570\times\text{-}4{\cdot}9)$ **(1)** $=0{\cdot}51\text{ kg m s}^{-1}$ **(1)**	3	Accept: $0{\cdot}5, 0{\cdot}507, 0{\cdot}5073$ Accept: $\Delta p = m\Delta v$ $Ft = mv - mu$ Do not accept: $p = mv - mu$ - 0 marks Sign convention must be consistent within this part of the question. v and u must have opposite signs. $p = mv$ **(1)** **all** substitutions **including** subtraction **(1)** final answer **(1)**

Question			Expected response	Max mark	Additional guidance
1.	(b)	(ii)	$Ft = mv - mu$ **(1)** $F \times 0{\cdot}27 = 0{\cdot}51$ **(1)** $F = 1{\cdot}9\ \mathrm{N}$ **(1)**	3	Or consistent with (b)(i) Accept: $2, 1{\cdot}89, 1{\cdot}889$ Alternative method: Sign convention must be consistent for this method. v and u must have opposite signs. $v = u + at$ $4{\cdot}0 = -4{\cdot}9 + a \times 0{\cdot}27$ $(a = 32{\cdot}96296296\ (\mathrm{m\,s^{-2}}))$ $F = ma$ $F = 0{\cdot}0570 \times 32{\cdot}96296296$ $F = 1{\cdot}9\ \mathrm{N}$ For **this** method accept 2, 1·88, 1·879 Both relationships **(1)** Both substitutions **(1)** Final answer **(1)**
		(c)	Same constant negative acceleration between 0 and 0·50 s **and** between 0·77 and 1·18 s **(1)** Constant positive acceleration between the two negative accelerations. Positive acceleration must be (clearly) greater than the negative acceleration **(1)**  	2	Accept solid vertical lines If values are included on the acceleration axis, they must be correct (-9·8 and 33). If no positive acceleration is shown, maximum **(1 mark)** for a constant negative acceleration between 0 and 1·18 s.

MARKS DO NOT WRITE IN THIS MARGIN

2. A student abseils down the outside of a building using a rope.



not to scale

The mass of the student is 55 kg.

The rope, of negligible mass, is attached to a fixed point X at the top of the building.

The rope makes an angle of 15° to the building.

(a) Calculate the weight W of the student. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

2. (continued)

(b) Determine the tension T in the rope. **3**

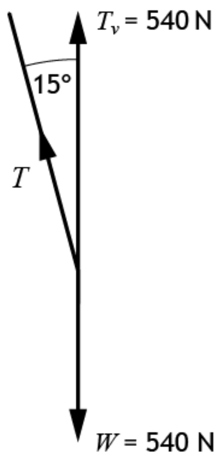
Space for working and answer

(c) As the student abseils down the building the angle the rope makes with the building decreases.

State whether the tension in the rope increases, decreases or stays the same.

Justify your answer. **2**

[Turn over

Question			Expected response	Max mark	Additional guidance
2.	(a)		$W = m$ **(1)** $= 55 \times 9{\cdot}8$ **(1)** $= 540$ N **(1)**	**3**	Accept: $500, 539, 539{\cdot}0$ Accept: $F = mg$ Do not accept: $F = ma$ - 0 marks
	(b)		 $T_v = T\cos\theta$ **(1)** $540 = T\cos 15$ **(1)** $T = 560$ N **(1)**	**3**	Or consistent with (a) Accept: $600, 559, 559{\cdot}0$ Accept: $600, 558, 558{\cdot}0$ for this value of W Accept: $W = T\cos\theta$ Ignore any indication of direction given.
	(c)		(Tension) decreases **(1)** (As the angle decreases) the cosine of the angle increases **(1)** **OR** the horizontal (component of the) force decreases **OR** shown by calculation with smaller angle	**2**	Look for this statement **first** - if incorrect or missing then (**0 marks**).

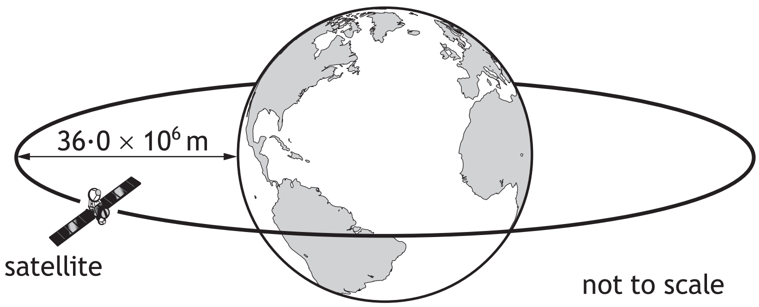
MARKS DO NOT WRITE IN THIS MARGIN

3. A footballer tells teammates that a football can be kicked a much greater distance when the ball is initially travelling towards them, compared to kicking a stationary ball.

Use your knowledge of physics to comment on this statement. **3**

MARKS DO NOT WRITE IN THIS MARGIN

4. A communications satellite orbits the Earth at a height of $36{\cdot}0 \times 10^6$ m above the surface of the Earth.



The mass of the Earth is $6{\cdot}0 \times 10^{24}$ kg and the radius of the Earth is $6{\cdot}4 \times 10^6$ m.

(a) Determine the distance between the centre of the Earth and the satellite. **1**

Space for working and answer

(b) The gravitational force of attraction between the Earth and the satellite is 57 N.

Calculate the mass of the satellite. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

4. (continued)

(c) Determine the value of the Earth's gravitational field strength g at the satellite. **3**

Space for working and answer

(d) A second satellite has a **quarter** of the mass of the first satellite.

The distance from the centre of the Earth to the second satellite is **half** the distance from the centre of the Earth to the first satellite.

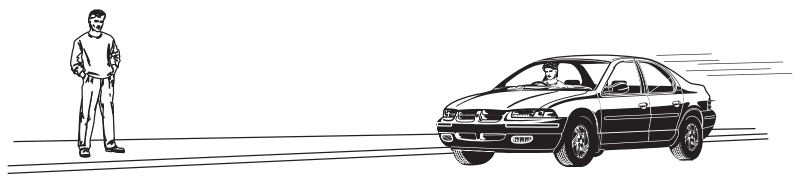
State how the gravitational force of attraction between the second satellite and the Earth compares to the gravitational force of attraction between the first satellite and the Earth.

Justify your answer. **3**

Question			Expected response	Max mark	Additional guidance
4.	(a)		$(\text{distance} = 6{\cdot}4\times10^6 + 36{\cdot}0\times10^6)$ $= 42{\cdot}4\times10^6$ m	**1**	
	(b)		$F = G\dfrac{m_1m_2}{r^2}$ **(1)** $57 = 6{\cdot}67\times10^{-11}\times\dfrac{6{\cdot}0\times10^{24}\times m_2}{(42{\cdot}4\times10^6)^2}$ **(1)** $m_2 = 260$ kg **(1)**	**3**	Or consistent with (a) Accept: 300, 256, 256·1
	(c)		$W = mg$ **(1)** $57 = 260\times g$ **(1)** $g = 0{\cdot}22$ N kg^{-1} **(1)**	**3**	Or consistent with (b) Accept: 0·2, 0·219, 0·2192 Accept: $F=mg$ Do not accept: $F=ma$ - **(0 marks)** Alternative method: $g = G\dfrac{M}{r^2}$ **(1)** $g = 6{\cdot}67\times10^{-11}\times\dfrac{6{\cdot}0\times10^{24}}{(42{\cdot}4\times10^6)^2}$ **(1)** $g = 0{\cdot}22$ N kg^{-1} **(1)**
	(d)		Force is the same **(1)** ¼ the mass has an effect of quartering the force **(1)** ½ the orbital height has an effect of quadrupling the force **(1)**	**3**	Look for this statement first - if incorrect or missing then 0 marks. Can justify by calculation Correct substitution of $\frac{1}{2}r$ and $\frac{1}{4}m$ or consistent with (a) and (b) **(1)** Correct final answer **(1)**

MARKS DO NOT WRITE IN THIS MARGIN

5. (a) A person is standing at the side of a road. A car travels along the road towards the person, at a constant speed of $12\,m\,s^{-1}$. The car emits a sound of frequency 510 Hz.



The person observes that the frequency of the sound heard changes as the car passes.

(i) State the name given to this effect. **1**

(ii) Calculate the frequency of the sound heard by the person as the car approaches.

The speed of sound in air is $340\,m\,s^{-1}$. **3**

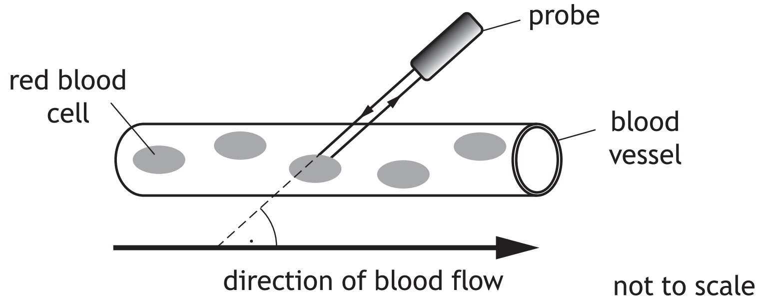
Space for working and answer

X857760114

5. (continued)

MARKS DO NOT WRITE IN THIS MARGIN

(b) This same effect is used to determine the speed of red blood cells through blood vessels.



Ultrasound waves are transmitted by a probe. The frequency of the ultrasound waves changes as they reflect from the blood cells. The probe detects the reflected waves.

The velocity of the red blood cells can be determined using the following relationship

$$\Delta f = \frac{2f\ v_{rbc}\ \cos\theta}{v}$$

where Δf is the change in frequency

f is the transmitted frequency

v_{rbc} is the velocity of the red blood cells

v is the velocity of the ultrasound

θ is the angle between the direction of the waves and the direction of the blood flow.

The frequency of the ultrasound transmitted by the probe is 3·70 MHz.

The velocity of the ultrasound is $1540\ m\ s^{-1}$.

During one test, the angle between the direction of the waves and blood flow is 60·0°. The change in frequency of the ultrasound is 286 Hz.

Calculate the velocity of the red blood cells during this test. **2**

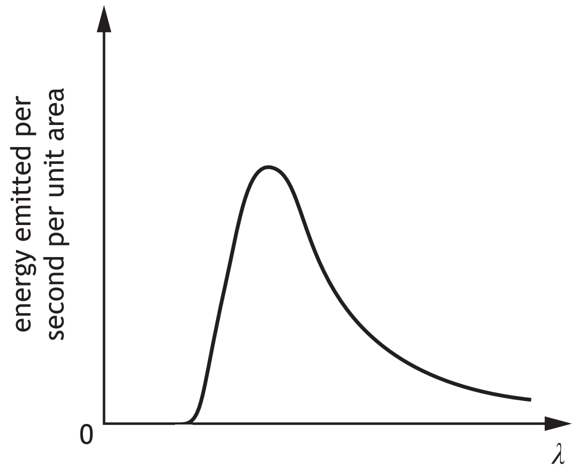
Space for working and answer

Question			Expected response	Max mark	Additional guidance
5.	(a)	(i)	Doppler (effect)	**1**	
		(ii)	$f_0 = f_s\left(\frac{v}{v \pm v_s}\right)$ **(1)** $f_0 = 510\left(\frac{340}{340-12}\right)$ **(1)** $f_0 = 530\text{ Hz}$ **(1)**	**3**	Accept: 500, 529, 528·7 Accept: $f_0 = f_s\left(\frac{v}{v - v_s}\right)$
	(b)		$\Delta f = \frac{2f\ v_{rbc}\cos\theta}{v}$ $286 = \frac{2 \times 3{\cdot}70 \times 10^6 \times v_{rbc}\cos 60{\cdot}0}{1540}$ **(1)** $v_{rbc} = 0{\cdot}119\text{ m s}^{-1}$ **(1)**	**2**	Accept: 0·12, 0·1190, 0·11904

MARKS DO NOT WRITE IN THIS MARGIN

6. Stars emit radiation with a range of wavelengths. The peak wavelength of the radiation depends on the surface temperature of the star.

(a) The graph shows how the energy emitted per second per unit area varies with the wavelength λ of the radiation for a star with a surface temperature of 5000 K.



A second star has a surface temperature of 6000 K.

On the graph above, add a line to show how the energy emitted per second per unit area varies with the wavelength λ of the radiation for the second star. **2**

(An additional graph, if required, can be found on *page 44*)

MARKS DO NOT WRITE IN THIS MARGIN

6. (continued)

(b) The table gives the surface temperature T, in kelvin, of four different stars and the peak wavelength λ_{peak} of radiation emitted from each star.

T (K)	λ_{peak} (m)
7700	$3{\cdot}76 \times 10^{-7}$
8500	$3{\cdot}42 \times 10^{-7}$
9600	$3{\cdot}01 \times 10^{-7}$
12 000	$2{\cdot}42 \times 10^{-7}$

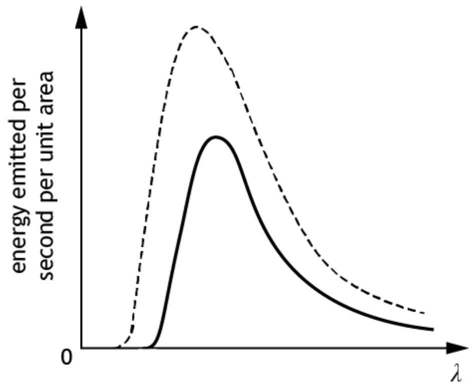
Use **all** the data in the table to show that the relationship between the surface temperature T of a star and the peak wavelength λ_{peak} radiated from the star is 3

$$T = \frac{2 \cdot 9 \times 10^{-3}}{\lambda_{peak}}$$

Space for working and answer

[Turn over

X857760117

Question			Expected response	Max mark	Additional guidance
6.	(a)			2	Peak wavelength less **(1)** Line added should always be above original line **(1)**
	(b)		$7700 \times 3{\cdot}76{\times}10^{-7} = 2{\cdot}9{\times}10^{-3}$ $8500 \times 3{\cdot}42{\times}10^{-7} = 2{\cdot}9{\times}10^{-3}$ $9600 \times 3{\cdot}01{\times}10^{-7} = 2{\cdot}9{\times}10^{-3}$ $12000 \times 2{\cdot}42{\times}10^{-7} = 2{\cdot}9{\times}10^{-3}$ **(2)** therefore $T \times \lambda_{peak} = 2{\cdot}9{\times}10^{-3}$ **(1)**	3	All four calculations correct **(2)** Three correct calculations **(1)** < Three correct calculations **(0)** $7700 \times 3{\cdot}76{\times}0^{-7} = 2{\cdot}895{\times}10^{-3}$ $8500 \times 3{\cdot}42{\times}10^{-7} = 2{\cdot}907{\times}10^{-3}$ $9600 \times 3{\cdot}01{\times}10^{-7} = 2{\cdot}890{\times}10^{-3}$ $12000 \times 2{\cdot}42{\times}10^{-7} = 2{\cdot}904{\times}10^{-3}$ therefore $T \times \lambda_{peak} = 2{\cdot}9{\times}10^{-3}$ **(1)** This 'conclusion' mark is only available if consistent with the calculations shown. For 'finding the constant' method, accept restatement of relationship for final mark. Alternative methods: Can calculate the temperatures **or** wavelengths using the relationship. Final mark is given for a statement that the calculated temperatures or wavelengths match values in the table. Graphical method: Graph drawn correctly **(1)** Gradient calculated **(1)** restatement of relationship **(1)**

MARKS DO NOT WRITE IN THIS MARGIN

7. Scientists have recently discovered a type of particle called a pentaquark. Pentaquarks are very short lived and contain five quarks.

A lambda b (. $_b$) pentaquark contains the following quarks: 2 up, 1 down, 1 charm, and 1 anticharm quark.

(a) Quarks and leptons are fundamental particles.

(i) Explain what is meant by the term *fundamental particle*. **1**

(ii) State the name given to the group of matter particles that contains quarks and leptons. **1**

(b) The table contains information about the charge on the quarks that make up the Λ_b pentaquark.

Type of quark	Charge
up	$+\frac{2}{3}e$
down	$-\frac{1}{3}e$
charm	$+\frac{2}{3}e$
anticharm	$-\frac{2}{3}e$

Determine the total charge on the Λ_b pentaquark. **2**

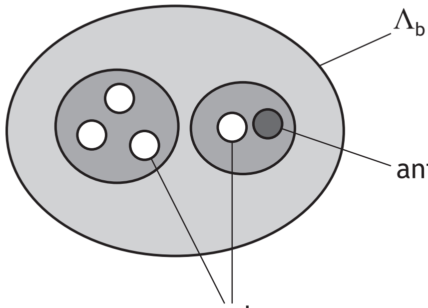
Space for working and answer

* X 8 5 7 7 6 0 1 1 8 *

MARKS DO NOT WRITE IN THIS MARGIN

7. (continued)

(c) One theory to explain the structure of the Λ_b pentaquark suggests that three of the quarks group together and one quark and the antiquark group together within the pentaquark.



(i) State the type of particle that is made of a quark-antiquark pair. **1**

(ii) The mean lifetime of another quark-antiquark pair is $8{\cdot}0 \times 10^{-21}$ s in its own frame of reference.

During an experiment the quark-antiquark pair is travelling with a velocity of $0{\cdot}91c$ relative to a stationary observer.

Calculate the mean lifetime of this quark-antiquark pair relative to the stationary observer. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

7. (continued)

(d) The Λ_b pentaquark has a mass-energy equivalence of 4450 MeV.

One eV is equal to $1{\cdot}60 \times 10^{-19}$ J.

(i) Determine the energy, in joules, of the Λ_b pentaquark. **1**

Space for working and answer

(ii) Calculate the mass of the Λ_b pentaquark. **3**

Space for working and answer

Question			Expected response	Max mark	Additional guidance
7.	(a)	(i)	Fundamental particles are not composed of other particles.	**1**	Accept: Fundamental particles cannot be 'broken down' into other/smaller particles. Fundamental particles cannot be 'broken down' any further.
		(ii)	Fermions	**1**	
	(b)		$\frac{2}{3}e+\frac{2}{3}e-\frac{1}{3}e+\frac{2}{3}e-\frac{2}{3}e$ **(1)** = 1*e* or +1*e* or *e* **(1)**	**2**	Accept: $\frac{2}{3}+\frac{2}{3}-\frac{1}{3}+\frac{2}{3}-\frac{2}{3}$ OR $2\left(\frac{2}{3}e\right)-\frac{1}{3}e+\frac{2}{3}e-\frac{2}{3}e$ **(1)** = 1e or +1e or e **(1)**
	(c)	(i)	Meson	**1**	
		(ii)	$t'=\frac{t}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$ **(1)** $t'=\frac{8\cdot0\times10^{-21}}{\sqrt{1-\left(\frac{0\cdot91c}{c}\right)^2}}$ **(1)** $t'=1\cdot9\times10^{-20}$ s **(1)**	**3**	Accept: $2, 1\cdot93, 1\cdot930$
	(d)	(i)	$(4450\times10^{6}\times1\cdot60\times10^{-19})$ $=7\cdot12\times10^{-10}$ (J)	**1**	A unit is not required but, if a unit is given, it must be correct.
		(ii)	$E=mc^2$ **(1)** $7\cdot12\times10^{-10}=m\times\left(3\cdot00\times10^{8}\right)^2$ **(1)** $m=7\cdot91\times10^{-27}$ kg **(1)**	**3**	Or consistent with (d) (i) Accept: $7\cdot9, 7\cdot911, 7\cdot9111$

MARKS DO NOT WRITE IN THIS MARGIN

8. The Sun emits energy at an average rate of $4{\cdot}1 \times 10^{26}\,\mathrm{J\,s^{-1}}$. This energy is produced by nuclear reactions taking place inside the Sun.

The following statement shows one reaction that takes place inside the Sun.

$$ {}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} $$

(a) State the name given to this type of nuclear reaction. **1**

(b) The mass of the particles involved in this reaction are shown in the table.

Particle	Mass (kg)
${}^{2}_{1}\mathrm{H}$	$3{\cdot}3436 \times 10^{-27}$
${}^{3}_{2}\mathrm{He}$	$5{\cdot}0082 \times 10^{-27}$
${}^{1}_{0}\mathrm{n}$	$1{\cdot}6749 \times 10^{-27}$

Determine the energy released in this reaction. **4**

Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

8. (continued)

(c) Determine the number of these reactions that would be required per second to produce the Sun's average energy output. **2**

Space for working and answer

[Turn over

X857760123

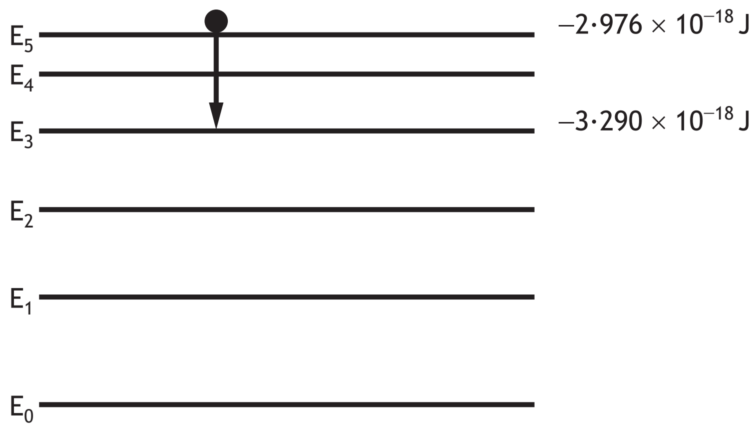
Question			Expected response	Max mark	Additional guidance
8.	(a)		(Nuclear) Fusion	1	
	(b)		Mass before $=2\times3{\cdot}3436\times10^{-27}$ $=6{\cdot}6872\times10^{-27}$ Mass after $=5{\cdot}0082\times10^{-27}+1{\cdot}6749\times10^{-27}$ $=6{\cdot}6831\times10^{-27}$ Mass lost $=4{\cdot}1\times10^{-30}$ (kg) **(1)** $E=mc^2$ **(1)** $E=4{\cdot}1\times10^{-30}\times(3{\cdot}00\times10^8)^2$ **(1)** $E=3{\cdot}69\times10^{-13}$ J **(1)**	4	Accept: 3·7, 3·690, 3·6900 Check for correct substitutions of values in calculation of mass "lost". If values are incorrect, maximum **(1 mark)** for relationship. $E=mc^2$ anywhere **(1 mark)** If mass before and after not used to full 5 significant figures from table, then maximum **(1 mark)** for relationship. Ignore inappropriate reference to mass defect. Arithmetic mistake can be carried forward through the response. Truncation error in mass before and/or mass after- maximum **(1 mark)** for relationship.
	(c)		$\dfrac{4{\cdot}1\times10^{26}}{3{\cdot}69\times10^{-13}}$ **(1)** $=1{\cdot}1\times10^{39}$ **(1)**	2	Or consistent with (b) Accept: 1, 1·11, 1·111

MARKS DO NOT WRITE IN THIS MARGIN

9. A laser emits light when electrons are stimulated to fall from a high energy level to a lower energy level.

The diagram shows some of the energy levels involved.

In one particular laser, a photon is produced by the electron transition from E_5 to E_3 as shown.



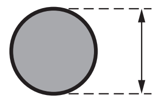
(a) (i) Determine the wavelength of the photon emitted. **4**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

9. (a) (continued)

(ii) The laser beam is shone onto a screen. The beam produces a spot of diameter $8{\cdot}00 \times 10^{-4}$ m.

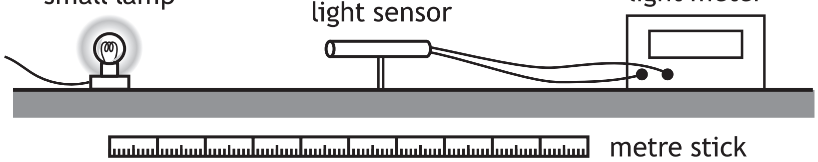


The irradiance of the spot of light on the screen is $9950\,W\,m^{-2}$.

Determine the power of the laser beam. **4**

Space for working and answer

(b) A student investigates how irradiance I varies with distance d from a point source of light, using the apparatus shown.



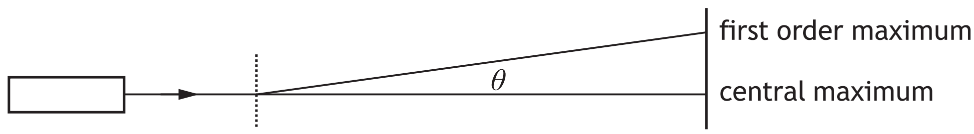
Describe how this apparatus could be used to verify the inverse square law for a point source of light. **3**

Question			Expected response	Max mark	Additional guidance
9.	(a)	(i)	$E_2 - E_1 = hf$ $-2{\cdot}976\times10^{-18} - (-3{\cdot}290\times10^{-18})$ $= 6{\cdot}63\times10^{-34}\times f$ **(1)** $(f = 4{\cdot}736048265\times10^{14}\ Hz)$ $v = f\lambda$ **(1)** (**for both relationships** anywhere) $3{\cdot}00\times10^{8} = 4{\cdot}736048265\times10^{14}\times\lambda$ **(1)** $\lambda = 6{\cdot}33\times10^{-7}$ m **(1)**	4	Accept: $6{\cdot}3, 6{\cdot}334, 6{\cdot}3344$ Accept: $(\Delta)E = hf$ with $v = f\lambda$ **OR** $E_5 - E_3 = hf$ with $v = f\lambda$ for relationship mark anywhere Note: $\Delta E = 3{\cdot}14\times10^{-19}$ (J) Accept: $3{\cdot}290\times10^{-18} - 2{\cdot}976\times10^{-18}$ $= 6{\cdot}63\times10^{-34}\times f$ for energy substitution mark If $2{\cdot}976\times10^{-18} - 3{\cdot}290\times10^{-18}$ is shown for ΔE, maximum (**1 mark**) for **both relationships.** Alternative method: $E_2 - E_1 = \frac{hc}{\lambda}$ **OR** $(\Delta)E = \frac{hc}{\lambda}$ Combined relationship **(1)** Substitution for h and ΔE **(1)** Substitution for c **(1)** Final answer **(1)**
		(ii)	$A = \pi r^2$ $= \pi\times(4{\cdot}00\times10^{-4})^2$ **(1)** $I = \frac{P}{A}$ **(1)** $9950 = \frac{P}{\pi\times(4{\cdot}00\times10^{-4})^2}$ **(1)** $P = 5{\cdot}00\times10^{-3}$ W **(1)**	4	Accept a range of 1 to 5 significant figures for **this question.** The use of $3{\cdot}14$ for π is acceptable. $I = \frac{P}{A}$ anywhere - **(1)** If no attempt to calculate area, maximum **(1 mark)** for relationship.

Question			Expected response	Max mark	Additional guidance
9.	(b)		Obtain values of irradiance for different distances **(1)** Plot graph of I against $1/d^2$ **(1)** Graph of I against $1/d^2$ is a straight line <u>through the origin</u> (then this verifies the inverse square law of light) **(1)**	**3**	Look for this statement or equivalent first – if incorrect or missing then **(0 marks).** Alternative method: Obtain values of irradiance for different distances **(1)** Determine $I \times d^2$ **(1)** Values of Id^2 are a constant (then this verifies the inverse square law of light) **(1)**

MARKS DO NOT WRITE IN THIS MARGIN

10. A student carries out an experiment to investigate the effect of a grating on beams of light from three different lasers.



The three different lasers produce red, green and blue light respectively.

Each laser beam is directed in turn towards the grating.

The grating has a slit separation of $3{\cdot}3 \times 10^{-6}$ m.

(a) State which of these three colours of laser light would produce the smallest angle θ between the central maximum and the first order maximum.

Justify your answer. **3**

MARKS DO NOT WRITE IN THIS MARGIN

10. (continued)

(b) The angle θ between the central maximum and the first order maximum for light from one of the lasers is 8·9°.

(i) Calculate the wavelength of this light. **3**

Space for working and answer

(ii) Determine the colour of the light from this laser. **1**

(iii) Another student suggests that a more accurate value for the wavelength of this laser light can be found if a grating with a slit separation of $5\cdot0 \times 10^{-6}$ m is used.

Explain why this suggestion is incorrect. **2**

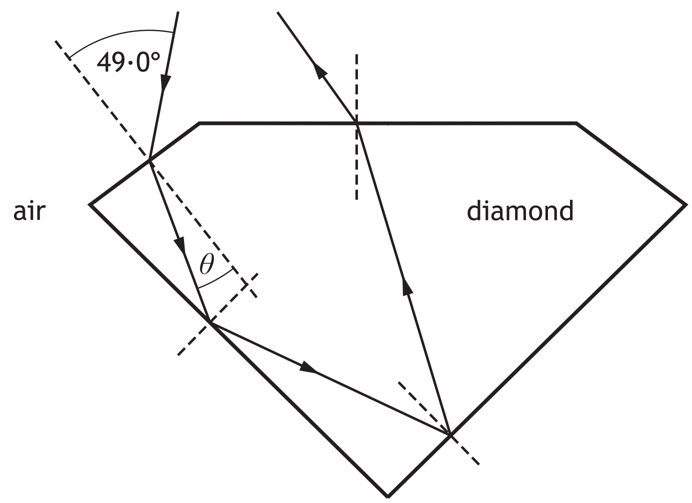
[Turn over

Question			Expected response	Max mark	Additional guidance
10.	(a)		Blue (light) **(1)** Shortest wavelength of light **(1)** Path difference is smaller/equals the wavelength so the spots are closer together **OR** sin θ is proportional to λ **(1)**	**3**	Look for this statement first - if incorrect or missing then **(0 marks)**. Accept: $d \sin \theta = m\lambda$ and shortest λ gives smallest sin θ (which gives smallest θ) Alternative methods: Can be shown by calculation but it must be clear the candidate has used **appropriate** wavelengths.
	(b)	(i)	$m\lambda = d \sin\theta$ **(1)** $(1\times)\lambda = 3{\cdot}3\times10^{-6} \times \sin 8{\cdot}9$ **(1)** $\lambda = 5{\cdot}1\times10^{-7}$ m (510 nm) **(1)**	**3**	Accept: 5, 5·11, 5·105 Accept: $\lambda = d \sin\theta$ in this case
		(ii)	Green	**1**	Or consistent with (b)(i) but **must be** red, green or blue. If λ in (b)(i) lies outside of range of red, green or blue this mark is not accessible.

Question			Expected response	Max mark	Additional guidance
10.	(b)	(iii)	($\sin\theta = \frac{m\lambda}{d}$ so if d is greater then) angle θ will be smaller **(1)** Smaller angle more difficult to measure accurately/greater percentage uncertainty. **(1)**	**2**	Accept: maxima are closer together **(1)** Smaller distance between maxima more difficult to measure accurately/greater percentage uncertainty.**(1)**

MARKS DO NOT WRITE IN THIS MARGIN

11. Diamonds sparkle because light that enters the diamond is reflected back to an observer.



(a) A ray of monochromatic light is incident on a diamond at an angle of 49·0°.

The refractive index of diamond for this light is 2·42.

Calculate the angle of refraction θ. **3**

Space for working and answer

(b) Calculate the critical angle of the diamond for this light. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

11. (continued)

(c) Moissanite is a transparent material with a greater refractive index than diamond. A sample of moissanite is made into the same shape as the diamond.

State whether the sample of moissanite sparkles more or less than the diamond.

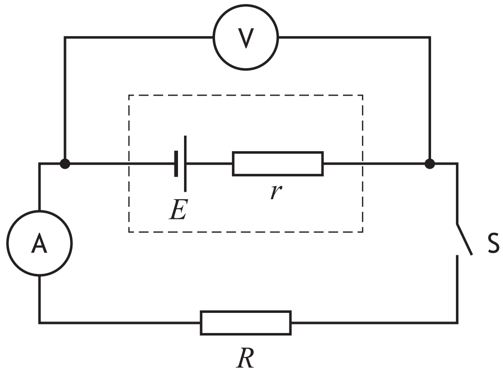
You must justify your answer. **3**

[Turn over

Question			Expected response	Max mark	Additional guidance
11.	(a)		$n = \frac{\sin\theta_1}{\sin\theta_2}$ **(1)** $2{\cdot}42 = \frac{\sin 49{\cdot}0}{\sin\theta_2}$ **(1)** $\theta_2 = 18{\cdot}2°$ **(1)**	**3**	Accept: 18, 18·17, 18·172 Accept: $\frac{n_2}{n_1} = \frac{\sin\theta_1}{\sin\theta_2}$ **(1)** $\frac{2{\cdot}42}{1} = \frac{\sin 49{\cdot}0}{\sin\theta_2}$ **(1)** $\theta_2 = 18{\cdot}2°$ **(1)**
	(b)		$\sin\theta_c = \frac{1}{n}$ **(1)** $\sin\theta_c = \frac{1}{2{\cdot}42}$ **(1)** $\theta_c = 24{\cdot}4°$ **(1)**	**3**	Accept: 24, 24·41, 24·407
	(c)		more (sparkle) **(1)** Critical angle for moissanite is smaller than for diamond **(1)** (Total internal) reflection more likely (with moissanite). **(1)**	**3**	Look for this statement first - if incorrect or missing then (**0 marks**). Critical angle for moissanite is smaller than for diamond can be shown by calculation.

MARKS DO NOT WRITE IN THIS MARGIN

12. (a) A student sets up the circuit shown.



When switch S is open the reading on the voltmeter is 1·5 V.

Switch S is now closed.

The reading on the voltmeter is now 1·3 V and the reading on the ammeter is 0·88 A.

(i) State the EMF E of the cell. **1**

(ii) Calculate the internal resistance r of the cell. **3**

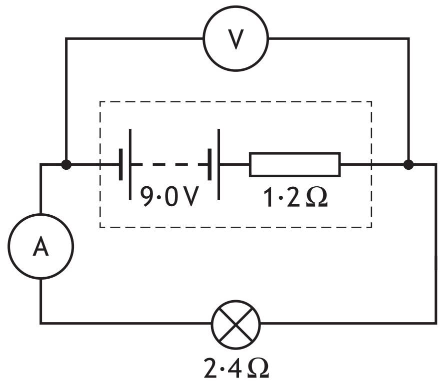
Space for working and answer

(iii) Explain why the reading on the voltmeter decreases when the switch is closed. **2**

* X 8 5 7 7 6 0 1 3 0 *

12. (continued)

(b) A battery of EMF 9·0 V and internal resistance 1·2 Ω is connected in series with a lamp. The lamp has a resistance of 2·4 Ω.



(i) Determine the current in the lamp. **3**

Space for working and answer

(ii) Calculate the power dissipated in the lamp. **3**

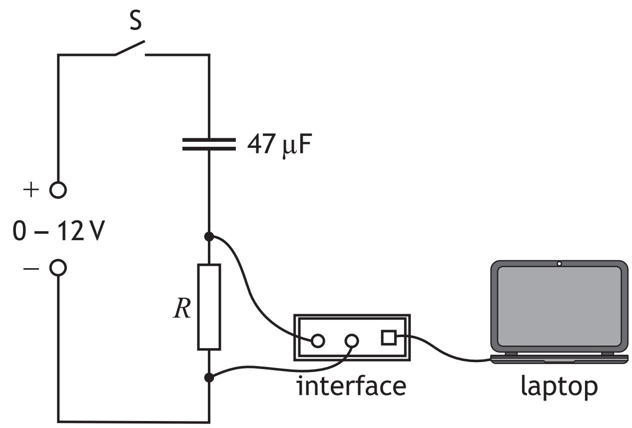
Space for working and answer

Question			Expected response	Max mark	Additional guidance
12.	(a)	(i)	1·5 V	**1**	
		(ii)	$E=V+Ir$ **(1)** $1{\cdot}5=1{\cdot}3+0{\cdot}88r$ **(1)** $r=0{\cdot}23\,\Omega$ **(1)**	**3**	Accept: $0{\cdot}2, 0{\cdot}227, 0{\cdot}2273$ Alternative methods: $V=IR$ **(1)** $0{\cdot}2=0{\cdot}88\times R$ **(1)** $R=0{\cdot}23\,\Omega$ **(1)** lost volts$=Ir$ **(1)** $0{\cdot}2=0{\cdot}88\times R$ **(1)** $R=0{\cdot}23\,\Omega$ **(1)**
		(iii)	(When the switch is closed) there is a current (in the circuit). **(1)** Voltage (is dropped) across the internal resistance. **(1)**	**2**	**Independent marks** Do not accept 'current increases' on its own. 'Lost volts' is not sufficient on its own
	(b)	(i)	$E=V+Ir$ and $V=IR$ **(1)** **OR** $E=I(R+r)$ $9{\cdot}0=I(2{\cdot}4+1{\cdot}2)$ **(1)** $I=2{\cdot}5\ A$ **(1)**	**3**	Accept: $3, 2{\cdot}50, 2{\cdot}500$ Both relationships **(1)** Both substitutions **(1)** Alternative method: $V=IR$ **(1)** $9{\cdot}0=I\times 3{\cdot}6$ **(1)** $I=2{\cdot}5$ A **(1)** For other alternative methods: All relationships **(1)** All substitutions **(1)** Correct final answer **(1)**
		(ii)	$P=I^2R$ **(1)** $P=2{\cdot}5^2\times 2{\cdot}4$ **(1)** $P=15$ W **(1)**	**3**	Or consistent with (b)(i) Accept $20, 15{\cdot}0, 15{\cdot}00$ For alternative methods: All relationships **(1)** All substitutions **(1)** Correct final answer **(1)**

MARKS DO NOT WRITE IN THIS MARGIN

13. A student investigates the charging of a capacitor.

The student sets up the circuit as shown using a 47 μF capacitor.



The capacitor is initially uncharged. The switch S is now closed. A laptop connected to an interface displays a graph of current against time as the capacitor charges.

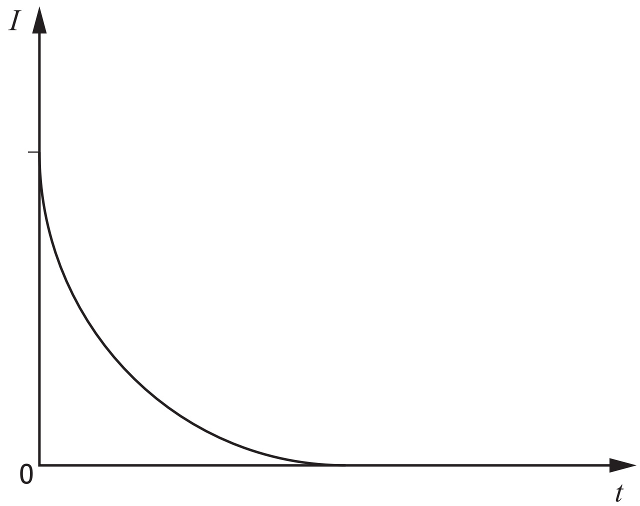
(a) The variable voltage supply is set at 6·0 V.

Calculate the maximum charge stored by the capacitor. **3**

Space for working and answer

13. (continued)

(b) The graph shows how the current I varies with time t as the capacitor charges.



Switch S is opened, and the capacitor is discharged.

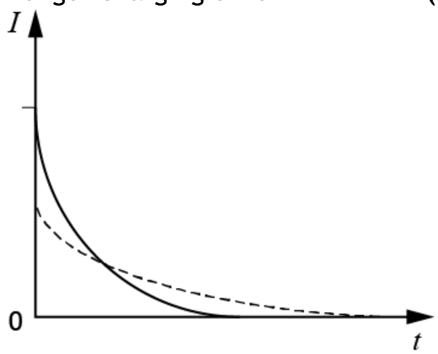
The resistor is now replaced with one that has a greater resistance.

Switch S is again closed and the capacitor charges.

Add a line to the graph above to show how the current now varies with time as the capacitor charges. **2**

(An additional graph, if required, can be found on *page 45*.)

(c) Suggest an alteration the student could make to this circuit to increase the maximum energy stored by the 47 μF capacitor. **1**

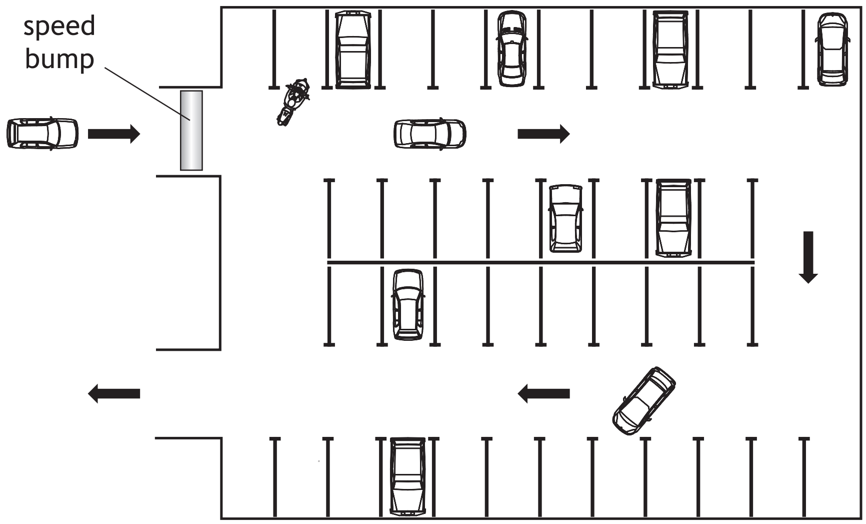
Question			Expected response	Max mark	Additional guidance
13.	(a)		$C=\frac{Q}{V}$ **(1)** $47\times10^{-6}=\frac{Q}{6\times0}$ **(1)** $Q=2{\cdot}8\times10^{-4}\ C$ **(1)**	**3**	Accept: $3, 2{\cdot}82, 2{\cdot}820$
	(b)		Lower initial current **(1)** Longer charging time **(1)** 	**2**	**Independent marks** Line crossing x-axis – maximum **(1)** Line crossing y-axis - maximum **(1)** Line must be a curve to award the second mark. Line must tend towards the time axis to gain the second mark. Do not accept: increasing curve – **0 marks** straight line – **0 marks**
	(c)		Increase the supply voltage	**1**	Must clearly indicate the supply voltage is increased/greater. Accept: 'increase the voltage supplied to the circuit'. 'increase the voltage supplied to the capacitor'. Do not accept: 'increase the voltage across the capacitor' **on its own**. Do not accept any implication of power supply being replaced by another power supply.

MARKS DO NOT WRITE IN THIS MARGIN

13. (continued)

(d) The use of analogies from everyday life can help improve the understanding of physics concepts.

Vehicles using a car park may be taken as an analogy for the charging of a capacitor.



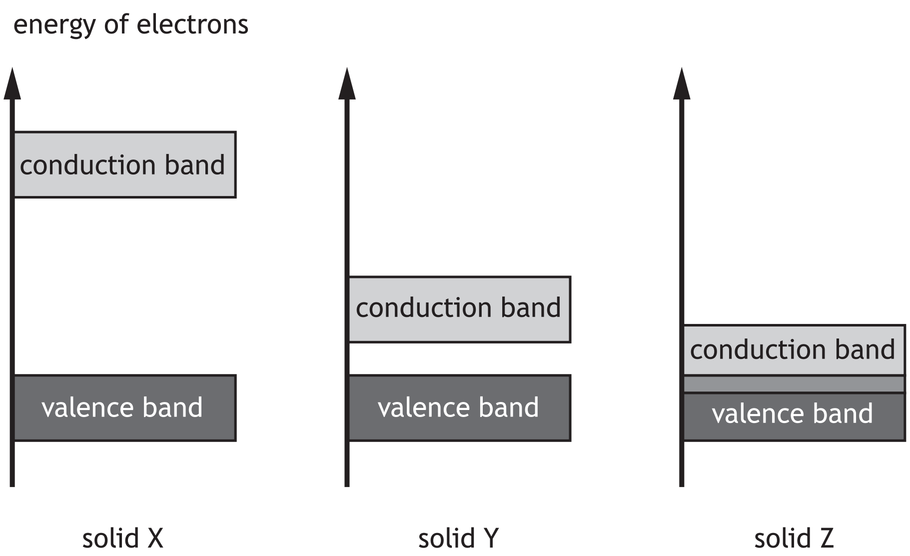
Use your knowledge of physics to comment on this analogy. **3**

MARKS DO NOT WRITE IN THIS MARGIN

14. Solids can be categorised as conductors, insulators or semiconductors depending on their ability to conduct electricity. Their electrical conductivity can be explained using band theory.

The diagrams show the valence and conduction bands of three solids X, Y and Z.

One represents a conductor, one represents an insulator and one represents a semiconductor.



(a) Complete the table to show which solid represents a conductor, an insulator and a semiconductor. **1**

Solid	Category
X	
Y	
Z	

X857760136

MARKS DO NOT WRITE IN THIS MARGIN

14. (continued)

(b) Using **band theory**, explain why conduction can take place in a semiconductor at room temperature. **2**

(c) Silicon can be doped with arsenic to produce an n-type semiconductor.

State the effect that doping has on the conductivity of silicon. **1**

(d) Resistivity is a measure of a material's property to oppose the flow of charge.

The resistivity of silicon is $2{\cdot}3 \times 10^{3}\,\Omega\,\text{m}$.

The resistivity of copper is $1{\cdot}7 \times 10^{-8}\,\Omega\,\text{m}$.

Compare the resistivity of silicon to the resistivity of copper in terms of orders of magnitude. **2**

Space for working and answer

* X 8 5 7 7 6 0 1 3 7 *

<table>
<tr><th colspan="3">Question</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>14.</td><td>(a)</td><td></td><td><table><tr><td>Solid</td><td>Category</td></tr><tr><td>X</td><td>insulator</td></tr><tr><td>Y</td><td>semiconductor</td></tr><tr><td>Z</td><td>conductor</td></tr></table></td><td>1</td><td>Must have all 3 correct.</td></tr>
<tr><td></td><td>(b)</td><td></td><td>The energy gap/band gap (between the valence and conduction bands) is small. (1)

Some electrons have enough energy to move from the valence to the conduction band. (1)</td><td>2</td><td>Independent marks

To access second mark, valence and conduction band must be included in answer.
The direction the electrons move must be clear.

Do not accept:
‘valency’ as a name for the valence band.</td></tr>
<tr><td></td><td>(c)</td><td></td><td>Increases (conductivity).</td><td>1</td><td>Do not accept:
‘reduces resistance’ on its own.</td></tr>
<tr><td></td><td>(d)</td><td></td><td>$\left(\frac{2{\cdot}3\times10^{3}}{1{\cdot}7\times10^{-8}}\right)=1{\cdot}4\times10^{11}$ (1)

Resistivity of silicon is 11 (orders of magnitude) greater (1)</td><td>2</td><td>Accept:
$\left(\frac{10^{3}}{10^{-8}}\right)=10^{11}$

OR

(3-(-8)) = 11 (1)

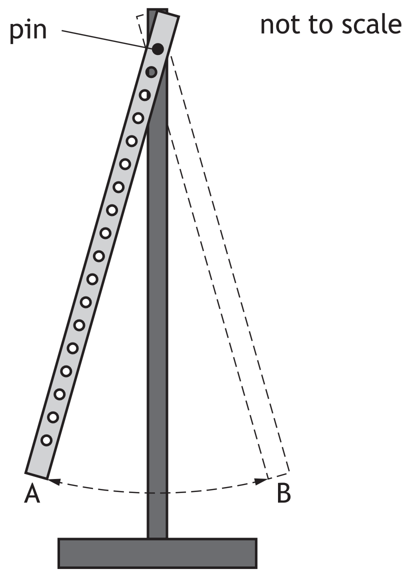
Accept:
11 greater on its own (2)

OR

Resistivity of copper is 11 (orders of magnitude) smaller. (2)</td></tr>
</table>

MARKS DO NOT WRITE IN THIS MARGIN

15. A 1·00 m long wooden rod has a series of small holes drilled at 10 mm intervals along its length. The rod is hung on a horizontal pin passing through a hole 50 mm from one end.



The rod is then raised through a small angle and released.

The period T is the time for the rod to travel from A to B and back to A.

(a) Describe a method to obtain an accurate value for the period T using only a stopwatch. **2**

MARKS DO NOT WRITE IN THIS MARGIN

15. (continued)

(b) The rod is hung from different holes in turn, and the distance h from the pin to the midpoint of the rod is recorded.

T is determined for each value of h. The results are shown in the table.

h (m)	T (s)
0·45	1·60
0·40	1·56
0·35	1·54
0·30	1·53
0·25	1·53
0·22	1·55
0·20	1·58

(i) Using the square-ruled paper on *page 41*, draw a graph of T against h. **3**

(ii) Using your graph, state the **two** values of h that produce a period of 1·57 s. **1**

(iii) (A) Using your graph, estimate the minimum period T. **1**

(B) Suggest an improvement to the experimental procedure that would allow a more precise value for the minimum period T to be determined. **1**

X857760141

MARKS DO NOT WRITE IN THIS MARGIN

15. (continued)

(c) The quantities T and h are related by the relationship

$$T^2 h = \frac{4\pi^2 h^2}{g} + C$$

where g is the gravitational field strength and C is a constant.

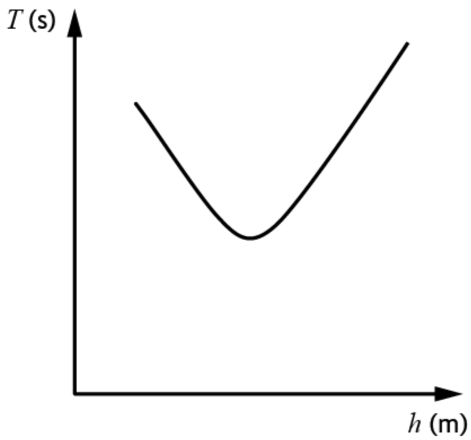
Use data **from the table on *page 40*** to calculate a value for C when h is 0·30 m.

A unit is not required. **2**

Space for working and answer

[END OF QUESTION PAPER]

* X 8 5 7 7 6 0 1 4 2 *

Question			Expected response	Max mark	Additional guidance
15.	(a)		Measure the total time over a number of swings **(1)** Divide total time by number of swings **(1)**	**2**	
	(b)	(i)		**3**	Appropriate labels and units **(1)** Suitable scales **(1)** Plotting and curve of best fit **(1)** Allow for axes starting at zero or broken axes or at an appropriate value. Accuracy of plotting should be easily checkable with the scale chosen If the origin is shown the scale must either be continuous or the axis must be 'broken'. Otherwise maximum (**2 marks)**. Do not penalise if the candidate plots h against T.
		(ii)	0·21 and 0·42 m	**1**	must be consistent with candidate's graph
		(iii) (A)	1·53 s	**1**	must be consistent with candidate's graph
		(B)	Use smaller increments around the 'turning point'. **OR** Take more measurements about the 'turning point'. **OR** Take more measurements over the whole range.	**1**	Accept: More readings around/close to turning point **or** smaller 'steps' in h. Do not accept: 'Repeat experiment' on its own.
	(c)		$T^2h = \dfrac{4\pi^2h^2}{g} + C$ $1{\cdot}53^2 \times 0 \times 30 = \dfrac{4\times\pi^2\times0{\cdot}30^2}{9{\cdot}8} + C$ **(1)** $C = 0{\cdot}34$ **(1)**	**2**	Accept: 0·3, 0·340, 0·3397 If candidate uses 3·14 for π, accept 0·3401. Ignore any unit given.

[END OF MARKING INSTRUCTIONS]

H

National Qualifications

X857/76/12

Physics
Paper 1 — Multiple choice

Duration — 45 minutes

Total marks — 25

Attempt ALL questions.

You may use a calculator.

Instructions for the completion of Paper 1 are given on *page 02* of your answer booklet X857/76/02.

Record your answers on the answer grid on *page 03* of your answer booklet.

Reference may be made to the data sheet on *page 02* of this question paper and to the relationships sheet X857/76/22.

Space for rough work is provided at the end of this booklet.

Before leaving the examination room you must give your answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

X8577612

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	Symbol	Value	Quantity	Symbol	Value
Speed of light in vacuum	c	$3{\cdot}00 \times 10^{8}$ m s^{-1}	Planck's constant	h	$6{\cdot}63 \times 10^{-34}$ J s
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}$ C	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}$ kg
Universal Constant of Gravitation	G	$6{\cdot}67 \times 10^{-11}$ m^3 kg^{-1} s^{-2}	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}$ kg
Gravitational acceleration on Earth	g	$9{\cdot}8$ m s^{-2}	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}$ kg
Hubble's constant	H_0	$2{\cdot}3 \times 10^{-18}$ s^{-1}			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	Refractive index	Substance	Refractive index
Diamond	2·42	Water	1·33
Crown glass	1·50	Air	1·00

SPECTRAL LINES

Element	Wavelength (nm)	Colour
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	Wavelength (nm)	Colour
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	Wavelength (nm)	Colour
Carbon dioxide	9550, 10 590	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

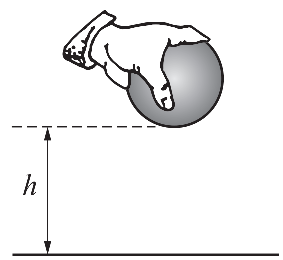
Substance	Density (kg m^{-3})	Melting point (K)	Boiling point (K)
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853
Ice	$9{\cdot}20 \times 10^{2}$	273	....
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377
Water	$1{\cdot}00 \times 10^{3}$	273	373
Air	1·29	....	....
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

Total marks — 25

Attempt ALL questions

1. A specially adapted ball has an electronic timer, which starts to time when the ball is released and stops timing when the ball strikes a surface.



The ball is dropped from rest through a height h onto a hard surface.

The time recorded on the ball is 0·40 s.

The effects of air resistance can be ignored.

The height h is

A 0·20 m

B 0·78 m

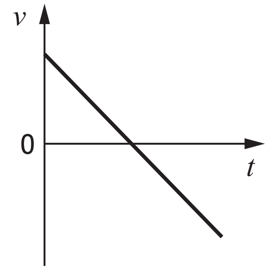
C 1·56 m

D 1·96 m

E 3·92 m.

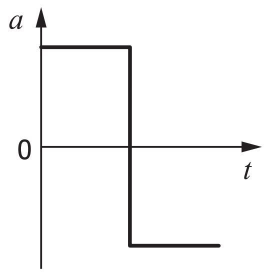
[Turn over

2. The velocity-time (v-t) graph for an object travelling in a straight line is shown below.

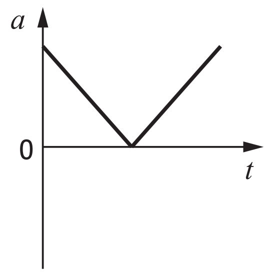


Which of the following is the corresponding acceleration-time (a-t) graph?

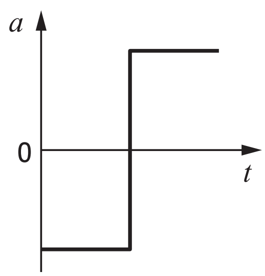
A



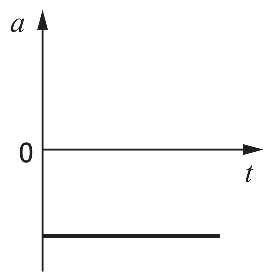
D



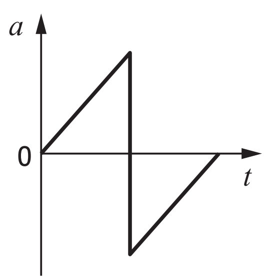
B



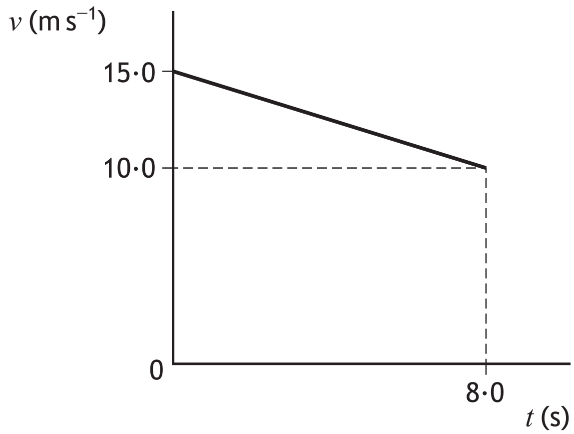
E



C



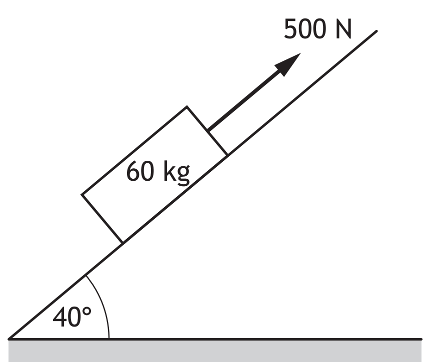
3. The velocity-time (v-t) graph for an object travelling along a straight line is shown.



Which row in the table shows the acceleration of the object during the 8·0 s and the displacement of the object at 8·0 s?

	Acceleration (m s^{-2})	Displacement (m)
A	–0·63	100
B	–0·63	140
C	–1·9	100
D	–1·9	120
E	–3·1	140

4. A pulling force of 500 N is applied to a 60 kg block on a slope as shown.



The maximum acceleration of the block is

A 2·0 m s^{-2}

B 5·4 m s^{-2}

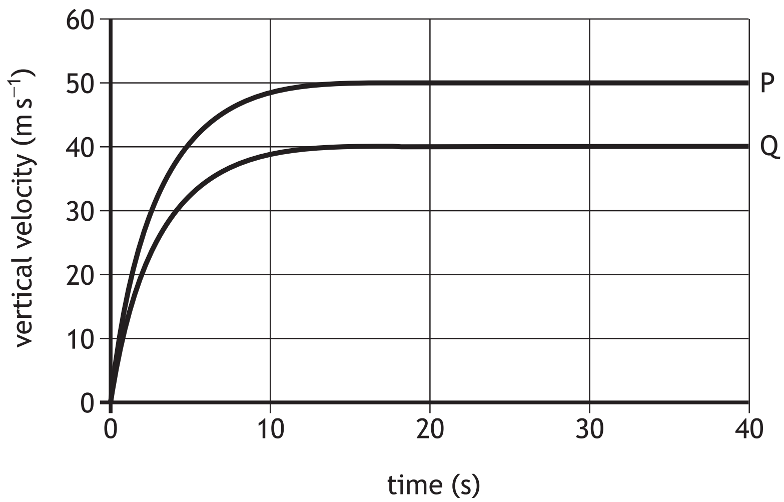
C 6·3 m s^{-2}

D 7·5 m s^{-2}

E 8·3 m s^{-2}.

5. Two objects, P and Q, of the same mass are dropped from the same height.

The graph shows how the vertical velocities of the two objects vary with time for the first 40 s of their fall.



A group of students make the following statements based on information from the graph.

I The terminal velocity of object P is $50\ m\,s^{-1}$.

II Object Q reaches its terminal velocity at 10 s.

III At 40 s, both objects have fallen through the same distance.

Which of these statements is/are correct?

A I only

B I and II only

C I and III only

D II and III only

E I, II and III

6. The total mass of a motorcycle and rider is 250 kg.

During braking they are brought to rest from a speed of $16\ m\,s^{-1}$ in a time of 10·0 s.

The maximum energy that could be converted to heat in the brakes is

A 2000 J

B 4000 J

C 32 000 J

D 40 000 J

E 64 000 J.

7. A carpenter is building a doorframe using a nail gun. The nail gun of mass 5·0 kg fires a nail of mass 4·0 g.

The nail gun and nail are initially at rest.

The speed of the nail immediately after firing is 150 $m\,s^{-1}$.

The recoil speed of the nail gun immediately after firing is

A 0·005 $m\,s^{-1}$

B 0·05 $m\,s^{-1}$

C 0·12 $m\,s^{-1}$

D 1·2 $m\,s^{-1}$

E 120 $m\,s^{-1}$.

8. The escape velocity v of an object is the minimum velocity required to allow the object to escape the gravitational field of a planet.

The following relationship is used to determine the escape velocity

$$v = \sqrt{\frac{2GM}{r}}$$

where G is the Universal Constant of Gravitation

M is the mass of the planet

r is the radius of the planet.

A planet has a mass of $4{\cdot}87 \times 10^{24}$ kg and a radius of $6{\cdot}05 \times 10^{6}$ m.

Based on this information, the escape velocity from this planet is

A $1{\cdot}66 \times 10^{-28}$ $m\,s^{-1}$

B $1{\cdot}29 \times 10^{-14}$ $m\,s^{-1}$

C $7{\cdot}33 \times 10^{3}$ $m\,s^{-1}$

D $1{\cdot}04 \times 10^{4}$ $m\,s^{-1}$

E $3{\cdot}97 \times 10^{9}$ $m\,s^{-1}$.

9. A spacecraft is travelling at $6{\cdot}0 \times 10^{7}$ $m\,s^{-1}$ relative to a star.

An observer on the spacecraft measures the speed of light emitted by the star to be

A $2{\cdot}4 \times 10^{8}$ $m\,s^{-1}$

B $2{\cdot}9 \times 10^{8}$ $m\,s^{-1}$

C $3{\cdot}0 \times 10^{8}$ $m\,s^{-1}$

D $3{\cdot}1 \times 10^{8}$ $m\,s^{-1}$

E $3{\cdot}6 \times 10^{8}$ $m\,s^{-1}$.

[Turn over

10. A spacecraft is travelling at a speed of $0\cdot45c$ relative to Earth.

An observer on Earth measures the time taken for the spacecraft to travel between two points to be 72 hours.

An observer on the spacecraft measures the time taken to travel between these two points to be

A 53 hours

B 64 hours

C 72 hours

D 81 hours

E 90 hours.

11. The redshift of light from a distant galaxy is 0·125.

The approximate distance to this distant galaxy is

A $3\cdot75 \times 10^{7}$ m

B $1\cdot81 \times 10^{8}$ m

C $5\cdot43 \times 10^{16}$ m

D $1\cdot63 \times 10^{25}$ m

E $1\cdot30 \times 10^{26}$ m.

12. A student makes the following statements about the Universe.

I Measurements of the velocities of galaxies and their distances from us lead to the theory of the origin of the expanding Universe.

II The mass of a galaxy can be estimated by the orbital speed of stars within it.

III Evidence supporting the existence of dark matter comes from the accelerating rate of expansion of the Universe.

Which of these statements is/are correct?

A I only

B I and II only

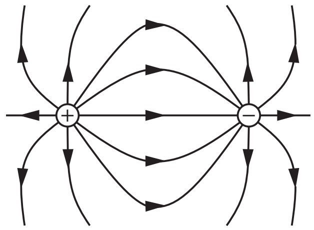
C I and III only

D II and III only

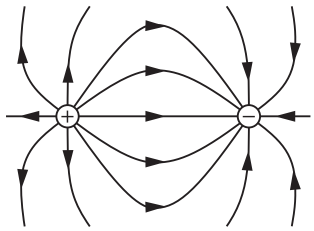
E I, II and III

13. Which of the following diagrams represents the electric field between a positive point charge and a negative point charge?

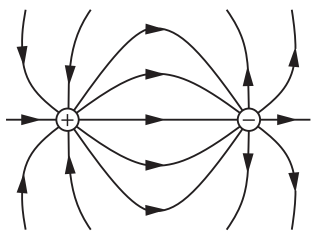
A



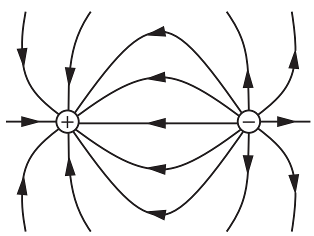
B



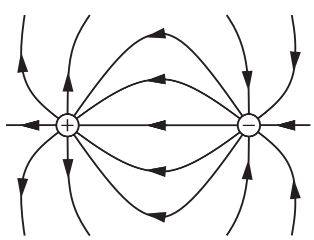
C



D



E



[Turn over

14. The group of matter particles known as fermions consists of

A baryons only
B quarks only
C leptons only
D quarks and leptons only
E baryons and mesons only.

15. A certain type of composite particle is made of two up quarks and a strange quark.

The charge on an up quark is $+\frac{2}{3}e$.
The charge on a strange quark is $-\frac{1}{3}e$.

Which of the following statements describes the nature and charge of this composite particle?

A The particle is a meson with a charge of $+1e$.
B The particle is a meson with a charge of $-1e$.
C The particle is a meson with no charge.
D The particle is a baryon with a charge of $-1e$.
E The particle is a baryon with a charge of $+1e$.

16. Two changes in a radioactive decay series are shown below.

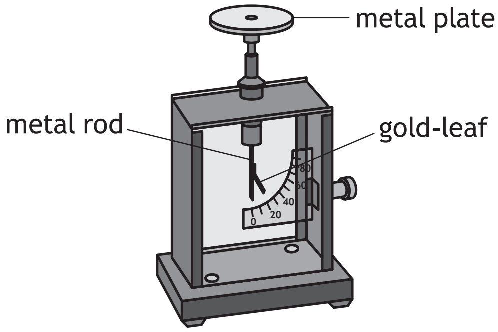
$$^{231}_{90}\text{Th} \xrightarrow{\beta} {}^{\text{P}}_{\text{Q}}\text{Pa} \xrightarrow{\alpha} {}^{\text{R}}_{\text{S}}\text{Ac}$$

A Thorium nucleus emits a beta particle and the product, a Protactinium nucleus, emits an alpha particle.

Which row in the table shows the numbers represented by P, Q, R, and S?

	P	Q	R	S
A	231	89	227	87
B	231	91	227	89
C	227	88	227	87
D	231	91	231	89
E	227	88	223	86

17. An experiment to demonstrate the photoelectric effect is set up as shown.



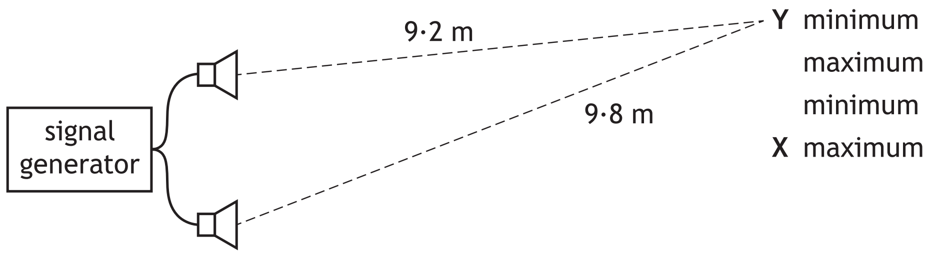
gold-leaf electroscope

Which row in the table shows the charge on the metal plate and the type of incident radiation most likely to cause photoelectric emission?

	Charge on metal plate	Type of incident radiation
A	negative	green light
B	positive	ultraviolet
C	negative	infrared
D	positive	red light
E	negative	ultraviolet

[Turn over

18. Two identical loudspeakers are connected to a signal generator as shown.



A microphone detects a maximum of sound at position X.

The microphone is now moved from X to Y.

As the microphone is moved from X to Y, a series of maxima and minima of sound are detected.

The microphone detects the second **minimum** of sound at position Y.

The wavelength of sound emitted by the loudspeakers is

A 0·17 m

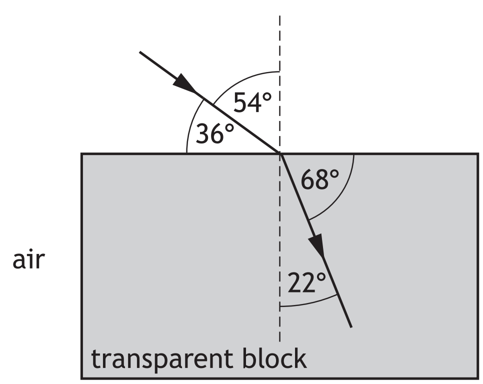
B 0·24 m

C 0·30 m

D 0·40 m

E 0·60 m.

19. A ray of red light passes from air into a transparent block as shown.



The speed of this light in the block is

A $1{\cdot}39 \times 10^8$ m s^{-1}

B $1{\cdot}91 \times 10^8$ m s^{-1}

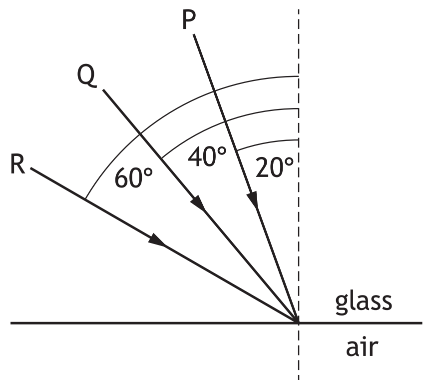
C $2{\cdot}62 \times 10^8$ m s^{-1}

D $3{\cdot}00 \times 10^8$ m s^{-1}

E $4{\cdot}73 \times 10^8$ m s^{-1}.

20. The diagram shows the path of three rays of red light P, Q and R in glass.

The rays are incident at the glass-air boundary as shown.



The refractive index of the glass for this light is 1·50.

Which of these rays pass from the glass into the air at this boundary?

A P only

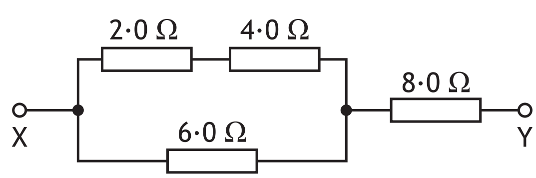
B R only

C Q and R only

D P and Q only

E P, Q and R

21. Four resistors are connected as shown.



The total resistance between X and Y is

A 1·0 Ω

B 8·9 Ω

C 9·1 Ω

D 11 Ω

E 20 Ω.

[Turn over

22. A resistor of resistance 100 Ω is rated at 4 W.

The maximum voltage which can be applied across the resistor without exceeding its power rating is

A 0·04 V

B 5 V

C 20 V

D 25 V

E 400 V.

23. Capacitance is measured in farads.

One farad is equivalent to

A one coulomb per volt

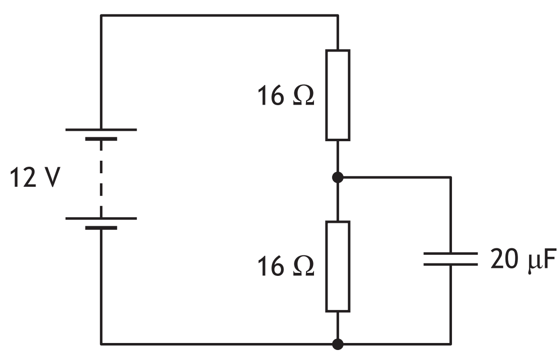
B one joule per volt

C one joule per coulomb

D one volt per second

E one joule per second.

24. A circuit containing a capacitor is set up as shown.



The battery has negligible internal resistance.

The maximum charge stored by the capacitor is

A $3{\cdot}6 \times 10^{-4}$ C

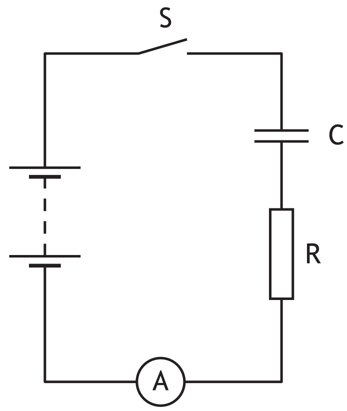
B $2{\cdot}4 \times 10^{-4}$ C

C $1{\cdot}2 \times 10^{-4}$ C

D $3{\cdot}3 \times 10^{-6}$ C

E $1{\cdot}7 \times 10^{-6}$ C.

25. A circuit is set up as shown.



Capacitor C is initially uncharged.

Switch S is closed and the time taken for the capacitor to fully charge is recorded.

The switch is now opened and the capacitor is discharged.

Resistor R is replaced by a resistor of greater resistance.

The switch is again closed and the capacitor charges.

Which row in the table shows the effect of this change, if any, on the time taken to fully charge the capacitor and the maximum energy stored in the capacitor?

	Time taken to fully charge the capacitor	**Maximum energy stored in the capacitor**
A	increases	increases
B	decreases	decreases
C	decreases	stays the same
D	increases	stays the same
E	stays the same	decreases

[END OF QUESTION PAPER]

Marking instructions for each question

Question	Answer	Mark
1.	B	1
2.	E	1
3.	A	1
4.	A	1
5.	A	1
6.	C	1
7.	C	1
8.	D	1
9.	C	1
10.	B	1
11.	D	1
12.	B	1
13.	B	1
14.	D	1
15.	E	1
16.	B	1
17.	E	1
18.	D	1
19.	A	1
20.	D	1
21.	D	1
22.	C	1
23.	A	1
24.	C	1
25.	D	1

[END OF MARKING INSTRUCTIONS]

FOR OFFICIAL USE

National
Qualifications

Mark

X857/76/01

Physics
Paper 2

Duration — 2 hours 15 minutes

* X 8 5 7 7 6 0 1 *

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth
Day Month Year

Scottish candidate number

Total marks — 130

Attempt ALL questions.

You may use a calculator.

Reference may be made to the data sheet on *page 02* of this booklet and to the relationships sheet X857/76/11.

Care should be taken to give an appropriate number of significant figures in the final answers to calculations.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. Score through your rough work when you have written your final copy.

Use **blue** or **black** ink.

Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

* X 8 5 7 7 6 0 1 0 1 *

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	Symbol	Value	Quantity	Symbol	Value
Speed of light in vacuum	c	$3{\cdot}00 \times 10^8$ m s^{-1}	Planck's constant	h	$6{\cdot}63 \times 10^{-34}$ J s
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}$ C	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}$ kg
Universal Constant of Gravitation	G	$6{\cdot}67 \times 10^{-11}$ m^3 kg^{-1} s^{-2}	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}$ kg
Gravitational acceleration on Earth	g	$9{\cdot}8$ m s^{-2}	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}$ kg
Hubble's constant	H_0	$2{\cdot}3 \times 10^{-18}$ s^{-1}			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	Refractive index	Substance	Refractive index
Diamond	2·42	Water	1·33
Crown glass	1·50	Air	1·00

SPECTRAL LINES

Element	Wavelength (nm)	Colour	Element	Wavelength (nm)	Colour
Hydrogen	656	Red	Cadmium	644	Red
	486	Blue-green		509	Green
	434	Blue-violet		480	Blue
	410	Violet	Lasers		
	397	Ultraviolet	**Element**	**Wavelength (nm)**	**Colour**
	389	Ultraviolet	Carbon dioxide	9550	Infrared
Sodium	589	Yellow		10 590	
			Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	Density (kg m^{-3})	Melting point (K)	Boiling point (K)
Aluminium	$2{\cdot}70 \times 10^3$	933	2623
Copper	$8{\cdot}96 \times 10^3$	1357	2853
Ice	$9{\cdot}20 \times 10^2$	273	. . . .
Sea Water	$1{\cdot}02 \times 10^3$	264	377
Water	$1{\cdot}00 \times 10^3$	273	373
Air	1·29	. . . .	. . . .
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^5$ Pa.

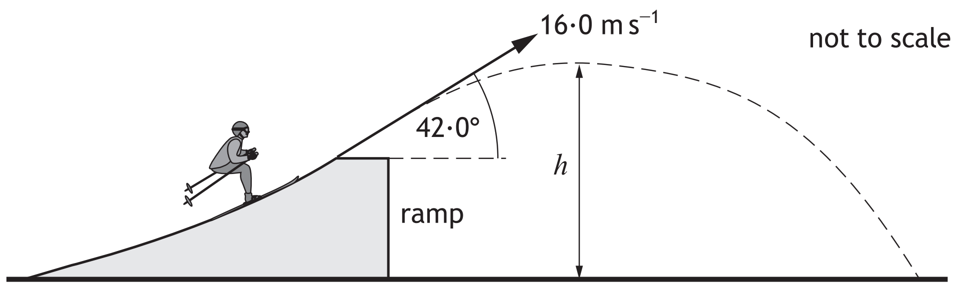
X857760102

MARKS DO NOT WRITE IN THIS MARGIN

Total marks — 130

Attempt ALL questions

1. A skier launches from a ramp. The skier leaves the ramp with a launch velocity of 16·0 m s^{-1} at 42·0° to the horizontal.



The effects of air resistance can be ignored.

(a) Calculate

(i) the horizontal component of the launch velocity of the skier **1**

Space for working and answer

(ii) the vertical component of the launch velocity of the skier. **1**

Space for working and answer

1. (continued)

MARKS | DO NOT WRITE IN THIS MARGIN

(b) Calculate the time taken for the skier to reach the maximum height h after launch. **3**

Space for working and answer

(c) The skier takes a further 1·40 s to travel from the maximum height h to the ground.

Determine the horizontal distance the skier travels from leaving the ramp until landing. **3**

Space for working and answer

(d) State how the value of the kinetic energy of the skier just before landing on the ground compares to their kinetic energy as they leave the ramp.

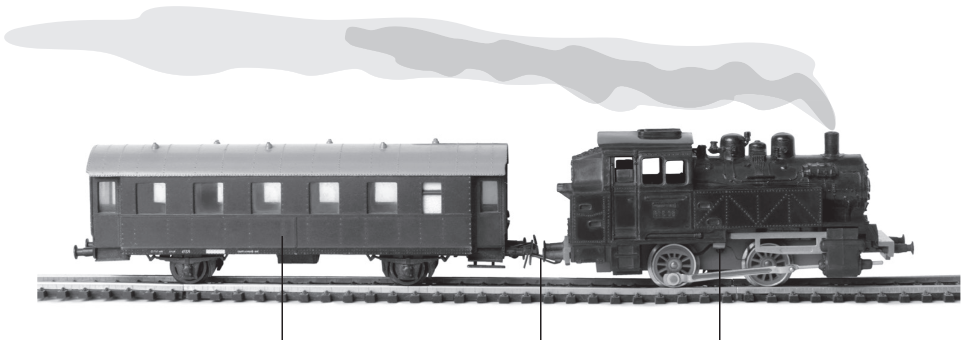
Justify your answer. **2**

Marking instructions for each question

Question			Expected response	Max mark	Additional guidance
1.	(a)	(i)	$(v_h = 16\cdot0\cos42\cdot0)$ $v_h = 11\cdot9$ m s^{-1}	1	Accept:12, 11·89, 11·890
		(ii)	$(v_v = 16\cdot0\sin42\cdot0)$ $v_v = 10\cdot7$ m s^{-1}	1	Accept: 11, 10·71, 10·706
	(b)		$v = u + at$ **(1)** $0 = 10\cdot7 + (-9\cdot8)t$ **(1)** $t = 1\cdot1$ s **(1)**	3	Or consistent with (a)(ii) u and a must have opposite signs Accept: 1, 1·09, 1·092 For alternative methods: 1 mark for **all** relationships 1 mark for **all** substitutions 1 mark for final answer
	(c)		$s = vt$ **(1)** $s = 11\cdot9 \times (1\cdot1 + 1\cdot40)$ **(1)** $s = 29\cdot8$ m **(1)**	3	Or consistent with (a)(i) and (b) Accept: 29·75, 29·750 Also accept 30
	(d)		Greater **(1)** The skier has a greater speed/ velocity as they land. **(1)**	2	Potential energy at take-off is transferred/converted to kinetic energy.

MARKS DO NOT WRITE IN THIS MARGIN

2. A train consists of a steam engine coupled to a carriage. The train is accelerating along a straight level track.



The steam engine provides a driving force of $1{\cdot}15 \times 10^5$ N.

The mass of the steam engine is $9{\cdot}75 \times 10^4$ kg.

The mass of the carriage and passengers is $3{\cdot}56 \times 10^4$ kg.

The effects of friction can be ignored.

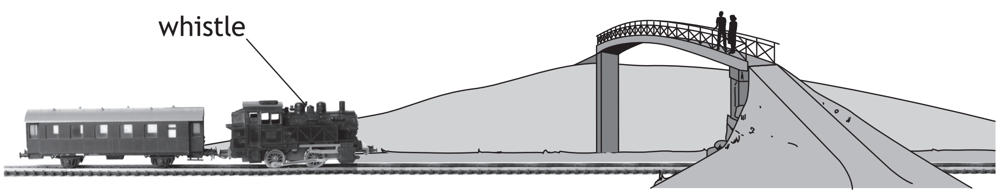
(a) Determine the tension in the coupling between the steam engine and the carriage. **4**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

2. (continued)

(b) Later in the journey, the train is travelling at a constant speed as it approaches a bridge. Two students are standing on the bridge.



(i) The engine driver sounds a whistle. The whistle emits sound with a frequency of 511 Hz.

The frequency of the sound heard by the students standing on the bridge is 531 Hz.

The speed of sound in air is $340\ \mathrm{m\,s^{-1}}$.

Calculate the speed of the train. **3**

Space for working and answer

(ii) One student suggests that a passenger sitting in the carriage behind the engine will hear a lower frequency of sound than the frequency emitted by the whistle.

State whether the student is correct.

You must justify your answer. **2**

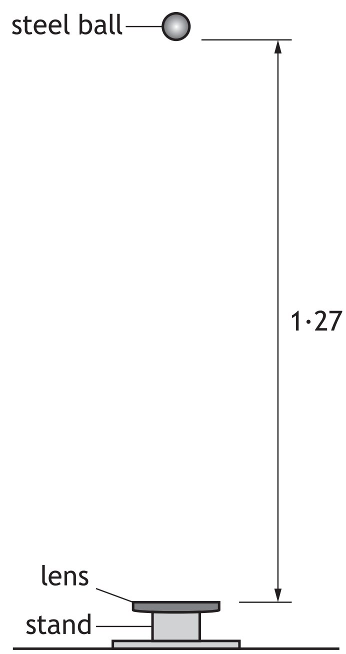
Question			Expected response	Max mark	Additional guidance
2.	(a)		$F = ma$ **(1)** $1{\cdot}15\times10^5 = (9{\cdot}75\times10^4 + 3{\cdot}56\times10^4)\times a$ **(1)** $(F = ma)$ $F = 3{\cdot}56\times10^4 \times\left(\dfrac{1{\cdot}15\times10^5}{1{\cdot}331\times10^5}\right)$ **(1)** $F = 3{\cdot}08\times10^4$ N **(1)**	4	Accept 3·1, 3·076, 3·0759 $F = ma$ anywhere, 1 mark
	(b)	(i)	$f_0 = f_s\left(\dfrac{v}{v \pm v_S}\right)$ **(1)** $531 = 511\left(\dfrac{340}{340 - v_S}\right)$ **(1)** $v_S = 13$ m s^{-1} **(1)**	3	Accept $f_0 = f_s\left(\dfrac{v}{v - v_S}\right)$ Accept 10, 12·8, 12·81
		(ii)	Not correct/incorrect **(1)** The passenger and engine are travelling at the same velocity. **(1)**	2	MUST JUSTIFY Accept: The passenger is travelling at the <u>same speed and in the same direction</u> as the whistle/engine. The distance between the whistle/engine and passenger remains constant.

MARKS DO NOT WRITE IN THIS MARGIN

3. A manufacturer tests whether a Perspex lens will break during an impact.

The lens is placed on a stand and a steel ball is dropped from rest onto the lens.

The ball has a mass of $1{\cdot}59 \times 10^{-2}$ kg and is dropped from a height of $1{\cdot}27$ m above the lens.



(a) Calculate the speed of the ball as it reaches the lens. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

3. (continued)

(b) The ball collides with the lens and rebounds upwards.

The magnitude of the change in momentum of the ball is $0{\cdot}14\ \text{kg m s}^{-1}$.

Calculate the speed of the ball immediately after it rebounds from the lens. **3**

Space for working and answer

(c) The collision between the ball and the lens is inelastic.

Explain what is meant by an *inelastic collision*. **1**

(d) The test is repeated with a second lens made of a softer material.

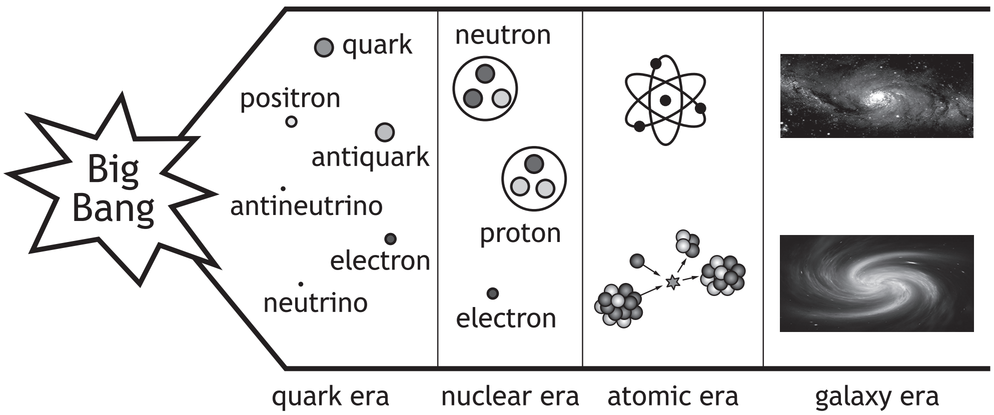
Explain why this would make the lens less likely to break. **2**

X857760109

Question			Expected response	Max mark	Additional guidance
3.	(a)		$v^2 = u^2 + 2as$ **(1)** $v^2 = 0^2 + 2\times(-)9{\cdot}8\times(-)1{\cdot}27$ **(1)** $v = 5{\cdot}0$ m s^{-1} **(1)**	**3**	Accept: 5, 4·99, 4·989 a and s **must** have the same sign, otherwise max 1 mark. For alternative methods: 1 mark for **all** relationships 1 mark for **all** substitutions 1 mark for final answer eg $E_p = mgh$ $E_p = 1{\cdot}59\times10^{-2}\times9{\cdot}8\times1{\cdot}27$ $E_k = \frac{1}{2}mv^2$ $\left(1{\cdot}59\times10^{-2}\times9{\cdot}8\times1{\cdot}27\right) = \frac{1}{2}\times1{\cdot}59\times10^{-2}\times v^2$ $v = 5{\cdot}0$ ms^{-1}
	(b)		$Ft = mv - mu$ **(1)** $0{\cdot}14 = \left(1{\cdot}59\times10^{-2}\times v\right) - \left(1{\cdot}59\times10^{-2}\times -5{\cdot}0\right)$ **(1)** $v = 3{\cdot}8$ m s^{-1} **(1)**	**3**	**Or** consistent with (a) Accept: 4, 3·81, 3·805 Ft and u must have opposite signs otherwise max 1 mark. Accept: $\Delta p=mv-mu$ $p = mv$ Do not accept $p=mv-mu$
	(c)		Kinetic energy is greater before (the collision) than after. **OR** Kinetic energy is lost (during the collision)	**1**	Do not accept E_k before not equal to E_k after. Do not accept E_k is not conserved.
	(d)		(Softer material would) increase the time of contact **(1)** and decrease the (maximum/ average) force **(1)**	**2**	Independent marks

MARKS DO NOT WRITE IN THIS MARGIN

4. A student finds the following diagram on a website. The website states that the diagram illustrates the evolution of the Universe from the Big Bang to the present day.

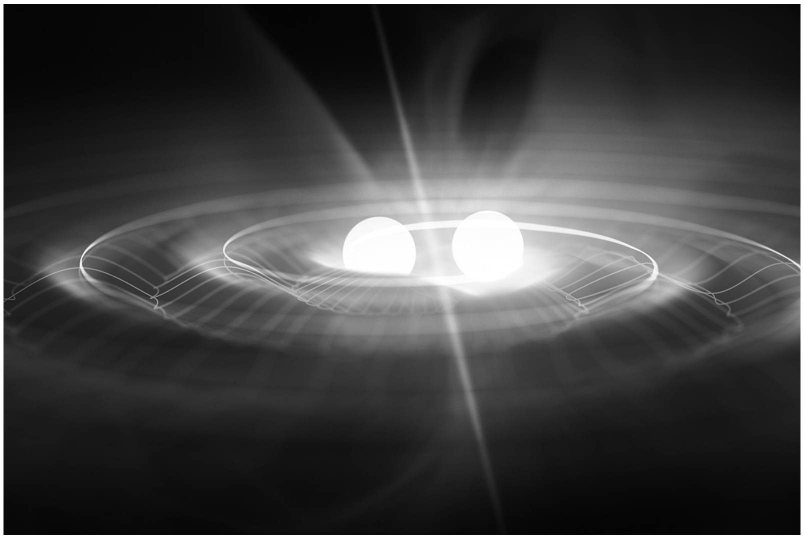


Using your knowledge of physics, comment on the diagram. **3**

MARKS DO NOT WRITE IN THIS MARGIN

5. Astronomers have recently detected gravitational waves produced by the merging of two neutron stars.

An artist's illustration of two neutron stars merging is shown.



One of the neutron stars had a mass of $3{\cdot}18 \times 10^{30}$ kg.

The second neutron star had a mass of $2{\cdot}27 \times 10^{30}$ kg.

(a) Calculate the separation of the neutron stars when the gravitational force of attraction between them was $1{\cdot}59 \times 10^{39}$ N. **3**

Space for working and answer

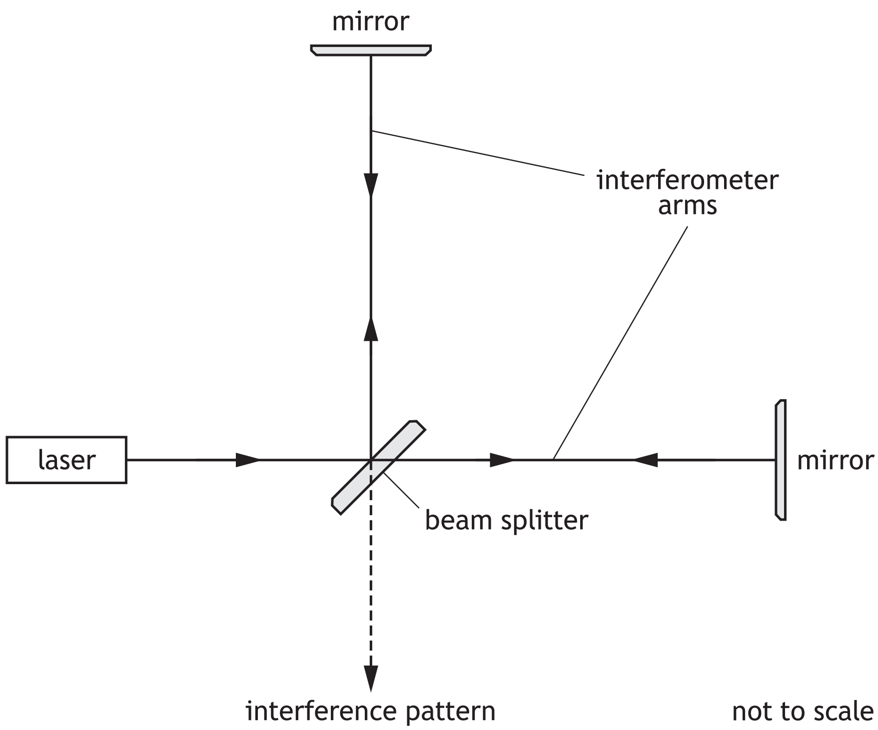
MARKS DO NOT WRITE IN THIS MARGIN

5. (continued)

(b) An interferometer is a device that can be used to detect gravitational waves.

In the interferometer, a beam of coherent light from a laser is split into two by a beam splitter.

The two beams then travel down the interferometer arms, reflect from mirrors, and finally meet to produce an interference pattern.



(i) Explain, in terms of waves, how a minimum is formed in the interference pattern. **1**

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

5. (b) (continued)

(ii) Each interferometer arm is 4·0 km long.

A gravitational wave changes the length of the arms, affecting the interference pattern produced.

The change in length of one of the arms is approximately $4{\cdot}0 \times 10^{-18}$ m.

In terms of orders of magnitude, compare the change in length of the interferometer arm with its original length. **2**

Space for working and answer

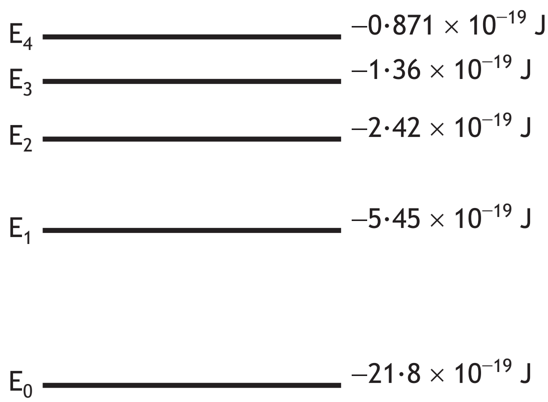
Question			Expected response	Max mark	Additional guidance
5.	(a)		$F = G\frac{m_1 m_2}{r^2}$ **(1)** $1{\cdot}59\times10^{39} = 6{\cdot}67\times10^{-11}\times\frac{3{\cdot}18\times10^{30}\times2{\cdot}27\times10^{30}}{r^2}$ **(1)** $r = 5{\cdot}50\times10^{5}$ m **(1)**	3	Accept: 5·5, 5·503, 5·5029
	(b)	(i)	Waves meet 180°/completely/totally/exactly out of phase **OR** Crest meets trough **OR** Path difference = $\left(m+\frac{1}{2}\right)\lambda$	1	Can be shown by appropriate diagram
		(ii)	$\left(\frac{4\cdot0\times10^{-18}}{4\cdot0\times10^{3}}=\right)10^{-21}$ **(1)** (change in length is) 21 orders of magnitude smaller **(1)**	2	Accept $\left(\frac{10^{-18}}{10^{3}}=\right)10^{-21}$ **OR** (-18-3) = -21 **(1)** Accept 21 smaller on its own **(2)** Do not accept 21 times smaller on its own (0) Accept $\left(\frac{10^{3}}{10^{-18}}=\right)10^{21}$ **OR** 3-(-18) = 21 **(1)** Accept: the length of the arm is 21 orders of magnitude greater than the change in length. **(1)**

6. White light from the Sun is analysed to produce the following absorption spectrum.

The spectral lines are known as Fraunhofer lines.

(a) Some Fraunhofer lines are produced by the transition of electrons between energy levels in hydrogen atoms.

Some of the energy levels of the hydrogen atom are shown.



(i) One of the Fraunhofer lines is due to the electron transition from E_1 to E_4.

Determine the frequency of the photon absorbed when an electron makes this transition. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

6. (a) (continued)

(ii) Calculate the wavelength of the photon absorbed. **3**

Space for working and answer

(iii) Determine the colour of the light absorbed during this electron transition. **1**

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

6. (continued)

(b) The spectral lines observed in the spectrum from a distant galaxy are redshifted. A galaxy known as NGC 6745 has a recessional velocity of $4{\cdot}51 \times 10^6$ m s^{-1}.

Calculate the redshift of the light from this galaxy. **3**

Space for working and answer

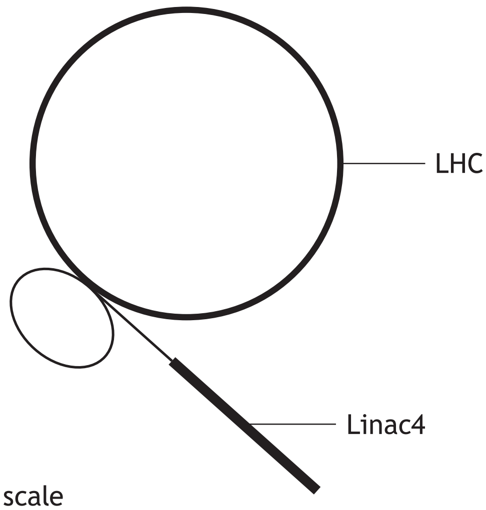
(c) The light from the majority of galaxies in the Universe is redshifted.

Explain how this evidence supports the Big Bang theory. **2**

Question			Expected response	Max mark	Additional guidance
6.	(a)	(i)	$E_2 - E_1 = hf$ **(1)** $(-0{\cdot}871\times10^{-19} - (-5{\cdot}45\times10^{-19}) = 6{\cdot}63\times10^{-34}\times f$ **(1)** $f = 6{\cdot}91\times10^{14}$ Hz **(1)**	**3**	Accept: 6·9, 6·906, 6·9065 Accept: $E_1 - E_4 = -hf$ $E_4 - E_1 = hf$ $(\Delta)E = hf$ for relationship mark anywhere Accept: $(5{\cdot}45\times10^{-19} - 0{\cdot}871\times10^{-19}) = 6{\cdot}63\times10^{-34}\times f$ If $(0{\cdot}871\times10^{-19} - 5{\cdot}45\times10^{-19})$ shown for substitution, maximum 1 mark for relationship
		(ii)	$v = f\lambda$ **(1)** $3{\cdot}00\times10^{8} = 6{\cdot}91\times10^{14}\times\lambda$ **(1)** $\lambda = 4{\cdot}34\times10^{-7}$ m **(1)**	**3**	Or consistent with (a)(i) Accept: 4·3, 4·342, 4·3415
		(iii)	Blue-violet	**1**	Or consistent with (a)(ii)
	(b)		$z = \frac{v}{c}$ **(1)** $z = \frac{4{\cdot}51\times10^{6}}{3{\cdot}00\times10^{8}}$ **(1)** $z = 0{\cdot}0150$ **(1)**	**3**	Accept: 0·015, 0·01503, 0·015033
	(c)		Redshift is evidence that the Universe is expanding **(1)** <u>Expanding Universe</u> is evidence supporting the Big Bang theory **(1)**	**2**	Accept: Redshift is evidence that the galaxies are moving away from each other.

MARKS DO NOT WRITE IN THIS MARGIN

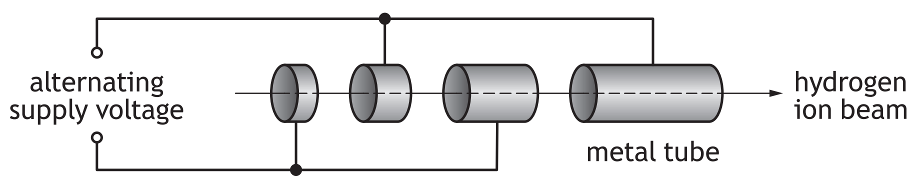
7. The Large Hadron Collider (LHC) at CERN has been upgraded recently. One of the upgrades is the addition of a linear particle accelerator known as Linac4.



Linac4 accelerates hydrogen ions before they enter the main LHC.

Linac4 consists of hollow metal tubes placed in a vacuum. The hydrogen ions are accelerated across the gaps between the tubes.

Part of Linac4 is shown below.



(a) (i) Explain why an alternating supply voltage is used in Linac4. **1**

(ii) Suggest one reason why the lengths of the tubes increase along Linac4. **1**

[Turn over

7. (continued)

MARKS DO NOT WRITE IN THIS MARGIN

(b) Linac4 accelerates the hydrogen ions to a speed of $0{\cdot}50c$. The hydrogen ions then travel through a connecting tube before entering the LHC.

The connecting tube has a length of 13 m in the frame of reference of a stationary observer.

Calculate the length of the connecting tube in the frame of reference of the hydrogen ions. **3**

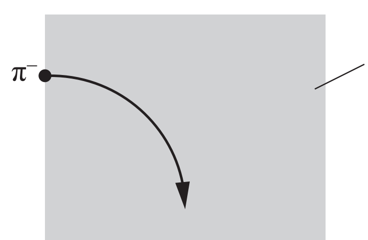
Space for working and answer

(c) Hydrogen ions can be collided within the LHC to produce other particles.

One of the particles produced is known as a . $^-$ meson. The π^- meson is negatively charged.

(i) State what is meant by the term *meson*. **1**

(ii) The π^- meson enters a region of magnetic field and follows the path shown.



Determine the direction of the magnetic field acting upon the π^- meson. **1**

MARKS DO NOT WRITE IN THIS MARGIN

7. (continued)

(d) In July 2018, scientists at CERN announced that the Higgs boson had been observed to decay into two bottom quarks.

(i) One of the fundamental forces involved in the decay of the Higgs boson is the weak nuclear force.

Name a force mediating particle for the weak nuclear force. **1**

(ii) A bottom quark has a mass-energy equivalence of 4·20 GeV.

(1 eV = $1{\cdot}60 \times 10^{-19}$ J)

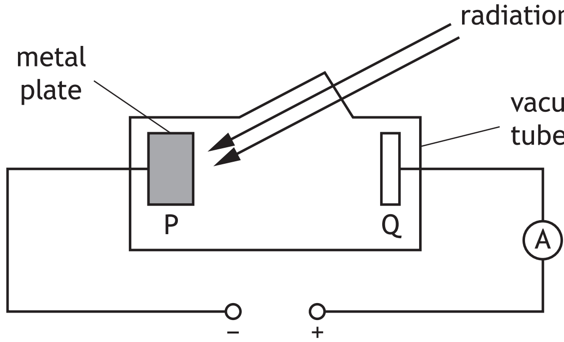
Determine the mass of the bottom quark. **4**

Space for working and answer

Question			Expected response	Max mark	Additional guidance
7.	(a)	(i)	To ensure the (accelerating) force on the hydrogen ion is in the same direction. **OR** To ensure the hydrogen ions accelerate in the same direction. **OR** To ensure that the direction of the electric field is correct when the hydrogen ions pass across the gaps.	**1**	Response must make some implication of 'same direction'.
		(ii)	As the speed of hydrogen ions increases, they travel further in the same time.	**1**	Accept: So that the hydrogen ions are at the ends of the tubes when the field changes polarity. **OR** So that a constant frequency AC supply can be used.
	(b)		$l' = l\sqrt{1-\left(\frac{v}{c}\right)^2}$ **(1)** $l' = 13\sqrt{1-\left(\frac{0{\cdot}50c}{c}\right)^2}$ **(1)** $l' = 11$ m **(1)**	**3**	Accept: 10, 11·3, 11·26 Alternative substitutions: $l' = 13\sqrt{1-(0{\cdot}50)^2}$ $l' = 13\sqrt{1-\left(\frac{0{\cdot}50\times3{\cdot}00\times10^8}{3{\cdot}00\times10^8}\right)^2}$
	(c)	(i)	A (composite) particle made of a quark-antiquark pair.	**1**	Do not accept: made of two quarks
		(ii)	Into the page	**1**	
	(d)	(i)	W boson **OR** Z boson	**1**	
		(ii)	4·20 GeV = $4{\cdot}20 \times 10^9 \times 1{\cdot}60 \times 10^{-19}$ **(1)** $E = mc^2$ **(1)** $\left(4{\cdot}20\times10^9\times\ 1{\cdot}60\times10^{-19}\right) = m\times(3{\cdot}00\times10^8)^2$ **(1)** $m = 7{\cdot}47\times10^{-27}$ kg **(1)**	**4**	Accept: 7·5, 7·467, 7·4667 Relationship anywhere 1 mark.

MARKS DO NOT WRITE IN THIS MARGIN

8. A student investigates the photoelectric effect using the apparatus shown.



The student notices that when white light is incident on metal plate P, the reading on the ammeter is 0 A. However, when ultraviolet radiation is incident on plate P, the reading on the ammeter is greater than 0 A.

(a) Explain why ultraviolet radiation produces a reading greater than 0 A on the ammeter, but white light does not. **1**

(b) The energy of a photon of ultraviolet radiation incident on plate P is $8{\cdot}0 \times 10^{-19}$ J.

The work function of the metal is $6{\cdot}9 \times 10^{-19}$ J.

The power supply is set to 12·0 V.

(i) Determine the maximum kinetic energy of an electron ejected from the surface of metal plate P. **1**

Space for working and answer

* X 8 5 7 7 6 0 1 2 2 *

MARKS DO NOT WRITE IN THIS MARGIN

8. (b) (continued)

(ii) Show that the kinetic energy gained by the electron as it accelerates from plate P to plate Q is $1{\cdot}92 \times 10^{-18}$ J. **2**

Space for working and answer

(iii) Determine the maximum speed of this electron as it reaches plate Q. **4**

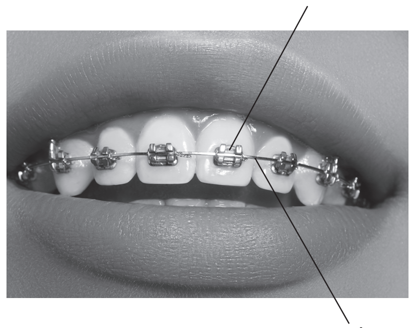
Space for working and answer

Question			Expected response	Max mark	Additional guidance
8.	(a)		The frequency of the UV is greater than the threshold frequency, whereas the frequency of white light is less than the threshold frequency. **OR** The energy of a photon of UV is greater than the work function, whereas the energy of a photon of white light is less than the work function.	1	Response must refer to both UV and white light.
	(b)	(i)	$1{\cdot}1 \times 10^{-19}$ J	1	
		(ii)	$W = QV$ **(1)** $W = 1{\cdot}60 \times 10^{-19} \times 12{\cdot}0$ **(1)** $W = 1{\cdot}92 \times 10^{-18}$ J	2	SHOW
		(iii)	$E_k = 1{\cdot}1 \times 10^{-19} + 1{\cdot}92 \times 10^{-18}$ **(1)** $E_k = \frac{1}{2}mv^2$ **(1)** $\left(1{\cdot}1 \times 10^{-19} + 1{\cdot}92 \times 10^{-18}\right) = \frac{1}{2} \times 9{\cdot}11 \times 10^{-31} \times v^2$ **(1)** $v = 2{\cdot}11 \times 10^{6}$ m s^{-1} **(1)**	4	Or consistent with (b)(i) Accept: 2·1, 2·111, 2·1111 Relationship anywhere 1 mark

MARKS DO NOT WRITE IN THIS MARGIN

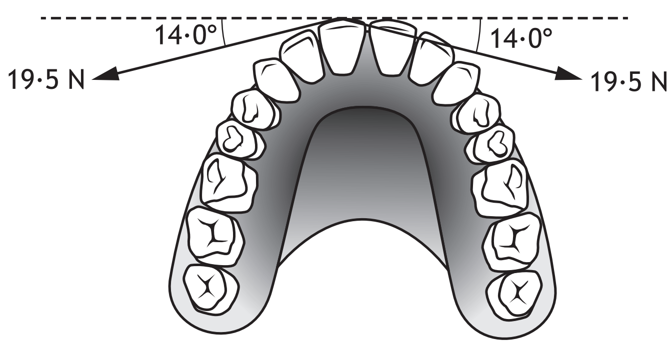
9. Dental braces are used to adjust the position of a patient's teeth.

Bonding cement is used to attach brackets to each tooth and then a stainless steel wire is attached to the brackets.



(a) The tension in the wire exerts two forces to move one of the patient's front teeth backward.

Both forces are 19·5 N as shown.



(i) Determine the magnitude of the resultant force applied to the tooth. **2**

Space for working and answer

(ii) Explain why the wire does not cause the tooth to move sideways. **1**

9. (continued) MARKS DO NOT WRITE IN THIS MARGIN

(b) Light from an LED is used to harden the bonding cement applied to the patient's teeth.

(i) The irradiance of the light from the LED on the cement on one tooth is $11\,800\ \mathrm{W\,m^{-2}}$.

The bonding cement on this tooth has an area of $1{\cdot}24 \times 10^{-5}\ \mathrm{m^2}$.

The cement requires $2{\cdot}10$ J of energy to harden.

Determine the minimum time for which the light from the LED must be applied. **5**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

9. (b) (continued)

(ii) Concern has been raised about the effect the light from the LED may have upon dental assistants' eyes.

A medical researcher investigates how the irradiance I varies with distance d from the LED.

The following results are obtained.

d (m)	0·30	0·40	0·50	0·60
I ($W\,m^{-2}$)	6·3	3·5	2·3	1·6

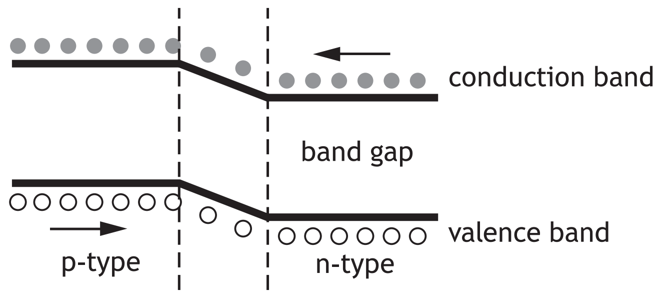
Use **all the data** to show that the LED acts as a point source over this range. **3**

MARKS DO NOT WRITE IN THIS MARGIN

9. (b) (continued)

(iii) The LED is made from doped semiconductor material to create a p-n junction.

The diagram represents the band structure of the LED.



(A) State what is meant by a *doped semiconductor*. **1**

(B) A voltage is applied across the LED so that it is forward biased and emits light.

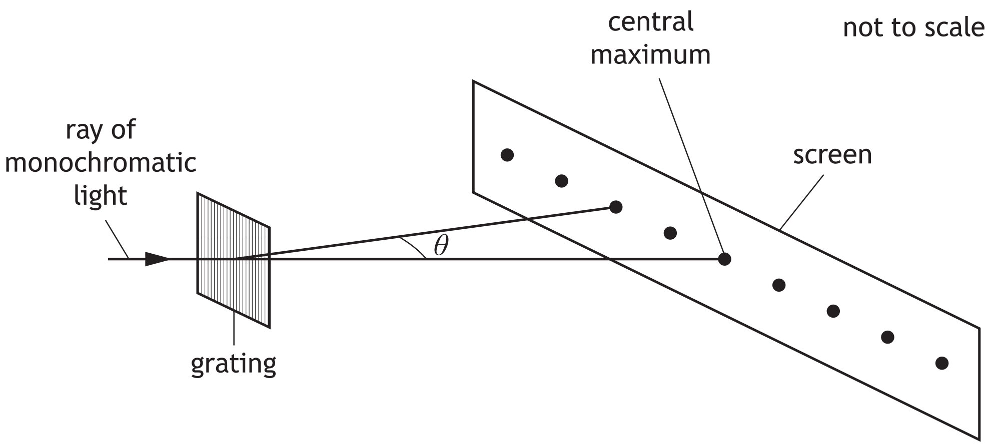
Using **band theory**, explain how the LED emits light. **3**

Question			Expected response	Max mark	Additional guidance
9.	(a)	(i)	$F = 19{\cdot}5\sin 14{\cdot}0$ **(1)** $F_R = (2 \times 19{\cdot}5\sin 14{\cdot}0) = 9{\cdot}43$ N **(1)** **OR** $F_R = 2 \times 19{\cdot}5\sin 14{\cdot}0$ **(1)** $F_R = 9{\cdot}43$ N **(1)**	2	Accept: 9·4, 9·435, 9·4350 Or by scale diagram: 1 for suitable scale diagram 1 for correct answer
		(ii)	No resultant force in this direction/ the sideways direction **OR** Unbalanced force in this direction/ the sideways direction is 0 N **OR** The components of the force at 90° to the direction of the movement are equal and opposite/balanced. **(1)**	1	Accept reference to horizontal forces/left and right direction, since the diagram orientation makes it clear which forces are being referred to. Do not accept: 'the forces are balanced' alone
	(b)	(i)	$I = \frac{P}{A}$ **(1)** $11800 = \frac{P}{1{\cdot}24 \times 10^{-5}}$ **(1)** $P = \frac{E}{t}$ **(1)** $(11800 \times 1{\cdot}24 \times 10^{-5}) = \frac{2{\cdot}10}{t}$ **(1)** $t = 14{\cdot}4$ s **(1)**	5	Accept: 14, 14·35, 14·352 $I = \frac{P}{A}$ anywhere, 1 mark $P = \frac{E}{t}$ anywhere, 1 mark
		(ii)	$6{\cdot}3 \times 0{\cdot}30^2 = 0{\cdot}57$ $3{\cdot}5 \times 0{\cdot}40^2 = 0{\cdot}56$ $2{\cdot}3 \times 0{\cdot}50^2 = 0{\cdot}58$ $1{\cdot}6 \times 0{\cdot}60^2 = 0{\cdot}58$ **(2)** Statement of $I \times d^2$ = constant, so LED is a point source **(1)**	3	All four calculations correct (2) Three calculations correct (1) <Three calculations correct (0) This conclusion mark is only available if consistent with the calculations shown. Graphical method: Graph drawn correctly (1) Best fit line through origin (1) Statement of $I \propto \frac{1}{d^2}$, so LED is a point source (1)
		(iii) (A)	A semiconductor that has (specific) impurities added	1	

		(B)		**3**	Any answer using recombination of holes and electrons **on its own**, with no reference to band theory, is worth 0 marks Any wrong physics eg holes move up (from valence band to conduction band)- 0 marks
			(Voltage applied causes) electrons to move from the conduction band of the n-type (semiconductor) towards the conduction band of the p-type (semiconductor). **(1)**		To access this mark, the direction the electrons move must be clear.
			Electrons 'fall' from the conduction band into the valence band (on either side of the junction) **(1)**		To access this mark, valence and conduction bands must be included in the answer. Do not accept: 'valency' as a name for the valence band or 'conductive' as a name for the conduction band.
			Photons are emitted. **(1)**		This mark is dependent upon having at least one of the first two statements.

MARKS DO NOT WRITE IN THIS MARGIN

10. A technician carries out an experiment to determine the wavelength of monochromatic light from a laser.



(a) A pattern of bright spots is observed on the screen.

The technician measures the angle θ between the central maximum and the second order maximum five times.

The results are shown.

14·0°	13·5°	14·5°	14·5°	13·0°

(i) Calculate

(A) the mean value for the angle θ **1**

Space for working and answer

(B) the approximate random uncertainty in this value. **2**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

10. (a) (continued)

(ii) The spacing between the lines on the grating is $4{\cdot}00 \times 10^{-6}$ m.

Calculate the wavelength of the light from the laser. **3**

Space for working and answer

(iii) The technician repeats the experiment and this time measures the angle between the central maximum and the third order maximum.

Explain why this gives a more precise value for the wavelength of the light. **1**

(b) The laser is now replaced by a source of white light. The pattern observed on the screen consists of a white central maximum and a series of continuous spectra on each side of the white central maximum.

Explain, in terms of path difference, why the central maximum is white. **1**

[Turn over

Question			Expected response		Max mark	Additional guidance
10.	(a)	(i)	(A)	$13{\cdot}9°$	1	Do not accept:14
			(B)	$\left(\Delta R = \frac{R_{max} - R_{min}}{n}\right)$ $\Delta R = \frac{14{\cdot}5 - 13{\cdot}0}{5}$ **(1)** $\Delta R = 0{\cdot}3°$ **(1)**	2	
		(ii)	$m\lambda = d\sin\theta$ **(1)** $2\times\lambda = 4{\cdot}00\times10^{-6}\sin13{\cdot}9$ **(1)** $\lambda = 4{\cdot}80\times10^{-7}\,\text{m}$ **(1)**		3	Or consistent with (a)(i)(A) Accept: 4·8, 4·805, 4·8046
		(iii)	Percentage (scale reading) uncertainty in the angle is smaller **(1)**		1	Accept: fractional uncertainty in place of percentage uncertainty Must be percentage or fractional uncertainty not just scale reading uncertainty or uncertainty alone.
	(b)		The path difference (at the central maximum) for each wavelength/ frequency/colour will be zero **(1)**		1	Must answer in terms of path difference.

MARKS DO NOT WRITE IN THIS MARGIN

11. The use of analogies from everyday life can help people to better understand physics concepts.

The arrangement of books on the shelves of a bookcase can be used as an analogy for the Bohr model of the atom.

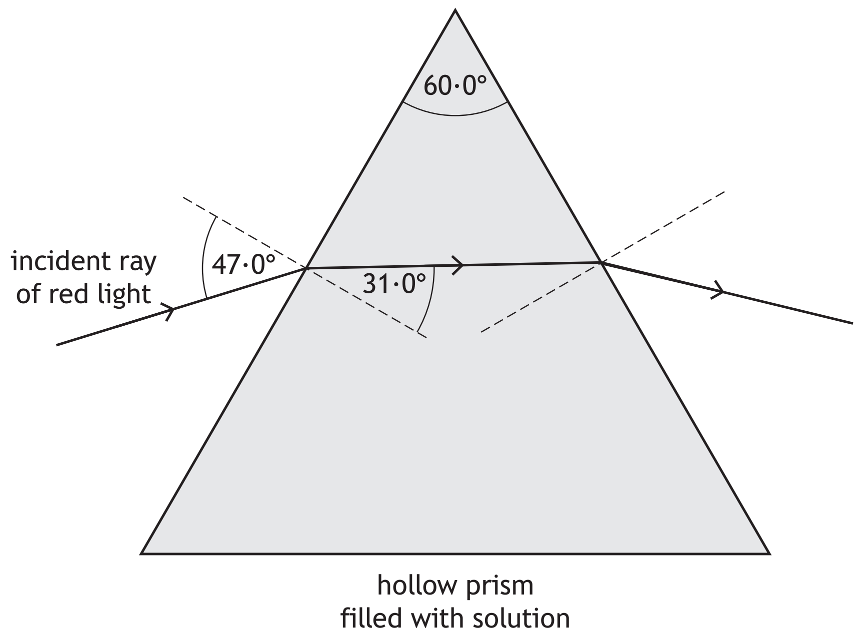
Using your knowledge of physics, comment on this analogy. **3**

MARKS DO NOT WRITE IN THIS MARGIN

12. A technician fills a hollow prism with a sugar solution.

The technician shines red light from a laser into the prism.

The angle through which the light refracts depends upon the concentration of the sugar solution.



(a) (i) Calculate the refractive index of this solution. **3**

Space for working and answer

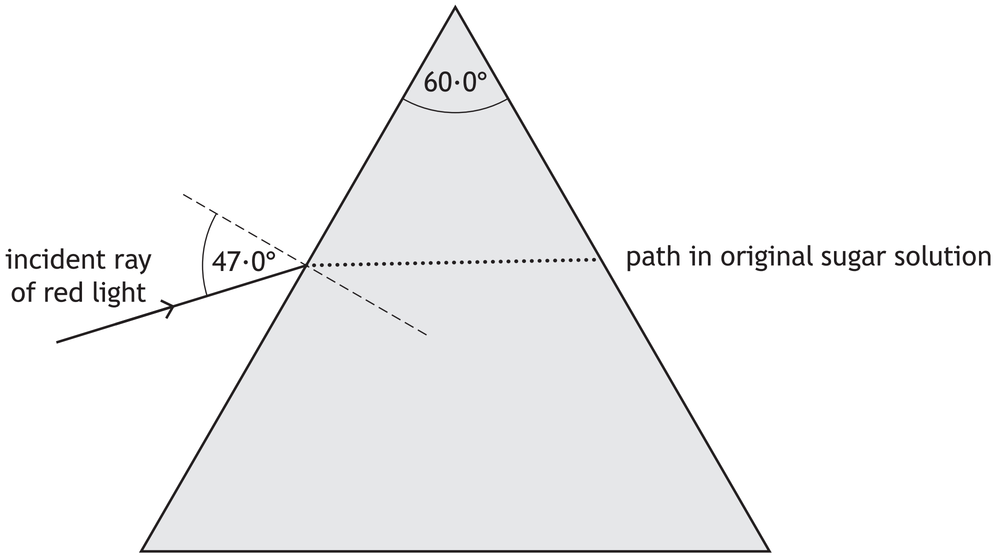
(ii) State how the frequency of the light in the solution compares to the frequency of the light in air. **1**

MARKS | DO NOT WRITE IN THIS MARGIN

12. (continued)

(b) The prism is now filled with a more concentrated sugar solution, which has a greater refractive index.

On the diagram below, draw the path the ray will now follow **inside** the prism. **1**



(An additional diagram, if required can be found on *page 45*.)

(c) The experiment is repeated using green light from a laser and the more concentrated sugar solution. The light enters the prism at the same angle as before.

Explain the difference in the path taken by the green light compared to the path taken by the red light. **2**

[Turn over

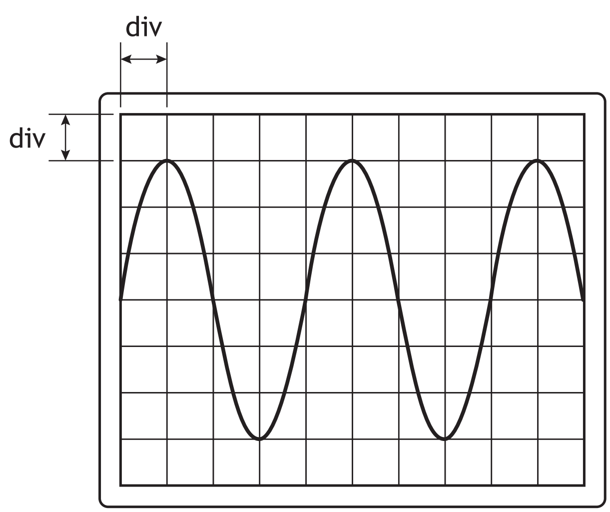
Question			Expected response	Max mark	Additional guidance
12.	(a)	(i)	$n=\dfrac{\sin\theta_1}{\sin\theta_2}$ **(1)** $n=\dfrac{\sin 47\cdot 0}{\sin 31\cdot 0}$ **(1)** $n=1\cdot 42$ **(1)**	**3**	Also accept 1·4, 1·420, 1·4200
		(ii)	(frequency is the) same	**1**	
	(b)		Ray drawn at smaller angle of refraction	**1**	Ignore any emergent rays Ray must be passably straight.
	(c)		green light has a higher/larger/ greater frequency (1) so the refractive index is greater (and the ray refracts more/at a smaller angle) (1)	**2**	Any mention of a greater angle of refraction or no change in the angle of refraction – 0 marks

MARKS DO NOT WRITE IN THIS MARGIN

13. A student connects a signal generator, which provides an alternating current, to an oscilloscope.

(a) State what is meant by an *alternating current*. **1**

(b) The oscilloscope screen shows the output of the signal generator.



The Y-gain setting on the oscilloscope is 5·0 V/div.

The timebase setting on the oscilloscope is 1·0 ms/div.

(i) Determine the peak voltage of the output of the signal generator. **1**

Space for working and answer

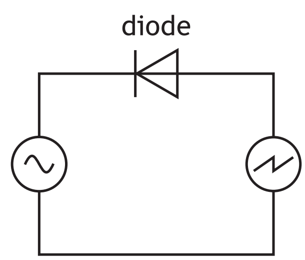
MARKS DO NOT WRITE IN THIS MARGIN

13. (b) (continued)

(ii) Determine the frequency of the output of the signal generator. **3**

Space for working and answer

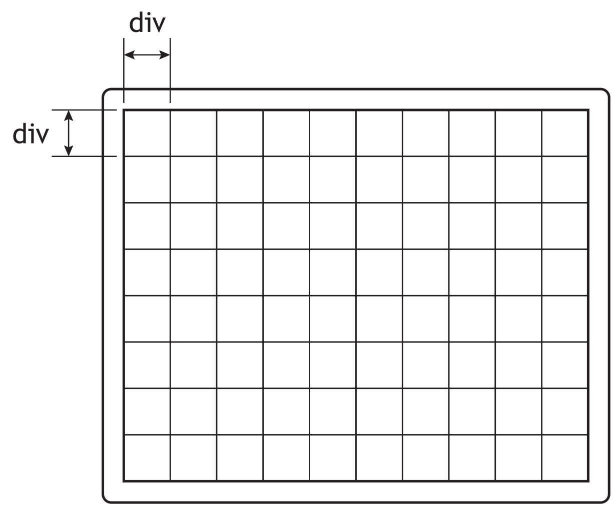
(c) The student connects a diode to the circuit as shown. The settings on the signal generator and the oscilloscope are unchanged.



Current can only flow in one direction through a diode.

This changes the trace on the oscilloscope screen.

On the diagram below, draw the new trace seen on the oscilloscope screen. **2**

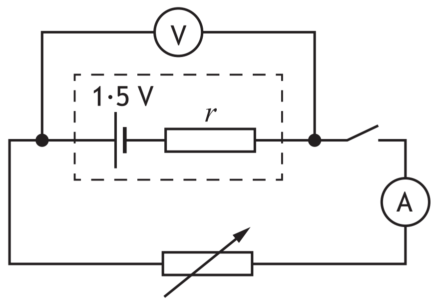


(An additional diagram, if required can be found on *page 45*.)

Question			Expected response	Max mark	Additional guidance
13.	(a)		(An alternating current) changes direction and (instantaneous) value with time.	1	
	(b)	(i)	$(V_{peak} = 5{\cdot}0 \times 3)$ $V_{peak} = 15$ V	1	
		(ii)	$\left(T = 1{\cdot}0 \times 10^{-3} \times 4 = 4{\cdot}0 \times 10^{-3}\ \text{s}\right)$ $f = \frac{1}{T}$ (1) $f = \frac{1}{4{\cdot}0 \times 10^{-3}}$ (1) $f = 250\text{Hz}$ (1)	3	
	(c)		Same frequency and peak voltage **(1)** Trace shows 'half-wave rectification' **(1)**	2	Positive or negative half of the cycle accepted.

MARKS DO NOT WRITE IN THIS MARGIN

14. A student carries out an experiment, using the apparatus shown, to determine a value for the internal resistance r of a cell.



(a) Describe how the student would use this apparatus, and analyse the data obtained, to determine the value for the internal resistance of the cell. **3**

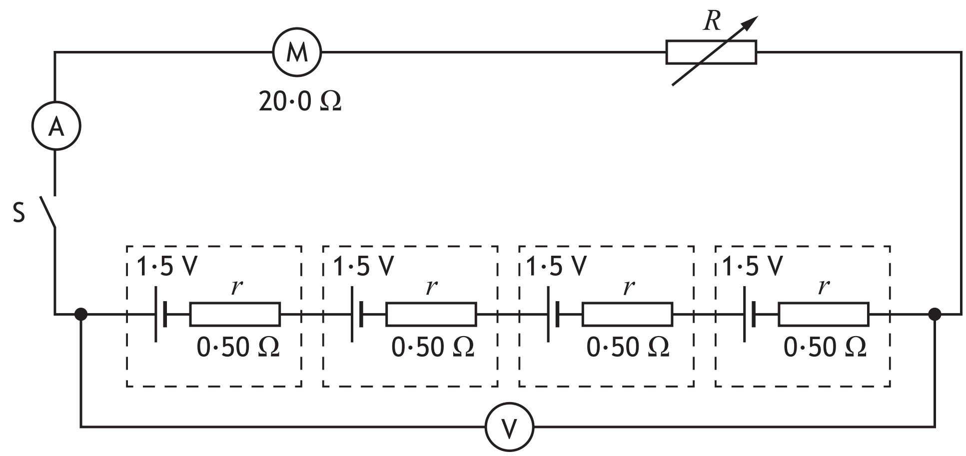
14. (continued)

MARKS DO NOT WRITE IN THIS MARGIN

(b) The internal resistance of the cell is determined to be 0·50 Ω.

Four identical cells are now connected to a motor and a variable resistor as shown.

The EMF of each cell is 1·5 V.



(i) State what is meant by an *EMF of 1·5 V*. **1**

(ii) Switch S is now closed. The reading on the ammeter is 0·20 A.

Determine the resistance R of the variable resistor. **4**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

14. (continued)

(c) The resistance of the variable resistor is now increased.

State what happens to the reading on the voltmeter.

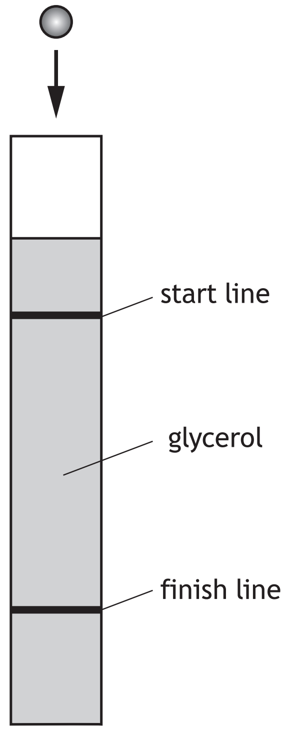
Justify your answer. **3**

Question			Expected response	Max mark	Additional guidance
14.	(a)		Adjust variable resistor and take readings of V and I. **(1)** Plot a graph of V against I. **(1)** Gradient of graph = $-r$. **(1)**	**3**	Measure open circuit voltage E/measure the voltage E when the switch is open. (1) Close the switch and take a reading of V and I. (1) Calculate r using $E = V + Ir$. (1)
	(b)	(i)	1·5 J of energy is supplied to/gained by each coulomb (of charge passing through the cell).	**1**	
		(ii)	$E = V + Ir$ and $V = IR$ **(1)** $6 \cdot 0 = (0 \cdot 20R + (0 \cdot 20 \times 2 \cdot 0))$ **(1)** $R = 28\ \Omega$ **(1)** $(R_v = 28 - 20)$ $R_v = 8{\cdot}0\ \Omega$ **(1)**	**4**	Accept: $E = I(R + r)$ Accept: 8, 8·00, 8·000
	(c)		Increases **(1)** Current is less **(1)** Lost volts (Ir) decreases **(1)**	**3**	Look for this statement first - if incorrect or missing then (0 marks).

MARKS DO NOT WRITE IN THIS MARGIN

15. A student carries out an experiment to measure the terminal velocity of ball bearings with different diameters falling through glycerol.

Each ball bearing is dropped into a long tube filled with glycerol.



(a) Explain in terms of the forces acting on the ball bearing, why it reaches its terminal velocity. **2**

[Turn over

15. (continued)

MARKS DO NOT WRITE IN THIS MARGIN

(b) The student measures the diameter d of each ball bearing and records the corresponding terminal velocity v_t.

The results are shown in the table.

d (m)	d^2 (m^2)	v_t ($m\,s^{-1}$)
$3{\cdot}15 \times 10^{-3}$	$0{\cdot}99 \times 10^{-5}$	0·05
$4{\cdot}77 \times 10^{-3}$	$2{\cdot}28 \times 10^{-5}$	0·10
$6{\cdot}34 \times 10^{-3}$	$4{\cdot}02 \times 10^{-5}$	0·18
$9{\cdot}52 \times 10^{-3}$	$9{\cdot}06 \times 10^{-5}$	0·32
$12{\cdot}65 \times 10^{-3}$	$16{\cdot}00 \times 10^{-5}$	0·52

(i) Using the square-ruled paper on *page 42*, draw a graph of v_t against d^2. **3**

(The table of results is also shown on *page 43*, opposite the square-ruled paper.)

(ii) The student suspects that the results show that there is a systematic uncertainty in the measurements.

Suggest a reason why the student has come to this conclusion. **1**

(iii) Calculate the gradient of your graph. **2**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

15. (b) (continued)

(iv) The terminal velocity v_t of each ball bearing is given by

$$v_t = \frac{375g}{\eta}\,!\; d^2$$

where η is the viscosity of the glycerol in pascal seconds (Pa s)

d is the diameter of the ball bearing in m

g is gravitational field strength on Earth in N kg^{-1}.

Use the gradient of your graph to determine the viscosity of the glycerol. **2**

Space for working and answer

[END OF QUESTION PAPER]

Question			Expected response	Max mark	Additional guidance
15.	(a)		The frictional force/drag acting on the ball bearing increases (as its speed increases). **(1)** The frictional force/drag and weight become balanced. **(1)**	**2**	
	(b)	(i)	Appropriate labels and units **(1)** Suitable scales **(1)** Correct plotting of points and appropriate line of best fit **(1)**	**3**	Allow for axes starting at zero or broken axes or at an appropriate value. Accuracy of plotting should be easily checkable with the scale chosen. Do not penalise if the candidate plots d^2 against v_t.
		(ii)	There is a non-zero y-intercept/ The line of best fit does not go through the origin	**1**	
		(iii)	$m = \frac{y_2 - y_1}{x_2 - x_1}$ **(1)** Correctly calculated gradient **(1)**	**2**	**Must** be consistent with graph drawn for (i). Candidates are asked to calculate the gradient of **their graph.** Unit not required but if a unit is given it must be correct. Tolerance required depending upon line of best fit drawn by the candidate.
		(iv)	$m = \frac{375g}{\eta}$ **(1)** Correctly calculated viscosity consistent with b(iii), including correct unit. **(1)**	**2**	

[END OF MARKING INSTRUCTIONS]

National Qualifications 2022

X857/76/12

Physics
Paper 1 — Multiple choice

FRIDAY, 13 MAY

9:00 AM – 9:45 AM

Total marks — 25

Attempt ALL questions.

You may use a calculator.

Instructions for the completion of Paper 1 are given on *page 02* of your answer booklet X857/76/02.

Record your answers on the answer grid on *page 03* of your answer booklet.

Reference may be made to the data sheet on *page 02* of this question paper and to the relationships sheet X857/76/22.

Space for rough work is provided at the end of this booklet.

Before leaving the examination room you must give your answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

SQA ©

* X 8 5 7 7 6 1 2 *

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	Symbol	Value	Quantity	Symbol	Value
Speed of light in vacuum	c	$3.00 \times 10^{8}\ \text{m s}^{-1}$	Planck's constant	h	$6.63 \times 10^{-34}\ \text{J s}$
Magnitude of the charge on an electron	e	$1.60 \times 10^{-19}\ \text{C}$	Mass of electron	m_e	$9.11 \times 10^{-31}\ \text{kg}$
Universal Constant of Gravitation	G	$6.67 \times 10^{-11}\ \text{m}^3\ \text{kg}^{-1}\ \text{s}^{-2}$	Mass of neutron	m_n	$1.675 \times 10^{-27}\ \text{kg}$
Gravitational acceleration on Earth	g	$9.8\ \text{m s}^{-2}$	Mass of proton	m_p	$1.673 \times 10^{-27}\ \text{kg}$
Hubble's constant	H_0	$2.3 \times 10^{-18}\ \text{s}^{-1}$			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	Refractive index	Substance	Refractive index
Diamond	2.42	Water	1.33
Crown glass	1.50	Air	1.00

SPECTRAL LINES

Element	Wavelength (nm)	Colour
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	Wavelength (nm)	Colour
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	Wavelength (nm)	Colour
Carbon dioxide	9550, 10 590	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	Density (kg m^{-3})	Melting point (K)	Boiling point (K)
Aluminium	2.70×10^{3}	933	2623
Copper	8.96×10^{3}	1357	2853
Ice	9.20×10^{2}	273	. . . .
Sea Water	1.02×10^{3}	264	377
Water	1.00×10^{3}	273	373
Air	1.29	. . . .	. . . .
Hydrogen	9.0×10^{-2}	14	20

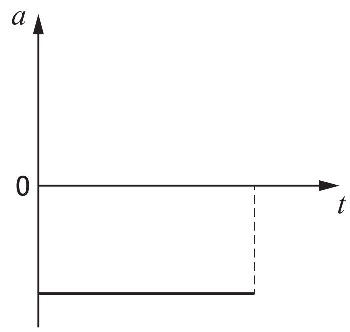
The gas densities refer to a temperature of 273 K and a pressure of 1.01×10^{5} Pa.

Total marks — 25

Attempt ALL questions

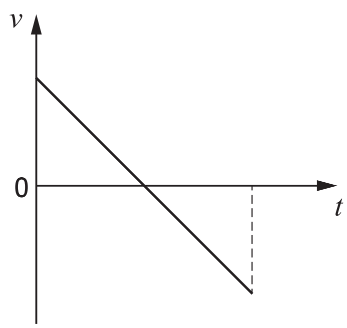
1. A ball is thrown vertically upwards and falls back to its starting position.

The acceleration-time graph represents the motion of the ball.

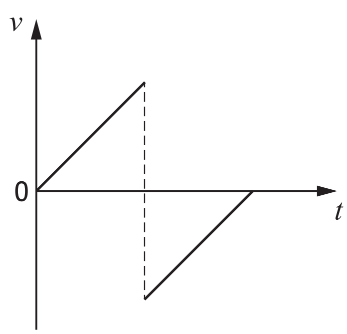


Which of the following velocity-time graphs represents the same motion?

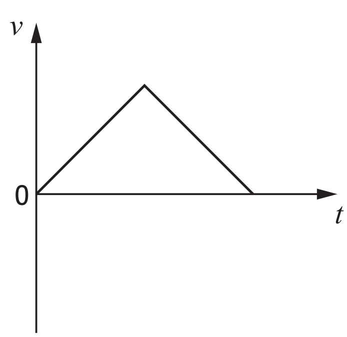
A



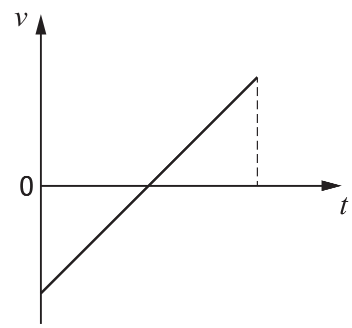
B



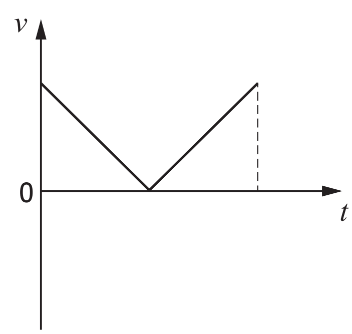
C



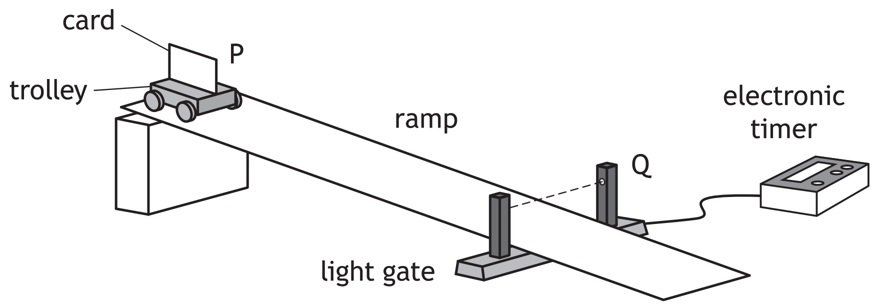
D



E



2. A student uses the apparatus shown to determine the acceleration of a trolley as it moves down a ramp.



The trolley is released from rest at point P and moves down the ramp.

A card attached to the trolley passes through a light gate at point Q.

The time for the card to pass through the light gate is displayed on the electronic timer.

The vehicle's acceleration a is determined using the relationship

$$v^2 = u^2 + 2as$$

The student makes the following statements about the terms u, s, and v:

I $u = 0\ \text{m s}^{-1}$

II $s =$ the length of the card

III $v = \dfrac{\text{distance between P and Q}}{\text{time displayed on timer}}$

Which of these statements is/are correct?

A I only

B II only

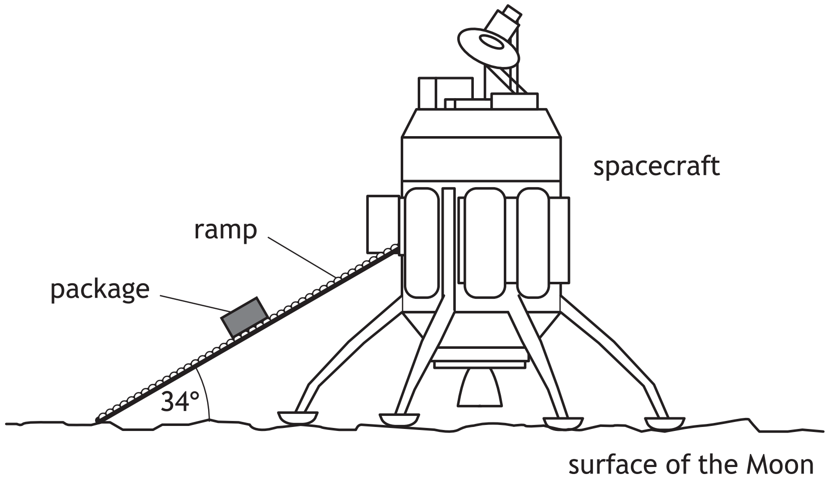
C I and II only

D I and III only

E I, II and III

3. A spacecraft unloads cargo on the surface of the Moon.

The gravitational field strength on the Moon is 1.6 $N\,kg^{-1}$.



A package of mass 3.0 kg moves down the ramp.

The component of the weight of the package acting parallel to the ramp is:

A 0.89 N

B 2.7 N

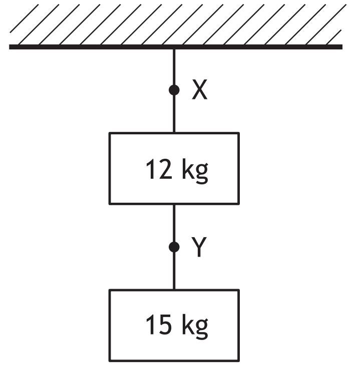
C 4.0 N

D 4.8 N

E 16 N.

[Turn over

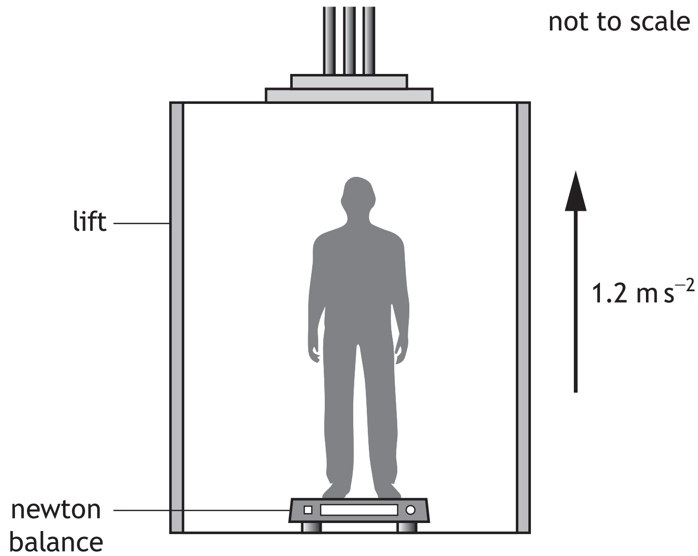
4. Two blocks are suspended from a ceiling by ropes as shown.



Which row in the table shows the tension in the rope at point X and the tension in the rope at point Y?

	Tension at point X (N)	Tension at point Y (N)
A	27	15
B	120	29
C	120	150
D	260	29
E	260	150

5. During an experiment a student inside a lift stands on a newton balance.



The mass of the student is 50.0 kg.

The lift accelerates upwards at 1.2 m s^{-2}.

The reading on the newton balance is:

A 60 N

B 430 N

C 490 N

D 550 N

E 590 N.

6. Water flows at a rate of 1.0×10^6 kg per second over the Victoria Falls.

The Victoria Falls are 120 m high.

The total power delivered by the water in falling through 120 m is:

A 1.2×10^{12} W

B 1.2×10^{9} W

C 1.2×10^{8} W

D 8.5×10^{-10} W

E 8.5×10^{-11} W.

[Turn over

7. A spacecraft passes the Earth at a speed of $0.4c$.

A light on the spacecraft pulses on and off.

A passenger on the spacecraft measures the time between the pulses as 2.5 s.

An observer on Earth measures the time between the pulses as:

A 2.3 s

B 2.5 s

C 2.7 s

D 3.0 s

E 3.2 s.

8. A student makes the following statements about the expanding Universe:

I The evidence supporting the existence of dark matter comes from estimations of the mass of galaxies.

II The evidence supporting the existence of dark energy comes from the accelerating rate of expansion of the Universe.

III The peak wavelength of radiation emitted by hotter stars is longer than that for cooler stars.

Which of these statements is/are correct?

A I only

B II only

C III only

D I and II only

E I, II and III

9. A police car is travelling at a constant speed of 31.0 m s^{-1} towards a stationary observer. The siren on the car emits a sound with a frequency of 820 Hz.

The speed of sound in air is 340 m s^{-1}.

The frequency of the sound heard by the observer is:

A 745 Hz

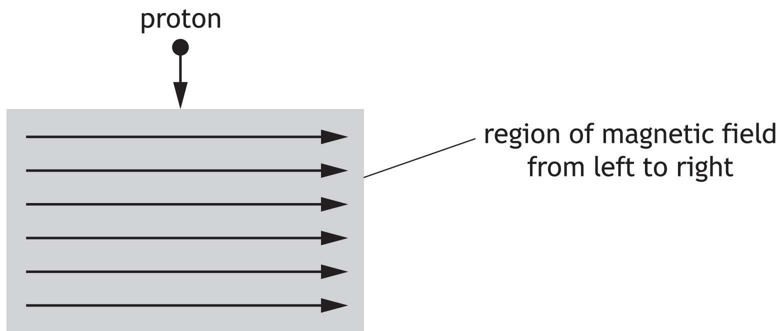
B 751 Hz

C 820 Hz

D 895 Hz

E 902 Hz.

10. A proton enters a region of magnetic field as shown.



The direction of the force exerted by the magnetic field on the proton as it enters the field is:

A out of the page

B into the page

C to the left

D to the right

E towards the bottom of the page.

11. The masses of three particles are shown.

Particle	Mass (kg)
Electron	9.11×10^{-31}
Proton	1.673×10^{-27}
Higgs boson	2.22×10^{-25}

How many orders of magnitude greater is the mass of a Higgs boson compared to the mass of a proton?

A 7.54×10^{-3}

B 2

C 5

D 133

E 2.44×10^{5}

[Turn over

12. A proton consists of two up quarks and a down quark.

A student makes the following statements about protons:

I Protons are baryons.

II Protons are hadrons.

III Protons are fermions.

Which of these statements is/are correct?

A I only

B II only

C III only

D I and II only

E I, II and III

13. The following statement represents part of a radioactive decay series.

$$X \xrightarrow{\alpha} Y \xrightarrow{\beta} {}^{214}_{83}Bi$$

Nucleus X undergoes alpha emission to produce nucleus Y.

Nucleus Y then undergoes beta emission.

Nucleus X is:

A ${}^{218}_{85}At$

B ${}^{214}_{82}Pb$

C ${}^{218}_{84}Po$

D ${}^{218}_{86}Rn$

E ${}^{210}_{80}Hg$.

14. The following statement represents a nuclear reaction.

$$^{240}_{94}\text{Pu} \rightarrow \, ^{236}_{92}\text{U} + \, ^{4}_{2}\text{He}$$

The total mass of the particles before the reaction is 398.626×10^{-27} kg.

The total mass of the particles after the reaction is 398.615×10^{-27} kg.

The energy released in this reaction is:

A 1.1×10^{-29} J

B 3.3×10^{-21} J

C 5.0×10^{-13} J

D 9.9×10^{-13} J

E 3.6×10^{-8} J.

15. The irradiance of light incident on a surface from a point source is $20.0\ \text{W m}^{-2}$.

The distance between the point source and the surface is 5.0 m.

The point source is now moved to a distance of 25.0 m from the surface.

The irradiance of the light incident on the surface is now:

A $0.032\ \text{W m}^{-2}$

B $0.80\ \text{W m}^{-2}$

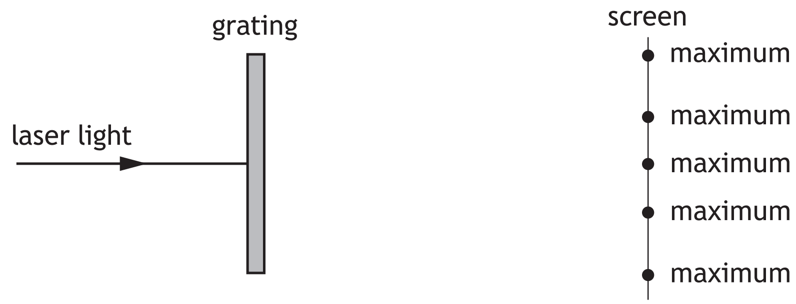
C $1.2\ \text{W m}^{-2}$

D $4.0\ \text{W m}^{-2}$

E $100\ \text{W m}^{-2}$.

[Turn over

16. Light from a laser is incident on a grating as shown.



A series of interference maxima are observed on the screen.

A student makes the following statements about the interference pattern observed on the screen:

I Increasing the distance between the grating and the screen increases the distance between the observed maxima.

II Increasing the distance between the laser and the grating increases the distance between the observed maxima.

III Decreasing the distance between the slits on the grating decreases the distance between the observed maxima.

Which of the statements is/are correct?

A I only

B II only

C I and III only

D II and III only

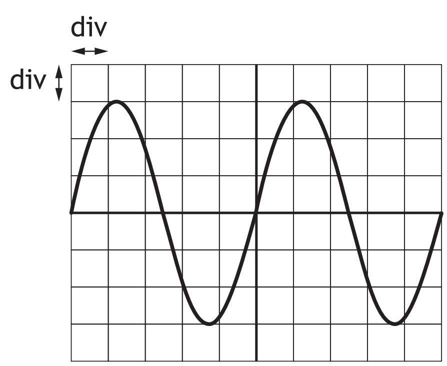
E I, II and III

17. Which row in the table shows what happens to the speed, frequency, and wavelength of red light as it passes from diamond into air?

	Speed	Frequency	Wavelength
A	decreases	decreases	no change
B	decreases	no change	decreases
C	decreases	increases	increases
D	increases	no change	increases
E	increases	increases	increases

18. The output from a signal generator is connected to an oscilloscope.

The trace seen on the oscilloscope screen is shown.



The Y-gain setting on the oscilloscope is 2.0 V/div.

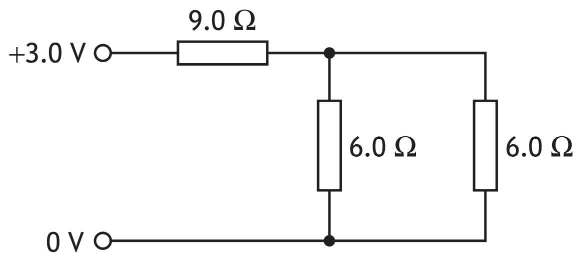
The time base setting on the oscilloscope is 5 ms/div.

Which row in the table gives the rms voltage and the frequency of the output from the signal generator?

	rms voltage (V)	Frequency (Hz)
A	4.2	25
B	4.2	40
C	6.0	40
D	6.0	200
E	8.5	25

[Turn over

19. Three resistors are connected to a 3.0 V power supply as shown.



The power supply has negligible internal resistance.

The power dissipated in the circuit is:

A 0.25 W

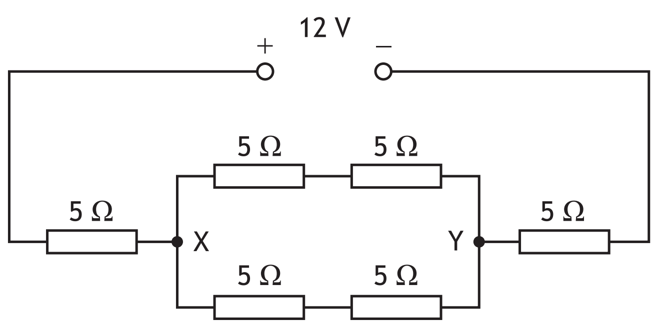
B 0.43 W

C 0.75 W

D 2.1 W

E 4.0 W.

20. Six resistors, each of resistance 5 Ω, are connected to a 12 V power supply as shown.

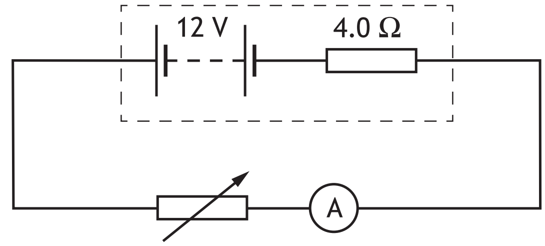


The power supply has negligible internal resistance.

Which row in the table shows the total circuit resistance and the potential difference across X and Y?

	Total circuit resistance (Ω)	**Potential difference across X and Y (V)**
A	15	2
B	15	4
C	20	6
D	30	8
E	30	12

21. A circuit is set up as shown.



The resistance of the variable resistor is set to 6.0 Ω.

The lost volts due to the internal resistance of the battery is:

A 1.2 V

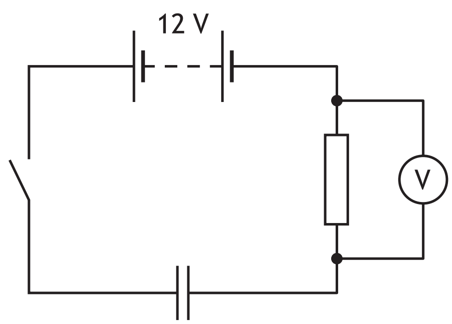
B 4.8 V

C 6.0 V

D 7.2 V

E 8.0 V.

22. A circuit is set up as shown.



The battery has negligible internal resistance.

The capacitor is initially uncharged.

The switch is now closed.

When the reading on the voltmeter is 7.0 V, the charge stored on the capacitor is:

A 3.1×10^{-5} C

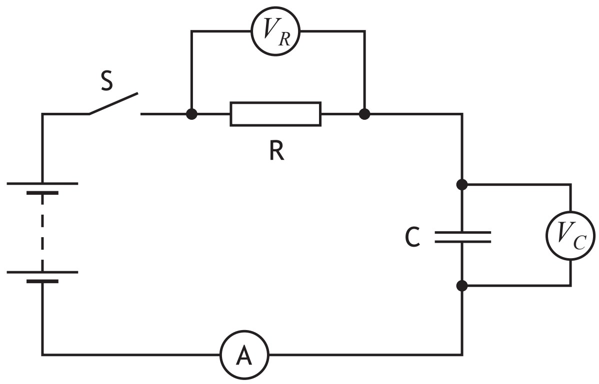
B 4.4×10^{-5} C

C 1.1×10^{-3} C

D 1.5×10^{-3} C

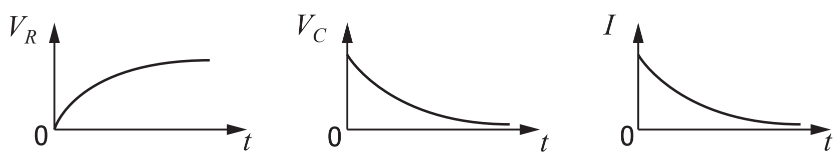
E 2.6×10^{-3} C.

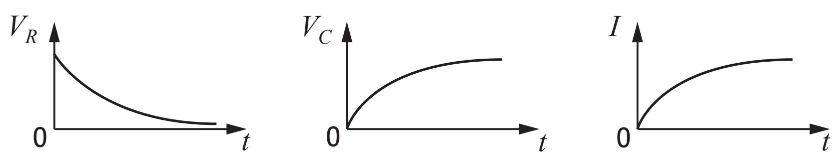
23. A circuit is set up as shown.

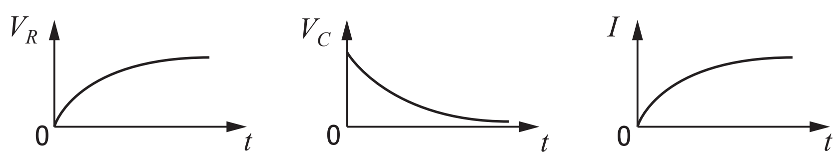


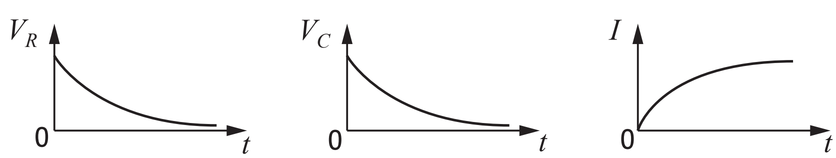
The capacitor is initially uncharged. Switch S is closed.

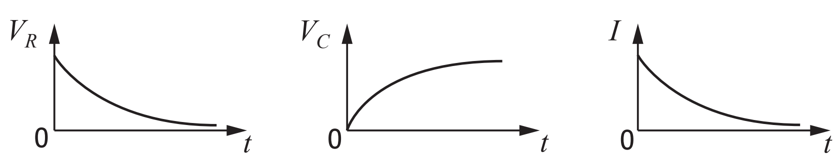
Which graphs show how the potential difference V_R across resistor R, the potential difference V_C across capacitor C, and the current I in the circuit, vary with time t as the capacitor charges?

A


B


C


D


E


24. Which row in the table describes the conduction band and the gap between the conduction band and the valence band in an insulator?

	Conduction band	Gap between conduction band and valence band
A	unfilled	bands overlap
B	full	bands overlap
C	unfilled	large gap
D	full	small gap
E	full	large gap

25. Astronomers use the following relationship to estimate the mass M of a galaxy

$$M = \frac{v^2 r}{G}$$

where v is the orbital speed of a star in the outer regions of the galaxy, in m s^{-1}

r is the orbital radius of the star, in m

G is the Universal Constant of Gravitation.

A star orbits at a radius of 4.0×10^{20} m in the outer regions of the Triangulum galaxy.

The orbital speed of the star is 120 km s^{-1}.

Based on this information, the mass of the Triangulum galaxy is:

A 3.8×10^{20} kg

B 7.2×10^{32} kg

C 8.6×10^{34} kg

D 7.2×10^{35} kg

E 8.6×10^{40} kg.

[END OF QUESTION PAPER]

Marking Instructions for each question

Question	Answer	Mark
1.	A	1
2.	A	1
3.	B	1
4.	E	1
5.	D	1
6.	B	1
7.	C	1
8.	D	1
9.	E	1
10.	A	1
11.	B	1
12.	E	1
13.	C	1
14.	D	1
15.	B	1
16.	A	1
17.	D	1
18.	B	1
19.	C	1
20.	B	1
21.	B	1
22.	C	1
23.	E	1
24.	C	1
25.	E	1

[END OF MARKING INSTRUCTIONS]

FOR OFFICIAL USE

H

National Qualifications 2022

Mark

X857/76/01

Physics Paper 2

FRIDAY, 13 MAY

10:15 AM – 12:30 PM

X857760 1

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth

Day Month Year

Scottish candidate number

Total marks — 130

Attempt ALL questions.

You may use a calculator.

Reference may be made to the Data Sheet on *page 02* of this booklet and to the relationship sheet X857/76/11.

Care should be taken to give an appropriate number of significant figures in the final answers to calculations.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. Score through your rough work when you have written your final copy.

Use **blue** or **black** ink.

Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

SQA ©

X85776010 1

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	Symbol	Value	Quantity	Symbol	Value
Speed of light in vacuum	c	3.00×10^{8} m s^{-1}	Planck's constant	h	6.63×10^{-34} J s
Magnitude of the charge on an electron	e	1.60×10^{-19} C	Mass of electron	m_e	9.11×10^{-31} kg
Universal Constant of Gravitation	G	6.67×10^{-11} m^{3} kg^{-1} s^{-2}	Mass of neutron	m_n	1.675×10^{-27} kg
Gravitational acceleration on Earth	g	9.8 m s^{-2}	Mass of proton	m_p	1.673×10^{-27} kg
Hubble's constant	H_0	2.3×10^{-18} s^{-1}			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	Refractive index	Substance	Refractive index
Diamond	2.42	Water	1.33
Crown glass	1.50	Air	1.00

SPECTRAL LINES

Element	Wavelength (nm)	Colour
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	Wavelength (nm)	Colour
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	Wavelength (nm)	Colour
Carbon dioxide	9550 } 10 590 }	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	Density (kg m^{-3})	Melting point (K)	Boiling point (K)
Aluminium	2.70×10^{3}	933	2623
Copper	8.96×10^{3}	1357	2853
Ice	9.20×10^{2}	273	. . . .
Sea Water	1.02×10^{3}	264	377
Water	1.00×10^{3}	273	373
Air	1.29	. . . .	. . . .
Hydrogen	9.0×10^{-2}	14	20

The gas densities refer to a temperature of 273 K and a pressure of 1.01×10^{5} Pa.

X857760102

MARKS DO NOT WRITE IN THIS MARGIN

Total marks — 130

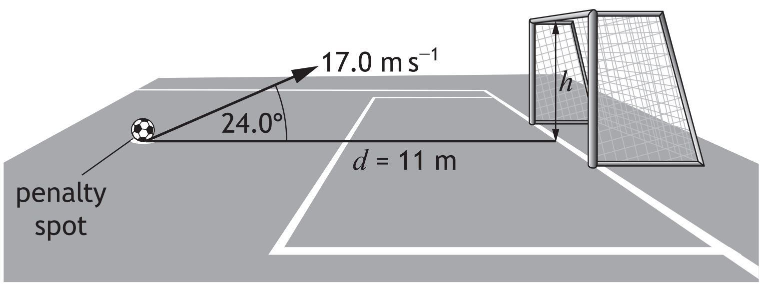
Attempt ALL questions

1. The crossbar challenge is a football contest in which competitors try and hit the crossbar of a goal by kicking a football from the penalty spot.

The horizontal distance between the penalty spot and the crossbar is 11 m.

One competitor kicks a football with an initial velocity of 17.0 m s^{-1} at an angle of 24.0° to the horizontal.

not to scale



The football hits the crossbar.

The effects of air resistance can be ignored.

(a) (i) Calculate:

(A) the horizontal component of the initial velocity of the football **1**

Space for working and answer

(B) the vertical component of the initial velocity of the football. **1**

Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

1. (a) (continued)

(ii) Show that the time taken for the football to travel from the penalty spot to the crossbar is 0.71 s. **2**

Space for working and answer

(iii) The football is at the maximum height in its trajectory when it hits the crossbar.

Calculate the height h above the ground at which the football hits the crossbar. **3**

Space for working and answer

(b) The next time the competitor tries the challenge, they kick the football at the same angle with an initial speed less than 17.0 $m\,s^{-1}$.

State whether the football hits the crossbar, passes over the crossbar, or passes under the crossbar.

Justify your answer. **2**

* X 8 5 7 7 6 0 1 0 5 *

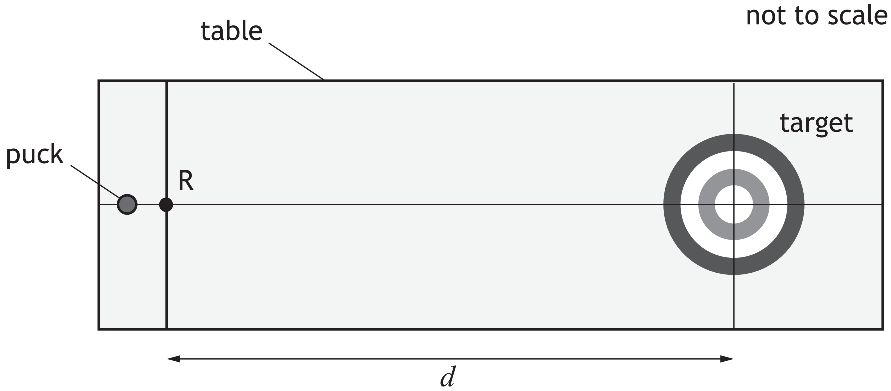
Marking Instructions for each question

Question			Expected response	Max mark	Additional guidance
1.	(a)	(i) (A)	$u_h = 17.0\cos 24.0$ $u_h = 15.5\ \text{m s}^{-1}$ **(1)**	**1**	Accept: 16, 15.53, 15.530
		(i) (B)	$u_v = 17.0\sin 24.0$ $u_v = 6.91\ \text{m s}^{-1}$ **(1)**	**1**	Accept: 6.9, 6.915, 6.9145
		(ii)	$s = \bar{v}t$ **(1)** $11 = 15.5 \times t$ **(1)** $t = 0.71\ \text{s}$	**2**	**SHOW question** Accept: $s = vt$ $s = ut$ $d = vt$ $d = \bar{v}t$ $s = ut + \frac{1}{2}at^2\ (\text{with } a = 0)$ $s = \frac{1}{2}(u+v)t\ (\text{with } u = v)$ Alternative method: (as ball is at its maximum height) $v = u + at$ (u and a must have opposite signs)

Question			Expected response	Max mark	Additional guidance
1.		(iii)	$s = ut + \frac{1}{2}at^2$ **(1)** $s = 6.91 \times 0.71 + \frac{1}{2} \times -9.8 \times 0.71^2$ **(1)** $s = 2.4$ m **(1)**	3	**OR** consistent with (a)(i)(B) Accept: 2, 2.44, 2.436 Alternative methods: $v^2 = u^2 + 2as$ $0^2 = 6.91^2 + 2 \times -9.8 \times s$ $s = 2.4$ m Accept: 2, 2.44, 2.436 for this method. $s = \frac{1}{2}(u+v)t$ $s = \frac{1}{2} \times (6.91 + 0) \times 0.71$ $s = 2.5$ m Accept: 2, 2.45, 2.453 for this method.
	(b)		under **(1)** The ball has a smaller (initial) vertical (component of) velocity (so never reaches the same height). **(1)**	2	**JUSTIFY question** Accept: below Accept: speed instead of velocity

MARKS DO NOT WRITE IN THIS MARGIN

2. A student carries out an experiment to investigate friction between a puck and the surface of a table.



The student measures the mass m of the puck.

The student pushes the puck and releases it at point R. The student measures the initial speed u of the puck as it is released at R.

The puck travels distance d before coming to rest in the centre of the target.

The student records the following measurements:

mass of puck, $m = 0.350$ kg

initial speed of puck, $u = 0.78$ m s^{-1}

distance travelled by puck, $d = 2.160$ m.

(a) (i) Calculate the average acceleration of the puck between point R and the centre of the target. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

2. (a) (continued)

(ii) Calculate the magnitude of the average force of friction between the puck and the table. **3**

Space for working and answer

(b) The student determines the absolute and percentage scale reading uncertainties for each measurement.

	Measurement	Absolute uncertainty	Percentage uncertainty
Mass of puck, m	0.350 kg	$\pm$0.001 kg	0.3%
Initial speed of puck, u	0.78 m s^{-1}	$\pm$0.01 m s^{-1}	1.3%
Distance travelled by puck, d	2.160 m	$\pm$0.001 m	0.05%

The student makes the following statement:

'The best way to reduce the uncertainty in the value calculated for the average force is to use a balance that measures to the nearest 0.0001 kg to measure the mass of the puck.'

Explain why the student's statement is incorrect. **1**

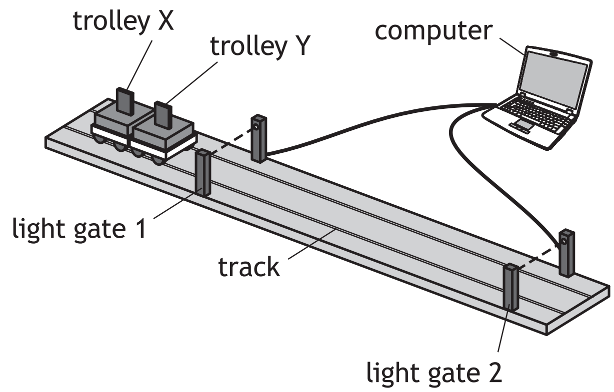
[Turn over

Question			Expected response	Max mark	Additional guidance
2.	(a)	(i)	$v^2 = u^2 + 2as$ **(1)** $0^2 = 0.78^2 + 2 \times a \times 2.160$ **(1)** $a = -0.14 \text{ m s}^{-2}$ **(1)**	**3**	Accept: -0.1, -0.141, -0.1408 Accept '0.14 m s^{-2} to the left' a must be opposite sign from u and s Alternative methods: Both relationships **(1)** Both substitutions **(1)** Final answer **(1)** Do not accept 'a = –0.14 m s^{-2} to the left'
		(ii)	$F = ma$ **(1)** $F = 0.350 \times (-)0.14$ **(1)** $F = (-)0.049 \text{ N}$ **(1)**	**3**	**OR** consistent with (a)(i) Accept: 0.05, 0.0490, 0.04900 In **<u>this</u>** question, ignore negative signs in both the substitution and final answer for force. Alternative method: $Fd = \frac{1}{2}mv^2$ $F \times 2.160 = \frac{1}{2} \times 0.350 \times 0.78^2$ F = 0.049 N Both relationships **(1)** Both substitutions **(1)** Final answer **(1)** Accept: 0.05, 0.0493, 0.04929 for <u>this</u> method.
	(b)		Mass does not have the largest <u>percentage</u> uncertainty. **OR** Initial speed has largest <u>percentage</u> uncertainty.	**1**	Accept: '%' for percentage 'fractional' for percentage Absolute uncertainty on its own, **(0)** marks.

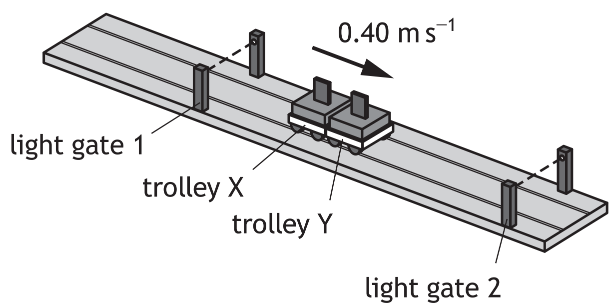
DO NOT WRITE IN THIS MARGIN

3. A student sets up an experiment to investigate the interaction between two trolleys on a smooth, horizontal track.

The mass of trolley X is 0.50 kg and the mass of trolley Y is 0.25 kg.



The trolleys X and Y are moving together to the right at $0.40\ \text{m s}^{-1}$.

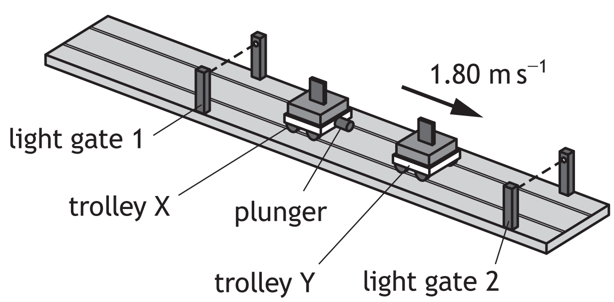


When the trolleys are between the light gates, a plunger in trolley X is activated.

The plunger extends and pushes trolley Y with an average force of 6.25 N for a short time, so that the trolleys separate.

Trolley Y now moves to the right at $1.80\ \text{m s}^{-1}$.

The effects of friction are negligible.



MARKS DO NOT WRITE IN THIS MARGIN

3. (continued)

(a) (i) Calculate the magnitude of the change in momentum of trolley Y when the plunger is activated. **3**

Space for working and answer

(ii) Calculate the time during which the plunger exerts a force on trolley Y. **3**

Space for working and answer

(b) Calculate the velocity of trolley X immediately after the trolleys separate. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

3. (continued)

(c) Explain how the student would determine whether this interaction was elastic. **2**

(d) The light gates used during the experiment each contain a lamp and a photodiode.

A photodiode is a p-n junction.

(i) A photodiode produces a potential difference when photons of light are incident on it.

State the name of this effect. **1**

(ii) Light from the lamp is incident on the photodiode.

Using **band theory**, explain how a potential difference is produced when photons of light are incident on the photodiode. **3**

Question			Expected response	Max mark	Additional guidance
3.	(a)	(i)	$\Delta mv = mv - mu$ **(1)** $\Delta mv = (0.25 \times 1.80) - (0.25 \times 0.40)$ **(1)** $\Delta mv = 0.35\ \text{kg m s}^{-1}$ **(1)**	**3**	Accept: 0.4, 0.350, 0.3500 Accept: $\Delta p = m\Delta v$ $Ft = mv - mu$ $p = mv$ Do not accept: $p = mv - mu$ - 0 marks For alternative methods: Acceptable relationship **(1)** **all** substitutions **including subtraction** **(1)** Final answer **(1)** Sign convention must be consistent within this part of the question. v and u must have same sign. Accept N s
		(ii)	$Ft = mv - mu$ **(1)** $6.25 \times t = 0.35$ **(1)** $t = 0.056\ \text{s}$ **(1)**	**3**	**OR** consistent with (a)(i) Accept: 0.06, 0.0560, 0.05600 Alternative method: $F = ma$ $6.25 = 0.25 \times a$ $v = u + at$ $1.80 = 0.40 + \left(\frac{6.25}{0.25}\right) \times t$ $t = 0.056\ \text{s}$ Both relationships **(1)** Both substitutions **(1)** Final answer **(1)**

Question			Expected response	Max mark	Additional guidance
3.	(b)		(total momentum before = total momentum after) $m_x u_x + m_y u_y = m_x v_x + m_y v_y$ **(1)** $(0.50\times0.40)+(0.25\times0.40)$ $=(0.50v_x)+(0.25\times1.80)$ **(1)** $v_x = -0.30\ \text{m s}^{-1}$ **(1)** **OR** $(m_x + m_y)u = m_x v_x + m_y v_y$ **(1)** $(0.50+0.25)\times0.40$ $=(0.50v_x)+(0.25\times1.80)$ **(1)** $v_x = -0.30\ \text{ms}^{-1}$ **(1)** (Accept '0.30 m s^{-1} to the left')	3	Accept: -0.3, -0.300, -0.3000 Equating the <u>total</u> momenta before and after **(1)** All substitutions **(1)** Final answer **(1)** Sign convention must be consistent. Do not accept: '$v_x = -0.30\ \text{m s}^{-1}$ to the left' Alternative methods: $\Delta mv = mv - mu$ $-0.35 = (0.50v)-(0.50\times0.40)$ $v = -0.30\ \text{m s}^{-1}$ Δmv and u must have opposite signs $Ft = mv - mu$ -6.25×0.056 $=(0.50v)-(0.50\times0.40)$ $v = -0.30\ \text{m s}^{-1}$ F and u must have opposite signs $F = ma$ $-6.25 = 0.50\times a$ $v = u + at$ $v = 0.40+\left(\left(\frac{-6.25}{0.5}\right)\times0.056\right)$ $v = -0.30\ \text{m s}^{-1}$ F and u must have opposite signs Both relationships **(1)** Both substitutions **(1)** Final answer **(1)**

Question			Expected response	Max mark	Additional guidance

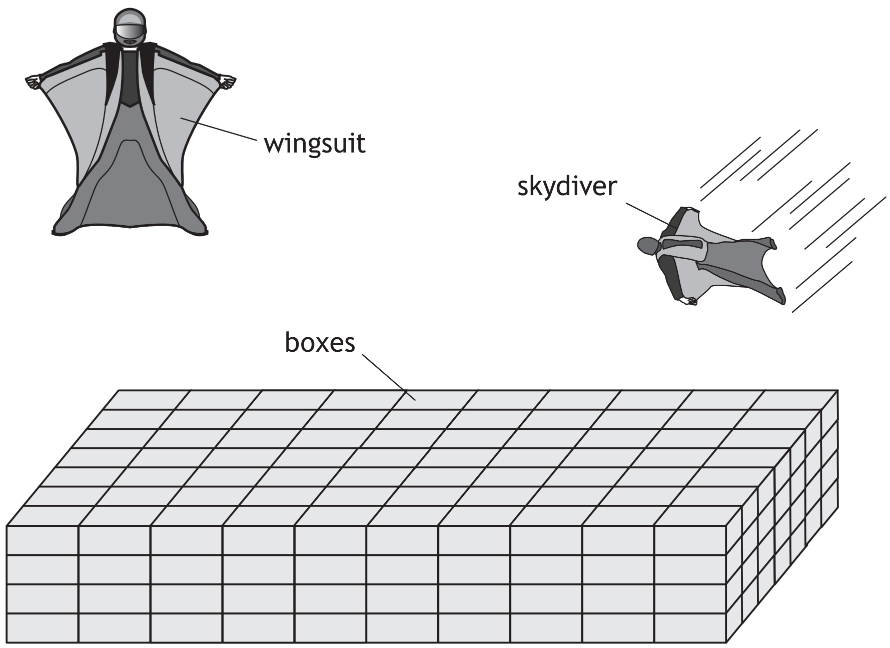
3.	(c)		Calculate/compare the total kinetic energy before and (total kinetic energy) after. **(1)**
			
			If (total) kinetic energy before is equal to (total) kinetic energy after, the interaction is elastic. **(1)**
			
			OR
			
			If (total) kinetic energy is conserved, the interaction is elastic.
				2	Accept: E_k for 'kinetic energy'.
					
					Look for a statement relating to calculating/finding the total E_k before and after first, otherwise **(0)** marks.
					
					There must be an indication of total kinetic energy or equivalent term.
					
					Accept:
					Can show by calculation but would still require a statement for the second mark.
					
					Do not accept:
					If (total) kinetic energy is not conserved, the interaction is inelastic, on its own.

	(d)	(i)	Photovoltaic (effect)	1	
		(ii)	Electrons gain/absorb energy from photons/light **(1)** Electrons move from valence band to conduction band **(1)** Electrons move towards n-type semiconductor (producing a potential difference). **(1)**	3	Look for reference to both conduction and valence band first, otherwise **(0)** marks. Bands must be named correctly, e.g. do not accept 'valency' or 'conductive'. Third statement is dependent on second statement. The direction the electrons move must be clear.

MARKS DO NOT WRITE IN THIS MARGIN

4. In 2012, a record was set for a stunt involving the highest skydive without deploying a parachute.

The person jumped from a helicopter at an altitude of 730 m above the ground. They ‘flew’ in a specially designed wing suit, at speeds of up to 130 km h^{-1}, for nearly 1.5 km before landing safely on empty cardboard boxes.



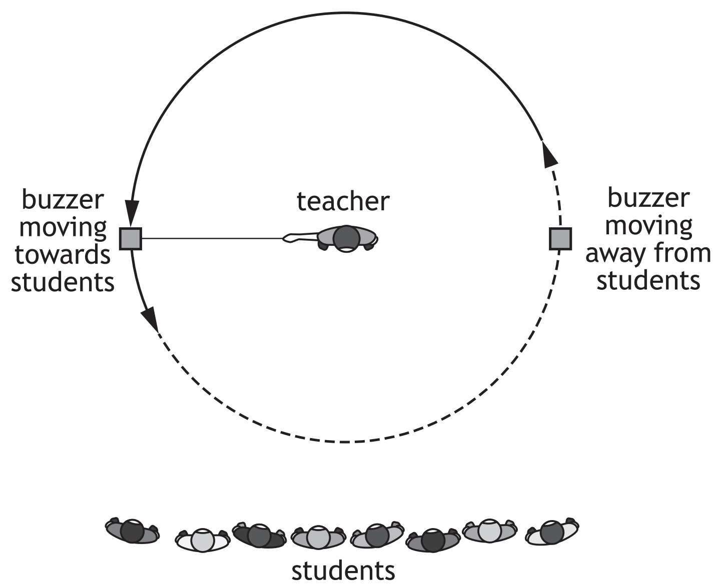
Using your knowledge of physics, comment on the challenges involved in carrying out the stunt successfully. **3**

MARKS DO NOT WRITE IN THIS MARGIN

5. A teacher uses a buzzer attached to a string to demonstrate the Doppler effect to a group of students.

The buzzer produces a sound of constant frequency.

The teacher swings the buzzer at a constant speed in a horizontal circle.



(a) Explain, in terms of wavefronts, why the frequency of the sound heard by the students is lower as the buzzer moves away from them compared to when the buzzer is moving towards them.

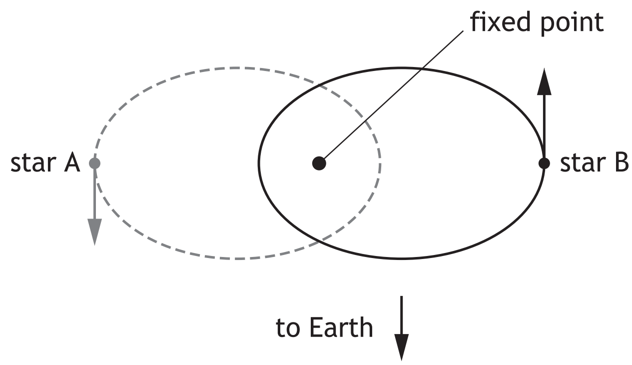
You may wish to use a diagram. **2**

DO NOT WRITE IN THIS MARGIN

5. (continued)

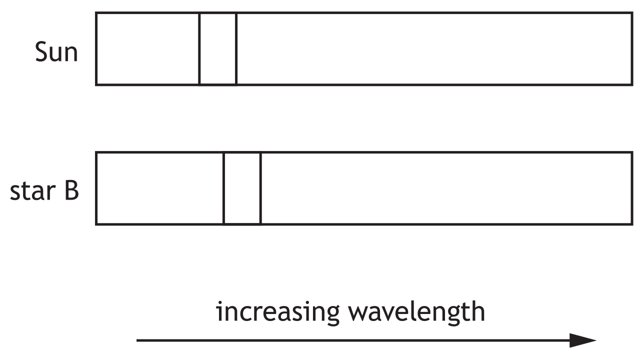
(b) The teacher uses the Doppler effect model to explain observations of the light emitted by a binary star system.

A binary star system consists of two stars that orbit a common fixed point.



Line spectra are obtained from the stars in the binary system and compared with the line spectrum from the Sun.

Part of the line spectra for star B and the Sun are shown below.



MARKS DO NOT WRITE IN THIS MARGIN

5. (b) (continued)

(i) One of the lines in the spectrum from the Sun has a wavelength of 580 nm. The wavelength of the corresponding line in the spectrum from star B has a wavelength of 610 nm.

Calculate the redshift of star B. **3**

Space for working and answer

(ii) Determine the approximate distance from Earth to the binary star system. **5**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

5. (continued)

(c) (i) At one instant in their orbits around the fixed point, the stars in the binary system are 3.44×10^{12} m apart.

The mass of star A is 2.19×10^{30} kg and the mass of star B is 1.80×10^{30} kg.

Calculate the gravitational force between star A and star B at this instant. **3**

Space for working and answer

(ii) At another point in their orbits the distance between the stars is half that in (c) (i).

State how many times greater the gravitational force between star A and star B is at this point, compared to that in (c) (i). **1**

Question			Expected response	Max mark	Additional guidance
5.	(a)		When moving away from the students: Statement that there are fewer wavefronts per second **OR** The wavefronts are further apart **(1)** When moving towards the students: Statement that there are more wavefronts per second **OR** The wavefronts are closer together **(1)** **OR** diagram showing wavefronts closer together ahead of the buzzer **(1)** and further apart behind it. **(1)** or any similar response	2	Look for reference to wavefronts/wavelengths/waves first, otherwise **(0)** marks. In a diagram, there must be an implication of direction of travel.
	(b)	(i)	$z = \frac{\lambda_{observed} - \lambda_{rest}}{\lambda_{rest}}$ **(1)** $z = \frac{610\times10^{-9} - 580\times10^{-9}}{580\times10^{-9}}$ **(1)** $z = 0.052$ **(1)**	3	Accept: 0.05, 0.0517, 0.05172 $z = \frac{\lambda_{observed} - \lambda_{rest}}{\lambda_{rest}}$ $z = \frac{610-580}{580}$ $z = 0.052$
		(ii)	$z = \frac{v}{c}$ **(1)** $0.052 = \frac{v}{3.00\times10^{8}}$ **(1)** $v = H_0 d$ **(1)** $0.052\times3.00\times10^{8} = 2.3\times10^{-18}\times d$ **(1)** $d = 6.8\times10^{24}$ m **(1)**	5	**OR** consistent with (b)(i) Accept: 7, 6.78, 6.783 $z = \frac{v}{c}$ relationship anywhere **(1)** $v = H_0 d$ relationship anywhere **(1)**
	(c)	(i)	$F = G\frac{m_1 m_2}{r^2}$ **(1)** $F = 6.67\times10^{-11}\times\frac{2.19\times10^{30}\times1.80\times10^{30}}{(3.44\times10^{12})^2}$ **(1)** $F = 2.22\times10^{25}$ N **(1)**	3	Accept: 2.2, 2.222, 2.2219
		(ii)	(Force is) four (times greater).	1	

MARKS DO NOT WRITE IN THIS MARGIN

6. The Standard Model explains how the basic building blocks of matter interact, governed by four fundamental forces.

(a) Name the type of particle that is composed of a quark–antiquark pair. **1**

(b) A particle known as a positive kaon (K^+) is composed of an up quark and an anti-strange quark.

(i) The negative kaon particle (K^-) is the antiparticle of the K^+ particle.

State the names of the quarks that make up the K^- particle. **1**

(ii) The W-boson is the force-mediating particle associated with the decay of kaons.

Name the fundamental force involved in the decay of kaons. **1**

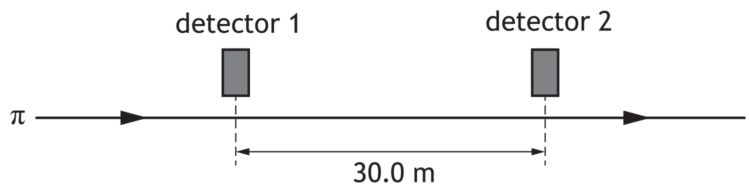
MARKS DO NOT WRITE IN THIS MARGIN

6. (continued)

(c) Another particle, known as a pion (π), is a product of kaon decay.

A beam of pions, travelling in a straight line at a speed of $0.95c$, passes between two detectors.

The detectors are 30.0 m apart as measured by a stationary observer.



(i) Calculate the time taken for a pion to travel between the two detectors in the frame of reference of the stationary observer. **3**

Space for working and answer

(ii) Calculate the distance between the two detectors in the frame of reference of the pions. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

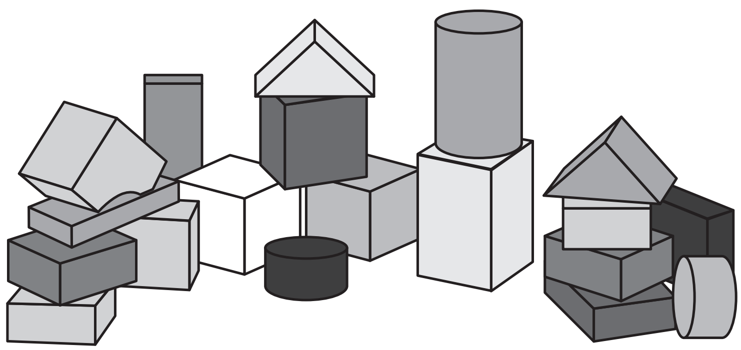
6. (continued)

(d) Pions have a mean lifetime of 26 ns in their frame of reference.

Explain why a greater number of pions are detected at the second detector than would be expected if relativistic effects are not taken into account. **1**

(e) The use of analogies from everyday life can help improve the understanding of physics concepts.

A website states that the Standard Model is like a set of children's building blocks with all sorts of different shapes and sizes, and these building blocks make up all matter.



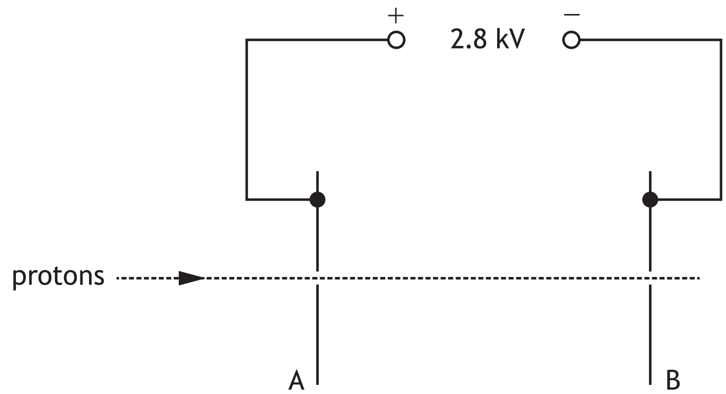
Using your knowledge of physics, comment on this analogy. **3**

Question			Expected response	Max mark	Additional guidance
6.	(a)		Meson(s)	**1**	
	(b)	(i)	Anti-up strange	**1**	**Both** required Do not accept: anti anti-strange
		(ii)	Weak (nuclear force)	**1**	
	(c)	(i)	$d = vt$ **(1)** $30.0 = (0.95 \times 3.00 \times 10^8) \times t$ **(1)** $t = 1.05 \times 10^{-7}$ s **(1)**	**3**	Accept: 1.1, 1.053, 1.0526
		(ii)	$l' = l\sqrt{1-\left(\frac{v}{c}\right)^2}$ **(1)** $l' = 30.0\sqrt{1-\left(\frac{0.95c}{c}\right)^2}$ **(1)** $l' = 9.37$ m **(1)**	**3**	Accept: 9.4, 9.367, 9.3675 Accept: $l' = 30.0\sqrt{1-(0.95)^2}$
	(d)		For a stationary observer's frame of reference, the mean lifetime of the pion is greater (than 26 ns) **OR** In a pion's frame of reference, the distance is shorter (than 30.0 m).	**1**	The response must involve a statement referring to, or implying, a frame of reference.

MARKS DO NOT WRITE IN THIS MARGIN

7. Protons are accelerated by an electric field between metal plates A and B, in a vacuum.

Part of the apparatus used is shown.



(a) Explain why the protons are accelerated by the electric field. **2**

(b) (i) A proton is travelling at a speed of 3.8×10^5 m s^{-1} at plate A.

Show that the kinetic energy of the proton at plate A is 1.2×10^{-16} J. **2**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

7. (b) (continued)

(ii) The potential difference between plates A and B is 2.8 kV.

Calculate the work done on the proton as it accelerates from plate A to plate B. **3**

Space for working and answer

(iii) Determine the speed of the proton at plate B. **4**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

7. (continued)

(c) The distance between plates A and B is now doubled.

The potential difference between plates A and B is unchanged.

Another proton, with the same initial speed at plate A, is accelerated between the plates.

State what effect, if any, this has on the speed of the proton at plate B.

You must justify your answer. **2**

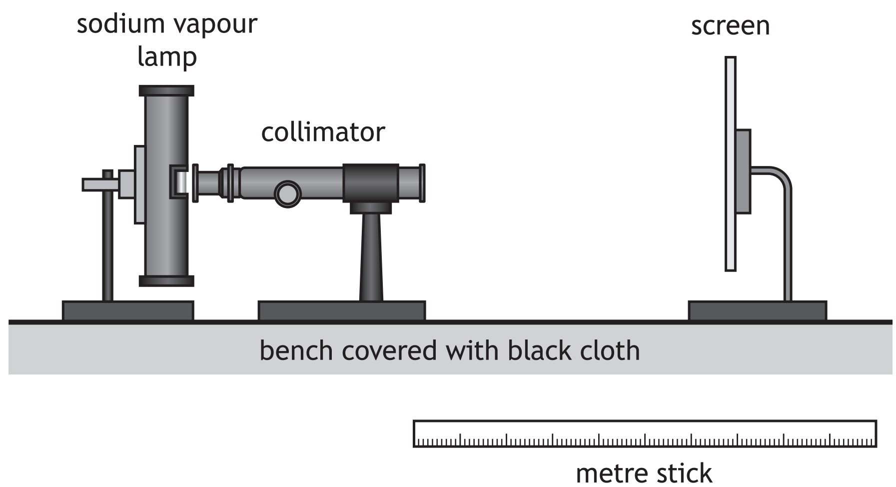
Question			Expected response	Max mark	Additional guidance
7.	(a)		Protons are (positively) charged **(1)** Protons experience a <u>force</u> (in the electric field) **(1)**	**2**	Must state protons are charged otherwise, maximum **(1)** mark. Any mention of protons being negatively charged or uncharged - award **(0)** marks. Charged particles experience a <u>force</u>, on its own, award **(1)** mark.
	(b)	(i)	$E_k = \frac{1}{2}mv^2$ **(1)** $E_k = \frac{1}{2}\times 1.673\times 10^{-27}\times(3.8\times 10^5)^2$ **(1)** $E_k = 1.2\times 10^{-16}$ J	**2**	**SHOW question**
		(ii)	$W = QV$ **(1)** $W = 1.60\times 10^{-19} \times 2.8\times 10^3$ **(1)** $W = 4.5\times 10^{-16}$ J **(1)**	**3**	Accept: 4, 4.48, 4.480
		(iii)	$E_k = 1.2\times 10^{-16} + 4.5\times 10^{-16}$ **(1)** $(E_k = 5.7\times 10^{-16}$ J) $E_k = \frac{1}{2}mv^2$ **(1)** $(1.2\times 10^{-16} + 4.5\times 10^{-16}) = \frac{1}{2}\times 1.673\times 10^{-27}\times v^2$ **(1)** $v = 8.3\times 10^5$ m s^{-1} **(1)**	**4**	**OR** consistent with (b)(ii) Accept: 8, 8.25, 8.255 $E_k = \frac{1}{2}mv^2$ anywhere **(1)** Must attempt addition of kinetic energy and work done, otherwise maximum **(1)** mark. Demonstrated arithmetic mistake can be carried forward through the response. If using 4.48 × 10^{-16} (J), accept: 8, 8.2, 8.24, 8.240
	(c)		No effect **(1)** Work done is the same OR <u>gain in</u> kinetic energy is the same **(1)**	**2**	**MUST JUSTIFY** Look for this statement first - if incorrect or missing then **(0)** marks. charge and potential difference are unchanged, on its own, is insufficient for second mark. Any mention of magnetic field/force on its own is insufficient for second mark.

DO NOT WRITE IN THIS MARGIN

8. A student investigates light from a sodium vapour lamp. Sodium vapour lamps emit yellow light.

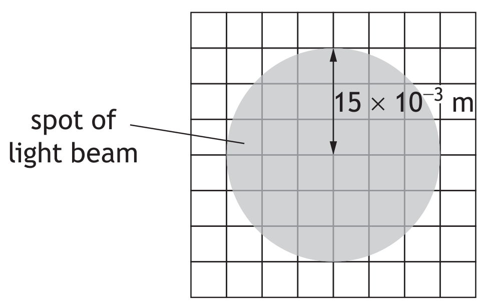
The light from the lamp is passed through a collimator. The collimator is used to produce a parallel beam of light.

The apparatus is set up in a darkened laboratory.



(a) The parallel beam is shone onto a screen. The distance between the end of the collimator and the screen is 0.40 m.

The beam produces a uniformly lit spot of radius 15×10^{-3} m as shown.



MARKS DO NOT WRITE IN THIS MARGIN

8. (a) (continued)

(i) The irradiance of the spot of light on the screen is 17 $W\,m^{-2}$.

Determine the power of the beam of light. **4**

Space for working and answer

(ii) The distance between the screen and the end of the collimator is now increased.

The spot produced on the screen has the same radius as before.

Explain why this experimental setup is not suitable for investigating the inverse square law. **1**

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

8. (continued)

(b) The student now looks at the beam of light through a spectroscope and views a bright yellow spectral line with a wavelength of 589.0 nm.

This light is emitted when electrons make a transition from one energy level to another within sodium atoms.

(i) State whether electrons are moving to a higher or a lower energy level when this light is emitted. **1**

(ii) Calculate the difference in energy between the two energy levels in the sodium atoms that produce this yellow light. **5**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

8. (b) (continued)

(iii) The student observes a second yellow spectral line at a wavelength of 589.6 nm.

The student observes that the line at 589.0 nm is brighter than the line at 589.6 nm.

Explain the student's observation. **2**

[Turn over

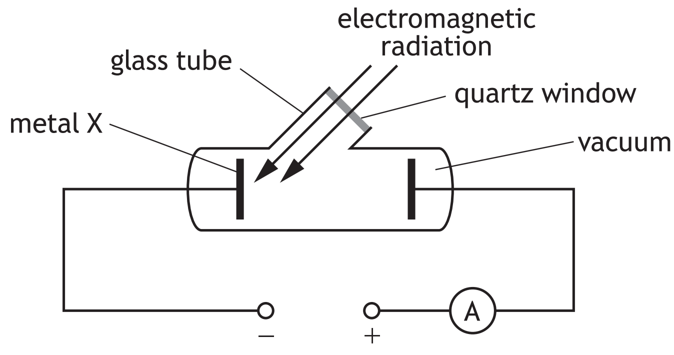
Question			Expected response	Max mark	Additional guidance
8.	(a)	(i)	$\left(A = \pi r^2\right)$ $A = \pi \times (15\times10^{-3})^2$ **(1)** $I = \frac{P}{A}$ **(1)** $17 = \frac{P}{\pi \times (15\times10^{-3})^2}$ **(1)** $P = 0.012$ W **(1)**	**4**	Accept: 0.01, 0.0120, 0.01202 The use of 3.14 is acceptable for π. For use of 3.14, accept: P = 0.01201 $I = \frac{P}{A}$ anywhere **(1)** If no attempt to calculate area, maximum **(1)** mark for irradiance relationship.
		(ii)	(Experimental setup is) not a point source **OR** Parallel beam so the irradiance does not change with distance.	**1**	Accept: The beam of light does not diverge Sodium lamp is not a point source, on its own – award **(0)** marks.
	(b)	(i)	Lower (energy level)	**1**	
		(ii)	$v = f\lambda$ **(1)** $3.00\times10^8 = f \times 589.0\times10^{-9}$ **(1)** $E = hf$ **(1)** $E = 6.63\times10^{-34} \times \left(\frac{3.00\times10^8}{589.0\times10^{-9}}\right)$ **(1)** $E = 3.38\times10^{-19}$ J **(1)**	**5**	Accept: 3.4, 3.377, 3.3769 Accept: $\Delta E = hf$ OR $E_2 - E_1 = hf$ $v = f\lambda$ anywhere **(1)** $E = hf$ anywhere **(1)** Alternative method: $(\Delta)E = \frac{hc}{\lambda}$ OR $E_2 - E_1 = \frac{hc}{\lambda}$ Combined relationship **(2)** Substitution for c and λ **(1)** Substitution for h **(1)** Final answer **(1)**

Question			Expected response	Max mark	Additional guidance
8.	(b)	(iii)	There are more electrons (per second) making the transition for the 589.0 nm line. **(1)** Meaning more photons (per second) are emitted. **(1)** **OR** There are fewer electrons (per second) making the transition for the 589.6 nm line. **(1)** Meaning fewer photons (per second) are emitted. **(1)**	**2**	Do not accept greater brightness due to greater frequency/energy of the photons.

MARKS DO NOT WRITE IN THIS MARGIN

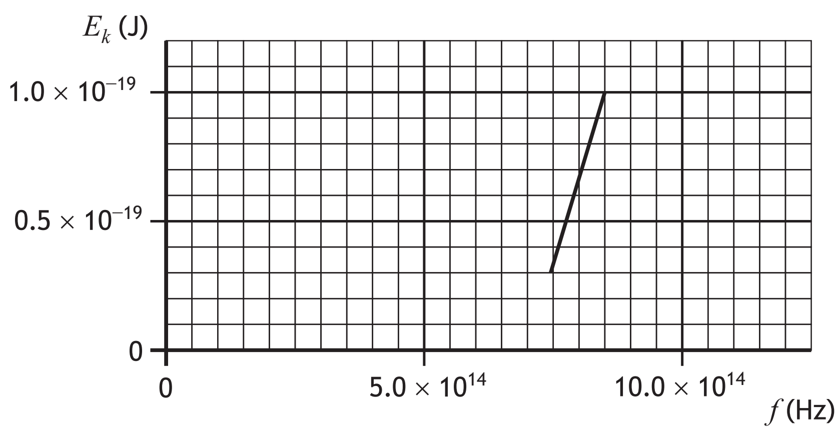
9. The apparatus shown is used to investigate photoemission.

Electromagnetic radiation is incident on metal X.



(a) The frequency of the electromagnetic radiation is varied. The maximum kinetic energy of the photoelectrons emitted from metal X is determined for a range of frequencies.

The graph shows how the maximum kinetic energy E_k of the photoelectrons varies with frequency f.



Using the graph, determine the threshold frequency f_0 of metal X. **1**

MARKS DO NOT WRITE IN THIS MARGIN

9. (continued)

(b) The work function of different metals is shown in the table.

Metal	Work function (J)
Potassium	3.7×10^{-19}
Calcium	4.6×10^{-19}
Zinc	5.8×10^{-19}
Gold	8.5×10^{-19}

Identify which of these metals is metal X.

Justify your answer by calculation. **4**

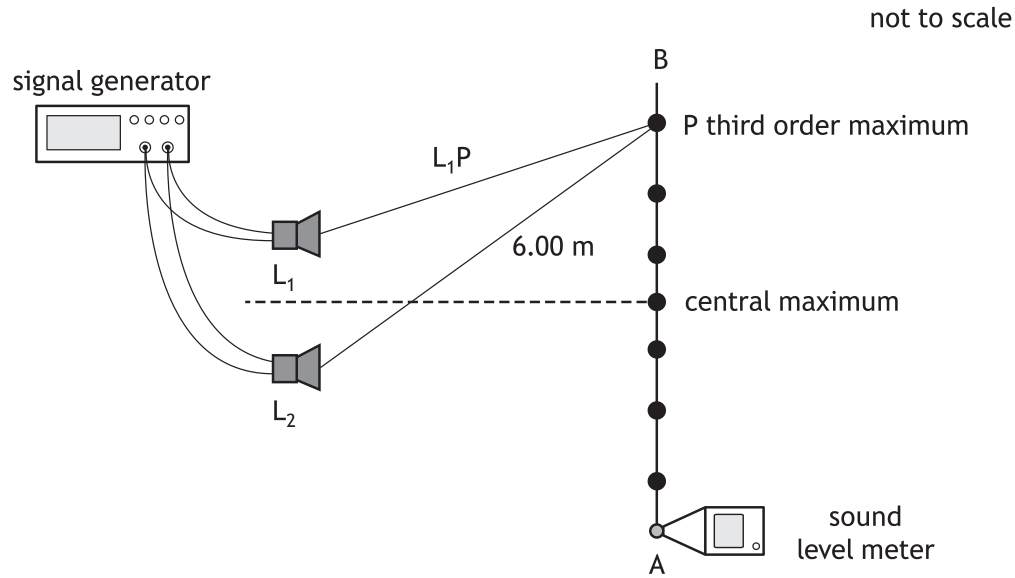
Space for working and answer

Question			Expected response	Max mark	Additional guidance
9.	(a)		(f_0 =) 7.0 × 10^{14} Hz	**1**	Accept: 7 × 10^{14} Hz Accept: 6.9 × 10^{14} - 7.1 × 10^{14} Hz
	(b)		$E = hf_0$ **(1)** $E = 6.63 \times 10^{-34} \times 7.0 \times 10^{14}$ **(1)** $E = 4.6 \times 10^{-19}$ (J) **(1)** Calcium/Ca **(1)**	**4**	**OR** consistent with (a) Accept: 5, 4.64, 4.641 If calcium is correctly identified with no calculation, maximum **(1)** mark. If there is a calculation with a value consistent with (a), then the metal chosen must be consistent with their calculation. If this calculated value does not match a value in the table, then maximum **(3)** marks. A unit is not required but, if a unit is given, it must be correct. If a candidate completes a calculation but does not go on to identify a metal, then a unit is required. In this question, if an incorrect metal or no metal identified, maximum **(3)** marks. Accept: $E = hf$ Alternative method: $E = hf_0$ **(1)** $4.6 \times 10^{-19} = 6.63 \times 10^{-34} \times f_0$ **(1)** $f_0 = 6.9 \times 10^{14}$ (Hz) **(1)** Therefore calcium **(1)** Accept: 7, 6.94, 6.938 Where more than one calculation is shown all substitutions must be correct for substitution mark, and all calculated values must be correct for calculated value mark. Accept: $E_k = hf - hf_o$ **(1)** Substituted values must be consistent with the line or the table, depending on the method chosen.

MARKS DO NOT WRITE IN THIS MARGIN

10. A student is carrying out an experiment to investigate the interference of sound waves.

Two identical loudspeakers, L_1 and L_2, are connected to a signal generator as shown.



A sound level meter is moved from A to B, and a series of maxima are detected.

(a) The sound waves emitted from the loudspeakers are coherent.

State what is meant by the term *coherent*. **1**

(b) Explain, in terms of waves, how a maximum is produced. **1**

MARKS DO NOT WRITE IN THIS MARGIN

10. (continued)

(c) The wavelength of the soundwaves is 0.400 m.

The distance from L_2 to the third order maximum at point P is 6.00 m.

Determine the distance from L_1 to P. **4**

Space for working and answer

(d) A second student in the room is wearing a pair of active noise cancelling (ANC) headphones.

Mohd Syis Zulkipli/shutterstock.com

The student switches on the ANC function. The sound level from the loudspeakers, heard by this student, decreases significantly.

Name the type of interference that the headphones use to reduce the sound level. **1**

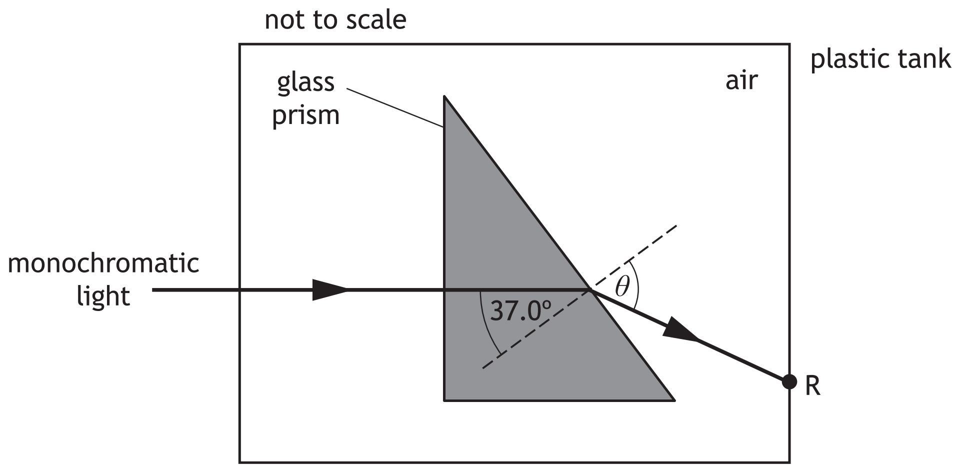
X857760135

Question			Expected response	Max mark	Additional guidance
10.	(a)		(The sound waves from the loudspeakers have a) constant phase relationship (and have the same frequency, wavelength, and velocity).	**1**	Accept: constant phase difference 'In phase' is not sufficient.
	(b)		Waves meet in phase. **OR** Crest meets crest. **OR** Trough meets trough. **OR** Path difference = $m\lambda$	**1**	Accept: peak for crest. Can be shown by diagram e.g.  Diagram must imply addition of two waves in phase. Do not accept: 'join' or 'merge' alone.
	(c)		path difference = mλ **(1)** path difference = 3 × 0.400 **(1)** path difference = $L_2P - L_1P$ (3 × 0.400) = 6.00 $-L_1P$ **(1)** L_1P = 4.80 m **(1)**	**4**	Accept: 4.8, 4.800, 4.8000 **OR** $L_2P - L_1P$ = mλ 6.00 − L_1P = 3 × 0.400 L_1P = 4.80 m An indication that path difference = m λ **(1)** Substitution for m and λ **(1)** Equate path difference to 6 - L_1P **(1)** Final answer **(1)**
	(d)		Destructive (interference)	**1**	Do not accept: deconstructive

MARKS DO NOT WRITE IN THIS MARGIN

11. A triangular prism of borosilicate glass is placed inside a tank that has clear plastic walls.

(a) A ray of monochromatic light passes through the glass prism and exits the plastic tank at point R, as shown.



The refractive index of the glass for this light is 1.47.

Calculate angle θ. **3**

Space for working and answer

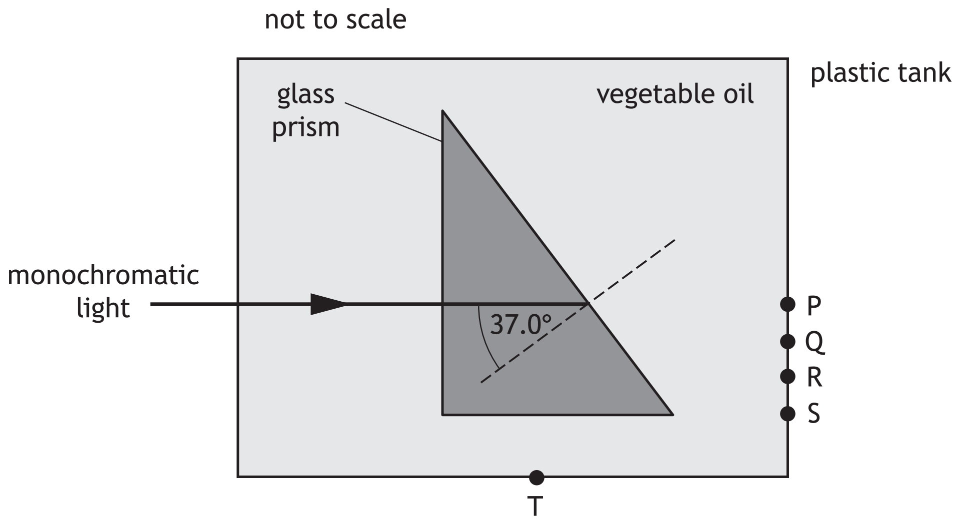
(b) Calculate the critical angle of the glass for this light. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

11. (continued)

(c) The plastic tank is now filled with vegetable oil. The refractive index of the vegetable oil for this light is 1.47.



State at which point, P, Q, R, S, or T, the ray of light will now leave the plastic tank.

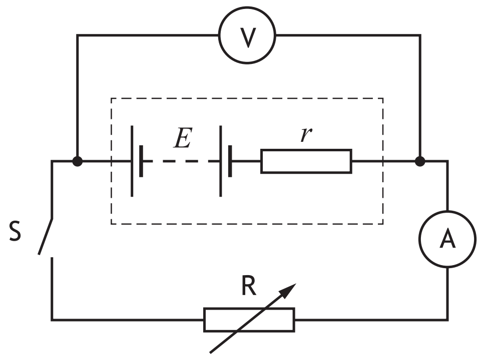
Justify your answer. **2**

[Turn over

Question			Expected response	Max mark	Additional guidance
11.	(a)		$n = \frac{\sin\theta_1}{\sin\theta_2}$ **(1)** $1.47 = \frac{\sin\theta_1}{\sin 37.0}$ **(1)** $\theta_1 = 62.2°$ **(1)**	**3**	Accept: 62, 62.21, 62.211 Accept: $\frac{n_2}{n_1} = \frac{\sin\theta_1}{\sin\theta_2}$ (1) $\frac{1.47}{1} = \frac{\sin\theta_1}{\sin 37.0}$ (1) $\theta_1 = 62.2°$ (1)
	(b)		$\sin\theta_c = \frac{1}{n}$ **(1)** $\sin\theta_c = \frac{1}{1.47}$ **(1)** $\theta_c = 42.9°$ **(1)**	**3**	Accept: 43, 42.86, 42.865
	(c)		(point) P **(1)** The (absolute) refractive index of the vegetable oil (for this light) is the same as the (absolute) refractive index of the glass (therefore there is no refraction/change in speed/ wavelength/direction). **(1)**	**2**	Look for this statement **first** - if incorrect or missing then (**0**) marks. Indication of point P being selected on the diagram can be accepted as an alternative for a statement. Accept: The refractive indices/indexes are the same. The refractive index is the same. The (value of) refractive index has not changed.

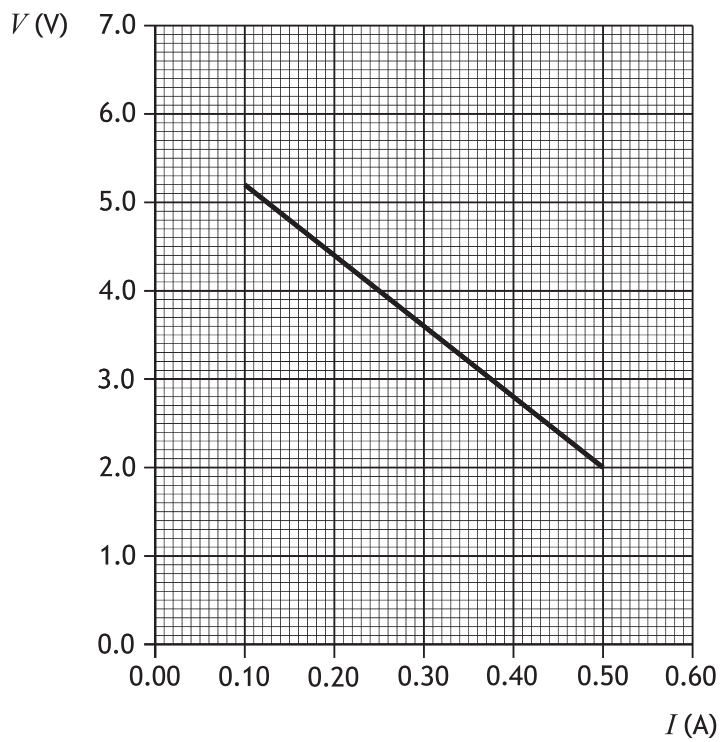
MARKS DO NOT WRITE IN THIS MARGIN

12. A student uses the following circuit to investigate the internal resistance r and EMF E of a battery.



Switch S is closed.

The student uses readings of current I and terminal potential difference V from this circuit to produce the graph shown.



(a) State what is meant by the term *electromotive force* (*EMF*). **1**

MARKS DO NOT WRITE IN THIS MARGIN

12. (continued)

(b) Using information from the graph, determine:

(i) the EMF E of the battery **1**

(ii) the internal resistance r of the battery. **3**

Space for working and answer

(c) Using the circuit shown, describe how the student could **measure** the value of the EMF. **1**

(d) Explain why the terminal potential difference of the battery decreases as the resistance of the variable resistor R is decreased. **2**

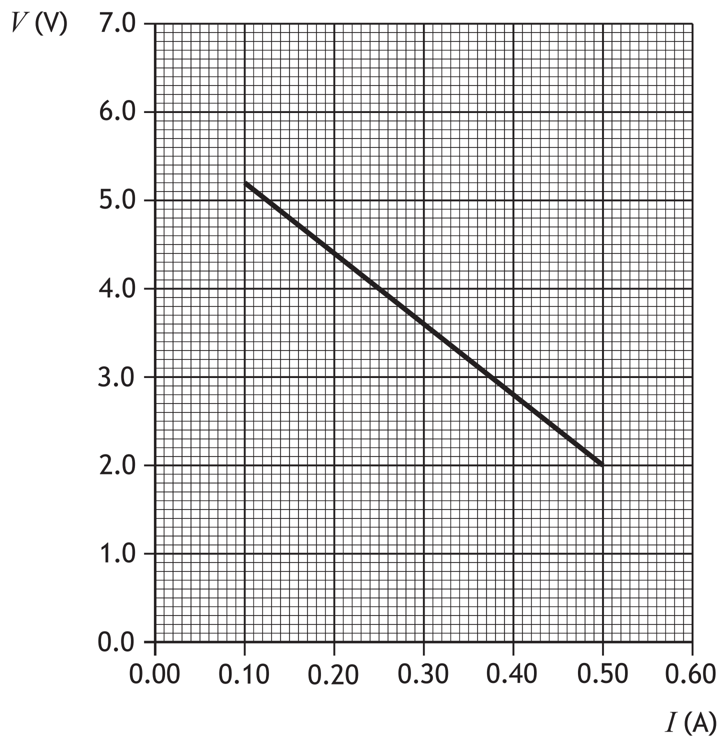
MARKS DO NOT WRITE IN THIS MARGIN

12. (continued)

(e) The student now repeats the experiment with a different battery that has a smaller EMF and the same internal resistance.

On the graph below, add a line to show how the results of this experiment compare with the original experiment. **2**

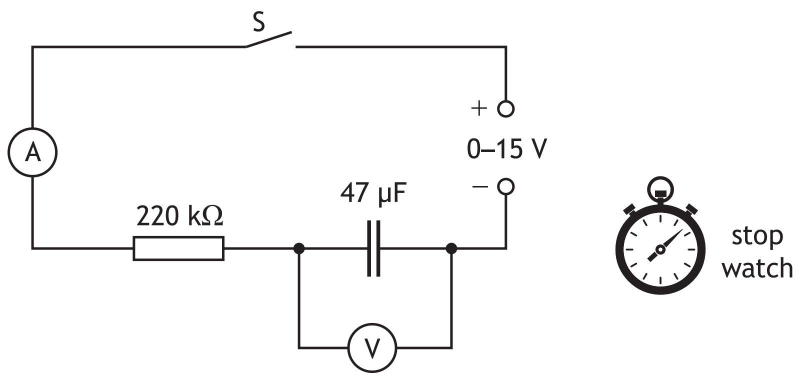
(An additional graph, if required, can be found on *page 49*.)



Question			Expected response	Max mark	Additional guidance
12.	(a)		The energy gained by/supplied to 1 coulomb (of charge passing through the battery).	**1**	Accept: 'number of joules' for energy Accept: 'unit charge' for 1 coulomb.
	(b)	(i)	6.0 V	**1**	Accept: 6 V Accept: 5.95 - 6.05 V
		(ii)	$\left(m = \frac{y_2 - y_1}{x_2 - x_1}\right)$ $m = \frac{2.0-4.0}{0.50-0.25}$ **(1)** $m = -8.0$ **(1)** $(m = -r)$ $r = 8.0\ \Omega$ **(1)**	**3**	Accept: 8, 8.00, 8.000 Gradient = r is wrong physics, award **(0)** marks. substitution of any valid pair of points into gradient formula **(1)** accept any point on a correctly extrapolated line e.g. (0.00,6.0) calculated value of gradient **(1)** Alternative method: $E = V + Ir$ **(1)** $6.0 = 2.0 + 0.50 \times r$ **(1)** $r = 8.0\ \Omega$ **(1)** If using this method, must use data from the line. **Or** value of E consistent with (b)(i)
	(c)		Open the switch, and take the reading on the <u>voltmeter</u> (which is the EMF)	**1**	Accept: reading on the <u>voltmeter</u> for an open circuit **OR** reading on <u>voltmeter</u> before closing switch
	(d)		(As resistance decreases,) current increases **(1)** Lost volts increases, (terminal potential difference decreases) **(1)**	**2**	If there is wrong physics in the answer, award **(0)** marks.
	(e)		The line drawn can be extrapolated to intercept y-axis at less than 6.0 V **(1)** Passably straight line of same gradient **(1)**	**2**	

MARKS DO NOT WRITE IN THIS MARGIN

13. A student carries out an experiment to investigate the charging of a capacitor, using the circuit shown.



(a) Describe how the results of this experiment are obtained **and** used to show how the voltage across the capacitor varies with time while the capacitor is charging. **2**

(b) The capacitor is initially uncharged.

The variable voltage supply is set at 12 V.

Switch S is closed.

The capacitor becomes fully charged.

(i) Calculate the maximum energy stored by the capacitor. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

13. (b) (continued)

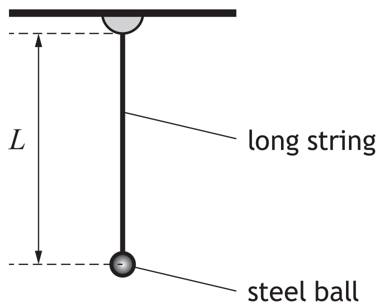
(ii) Suggest an alteration the student could make to this circuit to increase the maximum energy stored by the 47 μF capacitor. **1**

[Turn over

Question			Expected response	Max mark	Additional guidance
13.	(a)		(Close the switch and) take readings on voltmeter at (regular) time intervals **(1)** Plot a graph of voltage against time **(1)**	**2**	
	(b)	(i)	$E = \frac{1}{2}CV^2$ **(1)** $E = \frac{1}{2} \times 47 \times 10^{-6} \times 12^2$ **(1)** $E = 3.4 \times 10^{-3}$ J **(1)**	**3**	Accept: 3, 3.38, 3.384 Alternative methods: Both relationships **(1)** Both substitutions **(1)** Final answer **(1)**
		(ii)	Increase the supply voltage	**1**	Must clearly indicate the supply voltage is increased/greater. If a value is given for the supply voltage then it must be greater than 12 V and less than or equal to 15 V. Accept: 'increase the voltage supplied to the circuit'. 'increase the voltage supplied to the capacitor'. Do not accept: 'increase the voltage across the capacitor' on its own. Do not accept: any implication of power supply being replaced by another power supply.

MARKS DO NOT WRITE IN THIS MARGIN

14. A student carries out an investigation to determine the gravitational field strength on Earth, using a simple pendulum.



A long string has a steel ball attached to the end of it. The length L of the pendulum can be adjusted.

The ball is raised through a small angle and then released.

The student records the time for ten complete swings and uses this to determine a value for the period T of the pendulum. The student then determines the value of T^2.

The student repeats the experiment for different lengths.

The results are shown in the table.

L (m)	T^2 (s^2)
0.20	0.85
0.40	1.60
0.60	2.50
0.80	3.40
1.10	4.55

The gravitational field strength g can be determined using

$$\frac{T^2}{L} = \frac{4\pi^2}{g}$$

(a) Using the square-ruled paper on *page 46*, draw a graph of T^2 against L. **3**

(The table of results is also shown on *page 47*, opposite the square-ruled paper.)

Question			Expected response	Max mark	Additional guidance
14.	(c)		$(\frac{T^2}{L}=\frac{4\pi^2}{g}=\text{gradient})$ $\frac{4\pi^2}{g}=4.2$ **(1)** $g=9.4\ \text{N kg}^{-1}$ **(1)**	**2**	**<u>Must be</u>** consistent with (b) **<u>Must</u>** substitute the gradient of **<u>their graph</u>**, and not a single data point. If a single data point is substituted into in the calculation, award **(0)** marks. The use of 3.14 is acceptable for π. Accept m s^{-2}. If a candidate has plotted L against T^2, this becomes $(\frac{L}{T^2}=\frac{g}{4\pi^2}=\text{gradient})$ $\frac{g}{4\pi^2}=0.24$ **(1)** $g=9.5\ \text{N kg}^{-1}$ **(1)**

[END OF MARKING INSTRUCTIONS]

MARKS DO NOT WRITE IN THIS MARGIN

14. (continued)

(b) Calculate the gradient of your graph. **2**

Space for working and answer

(c) **Using the gradient of your graph**, determine the gravitational field strength g. **2**

[END OF QUESTION PAPER]

Question			Expected response	Max mark	Additional guidance
14.	(a)		Appropriate labels and units **(1)** Suitable scales **(1)** Plotting and line of best fit **(1)**	**3**	Allow for axes starting at zero, or broken axes, or at an appropriate value. Accuracy of plotting should be easily checkable with the scale chosen. An origin is not essential and can be implied by a suitable linear scale. If the origin is shown, the scale must either be continuous or the axis must be 'broken'. Otherwise maximum **(2)** marks. An appropriate scale must be linear over the range of the data. Accept: graph of L against T^2.
	(b)		$\left(m = \dfrac{y_2 - y_1}{x_2 - x_1}\right)$ $m = \dfrac{4-2}{0.96-0.48}$ (for example) **(1)** $m = 4.2$ (s^2 m^{-1}) **(1)**	**2**	**<u>Must</u>** be consistent with graph drawn for (a). Candidates are asked to calculate the gradient of **<u>their graph</u>.** Tolerance required depending upon best fit line drawn by the candidate. If candidates use values from the table, these points must lie on **<u>their line</u>**. A unit is not required in the final answer, but if stated it must be correct. If candidate has a non-linear scale over the range of the values used in the substitution, **(0)** marks. If candidate has drawn a 'dot to dot' graph or no line, **(0)** marks.

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Speed of light in vacuum	c	$3{\cdot}00 \times 10^{8}\,\mathrm{m\,s^{-1}}$	Planck's constant	h	$6{\cdot}63 \times 10^{-34}\,\mathrm{J\,s}$
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}\,\mathrm{C}$	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}\,\mathrm{kg}$
Universal Constant of Gravitation	G	$6{\cdot}67 \times 10^{-11}\,\mathrm{m^3\,kg^{-1}\,s^{-2}}$	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}\,\mathrm{kg}$
Gravitational acceleration on Earth	g	$9{\cdot}8\,\mathrm{m\,s^{-2}}$	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}\,\mathrm{kg}$
Hubble's constant	H_0	$2{\cdot}3 \times 10^{-18}\,\mathrm{s^{-1}}$			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	*Refractive index*	*Substance*	*Refractive index*
Diamond	2·42	Water	1·33
Crown glass	1·50	Air	1·00

SPECTRAL LINES

Element	*Wavelength*/nm	*Colour*	*Element*	*Wavelength*/nm	*Colour*
Hydrogen	656	Red	Cadmium	644	Red
	486	Blue-green		509	Green
	434	Blue-violet		480	Blue
	410	Violet	Lasers		
	397	Ultraviolet	*Element*	*Wavelength*/nm	*Colour*
	389	Ultraviolet	Carbon dioxide	9550 10 590	Infrared
Sodium	589	Yellow	Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	*Density*/kg $\mathrm{m^{-3}}$	*Melting point*/K	*Boiling point*/K
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853
Ice	$9{\cdot}20 \times 10^{2}$	273	....
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377
Water	$1{\cdot}00 \times 10^{3}$	273	373
Air	1·29	....	....
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

S857760102

H

National Qualifications 2023

X857/76/12

Physics
Paper 1 — Multiple choice

WEDNESDAY, 17 MAY

9:00 AM – 9:45 AM

Total marks — 25

Attempt ALL questions.

You may use a calculator.

Instructions for the completion of Paper 1 are given on *page 02* of your answer booklet X857/76/02.

Record your answers on the answer grid on *page 03* of your answer booklet.

Reference may be made to the data sheet on *page 02* of this question paper and to the relationships sheet X857/76/22.

Space for rough work is provided at the end of this booklet.

Before leaving the examination room you must give your answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

X857612

A/HTP

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	Symbol	Value	Quantity	Symbol	Value
Speed of light in vacuum	c	3.00×10^{8} m s^{-1}	Planck's constant	h	6.63×10^{-34} J s
Magnitude of the charge on an electron	e	1.60×10^{-19} C	Mass of electron	m_e	9.11×10^{-31} kg
Universal Constant of Gravitation	G	6.67×10^{-11} m^3 kg^{-1} s^{-2}	Mass of neutron	m_n	1.675×10^{-27} kg
Gravitational acceleration on Earth	g	9.8 m s^{-2}	Mass of proton	m_p	1.673×10^{-27} kg
Hubble's constant	H_0	2.3×10^{-18} s^{-1}			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	Refractive index	Substance	Refractive index
Diamond	2.42	Water	1.33
Crown glass	1.50	Air	1.00

SPECTRAL LINES

Element	Wavelength (nm)	Colour
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	Wavelength (nm)	Colour
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	Wavelength (nm)	Colour
Carbon dioxide	9550, 10 590	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	Density (kg m^{-3})	Melting point (K)	Boiling point (K)
Aluminium	2.70×10^{3}	933	2623
Copper	8.96×10^{3}	1357	2853
Ice	9.20×10^{2}	273	. . . .
Sea Water	1.02×10^{3}	264	377
Water	1.00×10^{3}	273	373
Air	1.29	. . . .	. . . .
Hydrogen	9.0×10^{-2}	14	20

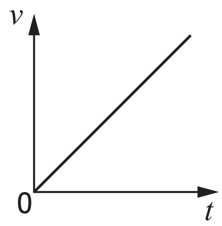
The gas densities refer to a temperature of 273 K and a pressure of 1.01×10^{5} Pa.

Total marks — 25

Attempt ALL questions

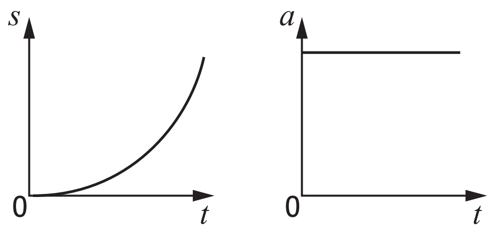
1. A cyclist is travelling along a straight, level road.

A velocity-time (v-t) graph of the motion of the cyclist is shown.

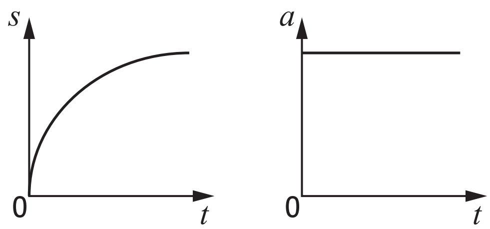


Which pair of displacement-time (s-t) and acceleration-time (a-t) graphs represent the motion of the cyclist?

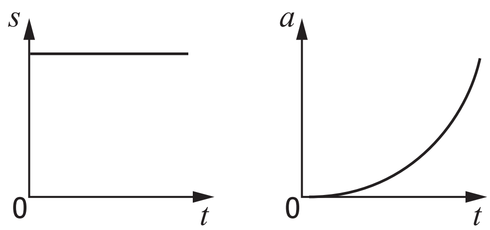
A



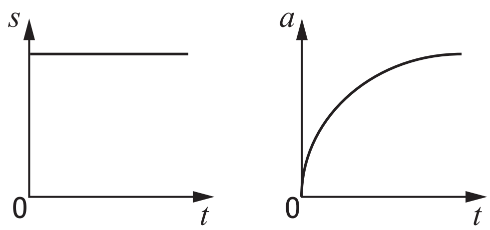
B



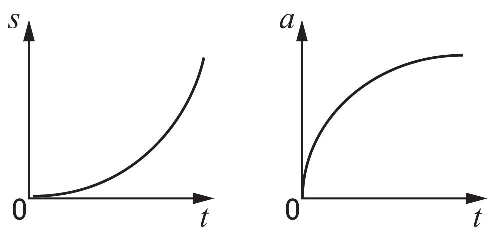
C



D



E



2. A hot air balloon is moving vertically.

At a height of 50 m a sandbag is released.

The sandbag takes 3.0 s to reach the ground.

The effects of air resistance can be ignored.

The initial velocity of the sandbag on release is

A 2.0 $m\,s^{-1}$ upwards

B 2.0 $m\,s^{-1}$ downwards

C 17 $m\,s^{-1}$ upwards

D 17 $m\,s^{-1}$ downwards

E 31 $m\,s^{-1}$ upwards.

3. The momentum of an object of mass 4 kg is 20 $kg\,m\,s^{-1}$.

The kinetic energy of the object is

A 10 J

B 50 J

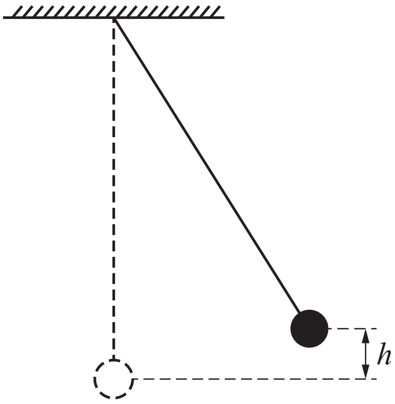
C 100 J

D 400 J

E 800 J.

4. A pendulum bob of mass m is released from rest at height h.

The bob reaches a speed v at the lowest point of its swing.



Neglecting air resistance, the speed of the bob at its lowest point is doubled by

A changing the height to $4h$

B changing the height to $2h$

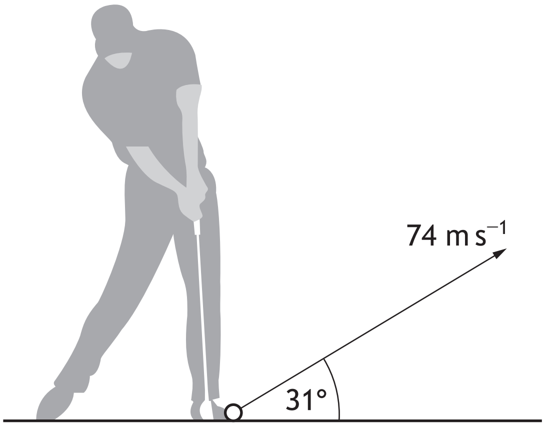
C changing the height to $\frac{h}{2}$

D changing the mass of the bob to $2m$

E changing the mass of the bob to $\frac{m}{2}$.

[Turn over

5. A golfer strikes a golf ball as shown.



The ball leaves the club with an initial velocity of 74 m s^{-1} at an angle of 31° to the horizontal.

Which row in the table shows the horizontal and vertical components of the initial velocity of the golf ball?

	Horizontal component of the initial velocity of the golf ball (m s^{-1})	Vertical component of the initial velocity of the golf ball (m s^{-1})
A	38	44
B	38	63
C	44	38
D	63	38
E	63	44

6. A satellite of mass 620 kg is placed into an Earth orbit of radius 23 000 km.

The mass of the Earth is 6.0×10^{24} kg.

The gravitational force that the satellite experiences from the Earth in this orbit is

A 4.7×10^{2} N

B 4.7×10^{8} N

C 1.1×10^{10} N

D 1.1×10^{13} N

E 6.9×10^{13} N.

7. Muons are created in the upper atmosphere of the Earth.

The mean lifetime of these muons in their frame of reference is 2.20 μs.

The muons are travelling at $0.99c$ relative to an observer on Earth.

The observer measures the mean lifetime of these muons as

A 1.56×10^{-2} s

B 2.20×10^{-3} s

C 1.11×10^{-4} s

D 1.56×10^{-5} s

E 3.10×10^{-7} s.

8. Evidence supporting the existence of dark energy comes from

A estimations of the mass of galaxies

B the darkness of the sky (Olbers' paradox)

C large numbers of galaxies showing redshift, rather than blueshift

D the accelerating rate of expansion of the Universe

E the abundance of the elements hydrogen and helium in the Universe.

[Turn over

9. A student makes the following statements about the emitted radiation from stellar objects.

I The peak wavelength of emitted radiation is longer for hotter objects than for cooler objects.

II A 'blue' star is likely to be hotter than a 'red' star.

III The radiation emitted per unit surface area per unit time is greater for hotter objects.

Which of these statements is/are correct?

A I only

B II only

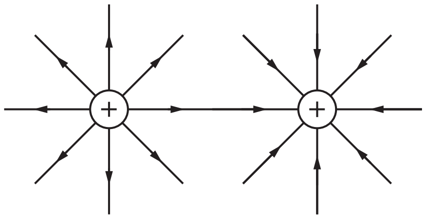
C III only

D I and III only

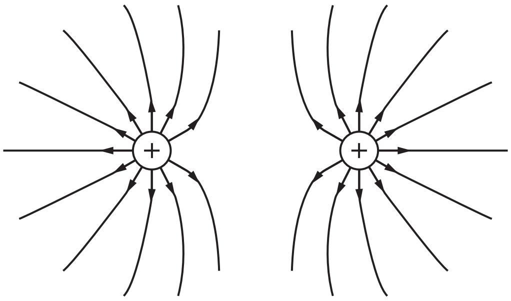
E II and III only

10. Which of the following diagrams represents the electric field pattern between two identical positively charged particles?

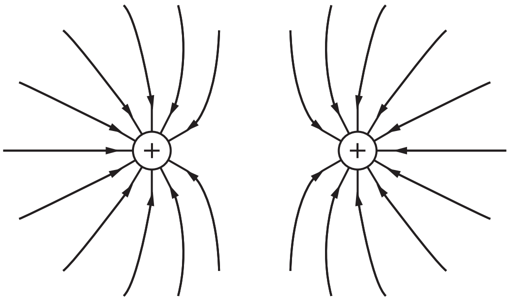
A



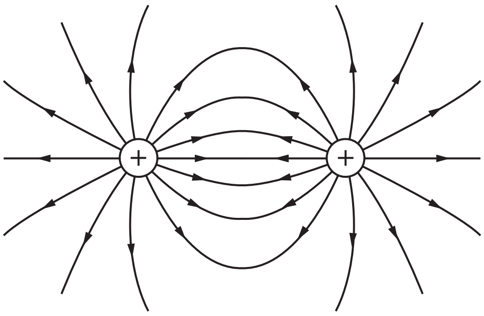
B



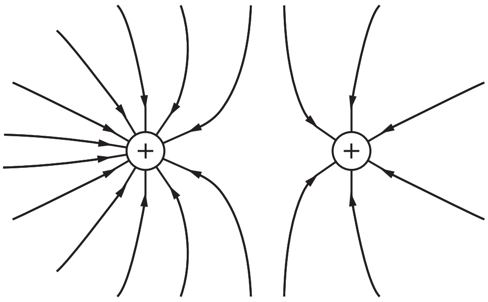
C



D



E



[Turn over

11. A neutron consists of one up quark and two down quarks.

A neutron is a

A gluon

B meson

C baryon

D lepton

E boson.

12. The following statement represents a nuclear fusion reaction.

$$^{3}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$$

The total mass of the particles before the reaction is 8.347×10^{-27} kg.

The total mass of the particles after the reaction is 8.317×10^{-27} kg.

The energy released in this reaction is

A 3.0×10^{-29} J

B 9.0×10^{-21} J

C 1.4×10^{-12} J

D 2.7×10^{-12} J

E 7.5×10^{-10} J.

13. A student makes the following statements about wave particle duality.

I The photoelectric effect is evidence supporting the particle model of light.

II Interference is evidence supporting the wave model of light.

III Photons of sufficient energy can eject electrons from the surface of metals.

Which of these statements is/are correct?

A I only

B II only

C III only

D I and III only

E I, II and III

14. Electromagnetic radiation of frequency 9.0×10^{14} Hz is incident on a clean, negatively charged metal surface.

The work function of the metal is 6.1×10^{-19} J.

There is no photoelectric emission from this metal caused by this radiation.

This is explained by the fact that

A photoemission can only occur from a positively charged metal surface

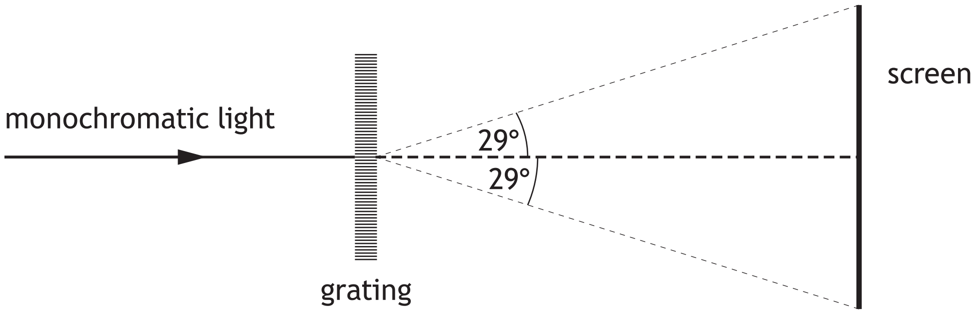
B the wavelength of the incident radiation is too short

C the frequency of the incident radiation is less than the threshold frequency of this metal

D the work function of the metal is less than the energy of the incident photons

E the number of photons per second incident on the surface of the metal is too low.

15. A ray of monochromatic light is incident on a grating. An interference pattern is observed on the screen.



The angle between the central maximum and the maximum observed at the edge of the screen is 29°.

The wavelength of the light is 605 nm.

The separation of the slits on the grating is 5.0×10^{-6} m.

The total number of maxima observed on the screen is

A 4

B 7

C 8

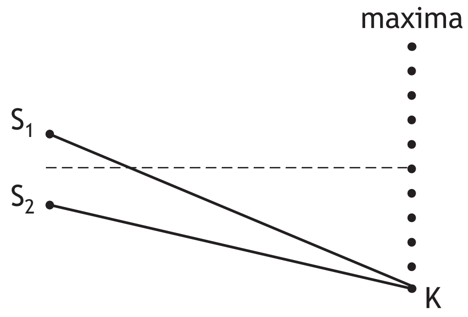
D 9

E 15.

[Turn over

16. Waves from coherent sources, S_1 and S_2, produce an interference pattern.

Maxima are detected at the positions shown.



The path difference $S_1K - S_2K$ is 154 mm.

The wavelength of the waves is

A 14.0 mm

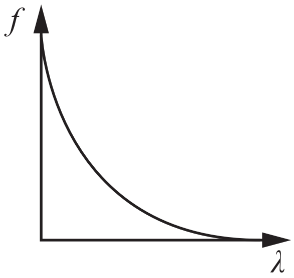
B 15.4 mm

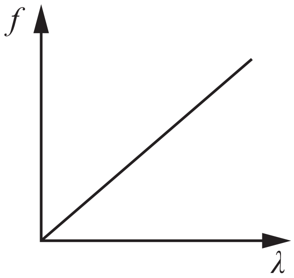
C 25.7 mm

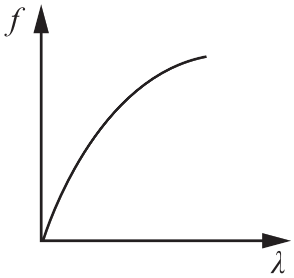
D 28.0 mm

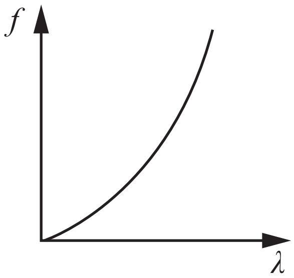
E 30.8 mm.

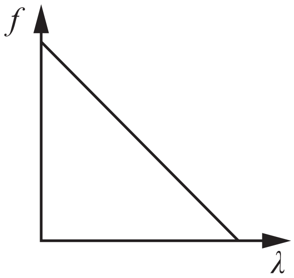
17. Which graph shows the relationship between frequency f and wavelength λ of photons of electromagnetic radiation?

A


B


C


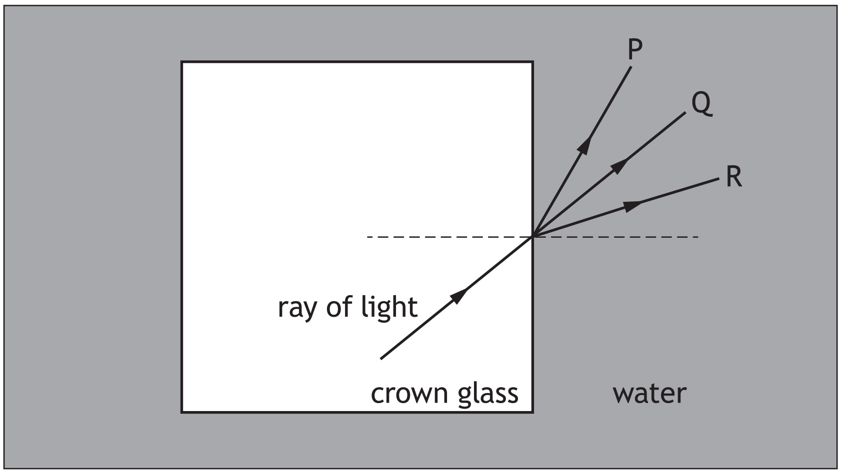
D


E


[Turn over

18. A ray of monochromatic light travels from a crown glass block into water.

The diagram shows three paths P, Q, and R for the ray of light in the water.



Which row in the table shows what happens to the speed and the wavelength, and the path the ray of light follows in the water?

	Speed	Wavelength	Path
A	decreases	decreases	R
B	decreases	decreases	P
C	stays the same	stays the same	Q
D	increases	increases	R
E	increases	increases	P

19. An AC power supply of negligible internal resistance is connected to an 8.0 Ω resistor.

The rms voltage of the power supply is 5.0 V.

The peak power dissipated in the 8.0 Ω resistor is

A 0.44 W

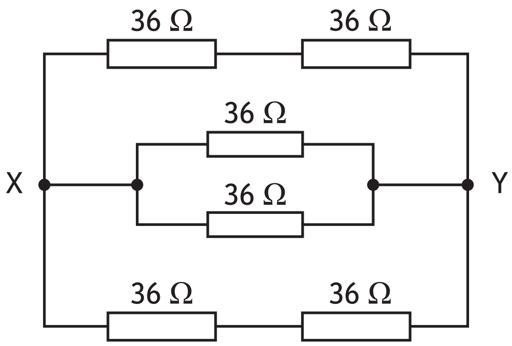
B 0.63 W

C 1.4 W

D 3.1 W

E 6.3 W.

20. Six 36 Ω resistors are connected as shown.



The total resistance between points X and Y is

A 6.0 Ω

B 8.0 Ω

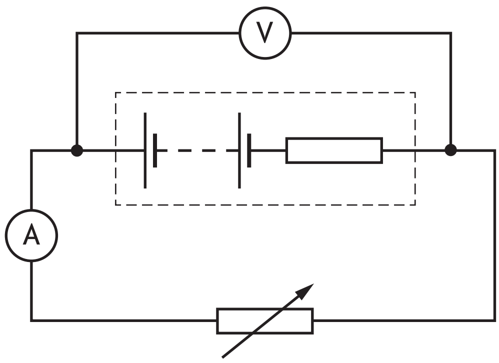
C 12 Ω

D 18 Ω

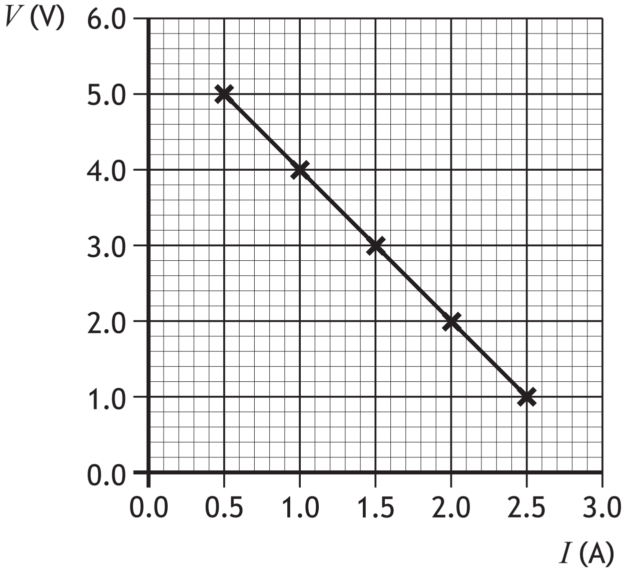
E 24 Ω.

[Turn over

21. A student carries out an experiment to determine the EMF and internal resistance of a battery using the circuit shown.



The resistance of the variable resistor is altered and readings of voltage V and current I are taken. These readings are used to produce the following graph.



Which row in the table shows the EMF and internal resistance of the battery?

	EMF (V)	Internal resistance (Ω)
A	2.0	6.0
B	5.0	0.50
C	5.0	2.0
D	6.0	0.50
E	6.0	2.0

22. One coulomb per volt is equivalent to one

A hertz

B farad

C ohm

D joule

E ampere.

23. A student makes the following statements about metals, insulators, and semiconductors.

I In some metals, the valence and conduction bands overlap and each band is partially filled.

II The band gap between the valence band and the conduction band in an insulator is large compared to the band gap in a semiconductor.

III An increase in temperature decreases the conductivity of a semiconductor.

Which of these statements is/are correct?

A I only

B II only

C I and II only

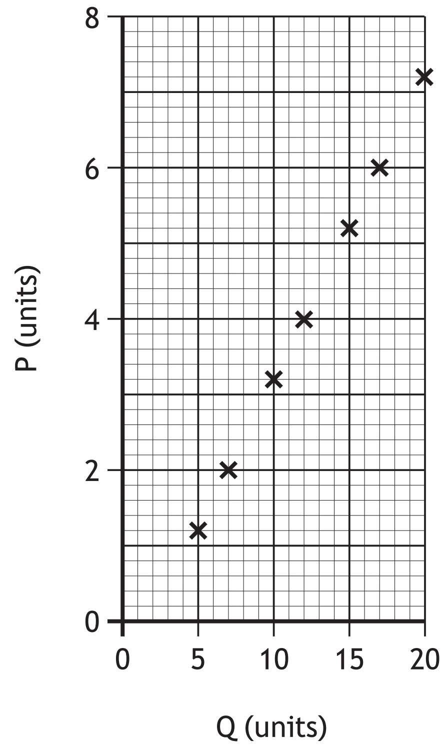
D I and III only

E II and III only

[Turn over

24. A group of students carry out an experiment to investigate how quantity P depends on quantity Q.

The results of the experiment are plotted on the graph shown.



A physics textbook states that quantity P is directly proportional to quantity Q.

The students make the following statements about the line of best fit that should be drawn using all the data points plotted.

I The line of best fit passes through the origin.

II The line of best fit does not pass through the origin.

III The line of best fit suggests the measurements have been affected by a systematic uncertainty.

Which of these statements is/are correct?

A I only

B II only

C III only

D I and III only

E II and III only

25. The mass m of a vibrating string can be determined using the following relationship.

$$f = \sqrt{\frac{T}{4mL}}$$

where f is the fundamental frequency

T is the tension

L is the length of the string.

For a particular string the following measurements are recorded:

$f = 110$ Hz

$T = 92$ N

$L = 0.63$ m.

Based on this information the mass of this string is

A 3.0×10^{-3} kg

B 1.2×10^{-2} kg

C 3.3×10^{-1} kg

D 5.8×10^{-1} kg

E 3.3×10^{2} kg.

[END OF QUESTION PAPER]

Marking Instructions for each question

Question	Answer	Mark
1.	A	1
2.	B	1
3.	B	1
4.	A	1
5.	D	1
6.	A	1
7.	D	1
8.	D	1
9.	E	1
10.	B	1
11.	C	1
12.	D	1
13.	E	1
14.	C	1
15.	D	1
16.	E	1
17.	A	1
18.	E	1
19.	E	1
20.	C	1
21.	E	1
22.	B	1
23.	C	1
24.	E	1
25.	A	1

[END OF MARKING INSTRUCTIONS]

FOR OFFICIAL USE

H

National Qualifications 2023

Mark

X857/76/01

Physics Paper 2

WEDNESDAY, 17 MAY

10:15 AM – 12:30 PM

X857760 1

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth

Day Month Year

Scottish candidate number

Total marks — 130

Attempt ALL questions.

You may use a calculator.

Reference may be made to the Data Sheet on *page 02* of this booklet and to the relationship sheet X857/76/11.

Care should be taken to give an appropriate number of significant figures in the final answers to calculations.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. Score through your rough work when you have written your final copy.

Use **blue** or **black** ink.

Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

X85776010 1

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	Symbol	Value	Quantity	Symbol	Value
Speed of light in vacuum	c	3.00×10^{8} m s^{-1}	Planck's constant	h	6.63×10^{-34} J s
Magnitude of the charge on an electron	e	1.60×10^{-19} C	Mass of electron	m_e	9.11×10^{-31} kg
Universal Constant of Gravitation	G	6.67×10^{-11} m^{3} kg^{-1} s^{-2}	Mass of neutron	m_n	1.675×10^{-27} kg
Gravitational acceleration on Earth	g	9.8 m s^{-2}	Mass of proton	m_p	1.673×10^{-27} kg
Hubble's constant	H_0	2.3×10^{-18} s^{-1}			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	Refractive index	Substance	Refractive index
Diamond	2.42	Water	1.33
Crown glass	1.50	Air	1.00

SPECTRAL LINES

Element	Wavelength (nm)	Colour
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	Wavelength (nm)	Colour
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	Wavelength (nm)	Colour
Carbon dioxide	9550 10 590	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	Density (kg m^{-3})	Melting point (K)	Boiling point (K)
Aluminium	2.70×10^{3}	933	2623
Copper	8.96×10^{3}	1357	2853
Ice	9.20×10^{2}	273	....
Sea Water	1.02×10^{3}	264	377
Water	1.00×10^{3}	273	373
Air	1.29	....	....
Hydrogen	9.0×10^{-2}	14	20

The gas densities refer to a temperature of 273 K and a pressure of 1.01×10^{5} Pa.

X857760102

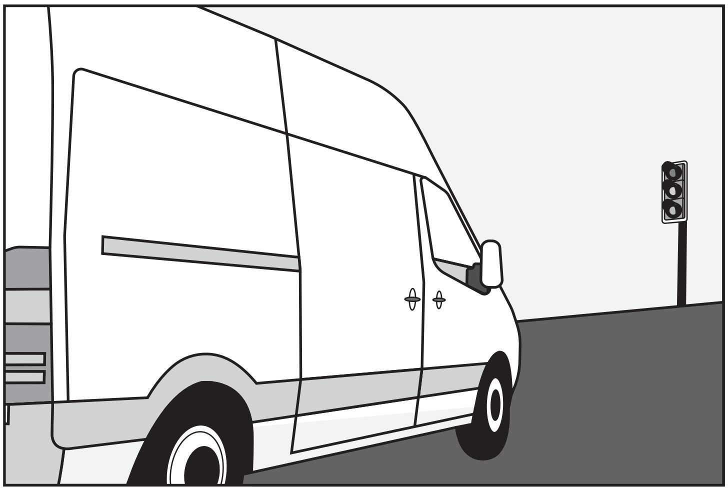
MARKS DO NOT WRITE IN THIS MARGIN

Total marks — 130

Attempt ALL questions

1. A van is travelling along a straight, level road at a constant speed of $13.4\ \mathrm{m\,s^{-1}}$ as it approaches a set of traffic lights. The driver sees the lights change to red and applies the brakes.

The van has a constant acceleration of $-2.85\ \mathrm{m\,s^{-2}}$ before coming to rest at the traffic lights.



(a) Calculate the distance travelled by the van during braking. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

1. (continued)

(b) Calculate the time taken for the van to come to rest during braking. **3**

Space for working and answer

(c) Complete the sketch graph of velocity against time for the van's motion during braking.

Numerical values are required on both axes. **2**

(An additional graph, if required, can be found on *page 43*.)

[Turn over

Marking instructions for each question

Question			Expected response	Max mark	Additional guidance
1.	(a)		$v^2 = u^2 + 2as$ **(1)** $0^2 = (13.4)^2 + 2 \times -2.85 \times s$ **(1)** $s = 31.5$ m **(1)**	3	Accept: 32, 31.50, 31.502 u and a must have opposite signs. Alternative methods: Both relationships **(1)** Both substitutions **(1)** Final answer **(1)**
	(b)		$v = u + at$ (1) $0 = 13.4 + (-2.85t)$ (1) $t = 4.70$ s (1)	3	Or consistent with (a) Accept: 4.7, 4.702, 4.7018 u and a must have opposite signs. Alternative methods eg $s = \frac{1}{2}(u+v)t$ **(1)** $31.5 = \frac{1}{2}(13.4+0)t$ **(1)** $t = 4.70$ s **(1)** For this method accept: 4.7, 4.701, 4.7015
	(c)		Straight line with negative gradient **(1)** Axes values **(1)**	2	Must be consistent with (b) Second mark conditional on first mark

MARKS DO NOT WRITE IN THIS MARGIN

2. An adult with a child is cycling along a straight level path. The child is in a trailer, which is connected to the bike by a tow bar.

The combined mass of the bike and the adult is 85 kg.

The combined mass of the child and trailer is 28 kg.

The forward force on the bike and trailer is 125 N.

A frictional force of 45 N acts on the bike.

A frictional force of 15 N acts on the trailer.

(a) Show that the acceleration of the bike and trailer is $0.58\ \mathrm{m\,s^{-2}}$. **2**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

2. (continued)

(b) Determine the magnitude of the tension in the tow bar. **4**

Space for working and answer

(c) As the speed of the bike and trailer increases, the friction forces on both the bike and the trailer increase.

The acceleration of the bike and trailer remains $0.58\ \text{m s}^{-2}$.

State whether the tension in the tow bar increases, decreases, or stays the same.

Justify your answer. **2**

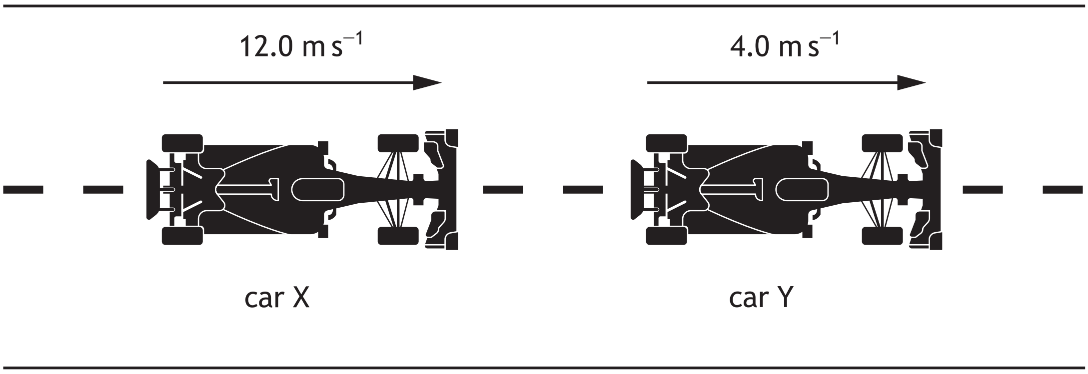
Question			Expected response	Max mark	Additional guidance
2.	(a)		$F = ma$ **(1)** $125-(15+45)=(28+85)\times a$ **(1)** $a = 0.58\ \text{m s}^{-2}$	2	**SHOW** Must show how both total mass and unbalanced force are arrived at.
	(b)		$F = ma$ **(1)** $F = 28\times 0.58$ **(1)** $(F = Tension + Friction)$ $28\times 0.58 = Tension + (-15)$ **(1)** $Tension = 31\ \text{N}$ **(1)**	4	Accept: 30, 31.2, 31.24 $T = ma$ **on its own** - 0 marks.
	(c)		(Tension) increases **(1)** (Friction increases but) unbalanced/ resultant force remains the same. **(1)**	2	**JUSTIFY** Must be clear it is the unbalanced force that remains constant. Accept: 'F' for unbalanced force Can be justified by calculation.

MARKS DO NOT WRITE IN THIS MARGIN

3. During a practice session for a Grand Prix, two Formula 1 cars collide in the pit lane.

Car X has a mass of 760 kg and is travelling at $12.0\ \mathrm{m\,s^{-1}}$.

Car Y has a mass of 840 kg and is travelling at $4.0\ \mathrm{m\,s^{-1}}$.



The cars collide and move off separately.

Car Y moves off with a velocity of $8.5\ \mathrm{m\,s^{-1}}$.

(a) Calculate the velocity of car X immediately after the collision. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

3. (continued)

(b) Show by calculation that the collision is inelastic. **4**

Space for working and answer

(c) During the collision, the cars are in contact for 0.82 s.

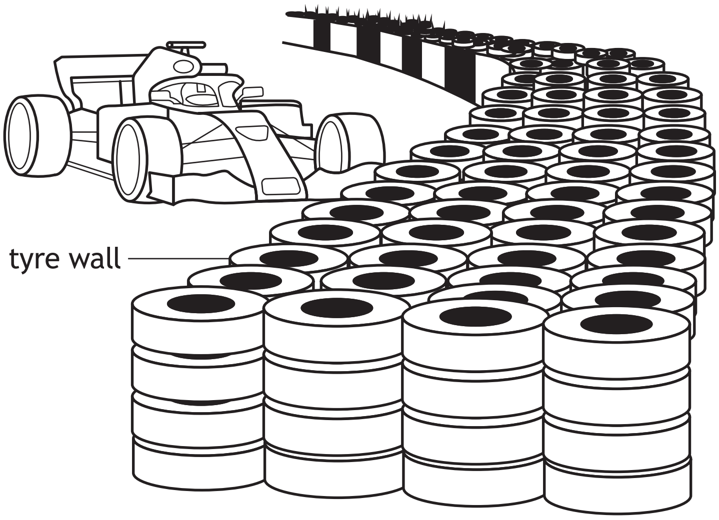
Calculate the magnitude of the average force car X exerts on car Y. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

3. (continued)

(d) One safety feature on Formula 1 racetracks is the use of tyre walls on bends. Tyre walls are designed to protect the driver in the event of their car leaving the track.



Explain how tyre walls protect the driver. **2**

Question			Expected response	Max mark	Additional guidance
3.	(a)		$m_x u_x + m_y u_y = m_x v_x + m_y v_y$ **(1)** $(760 \times 12.0) + (840 \times 4.0)$ $= (760 \times v_x) + (840 \times 8.5)$ **(1)** $v_x = 7.0 \text{ m s}^{-1}$ **(1)**	3	Accept: 7, 7.03, 7.026 Equating the <u>total</u> momenta before and after **(1)** All substitutions **(1)** Final answer **(1)** If a direction is stated it must be to the right otherwise MAX 2 marks.
	(b)		$E_k = \frac{1}{2}mv^2$ *Before* $E_k = \frac{1}{2}m_x u_x^{\ 2} + \frac{1}{2}m_y u_y^{\ 2}$ $E_k = (\frac{1}{2} \times 760 \times 12.0^2) + (\frac{1}{2} \times 840 \times 4.0^2)$ $E_k = 61440$ (J) *After* $E_k = \frac{1}{2}m_x v_x^{\ 2} + \frac{1}{2}m_y v_y^{\ 2}$ $E_k = (\frac{1}{2} \times 760 \times 7.0^2) + (\frac{1}{2} \times 840 \times 8.5^2)$ $E_k = 48965$ (J) (Total) E_k before is greater than (total) E_k after, (the collision is inelastic).	4	Or consistent with (a) 1 mark for relationship 1 mark for **<u>all</u>** substitutions 1 mark for **<u>both</u>** total kinetic energies 1 mark for correct final statement Suspend significant figure rule for calculated values of total kinetic energies in this question. <u>Kinetic</u> energy is lost.(Therefore inelastic.) E_k before ≠ E_k after is insufficient.
	(c)		$Ft = mv - mu$ **(1)** $F \times 0.82 = (840 \times 8.5) - (840 \times 4.0)$ **(1)** $F = 4.6 \times 10^3$ N **(1)**	3	Accept: 5, 4.61, 4.610 Accept: Impulse = $mv - mu$ u and v must be substituted correctly If the force that car Y exerts on car X is calculated, then there must be a statement that the forces have equal magnitude for final mark, otherwise MAX 2 marks. For this method - Accept: 5, 4.63, 4.634 (when v = 7.0) Or consistent with (a)
	(d)		(During a collision the tyre wall will) increase the time of contact (between the car and the wall). **(1)** (this will) reduce the (magnitude of the) force (experienced by the driver). **(1)**	2	**INDEPENDENT MARKS** Accept: time/duration of collision Accept: 'rate of change in momentum' for force.

MARKS DO NOT WRITE IN THIS MARGIN

4. Two trains depart from a station at the same time. The trains travel side by side in the same direction, along parallel tracks.

Train A is travelling at 3.5 m s^{-1} relative to the platform and train B is travelling at 4.0 m s^{-1} relative to the platform.

(a) Determine the speed of train B relative to train A. **1**

Space for working and answer

(b) Once the trains are moving, a passenger on train A walks towards the rear of the train at a speed of 1.3 m s^{-1}.

Determine the speed of the passenger on train A relative to a passenger seated on train B. **1**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

4. (continued)

(c) Two physics students on train A are discussing the possibility of travelling at relativistic speeds. The students consider the train travelling at a speed of $0.9c$ relative to a stationary observer.

(i) The train emits a beam of light towards the stationary observer.

State the speed of the emitted light as measured by the stationary observer.

Justify your answer. **2**

(ii) Train A has a length of 142 m, as measured in the frame of reference of the students on the train.

Calculate the length of train A when travelling at $0.9c$ as measured by the stationary observer. **3**

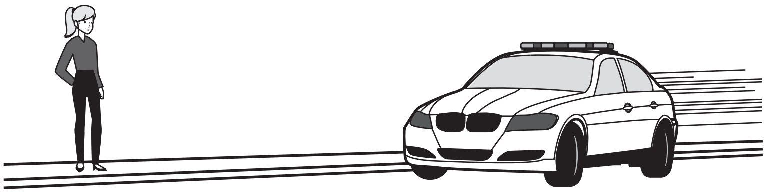
Space for working and answer

[Turn over

Question			Expected response	Max mark	Additional guidance
4.	(a)		0.5 m s^{-1}	1	Ignore minus sign if given in final answer.
	(b)		1.8 m s^{-1}	1	Ignore minus sign if given in final answer.
	(c)	(i)	3.00×10^8 m s^{-1} or c **(1)** Speed of light is the same for all observers **(1)**	2	**JUSTIFY** Accept: 3×10^8 m s^{-1} If the numerical value for speed is given, then unit is required, otherwise 0 marks. Accept: Speed of light is the same in all (inertial) frames of reference or equivalent.
		(ii)	$l' = l\sqrt{1-\left(\frac{v}{c}\right)^2}$ **(1)** $l' = 142\sqrt{1-\left(\frac{0.9c}{c}\right)^2}$ **(1)** $l' = 61.9$ m **(1)**	3	Accept: 62, 61.90, 61.896 Accept: $l' = 142\sqrt{1-(0.9)^2}$

MARKS DO NOT WRITE IN THIS MARGIN

5. A person is standing at the side of a road. A police car approaches and then passes the person at a constant speed of 31 m s^{-1}. A siren on the police car emits sound with a frequency of 440 Hz.



(a) (i) Calculate the frequency of the sound heard by the person as the police car approaches.

The speed of sound in air is 340 m s^{-1}. **3**

Space for working and answer

(ii) State whether the frequency of the sound heard by the person as the police car moves away is greater than, the same as, or less than the frequency heard by the person as the police car approached.

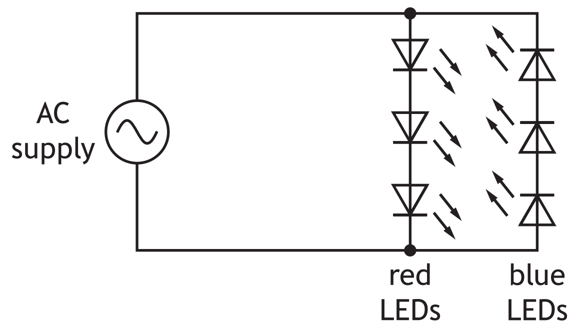
You must justify your answer. **2**

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

5. (continued)

(b) The emergency lights on top of the police car consist of an array of red LEDs and blue LEDs. A simplified diagram of the lighting circuit is shown.



The red LEDs and blue LEDs each flash twice per second.

(i) Determine the period of the AC supply used. **1**

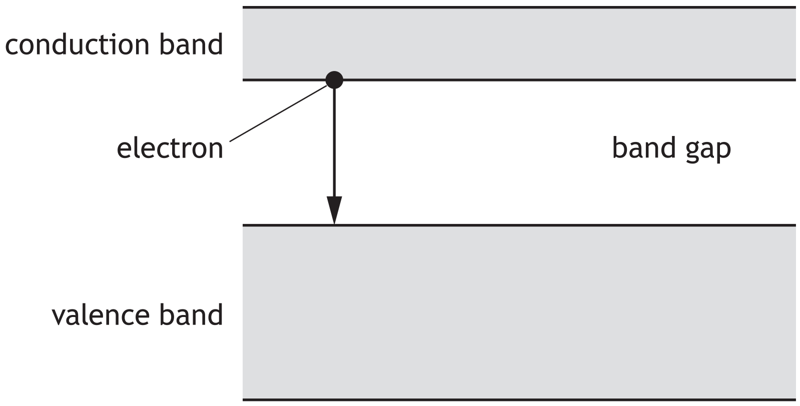
Space for working and answer

(ii) Explain why the red LEDs and the blue LEDs do not light at the same time. **2**

MARKS DO NOT WRITE IN THIS MARGIN

5. (b) (continued)

(iii) An energy band diagram for a red LED is shown.



A photon of wavelength 625 nm is emitted when an electron falls from the conduction band to the valence band, across the energy band gap.

(A) Determine the energy of the emitted photon. **4**

Space for working and answer

(B) Explain, in terms of the energy band gaps, the difference between photons emitted by the red LEDs and photons emitted by the blue LEDs. **2**

Question			Expected response	Max mark	Additional guidance
5.	(a)	(i)	$f_o = f_s\left(\frac{v}{v \pm v_s}\right)$ (1) $f_o = 440\left(\frac{340}{340-31}\right)$ (1) $f_o = 480$ Hz (1)	3	Accept: 500, 484, 484.1 Accept: $f_o = f_s\left(\frac{v}{v - v_s}\right)$
		(ii)	Less than **(1)** Statement that there are fewer wavefronts per second. **OR** The wavefronts are further apart **OR** The wavelength increases **OR** diagram showing wavefronts closer together ahead of the car and further apart behind it. **(1)** or any similar response	2	**MUST JUSTIFY** Accept: "It is less than" Do not accept: "Sound is less than" on its own. Accept: Waves or wave crests in place of wavefronts. Can be justified by calculation. Significant figure rule suspended for this calculation. Can be justified by explaining the <u>use</u> of the '+' version of the relationship. In a diagram, there must be an implication of direction of travel. Do not accept: Any answer that implies that the frequency/wavelength of the sound produced by the siren itself is changing.
	(b)	(i)	T = 0.5 s	1	

Question			Expected response	Max mark	Additional guidance
5.	(b)	(ii)	When the red LEDs are forward biased the blue LEDs are reverse biased (or vice versa). **(1)** LEDs (only) light when forward biased **(1)**	2	**INDEPENDENT MARKS** Accept: The red and blue LEDs are connected the opposite way round. LEDs will (only) conduct in one direction **OR** Red LEDs conduct during one half of the cycle the blue LEDs conduct during the other half of the cycle. Do not accept: 'different direction' alone.
	(b)	(iii) (A)	$v = f\lambda$ $3.00\times10^{8} = f\times625\times10^{-9}$ **(1)** $E = hf$ both relationships anywhere **(1)** $E = 6.63\times10^{-34}\times\left(\dfrac{3.00\times10^{8}}{625\times10^{-9}}\right)$ **(1)** $E = 3.18\times10^{-19}$ J **(1)**	4	Accept 3.2, 3.182, 3.1824 1 mark for **both** relationships 1 mark for **each** substitution 1 mark for final answer Alternative method: $E = \dfrac{hc}{\lambda}$ **(1)** $E = 6.63\times10^{-34}\times\left(\dfrac{3.00\times10^{8}}{625\times10^{-9}}\right)$ **(1),(1)** $E = 3.18\times10^{-19}$ J **(1)** Do not accept: $E_2 - E_1 = hf$
		(iii) (B)	The (energy) band gap in a blue LED is greater. **(1)** The <u>photons</u> of blue light have more energy (than the photons of red light). **(1)**	2	Accept: Converse arguments. If no mention of band gap, 0 marks. Accept: The <u>photons</u> of blue light have a higher frequency (than the photons of red light). **OR** The <u>photons</u> of blue light have a smaller wavelength (than the photons of red light).

MARKS DO NOT WRITE IN THIS MARGIN

6. The song History of Everything, used as the theme from the TV show The Big Bang Theory, contains the following lyrics.

"Our whole universe was in a hot, dense state
Then nearly fourteen billion years ago expansion started, wait. . .

Since the dawn of man is really not that long
As every galaxy was formed in less time than it takes to sing this song
A fraction of a second and the elements were made. . .

It's expanding ever outward but one day
It will cause the stars to go the other way. . ."

(*Written by Ed Robertson and Steven Page*)

Using your knowledge of physics, comment on these lyrics. **3**

MARKS DO NOT WRITE IN THIS MARGIN

6. (continued)

[Turn over

Question			Expected response	Max mark	Additional guidance
6.			**Award 3 marks** where the candidate has demonstrated a good understanding of the physics involved. They show a good comprehension of the physics of the situation and provide a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. The answer does not need to be 'excellent' or 'complete' for the candidate to gain full marks. **Award 2 marks** where the candidate has demonstrated a reasonable understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood the problem. **Award 1 mark** where the candidate has demonstrated a limited understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood at least a little of the physics within the problem. **Award 0 marks** where the candidate has not demonstrated an understanding of the physics involved. There is no evidence that they have recognised the area of physics involved, or they have not given any statement of a relevant physics principle. Award this mark also if the candidate merely restates the physics given in the question.	3	Candidates may use a variety of physics arguments to answer this question. Award marks based on candidates demonstrating overall good, reasonable, limited, or no understanding.

MARKS DO NOT WRITE IN THIS MARGIN

7. Beta decay occurs when a neutron in an unstable nucleus decays into a proton and releases an electron and an antineutrino.

The following statement represents an example of beta decay.

$$^{131}_{\text{P}}Z \rightarrow {}^{131}_{54}Xe + {}^{0}_{-1}e + \overline{v}_e$$

(a) (i) (A) Determine the number represented by P. **1**

Space for working and answer

(B) Identify element Z. **1**

(ii) (A) In the Standard Model, state the type of fermion that includes electrons. **1**

(B) W-bosons and Z-bosons are the force-mediating particles associated with beta decay.

Name the fundamental force associated with beta decay. **1**

[Turn over

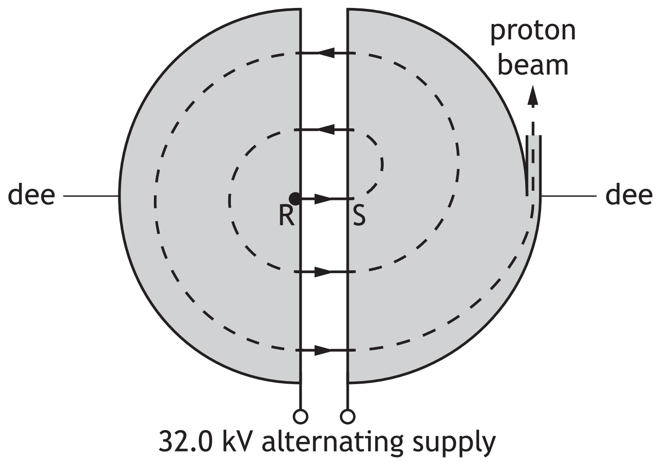
MARKS DO NOT WRITE IN THIS MARGIN

7. (continued)

(b) Positron Emission Tomography (PET) is a medical imaging technique, which uses isotopes that emit positrons.

Suitable isotopes are produced by bombarding a target with protons that have been accelerated in a cyclotron. A cyclotron consists of two D-shaped, hollow metal structures called ‘dees’, placed in a vacuum.

The diagram shows the cyclotron viewed from above.



Protons are released from rest at R and are accelerated across the gap between the ‘dees’ by a voltage of 32.0 kV.

(i) Determine the speed of a proton as it reaches S. **5**

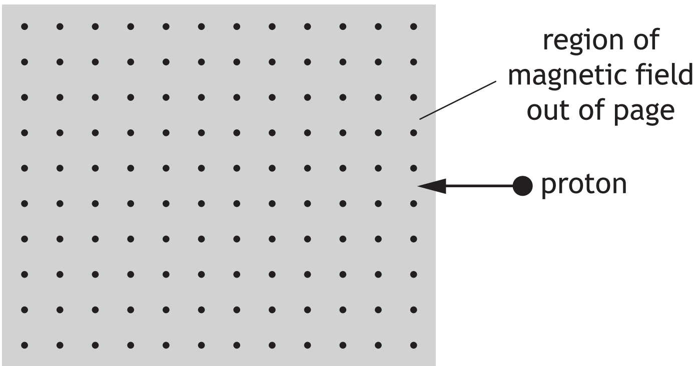
Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

7. (b) (continued)

(ii) Explain why an alternating voltage is used in the cyclotron. **1**

(c) A proton enters a region of magnetic field as shown.



Determine the direction of the force exerted by the magnetic field on the proton immediately after entering the magnetic field. **1**

[Turn over

Question			Expected response	Max mark	Additional guidance
7.	(a)	(i) (A)	(P =) 53	1	
		(i) (B)	Iodine	1	Or consistent with (a)(i)(A) Accept: I
		(ii) (A)	Lepton(s)	1	
		(ii) (B)	Weak (nuclear force)	1	
	(b)	(i)	$W = QV$ **(1)** $W = 1.60\times10^{-19}\times32.0\times10^{3}$ **(1)** $E_k = \frac{1}{2}mv^2$ **(1)** $1.60\times10^{-19}\times32.0\times10^{3}$ $= 0.5\times1.673\times10^{-27}\times v^2$ **(1)** $v = 2.47\times10^{6}\ \text{m s}^{-1}$ **(1)**	5	Accept: 2.5, 2.474, 2.4740 $W = QV$ anywhere $E_k = \frac{1}{2}mv^2$ anywhere
		(ii)	To ensure the electric field is always in the correct direction. OR To ensure the force acting on a proton is always in the correct direction (as it crosses the gap).	1	To ensure the protons accelerate in the correct direction. Do not accept: same direction
	(c)		Up the page	1	Accept: up/upwards/towards top of the page Arrow drawn pointing up the page is acceptable. If upwards arrow is drawn on the original diagram, it must be on the right-hand edge. The path of the particle on its own is not acceptable.

MARKS DO NOT WRITE IN THIS MARGIN

8. A student carries out an experiment to verify the inverse square law for a point source of light.

(a) Describe an experiment to verify the inverse square law for a point source of light. **2**

(b) The student records the following data from their experiment.

Distance d (m)	0.200	0.300	0.400	0.500	0.600
Irradiance I ($W\,m^{-2}$)	142.0	63.1	35.5	22.7	15.8

(i) State what is meant by the term *irradiance*. **1**

MARKS DO NOT WRITE IN THIS MARGIN

8. (b) (continued)

(ii) Use **all** the data to establish the relationship between irradiance I and distance d. **3**

Space for working and answer

(c) Explain why the irradiance decreases when the distance from a point source of light increases. **2**

[Turn over

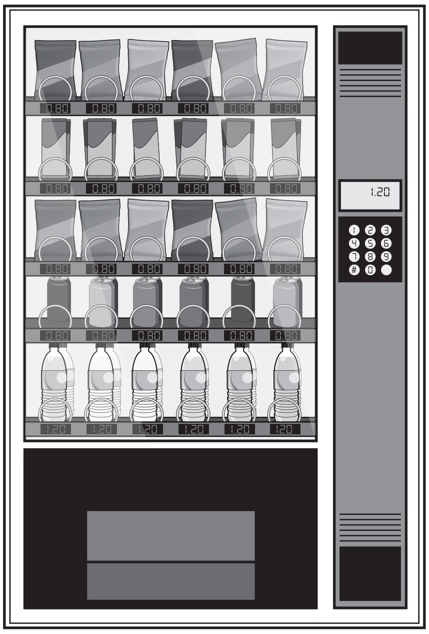
Question			Expected response	Max mark	Additional guidance
8.	(a)		Apparatus **(1)** Method used to collect data **(1)**	**2**	Any mention of laser - 0 marks. **INDEPENDENT MARKS** Must have either name or a labelled diagram of all measuring instruments. Do not accept: light sensor on its own for instrument to measure irradiance. Ignore any mention of analysis of data.
	(b)	(i)	The power per unit area (incident on a surface)	**1**	Accept: power per square metre/power per metre squared/(m^2) Do not accept: watts per square metre

Question			Expected response	Max mark	Additional guidance
8.	(b)	(ii)	$142 \times 0.200^2 = 5.68$ $63.1 \times 0.300^2 = 5.68$ $35.5 \times 0.400^2 = 5.68$ $22.7 \times 0.500^2 = 5.68$ $15.8 \times 0.600^2 = 5.69$ **(2)** statement of $I \times d^2 =$ constant **OR** $I \propto \frac{1}{d^2}$ **(1)**	3	If only 4 sets of data used correctly then maximum 2 marks. If only 3 sets of data used correctly then maximum 1 mark (for relationship). If only 1 or 2 sets of data used correctly, award 0 marks. Must be clear how the candidate has used the data to obtain the relationship. Accept: $I \times d^2 = 5.68$ Ignore inappropriate averaging in this case. The 'statement' mark is only available if consistent with the calculations shown. $I_1 d_1^2 = I_2 d_2^2$ is insufficient on its own for statement of relationship. $I \times d^2 = k$ is insufficient on its own for statement of relationship. Graphical method: Graph drawn correctly (1) Line of best fit through origin (1) Statement of relationship. (1) A sketch graph is not acceptable.
	(c)		Area increases **(1)** Power remains the same **(1)**	2	'light spreads out' is insufficient for 'area increases' Accept alternative explanation, provided the candidate refers to irradiance on light detector: Area remains the same (1) (Incident) power decreases (1)

MARKS DO NOT WRITE IN THIS MARGIN

9. The use of analogies from everyday life can help improve the understanding of physics concepts.

A group of students is discussing whether a vending machine can be used as an analogy for the photoelectric effect.



One student states "It's like putting money into a vending machine. You won't get your snack unless you have enough money, no matter how many coins you put in. If you put in too much money, your snack will come out of the vending machine and you will get change back."

Using your knowledge of physics, comment on this analogy. **3**

MARKS DO NOT WRITE IN THIS MARGIN

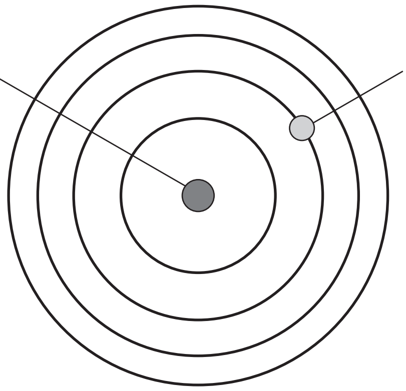
9. (continued)

[Turn over

Question			Expected response	Max mark	Additional guidance
9.			**Award 3 marks** where the candidate has demonstrated a good understanding of the physics involved. They show a good comprehension of the physics of the situation and provide a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. The answer does not need to be 'excellent' or 'complete' for the candidate to gain full marks. **Award 2 marks** where the candidate has demonstrated a reasonable understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood the problem. **Award 1 mark** where the candidate has demonstrated a limited understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood at least a little of the physics within the problem. **Award 0 marks** where the candidate has not demonstrated an understanding of the physics involved. There is no evidence that they have recognised the area of physics involved, or they have not given any statement of a relevant physics principle. Award this mark also if the candidate merely restates the physics given in the question.	3	Candidates may use a variety of physics arguments to answer this question. Award marks based on candidates demonstrating overall good, reasonable, limited, or no understanding.

MARKS DO NOT WRITE IN THIS MARGIN

10. The Bohr model of the hydrogen atom can be represented by the diagram shown.



(a) One of the features of the Bohr model of the hydrogen atom is that the electron can only occupy discrete energy levels.

State one other feature of the Bohr model of the hydrogen atom. **1**

(b) The line emission spectrum from a hydrogen discharge lamp has four lines in the visible region of the electromagnetic spectrum, as shown.

(i) Explain how a line emission spectrum is produced. **2**

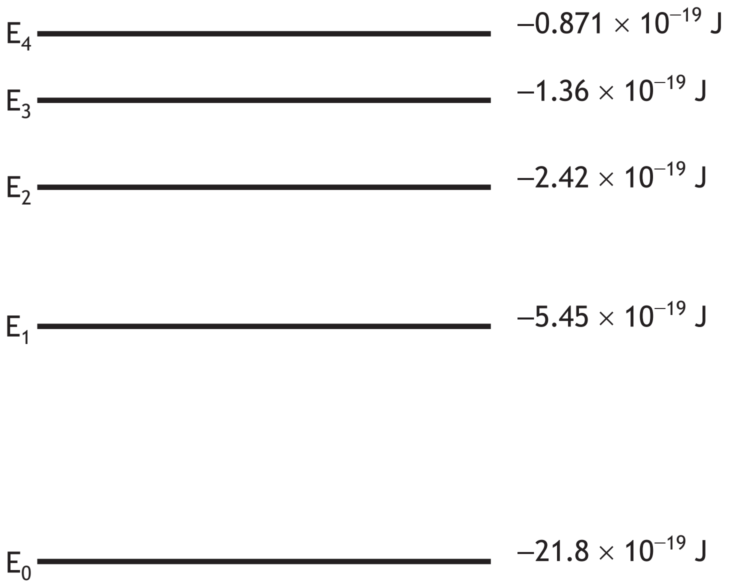
(ii) Explain why some of these lines appear brighter than others. **2**

* X 8 5 7 7 6 0 1 2 8 *

MARKS | DO NOT WRITE IN THIS MARGIN

10. (continued)

(c) Some of the energy levels of the hydrogen atom are shown.



(i) State the number of possible emission lines caused by the transition of electrons between the energy levels shown. **1**

(ii) (A) One of the emission lines produced is due to electron transitions from E_4 to E_1.

Calculate the frequency of the photon emitted when an electron makes this transition. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

10. (c) (ii) (continued)

(B) The photons produced by a different electron transition correspond to the blue-green spectral line in the hydrogen emission spectrum.

State the wavelength of these photons. **1**

(C) A distant galaxy has a recessional velocity of $4.52 \times 10^{6}\ \mathrm{m\,s^{-1}}$.

The hydrogen emission spectrum from the distant galaxy is viewed on Earth.

Determine the observed wavelength of the same spectral line as in (c) (ii) (B), when viewed on Earth. **5**

Space for working and answer

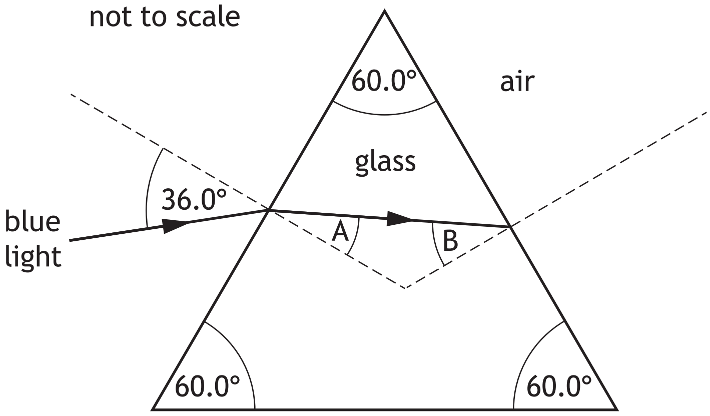
X857760130

Question			Expected response	Max mark	Additional guidance
10.	(a)		A (central) positively charged nucleus. **OR** When an electron moves from one state to another, the energy lost or gained is done so ONLY in very specific amounts of energy. **OR** Each line in a spectrum is produced when an electron moves from one energy level/orbit/shell to another.	1	Do not accept: Atom is mainly empty space. Nucleus is small compared to size of atom. Any statement referring to photons and photon frequency is a consequence, not a feature.
	(b)	(i)	If an electron is in an excited state it can return to a lower energy level. When it does this, it emits a photon. **(1)** Different transitions produce different lines/ frequencies (of photons). **(1)**	2	Accept: When an electron drops down a level it releases energy. If absorption described - 0 marks.
		(ii)	(For the brighter lines) more electrons are making those transitions (per second). **(1)** (Therefore), there are more photons (per second) emitted (of that specific energy and so produce brighter lines). **(1)**	2	**INDEPENDENT MARKS** Do not accept: greater brightness due to greater frequency/energy of the photons. 'More electrons release more photons' on its own - MAX 1 mark
	(c)	(i)	10	1	
		(ii)	$E_2 - E_1 = hf$ **(1)** $-0.871\times10^{-19} - (-5.45\times10^{-19}) = 6.63\times10^{-34}\times f$ **(1)** $f = 6.91\times10^{14}$ Hz **(1)**	3	Accept: 6.9, 6.906, 6.9065 Accept: $(\Delta)E=hf$ **OR** $E_4 - E_1 = hf$ Note: $\Delta E = 4.579\times10^{-19}$ (J) Accept: $5.45\times10^{-19} - 0.871\times10^{-19} = 6.63\times10^{-34}\times f$ for energy substitution mark If $0.871\times10^{-19} - 5.45\times10^{-19}$ is shown for ΔE, maximum (**1 mark)** for **relationship**.
		(ii) (B)	486 nm **(1)**	1	Accept: 4.86×10^{-7} m

Question			Expected response	Max mark	Additional guidance
10.	(c)	(ii) (C)	$z = \frac{v}{c}$ **(1)** $z = \frac{4.52\times10^6}{3.00\times10^8}$ **(1)** $z = \frac{\lambda_o - \lambda_r}{\lambda_r}$ **(1)** $\frac{4.52\times10^6}{3.00\times10^8} = \frac{\lambda_o - 486\times10^{-9}}{486\times10^{-9}}$ **(1)** $\lambda_o = 4.93\times10^{-7}$ m **(1)**	**5**	Or consistent with (c)(ii)(B) Accept: 4.9, 4.933, 4.9332 $z = \frac{v}{c}$ anywhere, 1 mark $z = \frac{\lambda_o - \lambda_r}{\lambda_r}$ anywhere, 1 mark substitution of 486×10^{-9} **(1)** Accept: 486 Alternative method: $\frac{v}{c} = \frac{\lambda_o - \lambda_r}{\lambda_r}$ $\frac{4.52\times10^6}{3.00\times10^8} = \frac{\lambda_o - 486}{486}$ $\lambda_o = 4.93\times10^{-7}$ m Equating formula, **(2)** Substitution of v and c **(1)** Substitution of λ_r **(1)** Final answer **(1)**

MARKS DO NOT WRITE IN THIS MARGIN

11. A ray of blue light is incident on a triangular glass prism as shown.



The refractive index of the glass for this blue light is 1.53.

(a) (i) Calculate angle A. **3**

Space for working and answer

(ii) Determine angle B. **2**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

11. (continued)

(b) (i) State what is meant by the term *critical angle*. **1**

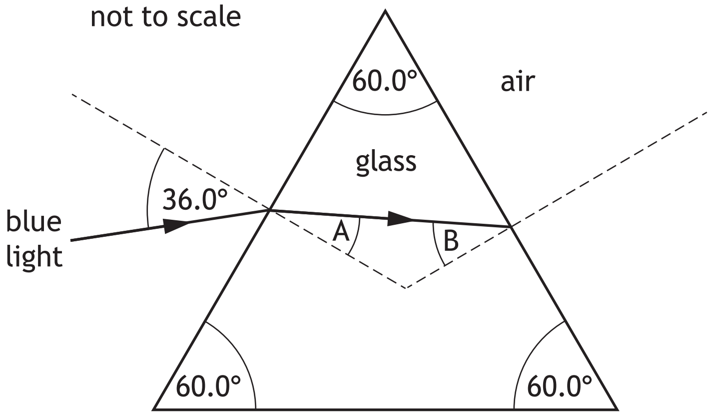
(ii) Calculate the critical angle for this blue light in the glass prism. **3**

Space for working and answer

(c) Complete the diagram below to show the path of the ray after it is incident on the glass-air boundary at the right-hand side of the prism.

Mark on the diagram the value of the angle between this ray and the normal after it is incident on this glass-air boundary. **3**

(An additional diagram, if required, can be found on *page 43*.)



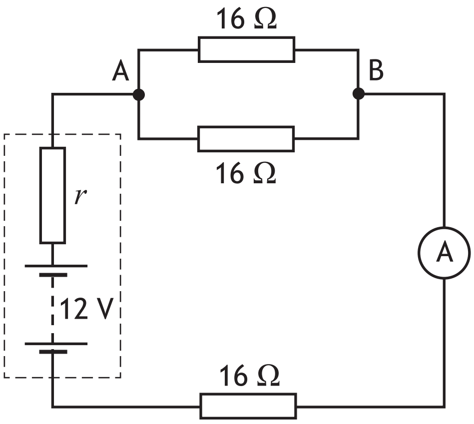
[Turn over

Question			Expected response	Max mark	Additional guidance
11.	(a)	(i)	$n = \frac{\sin\theta_1}{\sin\theta_2}$ **(1)** $1.53 = \frac{\sin 36.0}{\sin\theta_2}$ **(1)** $\theta_2 = 22.6°$ **(1)**	3	Accept: 23, 22.59, 22.592 Accept: $\frac{n_2}{n_1} = \frac{\sin\theta_1}{\sin\theta_2}$ **(1)** $\frac{1.53}{1} = \frac{\sin 36.0}{\sin\theta_2}$ **(1)** $\theta_2 = 22.6°$ **(1)**
		(ii)	$180 - 60 - [90 - 22.6]$ **(1)** $(= 52.6°)$ $(90 - 52.6 = B)$ B=37.4° **(1)**	2	Or consistent with (a)(i) Value must be given to 1 decimal place or consistent with the number of decimal places in answer to (a)(i)
	(b)	(i)	The angle of incidence that produces an angle of refraction of 90°.	1	Accept a description of the incident ray as an alternative to the word 'incidence'. Do not accept: The minimum angle of incidence that causes total internal reflection.
		(ii)	$\sin\theta_c = \frac{1}{n}$ **(1)** $\sin\theta_c = \frac{1}{1.53}$ **(1)** $\theta_c = 40.8°$ **(1)**	3	Accept: 41, 40.81, 40.813

Question			Expected response	Max mark	Additional guidance
11.	(c)		Emergent ray drawn at an angle greater than angle B **(1)** $\left(n = \dfrac{\sin\theta_1}{\sin\theta_2}\right)$ $1.53 = \dfrac{\sin\theta_1}{\sin 37.4}$ **(1)** $(\theta_1 = 68.3°)$ calculated angle correctly shown on diagram **(1)**	**3**	or consistent with (a)(ii) and/or (b)(ii) Accept: 68, 68.32, 68.324 Ignore any partially reflected rays. If (a)(ii) has a greater angle than (b)(ii) then the total internal reflection would be correct Internally reflected ray drawn (1) Angle of reflection approximately equal to angle B (1) Value for angle of reflection shown on diagram consistent with (a)(ii) (1) Ignore any further refraction at other glass-air boundaries.

MARKS DO NOT WRITE IN THIS MARGIN

12. A battery has an EMF of 12 V and internal resistance r. The battery is connected in a circuit as shown.



(a) The reading on the ammeter is 0.38 A.

(i) Determine the terminal potential difference (t.p.d.) of the battery. **5**

Space for working and answer

(ii) Calculate the internal resistance r of the battery. **3**

Space for working and answer

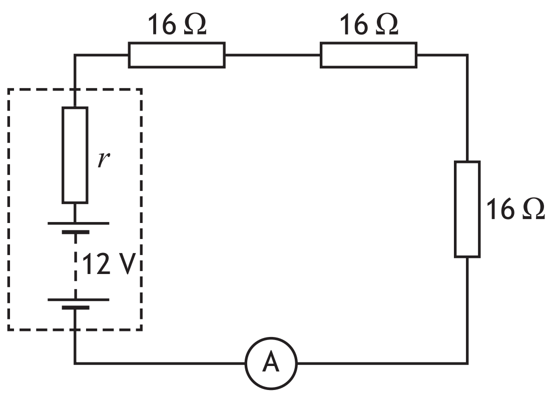
MARKS DO NOT WRITE IN THIS MARGIN

12. (a) (continued)

(iii) Calculate the power dissipated by the internal resistance of the battery. **3**

Space for working and answer

(b) The circuit is now rearranged as shown.



State whether the power dissipated by the internal resistance of the battery is greater than, equal to, or less than the value determined in (a) (iii).

You must justify your answer. **2**

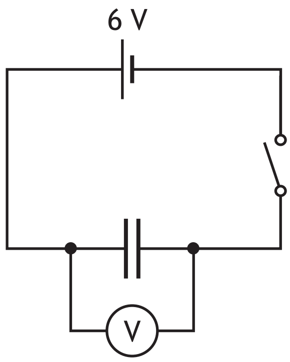
[Turn over

Question			Expected response	Max mark	Additional guidance
12.	(a)	(i)	$\left(\frac{1}{R_T}=\frac{1}{R_1}+\frac{1}{R_2}\right)$ $\left(\frac{1}{R_T}=\frac{1}{16}+\frac{1}{16}\right)$ $R_T=8(\Omega)$ **(1)** $R=((8+16)=)24(\Omega)$ **(1)** $V=IR$ **(1)** $V=0.38\times24$ **(1)** $V=9.1\text{ V}$ **(1)**	**5**	Accept: 9, 9.12, 9.120 24 (Ω) anywhere 2 marks $V=IR$ anywhere - 1 mark Alternative methods 2 marks for 24 (Ω) anywhere 1 mark for **all** relationships 1 mark for **all** substitutions 1 mark for final answer
		(ii)	$E=V+Ir$ **(1)** $12=9.1+(0.38\times r)$ **(1)** $r=7.6\ \Omega$ **(1)**	**3**	Or consistent with a(i)* Accept: 8, 7.63, 7.632 *If V = 12 V then max 1 mark for relationship. Alternative method: $E=I(R+r)$ **(1)** $12=0.38(24+r)$ **(1)** $r=7.6\ \Omega$ **(1)** For this method accept: 8, 7.58, 7.579 for 'lost volts' accept: $V=Ir$ $V=IR$

Question			Expected response	Max mark	Additional guidance
12.	(a)	(iii)	$P = I^2R$ **(1)** $P = 0.38^2 \times 7.6$ **(1)** $P = 1.1\text{ W}$ **(1)**	3	Or consistent with (a)(i) and/or(a)(ii) Accept: 1, 1.10, 1.097 Accept: $P = I^2r$ Alternative methods: $P = IV$ **(1)** $P = 0.38 \times (12 - 9.1)$ **(1)** $P = 1.1\text{ W}$ **(1)** **OR** $P = \frac{V^2}{R}$ **(1)** $P = \frac{(12-9.1)^2}{7.6}$ **(1)** $P = 1.1\text{ W}$ **(1)**
	(b)		(Power dissipated) less than **(1)** (Total circuit resistance increases), current decreases, internal resistance stays the same **(1)**	2	**MUST JUSTIFY** Accept: current decreases, and lost volts decreases. lost volts decreases, and internal resistance stays the same.

MARKS DO NOT WRITE IN THIS MARGIN

13. A student uses the circuit shown to determine the capacitance of a capacitor.



The capacitor is initially uncharged. The student closes the switch and the capacitor charges fully.

The student then measures the charge stored on the capacitor using a coulombmeter.

The student records the following measurements:

potential difference across the capacitor (5.7 ± 0.1) V;

charge stored on the capacitor (136.8 ± 0.1) mC.

(a) (i) Using these measurements, calculate the capacitance of the capacitor. **3**

Space for working and answer

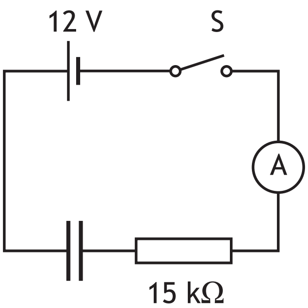
MARKS DO NOT WRITE IN THIS MARGIN

13. (a) (continued)

(ii) Determine the **absolute** uncertainty in the capacitance of the capacitor. **3**

Space for working and answer

(b) The student discharges the capacitor and then connects it in the circuit shown.



The student closes switch S and the capacitor charges.

The time t taken for the capacitor to charge fully can be estimated using the relationship

$$t = 5RC$$

where the symbols have their usual meaning.

Calculate the estimated time taken for the capacitor to charge fully. **2**

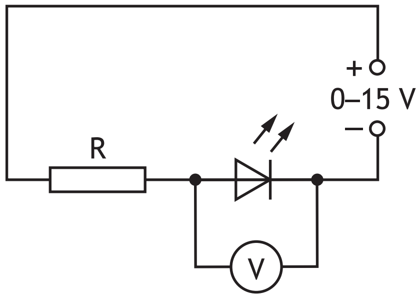
Space for working and answer

Question			Expected response	Max mark	Additional guidance
13.	(a)	(i)	$C = \frac{Q}{V}$ **(1)** $C = \frac{136.8 \times 10^{-3}}{5.7}$ **(1)** $C = 24 \times 10^{-3}$ F **(1)**	3	Accept: 20, 24.0, 24.00
		(ii)	$\%\Delta V = \left(\frac{0.1}{5.7} \times 100\right) = 1.8(\%)$ **(1)** $\Delta C = \frac{1.8}{100} \times 24 \times 10^{-3}$ **(1)** $\Delta C = 4 \times 10^{-4}$ F **(1)**	3	Or consistent with (a)(i) Suspend significant figures rule in this question. Anywhere Accept rounding at an intermediate stage in this question. Alternative method: $\Delta V = \left(\frac{0.1}{5.7}\right) = 0.018$ anywhere **(1)** $\Delta C = \frac{0.1}{5.7} \times 24 \times 10^{-3}$ **(1)** $\Delta C = 4 \times 10^{-4}$ F **(1)**
	(b)		$(t = 5RC)$ $t = 5 \times 15 \times 10^{3} \times 24 \times 10^{-3}$ **(1)** $t = 1800$ s **(1)**	2	Or consistent with (a)(i) Accept: 2000

MARKS DO NOT WRITE IN THIS MARGIN

14. A student carries out an experiment to determine the value of Planck's constant h, using various LEDs.

An LED that produces light of known frequency f is connected into the circuit as shown.



The student adjusts the voltage output of the variable power supply until they see the LED start to emit light.

The student records the potential difference across the LED at this point. This is the switch-on voltage V of the LED.

The student repeats this procedure using a number of LEDs, each producing light of a different known frequency.

To determine a value for Planck's constant, the student uses the relationship

$$eV = hf$$

where e is the charge on an electron.

The results obtained by the student are shown in the table.

f ($\times 10^{14}$ Hz)	V (V)
4.5	1.38
5.0	1.62
5.1	1.65
5.3	1.74
6.4	2.32

(a) Using the square-ruled paper on *page 40*, draw a graph of V against f. **3**

(The table of results is also shown on *page 41*, opposite the square-ruled paper).

* X 8 5 7 7 6 0 1 3 8 *

MARKS DO NOT WRITE IN THIS MARGIN

14. (continued)

(b) Calculate the gradient of your graph. **2**

Space for working and answer

(c) **Using the gradient of your graph**, determine a value for Planck's constant h. **2**

Space for working and answer

(d) Suggest one improvement to the experiment the student could make that would improve the accuracy of their final result. **1**

[END OF QUESTION PAPER]

Question			Expected response	Max mark	Additional guidance
14.	(a)		Axes appropriately labelled (quantity and units) and axes linearly scaled **(1)** [Allow for axes starting at zero or broken axes or an appropriate value] Data points plotted accurately **(1)** Appropriate line of best-fit **(1)**	**3**	If the origin is shown the scale must either be continuous, or the axis must be 'broken'. Otherwise, maximum 2 marks. If non-linear scale is used over the range of the data on either axis eg values from the table are used as the scale points. **(0)** marks Do not penalise if candidates plot *frequency* against *switch on voltage*. Accuracy of plotting should be easily checkable with the scale chosen. An appropriate scale to allow the accuracy of plotting to be checked must be linear over the range of the data.
	(b)		Choosing 2 points on their line **(1)** Calculate gradient: **(1)** (min 1 sig fig, max 4 sig figs) (Gradient works out as approx. 5.0×10^{-15})	**2**	**Must** be consistent with graph drawn for (a). Candidates are asked to calculate the gradient of **their graph**. Tolerance required depending upon best fit line drawn by the candidate. If candidates use values from the table, these points must lie on **their line**. If ($\times 10^{14}$) is not accounted for in the final answer, maximum 1 mark unless this being omitted is consistent with the graph drawn in (a). A unit is not required in the final answer, but if stated it must be correct. If candidate has a non-linear scale over the range of the values used in the substitution, **(0)** marks. If candidate has drawn a 'dot to dot' graph or no line, **(0)** marks.

Question			Expected response	Max mark	Additional guidance
14.	(c)		$(h = e \times gradient)$ $h = 1.60 \times 10^{-19} \times 5.0 \times 10^{-15}$ **(1)** $h = 8.0 \times 10^{-34}$ Js **(1)**	**2**	<u>**Must be**</u> consistent with (b) <u>**Must**</u> substitute the gradient of <u>**their graph**</u>, and not a single data point. If a single data point is substituted into in the calculation, award (0) marks Accept: correct alternative units If candidate has plotted frequency against switch on voltage, the formula becomes $\left(h = \dfrac{e}{gradient}\right)$ $h = \dfrac{1.60 \times 10^{-19}}{2.0 \times 10^{14}}$ **(1)** $h = 8.0 \times 10^{-34}$ Js **(1)**
	(d)		Repeat the measurements and take the mean. **OR** Use a greater range of colours/ frequencies of LEDs. **OR** Carry out experiment in a dark room/use a viewing tube to see when LED first emits light. **OR** Use a photodiode to detect when the LED lights/use an ammeter to detect when the circuit conducts.	**1**	Accept: 'Average' for 'mean' Do not accept: 'Repeat the **experiment** and take the mean' on its own. Accept: Use more colours/frequencies of LEDs. Do not accept: Use more LEDs take more measurements on its own.

[END OF MARKING INSTRUCTIONS]

H

National Qualifications 2024

X857/76/12

Physics
Paper 1 — Multiple choice

THURSDAY, 25 APRIL

9:00 AM – 9:45 AM

Total marks — 25

Attempt ALL questions.

You may use a calculator.

Instructions for the completion of Paper 1 are given on *page 02* of your answer booklet X857/76/02.

Record your answers on the answer grid on *page 03* of your answer booklet.

Reference may be made to the data sheet on *page 02* of this question paper and to the relationships sheet X857/76/22.

Space for rough work is provided at the end of this booklet.

Before leaving the examination room you must give your answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

X857712

A/HTP

Total marks — 25

Attempt ALL questions

1. A cyclist travelling along a straight track accelerates at $1.2\ \mathrm{m\,s^{-2}}$.

The speed of the cyclist increases from $4.0\ \mathrm{m\,s^{-1}}$ to $7.5\ \mathrm{m\,s^{-1}}$.

The distance travelled by the cyclist during this acceleration is

A 1.5 m

B 17 m

C 20 m

D 30 m

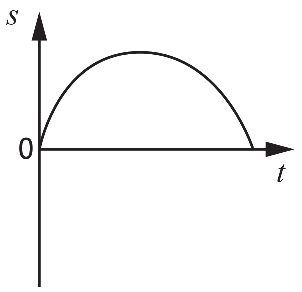
E 34 m.

[Turn over

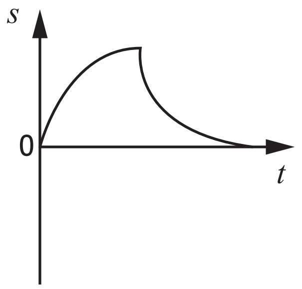
2. A ball is thrown vertically upwards and returns to its original position.

Neglecting air resistance, which displacement-time (s-t) graph represents its motion?

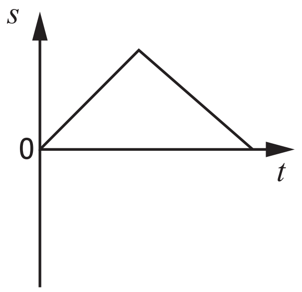
A



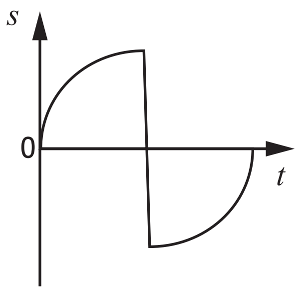
B



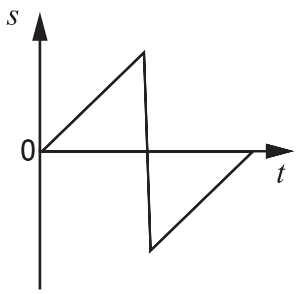
C



D



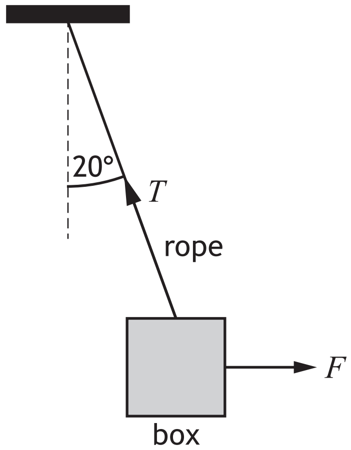
E



3. A box is suspended from a ceiling by a rope.

A horizontal force F is acting on the box.

The box is held stationary as shown.



The weight of the box is 4.9 N.

The tension T in the rope is

A 1.7 N

B 4.6 N

C 4.9 N

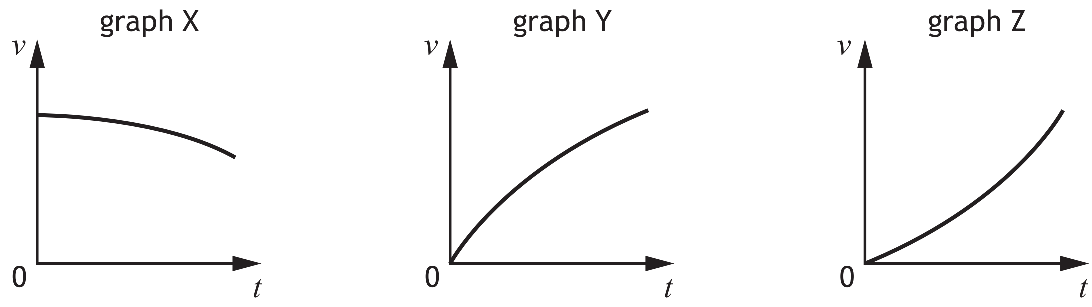
D 5.2 N

E 14 N.

[Turn over

4. A ball is thrown horizontally over the edge of a cliff.

A group of students draw three velocity-time (v-t) graphs to represent the motion of the ball, when air resistance is taken into account.



Which row in the table shows the graphs that represent the horizontal component of the velocity and the vertical component of the velocity?

	Horizontal component of the velocity	Vertical component of the velocity
A	graph X	graph Y
B	graph X	graph Z
C	graph Y	graph X
D	graph Y	graph Z
E	graph Z	graph X

5. In a hydroelectric power station water flows from a reservoir through turbines at a rate of 4.5×10^6 kg per minute.

The reservoir is 150 m above the turbines.

The total power delivered by the water in falling from the reservoir to the turbines is

A 3.0×10^4 W

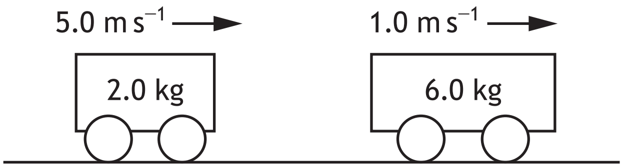
B 7.5×10^4 W

C 1.1×10^8 W

D 6.6×10^9 W

E 4.0×10^{12} W.

6. Two trolleys move along a level bench as shown.



The trolleys collide and stick together. They continue to move along the bench.

The velocity of the trolleys immediately after the collision is

A 0.50 m s^{-1}

B 1.3 m s^{-1}

C 2.0 m s^{-1}

D 2.7 m s^{-1}

E 8.0 m s^{-1}.

7. A spacecraft is travelling at a speed of 0.20c relative to the Earth.

The spacecraft emits a signal for 20.0 s as measured in the frame of reference of the spacecraft.

An observer on Earth measures the duration of the signal as

A 19.2 s

B 19.6 s

C 20.0 s

D 20.4 s

E 20.8 s.

8. The Queensferry Crossing has a length of 2700 m as measured by a stationary observer on Earth.

A spaceship travels past Earth at a constant speed of 1.80×10^8 m s^{-1} relative to Earth.

The length of the Queensferry Crossing as measured by an observer on the spaceship is

A 1100 m

B 1700 m

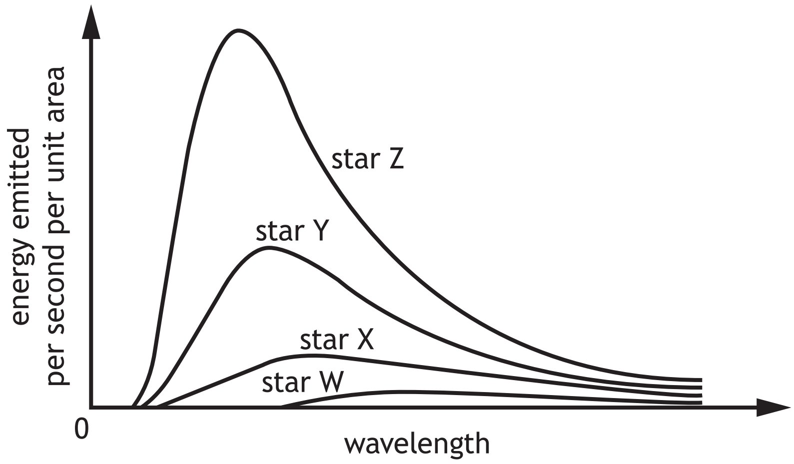
C 2200 m

D 3400 m

E 4300 m.

[Turn over

9. The graph shows how the energy emitted per second per unit area varies with the wavelength of the radiation for four stars W, X, Y, and Z.



A student makes the following statements based on the information shown in the graph:

I Star Z is hotter than star W.
II The peak frequency of radiation emitted is greatest for star W.
III Star Y emits more energy per second per unit area than star X.

Which of the statements is/are correct?

A I only
B II only
C III only
D I and III only
E I, II and III

10. Which of the following particles is a fermion?

A W-boson
B Z-boson
C Photon
D Gluon
E Muon

11. The following statement represents beta decay.

$$^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}e + \overline{\nu}_e$$

Beta decay provided the first evidence for the existence of the

A quark

B neutrino

C electron

D proton

E neutron.

12. Uranium-239 ($^{239}_{92}U$) undergoes decay by emitting a beta particle. The nucleus formed as a result of this decay also undergoes decay by emitting a beta particle to form nucleus X.

Nucleus X is

A $^{231}_{88}Ra$

B $^{235}_{90}Th$

C $^{239}_{90}Th$

D $^{239}_{93}Np$

E $^{239}_{94}Pu$.

13. The following statement represents a nuclear reaction.

$$^{12}_{6}C + {}^{4}_{2}He \rightarrow {}^{16}_{8}O + \gamma$$

The total mass of the particles before the reaction is 26.572×10^{-27} kg.

The total mass of the particles after the reaction is 26.560×10^{-27} kg.

The energy released in this reaction is

A 1.20×10^{-29} J

B 3.60×10^{-21} J

C 5.40×10^{-13} J

D 1.08×10^{-12} J

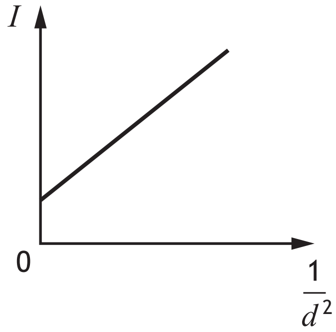
E 2.39×10^{-9} J.

[Turn over

14. A student carries out an experiment to investigate how irradiance of light varies with distance.

A small lamp is placed at a distance d from a light meter. The irradiance I at this distance is displayed on the light meter. This measurement is repeated for a range of different distances.

The student uses these results to plot the graph shown.



The graph indicates that there is a systematic uncertainty in the experiment.

Which of the following alterations would be most likely to reduce the systematic uncertainty in this experiment?

A Repeating the experiment in a darkened room

B Repeating the readings at each distance and calculating averages

C Decreasing the brightness of the lamp

D Replacing the small lamp with a larger lamp

E Increasing the range of distances

15. A group of students make the following statements about coherent waves:

I Coherent waves have a constant phase relationship.

II Coherent waves have the same frequency.

III Coherent waves have the same speed.

Which of the statements is/are correct?

A I only

B III only

C I and II only

D II and III only

E I, II and III

16. Dark lines in an absorption spectrum occur because

A photons move from higher to lower energy levels emitting electrons

B photons move from lower to higher energy levels by absorbing electrons

C electrons move from lower to higher energy levels emitting photons

D electrons move from higher to lower energy levels emitting photons

E electrons move from lower to higher energy levels by absorbing photons.

17. A ray of monochromatic light passes from air into diamond.

The frequency of the light in air is 5.09×10^{14} Hz.

The speed of this light in diamond is

A $1.40 \times 10^{2}\ \mathrm{m\,s^{-1}}$

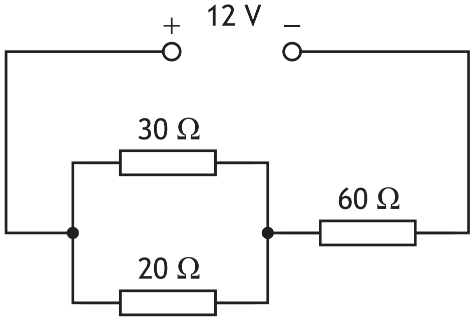
B $1.70 \times 10^{6}\ \mathrm{m\,s^{-1}}$

C $1.24 \times 10^{8}\ \mathrm{m\,s^{-1}}$

D $3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$

E $7.26 \times 10^{8}\ \mathrm{m\,s^{-1}}$.

18. A circuit is set up as shown.



The power supply has negligible internal resistance.

The potential difference across the 60 Ω resistor is

A 1.0 V

B 2.0 V

C 5.5 V

D 6.5 V

E 10 V.

[Turn over

19. A resistor of resistance 2.2 kΩ is rated at 0.25 W.

The potential difference across the resistor when operating at its rated power is

A 0.11 V

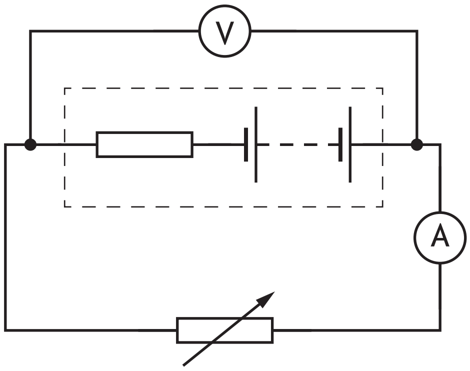
B 23 V

C 94 V

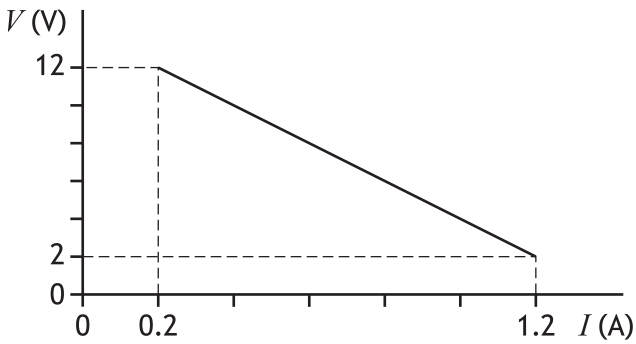
D 550 V

E 8800 V.

20. A circuit is set up as shown.



The resistance of the variable resistor is changed and the corresponding readings on the ammeter and voltmeter are used to produce the graph shown.



A student makes the following statements based on this information:

I The EMF of the battery is 12 V.

II The internal resistance of the battery is 10 Ω.

III The short circuit current is 1.2 A.

Which of these statements is/are correct?

A I only

B II only

C III only

D I and II only

E I, II and III

21. A capacitor is initially uncharged.

The capacitor is now charged for 20 s using a supply that provides a constant current of 0.10 mA.

The potential difference across the capacitor is now 12 V.

The energy stored in the capacitor is

A 0.06 mJ

B 12.0 mJ

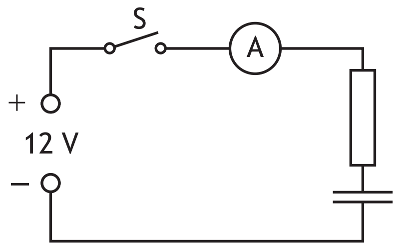
C 14.4 mJ

D 24.0 mJ

E 28.8 mJ.

[Turn over

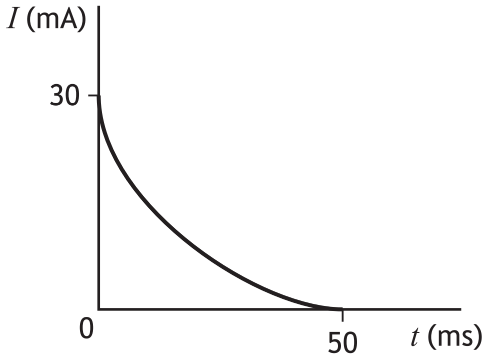
22. A circuit is set up as shown.



The capacitor is initially uncharged.

Switch S is now closed and the capacitor charges.

The graph shows how the charging current I in the circuit varies with time t.



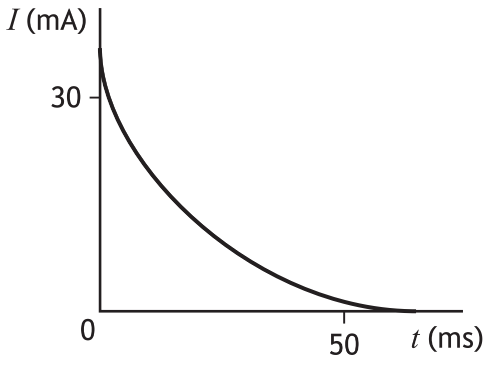
The capacitor is now replaced with an uncharged capacitor of greater capacitance.

The same charging process is repeated with this capacitor.

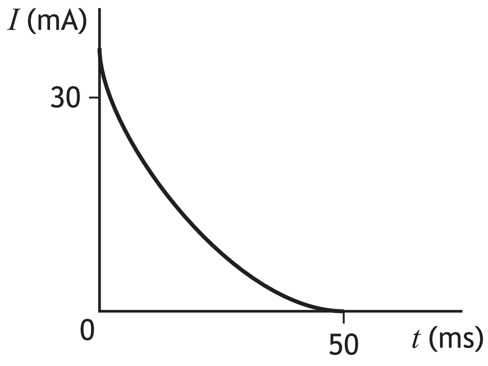
22. (continued)

Which graph shows how the current I varies with time t as this capacitor charges?

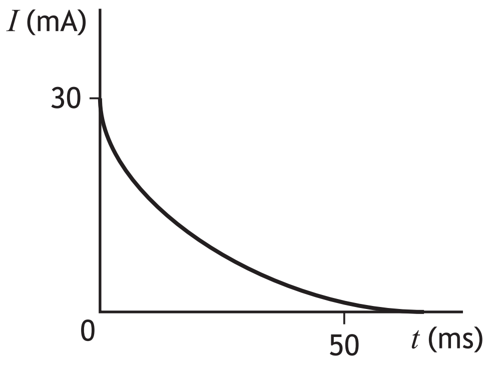
A



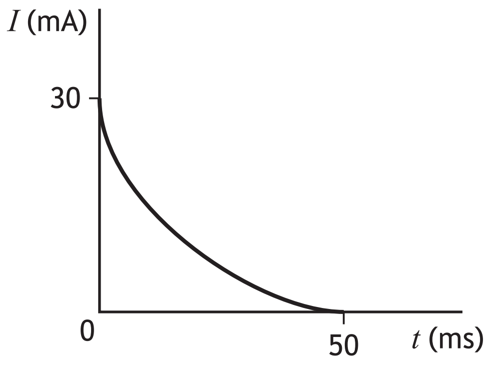
B



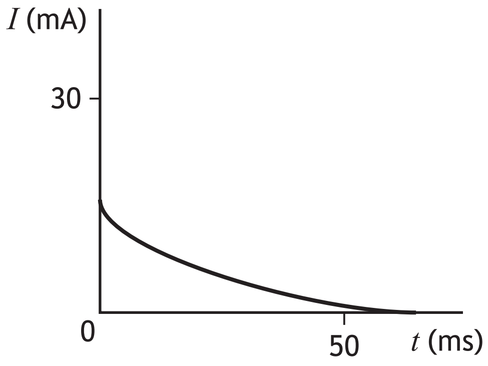
C



D



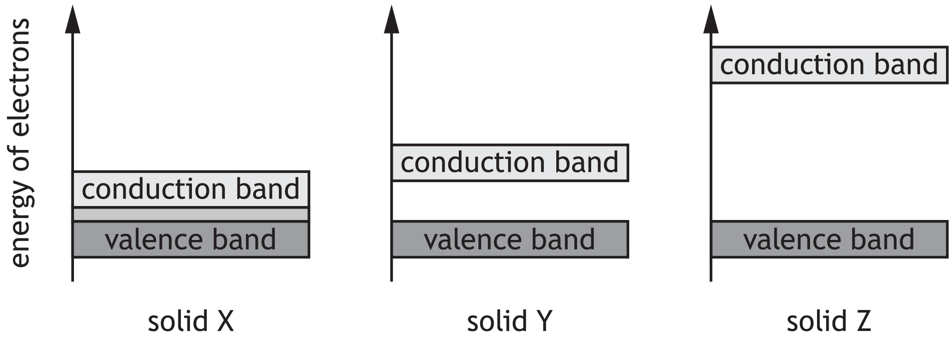
E



[Turn over

23. Solids can be categorised as conductors, insulators, or semiconductors.

The diagrams show the valence band and conduction bands of three solids X, Y, and Z.



Which row in the table shows the letters that represent a conductor, an insulator, and a semiconductor?

	Conductor	Insulator	Semiconductor
A	X	Y	Z
B	Z	X	Y
C	Y	Z	X
D	X	Z	Y
E	Z	Y	X

24. An increase in the temperature of a semiconductor

A increases its conductivity by allowing more electrons to reach the conduction band

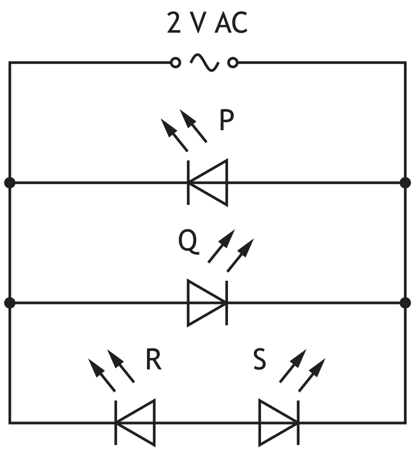
B increases its conductivity by increasing the band gap between the valence band and the conduction band

C decreases its conductivity by allowing more electrons to reach the conduction band

D decreases its conductivity by allowing fewer electrons to reach the conduction band

E has no effect on its conductivity.

25. A student connects four identical red light emitting diodes (LEDs) to a 2 V rms AC supply as shown.



Which of the LEDs P, Q, R, and S will emit light?

A P only

B Q only

C P and Q only

D P and R only

E Q and S only

[END OF QUESTION PAPER]

Marking Instructions for each question

Question	Answer	Mark
1.	B	1
2.	A	1
3.	D	1
4.	A	1
5.	C	1
6.	C	1
7.	D	1
8.	C	1
9.	D	1
10.	E	1
11.	B	1
12.	E	1
13.	D	1
14.	A	1
15.	E	1
16.	E	1
17.	C	1
18.	E	1
19.	B	1
20.	B	1
21.	B	1
22.	C	1
23.	D	1
24.	A	1
25.	C	1

[END OF MARKING INSTRUCTIONS]

FOR OFFICIAL USE

H

National Qualifications 2024

Mark

X857/76/01

Physics Paper 2

THURSDAY, 25 APRIL

10:15 AM – 12:30 PM

* X 8 5 7 7 6 0 1 *

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth

Day Month Year

Scottish candidate number

Total marks — 130

Attempt ALL questions.

You may use a calculator.

Reference may be made to the data sheet on *page 02* of this booklet and to the relationships sheet X857/76/11.

Care should be taken to give an appropriate number of significant figures in the final answers to calculations.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. Score through your rough work when you have written your final copy.

Use **blue** or **black** ink.

Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

MARKS DO NOT WRITE IN THIS MARGIN

Total marks — 130

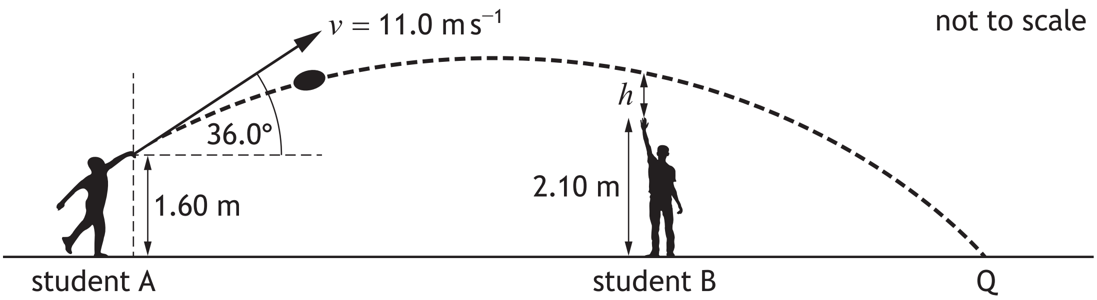
Attempt ALL questions

1. A Doppler ball consists of a loudspeaker and a battery-powered circuit board inside a foam ball.

Two students are throwing the ball to each other.

Student A throws the ball with a velocity of 11.0 m s^{-1} at an angle of 36.0° to the horizontal. The ball is released at a height of 1.60 m above the ground. The ball passes over the head of student B and lands on the ground at point Q.

The effects of air resistance can be ignored.



(a) (i) Calculate:

(A) the horizontal component of the initial velocity of the ball **1**

Space for working and answer

(B) the vertical component of the initial velocity of the ball. **1**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

1. (a) (continued)

(ii) The ball takes 1.53 s to travel from student A to point Q.

Calculate the horizontal distance travelled by the ball. **3**

Space for working and answer

(iii) The ball was directly above student B 0.95 s after it was released.

Student B has a maximum reach of 2.10 m.

Determine the height h between student B and the ball. **4**

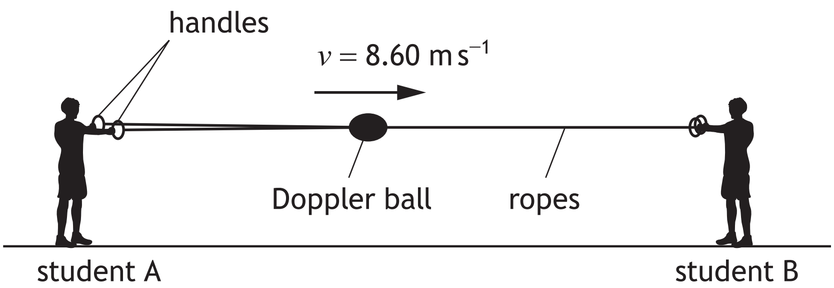
Space for working and answer

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

1. (continued)

(b) The Doppler ball is now threaded onto two ropes. There are handles at either end of the ropes.



The circuit in the Doppler ball is switched on. The loudspeaker produces a sound of frequency 622 Hz.

Student A pulls the ropes apart and the Doppler ball travels along the ropes towards student B.

The ball travels horizontally along the ropes at a constant velocity of $8.60\ \text{m s}^{-1}$.

(i) Calculate the frequency of the sound heard by student B as the Doppler ball approaches them. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

1. (b) (continued)

(ii) The foam Doppler ball collides with the handles at the end of the ropes held by student B and comes to rest.

Explain how the foam ball protects the circuit board during the collision. **2**

[Turn over

Marking instructions for each question

Question			Expected response	Max mark	Additional guidance
1.	(a)	(i) (A)	$(u_h = u\cos\theta)$ $(u_h = 11.0 \times \cos 36.0)$ $u_h = 8.90\ \text{ms}^{-1}$	1	Accept: 8.9, 8.899, 8.8992
		(B)	$(u_v = u\sin\theta)$ $(u_v = 11.0 \times \sin 36.0)$ $u_v = 6.47\ \text{ms}^{-1}$	1	Accept: 6.5, 6.466, 6.4656
		(ii)	$s = \bar{v}t$ **(1)** $s = 8.90 \times 1.53$ **(1)** $s = 13.6\ \text{m}$ **(1)**	3	**OR** consistent with (a)(i)(A) Accept: 14, 13.62, 13.617 Accept: $s = vt$ **OR** $d = vt$ **OR** $d = \bar{v}t$ **OR** $s = \frac{1}{2}(u+v)t$ **OR** $s = ut + \frac{1}{2}at^2$
		(iii)	$s = ut + \frac{1}{2}at^2$ (1) $s = (6.47 \times 0.95) + (0.5 \times (-9.8) \times 0.95^2)$ (1) $h = 1.60 + ((6.47 \times 0.95) + (0.5 \times (-9.8) \times 0.95^2)) - 2.10$ (1) $h = 1.2\ \text{m}$ (1)	4	**OR** consistent with (a)(i)(B) Accept: 1, 1.22, 1.224 u and a must have opposite signs Alternative methods eg using $v^2 = u^2 + 2as$ and $v = u + at$ 1 mark for both relationships 1 mark for substitutions into both relationships 1 mark for calculation to find h 1 mark for final answer

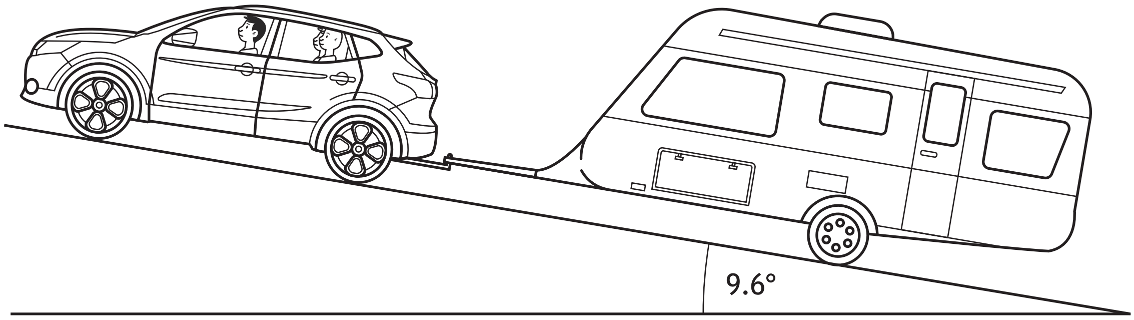
Question			Expected response	Max mark	Additional guidance
1.	(b)	(i)	$f_o = f_s\left(\frac{v}{v \pm v_s}\right)$ **(1)** $f_o = 622 \times \left(\frac{3.40 \times 10^2}{3.40 \times 10^2 - 8.60}\right)$ **(1)** $f_o = 638$ Hz **(1)**	3	Accept: 640, 638.1, 638.14 Accept: $f_o = f_s\left(\frac{v}{v - v_s}\right)$
		(ii)	(The foam) increases the time of contact (with the handles) **(1)** The force (on the circuit board) is less **(1)**	2	INDEPENDENT MARKS Accept: time/duration of collision Accept: force on ball is less Accept: 'rate of change of momentum' for force

MARKS DO NOT WRITE IN THIS MARGIN

2. A car pulls a caravan up a slope at a constant speed of 4.0 m s^{-1}. The slope is at an angle of 9.6° to the horizontal.

The car and passengers have a total mass of 1650 kg.

The caravan has a mass of 1350 kg.



(a) (i) Determine the component of the total weight of the car, passengers, and caravan acting down the slope. **3**

Space for working and answer

(ii) The total frictional force acting on the car and caravan is 1800 N.

Determine the forward force produced by the car. **1**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

2. (continued)

(b) The car and caravan now accelerate uniformly up the slope for 250 s to a velocity of 9.5 $m\,s^{-1}$.

(i) Show that the acceleration of the car and caravan is 0.022 $m\,s^{-2}$. **2**

Space for working and answer

(ii) Determine the minimum forward force produced by the car while accelerating. **3**

Space for working and answer

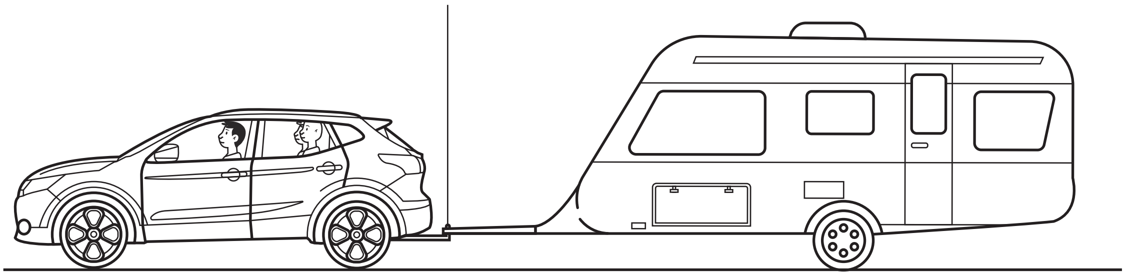
(iii) State one assumption you have made in your calculation for (b) (ii). **1**

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

2. (continued)

(c) Later in the journey the car and caravan are being driven along a straight, level road.



The car and caravan now accelerate at 0.16 $m\,s^{-2}$.

The frictional force acting on the car is 740 N.

The frictional force acting on the caravan is 1200 N.

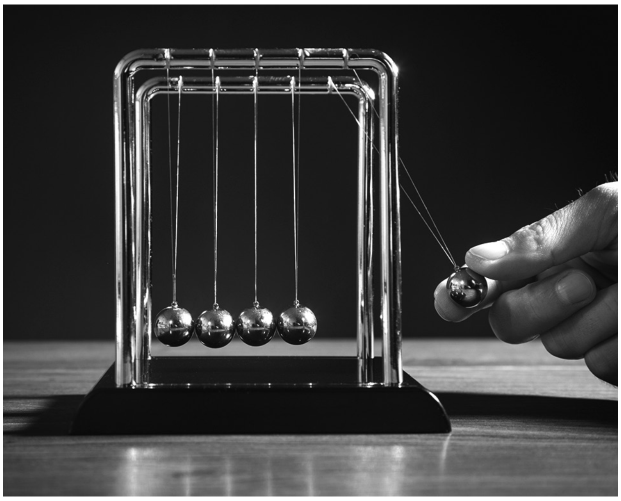
Determine the tension in the coupling between the car and caravan. **3**

Space for working and answer

Question			Expected response	Max mark	Additional guidance
2.	(a)	(i)	$F = mg\sin\theta$ **(1)** $F = (1650+1350)\times 9.8\times \sin 9.6$ **(1)** $F = 4900$ N **(1)**	**3**	Accept: 5000, 4903 Do not accept: $W = mg\sin\theta$ Accept: $W_{comp} = mg\sin\theta$ $W_{parallel} = mg\sin\theta$ $W_{down\ slope} = mg\sin\theta$ $W_{//} = mg\sin\theta$
		(ii)	$(1800+4900=)6700$ N	**1**	Must be consistent with (a)(i)
	(b)	(i)	$v = u + at$ **(1)** $9.5 = 4.0 + (a\times 250)$ **(1)** $a = 0.022$ ms^{-2}	**2**	SHOW question
		(ii)	$F = ma$ **(1)** $F = (1650+1350)\times 0.022$ **(1)** $\left(F_{forward} = ((1650+1350)\times 0.022)+6700\right)$ $F_{forward} = 6766$ N **(1)**	**3**	Or consistent with (a)(ii) Accept: 6800, 6770
		(iii)	The frictional force remains 1800 N/ constant	**1**	Accept: the slope does not change. **OR** mass does not change. **OR** air resistance does not change. Do not accept: acceleration is constant. **OR** friction/air resistance is negligible.
	(c)		$F = ma$ **(1)** $F = 1350\times 0.16$ **(1)** $\left(Tension = (1350\times 0.16)+1200\right)$ $Tension = 1400$ N **(1)**	**3**	Accept: 1000, 1420, 1416 $T = ma$ on its own - 0 marks

MARKS DO NOT WRITE IN THIS MARGIN

3. A Newton's Cradle is a popular desk ornament.



The ball at the end is raised and then released, striking the closest of the four stationary balls.

A force is transmitted through the stationary balls, which causes the ball at the opposite end to swing upwards.

This ball then swings back and strikes the stationary balls from the opposite direction and the process repeats.

A physics teacher states 'a Newton's Cradle can be used to demonstrate a number of physics principles.'

Using your knowledge of physics, comment on this statement. **3**

MARKS DO NOT WRITE IN THIS MARGIN

3. (continued)

[Turn over

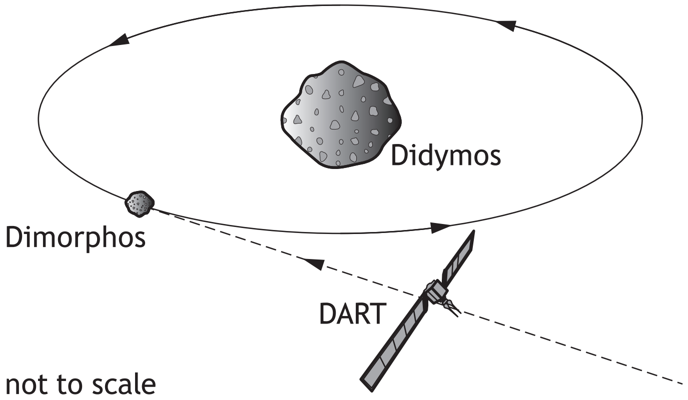
Question			Expected response	Max mark	Additional guidance
3.			**Award 3 marks** where the candidate has demonstrated a good understanding of the physics involved. They show a good comprehension of the physics of the situation and provide a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. The answer does not need to be 'excellent' or 'complete' for the candidate to gain full marks. **Award 2 marks** where the candidate has demonstrated a reasonable understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood the problem. **Award 1 mark** where the candidate has demonstrated a limited understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood at least a little of the physics within the problem. **Award 0 marks** where the candidate has not demonstrated an understanding of the physics involved. There is no evidence that they have recognised the area of physics involved, or they have not given any statement of a relevant physics principle. Award this mark also if the candidate merely restates the physics given in the question.	3	Candidates may use a variety of physics arguments to answer this question. Award marks based on candidates demonstrating overall good, reasonable, limited, or no understanding.

MARKS DO NOT WRITE IN THIS MARGIN

4. On 26 September 2022, Double Asteroid Redirection Test (DART) collided with Dimorphos, a small asteroid that is in orbit around the larger asteroid Didymos.

The aim of the mission was to test a defence system that could be used to redirect an asteroid that is on a collision course with Earth.

When DART collided with Dimorphos, the kinetic energy of DART was transferred to Dimorphos. This caused Dimorphos to change its path.



(a) The mass of Didymos is taken to be 5.3×10^{11} kg.

The mass of the Earth is 6.0×10^{24} kg.

(i) Compare the mass of the Earth with the mass of Didymos in terms of orders of magnitude. **2**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

4. (a) (continued)

(ii) When DART collided with Dimorphos, the distance between Earth and Didymos was 1.1×10^{10} m.

Determine the gravitational force between Earth and Didymos. **3**

Space for working and answer

(b) DART had a mass of 570 kg and was travelling at $6.6\ \text{km s}^{-1}$ when it collided head-on with Dimorphos.

(i) Calculate the maximum kinetic energy transferred from DART to Dimorphos during the collision. **3**

Space for working and answer

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

4. (b) (continued)

(ii) Complete the sketch graph of force F against time t for the force exerted on Dimorphos by DART during the collision.

Numerical values are not required on either axis. **1**

(An additional diagram, if required, can be found on *page 53*.)

Question			Expected response	Max mark	Additional guidance
4.	(a)	(i)	$\left(\frac{6.0\times10^{24}}{5.3\times10^{11}}\right)=1.1\times10^{13}$ **(1)** (Mass of Earth is) 13 (orders of magnitude) greater **OR** (mass of) Didymos is 13 (orders of magnitude) smaller **(1)**	2	Accept: $\left(\frac{10^{24}}{10^{11}}\right)=10^{13}$ **OR** (24-11) = 13 **(1)** Do not accept: 'heavier' for 'greater' Accept: '13 greater' on its own **(2)** Do not accept: '13 <u>times</u> greater' on its own **(0)** Care should be taken where candidates answer by the reciprocal method - 2 marks are still available. $\left(\frac{5.3\times10^{11}}{6.0\times10^{24}}\right)=8.8\times10^{-14}$ **(1)** Comparison statement **(1)**
		(ii)	$F=G\frac{m_1m_2}{r^2}$ **(1)** $F=6.67\times10^{-11}\times\left(\frac{5.3\times10^{11}\times6.0\times10^{24}}{\left(1.1\times10^{10}\right)^2}\right)$ **(1)** $F=1.8\times10^{6}$ N **(1)**	3	Accept: 2, 1.75, 1.753
	(b)	(i)	$E_k=\frac{1}{2}mv^2$ **(1)** $E_k=\frac{1}{2}\times570\times\left(6.6\times10^{3}\right)^2$ **(1)** $E_k=1.2\times10^{10}$ J **(1)**	3	Accept: 1, 1.24, 1.241
		(ii)	Force-time graph with bell-shaped curve or equivalent triangle	1	

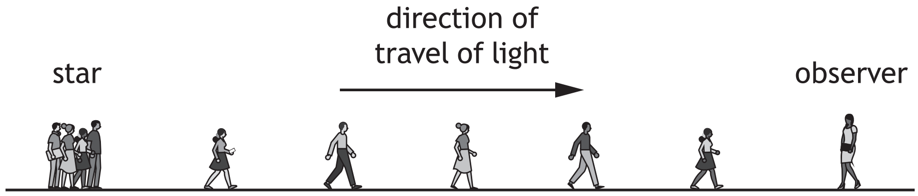
MARKS | DO NOT WRITE IN THIS MARGIN

5. A group of students are participating in a demonstration that models the redshift of light from a distant star relative to an observer.

The 'star' is initially stationary relative to the observer.

The students leave the 'star' at intervals of 3.5 s and walk towards the observer.

Each student represents a wavefront of the light emitted by the 'star'.



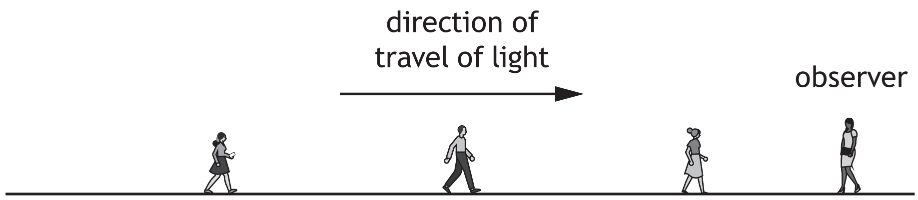
(a) The students representing the wavefronts walk with a constant speed of $1.5\ \mathrm{m\,s^{-1}}$ towards the observer.

Determine the wavelength of the light represented by the students. **3**

Space for working and answer

(b) The demonstration is repeated, and the 'star' now moves at a constant speed relative to the observer. The wavefronts are still emitted from the 'star' at intervals of 3.5 s.

The pattern now observed is shown below.



State if the 'star' is moving towards or away from the observer.

You must justify your answer. **2**

* X 8 5 7 7 6 0 1 1 8 *

MARKS DO NOT WRITE IN THIS MARGIN

5. (continued)

(c) Redshift is evidence for the concept of the expanding Universe. Another piece of evidence for the expansion of the Universe is Olber's paradox.

(i) Explain how Olber's paradox, also referred to as the dark sky paradox, supports the concept of the expanding Universe. **2**

(ii) State one other piece of evidence that supports the concept of the expanding Universe. **1**

[Turn over

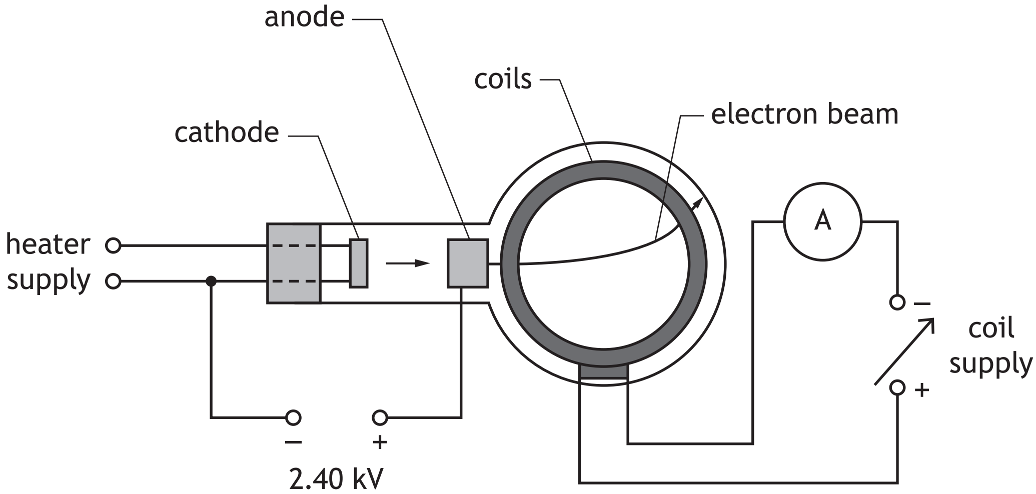
Question			Expected response	Max mark	Additional guidance
5.	(a)		$\left(\begin{array}{l} T = \frac{1}{f} \\ 3.5 = \frac{1}{f} \end{array} \right)$ $v = f\lambda$ **(1)** $1.5 = \frac{1}{3.5} \times \lambda$ **(1)** $\lambda = 5.3$ m **(1)**	**3**	Accept: 5, 5.25, 5.250 Accept: $d = vt$ **(1)** $d = 1.5 \times 3.5$ **(1)** $d = 5.3$ m **(1)** Accept: $s = \frac{1}{2}(u+v)t$ for this method
	(b)		(The star is moving) <u>away</u> (relative to the observer.) **(1)** The (observed) wavelength has increased. **(1)**	**2**	MUST JUSTIFY Accept: explanations about increased distance between wavefronts/students Accept: fewer wavefronts/students passing (the observer) per second **OR** observed frequency has decreased Do not accept: the (observed) wavelength is increasing Do not accept: Any answer that implies that the frequency/wavelength of the 'star' itself is changing.

Question			Expected response	Max mark	Additional guidance
5.	(c)	(i)	Statement of Olbers' paradox **(1)** Explanation of redshift of light to IR **OR** time delay argument **(1)**	2	INDEPENDENT MARKS Olbers' paradox states the darkness of the (night) sky disagrees with/is contrary to/conflicts with the idea of a non-expanding/static Universe **OR** If all stars/galaxies/celestial objects are (equally) bright at fixed distances from an observer on Earth, then we should see a bright night sky **OR** If the Universe had always existed the night sky would not be dark **OR** If the Universe is non-expanding / static/infinite the night sky would not be dark/would be bright **(1)** Many stars/galaxies/celestial objects are moving away from an observer on Earth and so the light from these objects is redshifted to the IR region of the EM spectrum and undetectable with the naked eye, leaving the sky dark. **OR** Many stars/galaxies/celestial objects are moving away from an observer on Earth and so the light from these objects has yet to reach an observer on Earth, leaving the sky dark. **OR** Light would have had sufficient time to reach the observer **(1)**

Question			Expected response	Max mark	Additional guidance
5.	(c)	(ii)	Cosmic Microwave Background Radiation	**1**	Do not accept: the abbreviation 'CMBR' on its own. Accept: Abundance of hydrogen and helium (in the Universe) **OR** the abundance of light elements (in the Universe) **OR** Hubble-Lemaître Law/Hubble's Law Do not accept: Redshift +/- rule applies (GMP 21)

MARKS DO NOT WRITE IN THIS MARGIN

6. A teacher uses the apparatus shown to demonstrate the deflection of a beam of electrons by a magnetic field.

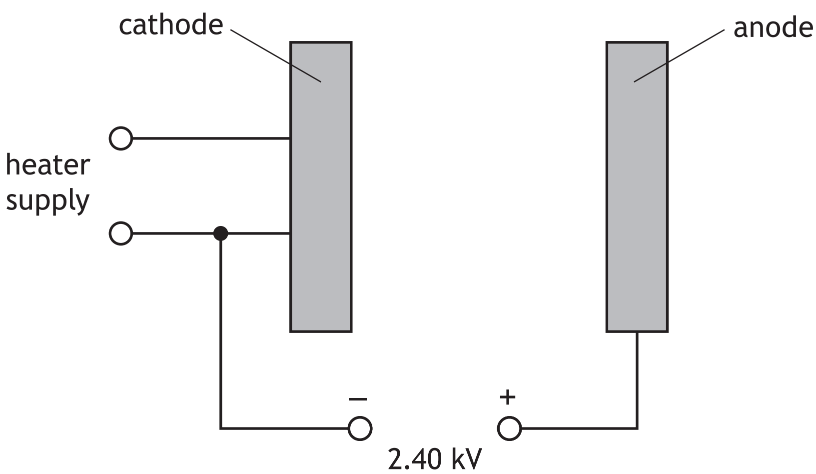


(a) The heater supply is used to heat the cathode, which causes electrons to be released from its surface.

The electrons are accelerated from rest towards the anode by a potential difference of 2.40 kV.

(i) Complete the diagram below, to show the electric field pattern between the cathode and anode. **1**

(An additional diagram, if required, can be found on *page 53*.)



MARKS DO NOT WRITE IN THIS MARGIN

6. (a) (continued)

(ii) The gain in kinetic energy for each electron moving from the cathode to the anode is 3.84×10^{-16} J.

Calculate the maximum speed of an electron as it reaches the anode. **3**

Space for working and answer

(iii) The cathode and anode are separated by a distance of 45.0 mm.

Calculate the maximum acceleration of an electron between the cathode and the anode. **3**

Space for working and answer

[Turn over

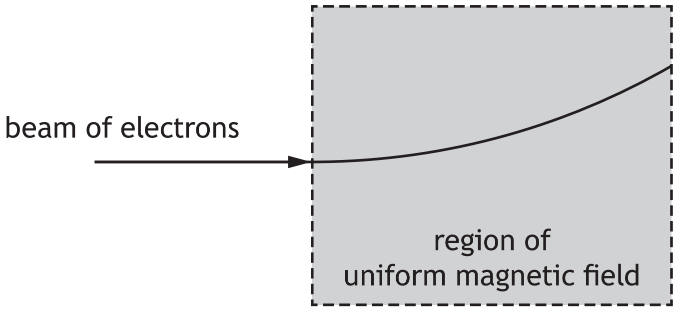
MARKS DO NOT WRITE IN THIS MARGIN

6. (continued)

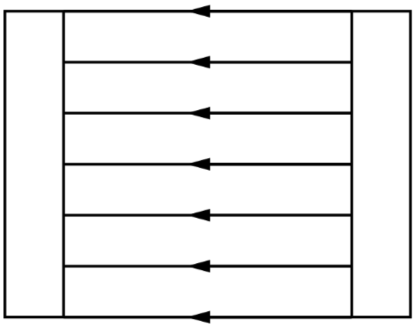
(b) A small hole in the anode allows a narrow beam of electrons to be produced.

The beam of electrons passes into a uniform magnetic field between the coils.

The diagram shows the path taken by the electrons in the uniform magnetic field.



Determine the direction of the uniform magnetic field. **1**

Question			Expected response	Max mark	Additional guidance
6.	(a)	(i)		1	Direction must be correct. Field lines must be passably straight/spaced approximately uniformly. Field lines must start and end on the plates and be perpendicular. Minimum 3 approximately equally spaced lines that cover most of the vertical space between the plates (that is one near the top, one at the middle, and one near the bottom). Ignore end effects.
		(ii)	$E_k = \frac{1}{2}mv^2$ (1) $3.84\times10^{-16} = \frac{1}{2}\times9.11\times10^{-31}\times v^2$ (1) $v = 2.90\times10^7 \text{ ms}^{-1}$ (1)	3	Accept: 2.9, 2.903, 2.9035
		(iii)	$v^2 = u^2 + 2as$ (1) $\left(2.90\times10^7\right)^2 = 0^2 + 2\times a\times45.0\times10^{-3}$ (1) $a = 9.34\times10^{15} \text{ ms}^{-2}$ (1)	3	Or consistent with (a)(ii) Accept: 9.3, 9.344, 9.3444 Alternative methods eg $W = Fd$ and $F = ma$ 1 for both relationships 1 for both substitutions 1 for final answer For this method accept: 9.4, 9.37, 9.367, 9.3670
	(b)		Out of page	1	

MARKS DO NOT WRITE IN THIS MARGIN

7. The art of matryoshka involves making a set of wooden dolls of decreasing size that are placed one inside another.

When one doll is opened up, a smaller one can be found inside, until eventually the last and smallest doll is reached. The smallest doll is a solid piece of wood.

A student states 'Particle physics is just like matryoshka dolls. Look inside a particle and you will always find something similar, just smaller.'

Using your knowledge of physics, comment on this statement. **3**

MARKS DO NOT WRITE IN THIS MARGIN

7. (continued)

[Turn over

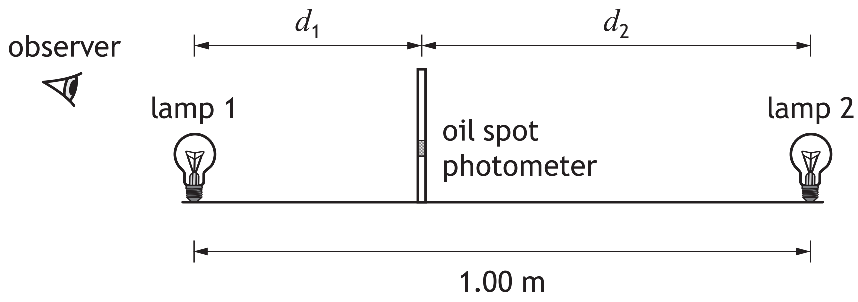
Question			Expected response	Max mark	Additional guidance
7.			**Award 3 marks** where the candidate has demonstrated a good understanding of the physics involved. They show a good comprehension of the physics of the situation and provide a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. The answer does not need to be 'excellent' or 'complete' for the candidate to gain full marks. **Award 2 marks** where the candidate has demonstrated a reasonable understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood the problem. **Award 1 mark** where the candidate has demonstrated a limited understanding of the physics involved. They make some statement(s) that are relevant to the situation, showing that they have understood at least a little of the physics within the problem. **Award 0 marks** where the candidate has not demonstrated an understanding of the physics involved. There is no evidence that they have recognised the area of physics involved, or they have not given any statement of a relevant physics principle. Award this mark also if the candidate merely restates the physics given in the question.	3	Candidates may use a variety of physics arguments to answer this question. Award marks based on candidates demonstrating overall good, reasonable, limited, or no understanding.

DO NOT WRITE IN THIS MARGIN

8. A group of students is conducting an experiment to investigate the relationship between the power output of two small filament lamps and the relative brightness of each lamp.

The relative brightness can be determined using an oil spot photometer.

The experiment is set up as shown.



The oil spot photometer is a piece of card with an oil spot on it, which is used to compare the brightness of two light sources on either side of the photometer. When the relative brightness of the light on either side of the photometer is equal, no spot is observed.

8. (continued) MARKS DO NOT WRITE IN THIS MARGIN

(a) The students keep the brightness of lamp 1 constant.

The brightness L_2 of lamp 2 is measured using a light meter.

The photometer is moved until no spot is observed.

The distance d_2 between lamp 2 and the photometer is measured.

The brightness of lamp 2 is then increased and the process is repeated.

The following results are obtained.

L_2 (units)	d_2 (m)
5.00	0.350
10.00	0.495
15.00	0.606
20.00	0.700

Use **all** of the data in the table to establish that the relationship between the brightness L_2 and the distance d_2 when no oil spot is observed is

$$\frac{L_2}{d_2^2} = \text{constant}$$

3

Space for working and answer

(b) Suggest why small, spherical lamps were used for this experimental procedure. **1**

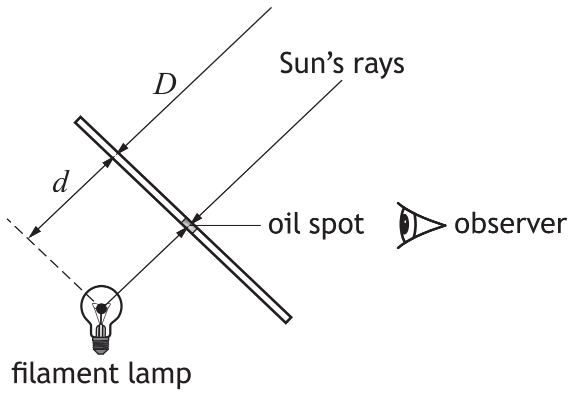
DO NOT WRITE IN THIS MARGIN

8. (continued)

(c) The students repeat the experiment outside, to determine the luminosity of the Sun.

Luminosity is a measure of radiated electromagnetic power, measured in watts.

The set up for this experiment is shown below.



The luminosity of the Sun can be determined using the relationship

$$\frac{L_{lamp}}{d^2} = \frac{L_{Sun}}{D^2}$$

where: L_{lamp} is the luminosity of the lamp, in watts

L_{Sun} is the luminosity of the Sun, in watts

d is the distance between the lamp and the photometer, in metres

D is the approximate distance from the Sun to Earth, in metres.

The luminosity of the lamp is 1.0×10^2 W.

The approximate distance between the Sun and the Earth is 1.5×10^{11} m.

The students adjust the photometer position until the oil spot disappears and note the distance between the centre of the lamp and photometer.

The students repeat the process five times and record the following results:

d = 0.88 m, 0.86 m, 0.90 m, 0.89 m, 0.86 m

X857760128

MARKS DO NOT WRITE IN THIS MARGIN

8. (c) (continued)

(i) Determine the mean value for d. **1**

Space for working and answer

(ii) Calculate the random uncertainty in the mean value for d. **2**

Space for working and answer

(iii) Using the data from this experiment, determine the luminosity of the Sun.

An uncertainty in this value is not required. **2**

Space for working and answer

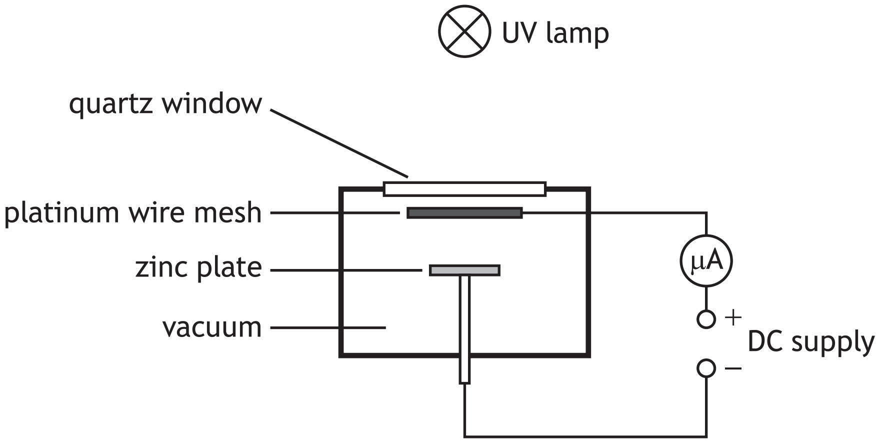
[Turn over

Question			Expected response	Max mark	Additional guidance
8.	(a)		$\frac{5.00}{0.350^2} = 40.8$ $\frac{10.00}{0.495^2} = 40.8$ **(2)** $\frac{15.00}{0.606^2} = 40.8$ $\frac{20.00}{0.700^2} = 40.8$ Therefore $\frac{L_2}{d_2^{\,2}} = \text{constant}$ **(1)**	3	If only 3 calculations completed correctly then maximum 2 marks. If only 2 calculations completed correctly then maximum 1 mark (for relationship). If only 1 calculation completed correctly, award 0 marks. Must be clear how the candidate has used the data to establish the relationship. Accept: $\frac{L}{d^2} = \text{constant}$ $\frac{L}{d^2} = k$ $\frac{L}{d^2} = 40.8$ Ignore inappropriate averaging in this case. The 'conclusion' mark is only available if consistent with the calculations shown. Graphical method: Graph drawn correctly **(1)** Line of best fit through origin **(1)** Statement of relationship. **(1)** A sketch graph is not acceptable.

Question			Expected response	Max mark	Additional guidance
8.	(b)		(Lamps can be considered as) point source(s of light.)	**1**	
	(c)	(i)	$\left(\bar{d} = \frac{(0.88+0.86+0.90+0.89+0.86)}{5}\right)$ $\bar{d} = 0.88$ m	**1**	Accept: 0.9, 0.878, 0.8780
		(ii)	$\left(\Delta R = \frac{R_{max} - R_{min}}{n}\right)$ $\Delta\bar{d} = \frac{0.90-0.86}{5}$ **(1)** $\Delta\bar{d} = (\pm)0.01$ **m** **(1)**	**2**	Accept: 0.008 Accept: $d = (0.88 \pm 0.01)$ m **OR** $\Delta R = (\pm)0.01$ m
		(iii)	$\left(\frac{L_{lamp}}{d^2} = \frac{L_{Sun}}{D^2}\right)$ $\frac{1.0\times10^2}{0.88^2} = \frac{L_{Sun}}{(1.5\times10^{11})^2}$ **(1)** $L_{Sun} = 2.9\times10^{24}$ W **(1)**	**2**	Or consistent with (c)(i) Accept: 3, 2.91, 2.905

MARKS DO NOT WRITE IN THIS MARGIN

9. A student uses the apparatus shown to investigate the photoelectric effect.



When the lamp is switched on, ultraviolet (UV) radiation passes through the quartz window and wire mesh, and is incident on the zinc plate.

A current of 5.00 μA is produced in the circuit.

(a) (i) The lamp emits UV radiation with a frequency of 1.25×10^{15} Hz.

Calculate the energy of a photon of the UV radiation. **3**

Space for working and answer

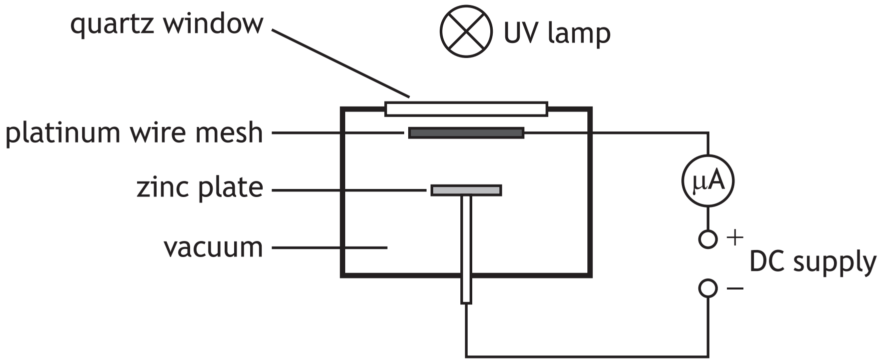
(ii) The work function of zinc is 5.81×10^{-19} J.

Explain why UV radiation with a frequency of 1.25×10^{15} Hz produces a current in this circuit. **2**

MARKS DO NOT WRITE IN THIS MARGIN

9. (continued)

(b) The student now moves the UV lamp closer to the quartz window.



State whether the current in the circuit increases, decreases, or stays the same.

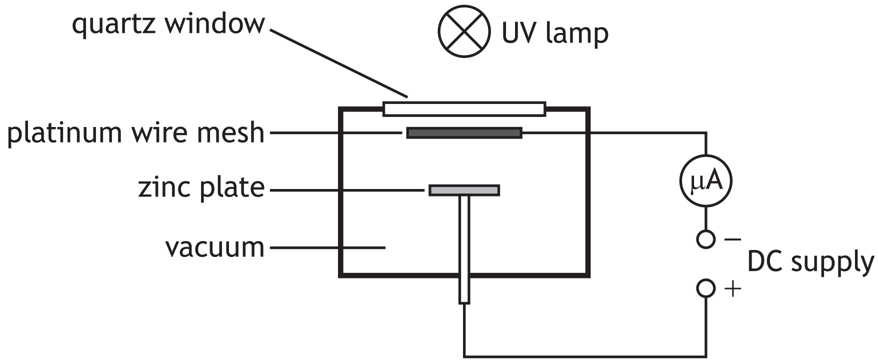
You must justify your answer. **2**

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

9. (continued)

(c) The student now reverses the polarity of the DC supply.



State the effect this change has on the current in the circuit.

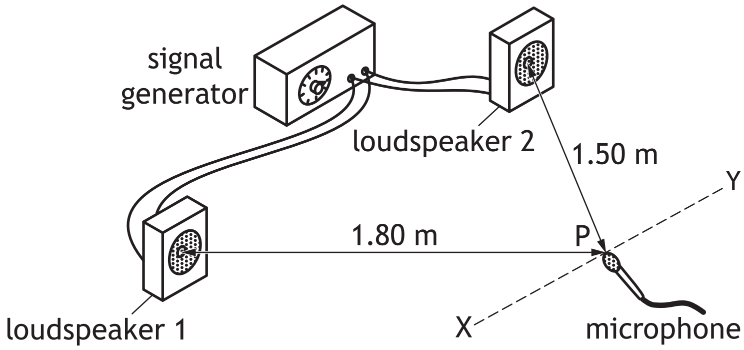
Justify your answer. **2**

Question			Expected response	Max mark	Additional guidance
9.	(a)	(i)	$E = hf$ **(1)** $E = 6.63 \times 10^{-34} \times 1.25 \times 10^{15}$ **(1)** $E = 8.29 \times 10^{-19}$ J **(1)**	3	Accept: 8.3, 8.288, 8.2875
		(ii)	Energy of photons is greater than work function. **OR** Energy of photons is high enough. **OR** Frequency (of UV/photons/radiation) is greater than threshold frequency. **OR** Frequency (of UV/photons/radiation) is high enough. **(1)** The (photo)electrons are attracted to/move towards the (positive) wire mesh. **(1)**	2	Must have first statement otherwise 0 marks. Accept: for the first mark arguments about the threshold frequency being less than the photon frequency. For second mark Looking for an indication that the (photo)electrons are completing the circuit. Accept: The electrons are attracted/move to the positive terminal.
	(b)		(Current) increases **(1)** More photons incident (on the zinc plate per second) **(1)**	2	MUST JUSTIFY Accept: there are more (photo)electrons ejected (per second).
	(c)		Current is zero **(1)** No (photo)electrons reach wire mesh **(1)**	2	JUSTIFY Accept: (Current) decreases **(1)** Accept: Zinc plate positively charged **OR** (photo)electrons are attracted back to the zinc plate **OR** Fewer (photo)electrons reach wire mesh (per second) **(1)**

MARKS DO NOT WRITE IN THIS MARGIN

10. A group of students is investigating interference of sound waves.

The students connect two loudspeakers to the same output of a signal generator.



The signal generator produces a signal of frequency 1700 Hz.

(a) Calculate the wavelength of the sound produced by the speakers. **3**

Space for working and answer

(b) As the microphone is moved from X to Y, regions of maxima and minima are detected.

Point P is a distance of 1.80 m from loudspeaker 1 and a distance of 1.50 m from loudspeaker 2.

Show by calculation whether constructive interference or destructive interference is detected at point P. **4**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

10. **(continued)**

(c) Loudspeaker 1 is now disconnected from the signal generator.

State the effect this has on the amplitude of the sound detected by the microphone at point P.

Justify your answer. **2**

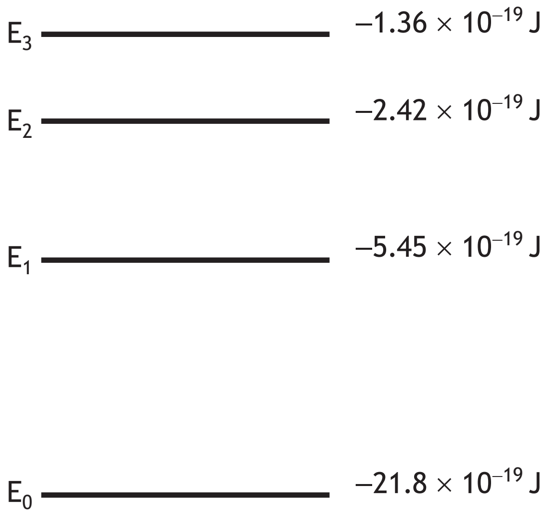
[Turn over

Question			Expected response	Max mark	Additional guidance
10.	(a)		$v = f\lambda$ **(1)** $3.40 \times 10^2 = 1700 \times \lambda$ **(1)** $\lambda = 0.20$ m **(1)**	3	Accept: 0.2, 0.200, 0.2000
	(b)		**path difference** $= m\lambda$ **(1)** $(1.80 - 1.50) = m \times 0.20$ **(1)** $m = 1.5$ **(1)** **destructive (interference)** **(1)**	4	Or consistent with (a) Accept: $m = \frac{3}{2}$ in this case. Accept: path difference $= (m + \frac{1}{2})\lambda$ **(1)** $(1.80 - 1.50) = (m + \frac{1}{2}) \times 0.20$ **(1)** $m = 1$ **(1)** destructive (interference) **(1)** Using either relationship, if m is not an integer multiple of ½ then final mark is not accessible.
	(c)		(The amplitude) increases. **(1)** (Destructive) interference no longer takes place. **(1)**	2	JUSTIFY Must be consistent with conclusion from (b) Accept: louder Second mark can be justified by diagram.

MARKS DO NOT WRITE IN THIS MARGIN

11. Spectral emission lines are unique to each element. These lines are produced when electrons make transitions between two energy levels and photons of light are emitted as a result.

The diagram represents some of the energy levels for a hydrogen atom.



(a) For the energy levels shown:

(i) determine the number of possible emission lines caused by the transition of electrons between the energy levels **1**

(ii) identify the electron transition that results in the emission of a photon with the shortest wavelength. **1**

11. (continued) MARKS DO NOT WRITE IN THIS MARGIN

(b) An electron makes the transition from E_3 to E_1.

(i) Determine the wavelength of the photon of light emitted. **4**

Space for working and answer

(ii) State the colour of this photon of light. **1**

(c) The image below shows part of the line emission spectrum for a hydrogen atom. The red emission line is brighter than the others.

Explain why the red emission line is brighter than the others. **2**

[Turn over

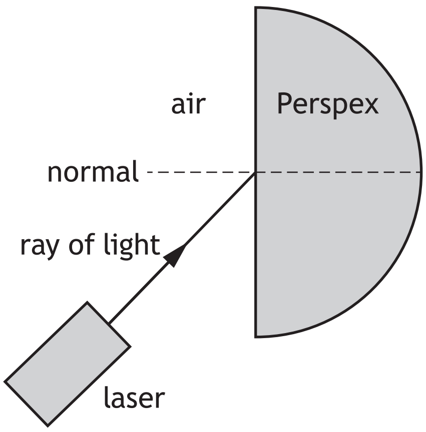
Question			Expected response	Max mark	Additional guidance
11.	(a)	(i)	6	**1**	
		(ii)	E_3 to E_0	**1**	Accept: $E_3 \rightarrow E_0$ Between E_3 and E_0 Direction must be correct. Do not accept: E_3 - E_0 'E_3 and E_0' on its own Between E_0 and E_3

Question			Expected response	Max mark	Additional guidance
11.	(b)	(i)	$E_2 - E_1 = hf$ $-1.36\times10^{-19} - (-5.45\times10^{-19}) = 6.63\times10^{-34}\times f$ (1) $v = f\lambda$ (1) (for both relationships anywhere) $3.00\times10^8 = \left(\dfrac{-1.36\times10^{-19} - (-5.45\times10^{-19})}{6.63\times10^{-34}}\right)\times\lambda$ (1) $\lambda = 4.86\times10^{-7}$ m (1)	**4**	Accept: 4.9, 4.863, 4.8631 1 mark for both relationships (anywhere) 1 mark for substitution into 1st relationship 1 mark for substitution into 2nd relationship 1 mark for final answer Accept: $E_3 - E_1 = hf$ Do not accept: $E_1 - E_3 = hf$ Accept: $5.45\times10^{-19} - 1.36\times10^{-19} = 6.63\times10^{-34}\times f$ for 1st substitution mark Note: $\Delta E = 4.09\times10^{-19}$ (J) Accept: $(\Delta)E = hf$ and $v = f\lambda$ If $1{\cdot}36\times10^{-19} - 5{\cdot}45\times10^{-19}$ is shown for ΔE, maximum 1 mark for correct relationships. Alternative methods: $(\Delta)E = \dfrac{hc}{\lambda}$ **OR** $E_2 - E_1 = \dfrac{hc}{\lambda}$ Combined relationship **(1)** Substitution for h and ΔE **(1)** Substitution for c **(1)** Final answer **(1)**
		(ii)	(emitted photon is) blue-green **(1)**	**1**	Must be consistent with (b)(i)

Question			Expected response	Max mark	Additional guidance
11.	(c)		(For the red line) more electrons are making this transition (per second). **(1)** (Therefore), there are more photons (per second) emitted (of that specific energy and so produce a brighter line). **(1)**	**2**	**INDEPENDENT MARKS** Do not accept greater brightness due to greater frequency/energy of the photons. 'More electrons release more photons' on its own - MAX 1 mark

MARKS DO NOT WRITE IN THIS MARGIN

12. A student is investigating refraction of light using the apparatus shown.



(a) The student measures a number of different angles of incidence θ_i and the corresponding angles of refraction θ_r.

Suggest how the student's measurements should be processed to find a reliable value for the refractive index of Perspex for the light from the laser. **2**

(b) The student determines the refractive index of the Perspex block for this light to be 1.50.

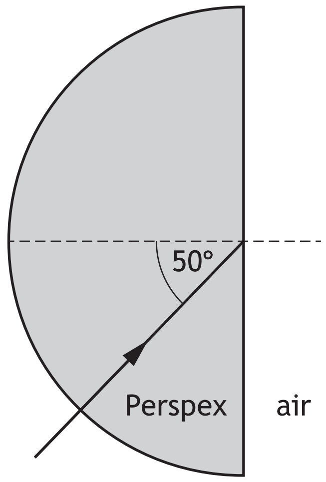
Calculate the critical angle of Perspex for this light. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

12. (continued)

(c) The student now directs the ray of light into the Perspex block as shown.



Complete the diagram to show the path of the ray of light after it is incident on this Perspex-air boundary.

Mark on the diagram the values of any relevant angles. **2**

(An additional diagram, if required, can be found on *page 53*.)

[Turn over

* X 8 5 7 7 6 0 1 3 9 *

Question			Expected response	Max mark	Additional guidance
12.	(a)		Plot a graph of $\sin\theta_i$ against $\sin\theta_r$ **(1)** Calculate gradient of graph **(1)**	**2**	Accept: $\sin i$ and $\sin r$ Accept: gradient of graph is n Accept reciprocal method: Plot a graph of $\sin\theta_r$ against $\sin\theta_i$ **(1)** Calculate inverse of gradient of graph **(1)** Do not accept: Calculating n for each angle of incidence and averaging (as this is an example of invalid averaging)
	(b)		$\sin\theta_c = \frac{1}{n}$ **(1)** $\sin\theta_c = \frac{1}{1.50}$ **(1)** $\theta_c = 41.8°$ **(1)**	**3**	Accept: 42, 41.81, 41.810
	(c)		Total internal reflection **(1)** 50° reflected angle shown on diagram **(1)**	**2**	Must be consistent with (b) Ray must be passably straight. Any change in direction at curved Perspex-air boundary MAX 1 mark. If answer for (b) is greater than 50°, MAX 1 mark for a ray that refracts away from the normal.

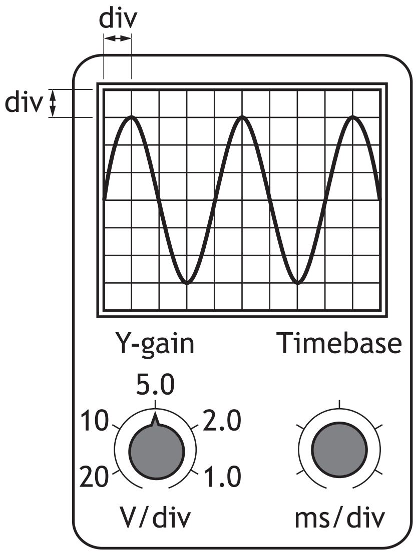
MARKS DO NOT WRITE IN THIS MARGIN

13. The output from a signal generator is connected to the input terminals of an oscilloscope.

The trace observed on the oscilloscope screen and the Y-gain setting are shown.

The timebase setting is not shown.

The frequency of the signal displayed on the oscilloscope is 250 Hz.



(a) State what is meant by the term *alternating current* (*AC*). **1**

(b) Determine the rms voltage of the signal. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

13. (continued)

(c) Determine the timebase setting on the oscilloscope. **3**

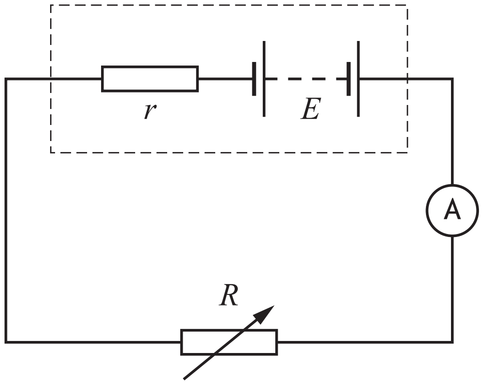
Space for working and answer

[Turn over

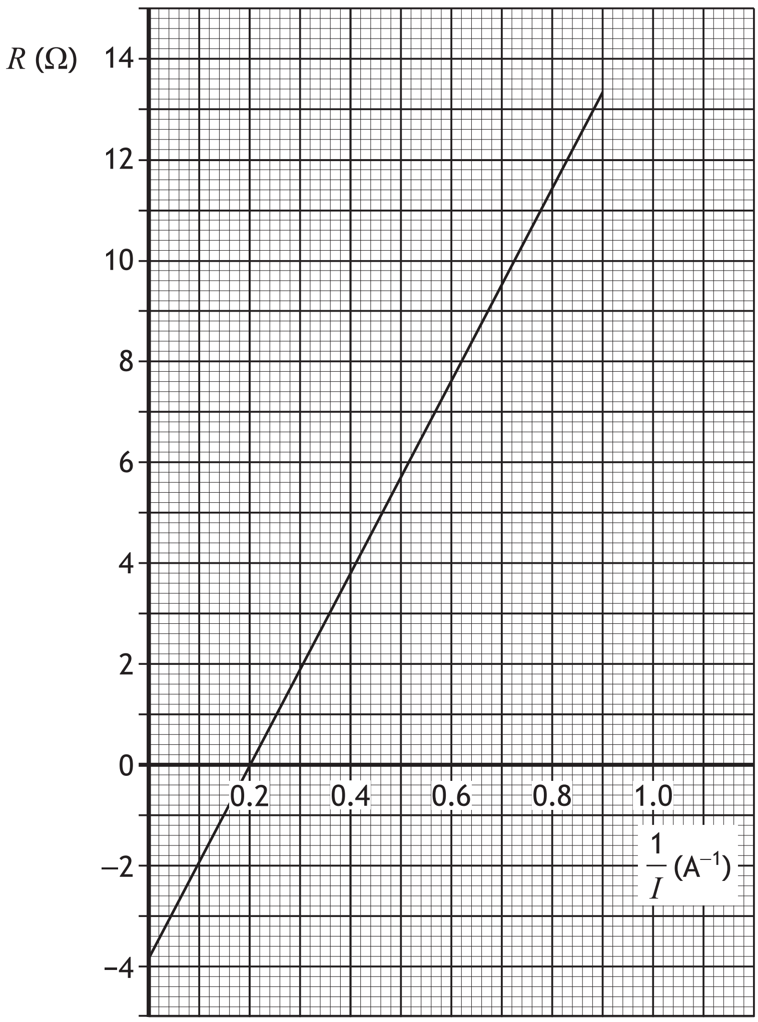
Question			Expected response	Max mark	Additional guidance
13.	(a)		(An alternating current) changes direction and (instantaneous) value with time.	**1**	Accept: 'magnitude' for 'value'
	(b)		$V_{rms} = \frac{V_{peak}}{\sqrt{2}}$ **(1)** $V_{rms} = \frac{(3 \times 5.0)}{\sqrt{2}}$ **(1)** $V_{rms} = 11$ **V** **(1)**	**3**	Accept: 10, 10.6, 10.61
	(c)		$T = \frac{1}{f}$ **(1)** $T = \frac{1}{250}$ **(1)** $(T = 4.0 \times 10^{-3}\ \text{s})$ $(\lambda = 4\ \text{div})$ Timebase setting = $\left(\frac{4.0 \times 10^{-3}}{4} = 1.0 \times 10^{-3} =\right)$ 1 (ms/div) **(1)**	**3**	Accept: 1 ms **OR** 1.0×10^{-3} s in this instance

DO NOT WRITE IN THIS MARGIN

14. A technician sets up the following circuit.



The technician uses readings of resistance R and current I from the circuit to produce the graph shown.



MARKS DO NOT WRITE IN THIS MARGIN

14. (continued)

Conservation of energy applied to the complete circuit gives the following relationship.

$$R = \frac{E}{I} - r$$

This relationship is in the form of the equation of a straight line.

$$y = mx + c$$

(a) Use the graph to determine:

(i) the internal resistance of the battery **1**

(ii) the EMF of the battery **2**

Space for working and answer

(iii) the short circuit current. **2**

Space for working and answer

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

14. (continued)

(b) The technician now connects a second variable resistor in parallel with the original variable resistor.

State whether the short circuit current for this circuit will be greater than, less than, or the same as the value determined in (a) (iii).

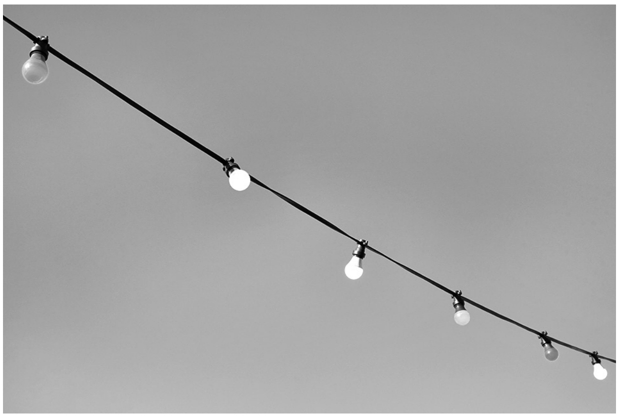
Justify your answer. **2**

Question			Expected response	Max mark	Additional guidance
14.	(a)	(i)	3.8 Ω	**1**	Accept: 3.7 - 3.8
		(ii)	$\left(gradient = E\right)$ $gradient = \dfrac{0-(-3.8)}{0.20-0}$ **(1)** $E = 19$ V **(1)**	**2**	Or consistent with (a)(i) substitution of any valid pair of points from line into gradient formula **(1)** value for E **(1)** For any value for E stated on its own, without any working, accept a value within the range: 18.5 - 20 V Alternative methods: $\left(R = \left(\dfrac{1}{I} \times E\right) - r\right)$ $11.4 = 0.8 \times E - 3.8$ (1) $E = 19$ V (1) **OR** $\left(R = \dfrac{E}{I} - r\right)$ $11.4 = \dfrac{E}{1.25} - 3.8$ (1) $E = 19$ V (1) If using this method, must use data from the line and value of r consistent with (a)(i) Do not accept: Any implication that $gradient \neq E$, eg $gradient = \dfrac{E}{I}$, **(0)**

Question			Expected response	Max mark	Additional guidance
14.	(a)	(iii)	$\left(I_{sc} = \frac{1}{x \text{ intercept}}\right)$ $I_{sc} = \frac{1}{0.20}$ **(1)** $I_{sc} = 5.0$ A **(1)**	**2**	Accept: 5, 5.00, 5.000 Alternative method: $\left(R = \frac{E}{I} - r\right)$ (I_{sc} **occurs when** $R = 0\ \Omega$) $0 = \frac{19}{I_{sc}} - 3.8$ **(1)** $I_{sc} = 5.0$ A **(1)** **OR** $(E = Ir)$ **OR** $(V = IR)$ $19 = I \times 3.8$ **(1)** $I = 5.0$ A **(1)** OR consistent with (a)(i) and/or (a)(ii)
	(b)		Same **(1)** $\left(I_{SC} = \frac{E}{r}\right)$ E and r are unchanged. **(1)**	**2**	JUSTIFY Short circuit current is not affected by load resistance/external resistance/R **OR** When a battery is short circuited the only resistance in the circuit is r (for the same E). **(1)**

MARKS DO NOT WRITE IN THIS MARGIN

15. A set of garden lights is powered by an array of solar cells.

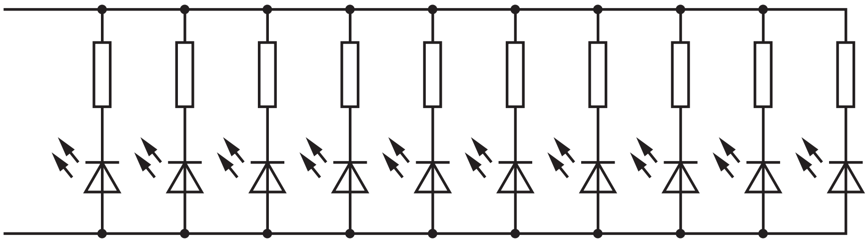


The set of garden lights consists of 10 LEDs connected in parallel.

Each LED is connected in series with a resistor.

The combined resistance of each LED and resistor is 220 Ω.

Part of the circuit is shown.



(a) Calculate the total resistance of this part of the circuit. **3**

Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

15. (continued)

(b) A solar cell is a p-n junction.

When photons of light are incident on the p-n junction, a potential difference is produced.

(i) State the name of this effect. **1**

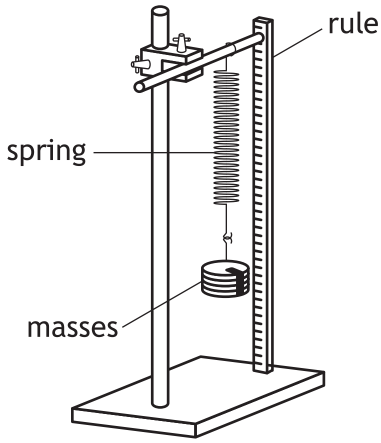
(ii) Using band theory, explain how a potential difference is produced when photons of light are incident on the p-n junction. **3**

[Turn over

Question			Expected response	Max mark	Additional guidance
15.	(a)		$\frac{1}{R_T}=\frac{1}{R_1}+\frac{1}{R_2}+\cdots$ **(1)** $\frac{1}{R_T}=\frac{1}{220}+\cdots+\frac{1}{220}$ **(1)** $R_T=22\ \Omega$ **(1)**	**3**	Accept: 20, 22.0, 22.00 If incorrect relationship used eg $R_T=\frac{1}{R_1}+\frac{1}{R_2}+\cdots$ then 0 marks Alternative method: $R_T=\frac{R}{n}$ **(1)** $R_T=\frac{220}{10}$ **(1)** $R_T=22\ \Omega$ **(1)**
	(b)	(i)	Photovoltaic (effect)	**1**	
		(ii)	Electrons gain/absorb energy from photons/light **(1)** Electrons move from <u>valence band</u> to <u>conduction band</u> **(1)** Electrons move towards n-type (semiconductor producing a potential difference). **(1)**	**3**	Look for reference to both conduction and valence band first, otherwise (0) marks. Bands must be named correctly, eg do not accept 'valency' or 'conductive'. Third statement is dependent on second statement.

MARKS DO NOT WRITE IN THIS MARGIN

16. A group of students use the apparatus shown to carry out an investigation into Hooke's Law and find the spring constant k of a spring.



The spring constant k is a measure of the stiffness of a spring.

Hooke's Law states that the increase in the length of a spring is proportional to the force used to stretch the spring:

$$F = ke$$

where: F is the force used to stretch the spring, in N

k is the spring constant, in $N\,m^{-1}$

e is the increase in the length of the spring, in m.

The students obtain the following data.

F (N)	e (mm)
1.0	3
2.0	8
2.9	11
3.9	15
4.9	20
5.9	24

(a) (i) Using the square-ruled paper on *page 50*, draw a graph of F against e. **3**

(The table of results is also shown on *page 51*, opposite the square-ruled paper.)

16. (a) (continued) **MARKS** DO NOT WRITE IN THIS MARGIN

(ii) Use your graph to determine the spring constant k. **2**

Space for working and answer

(iii) Suggest one improvement to the experimental procedure that the students could make to improve the accuracy of their final result. **1**

(b) When a spring is extended, work is done. Elastic potential energy is stored in the spring. If it is not over-stretched, the elastic potential energy is equal to the work done.

The elastic potential energy can be determined using the relationship

$$E_e = \frac{ke^2}{2}$$

where: E_e is the elastic potential energy, in J

k is the spring constant, in N m^{-1}

e is the increase in the length of the string, in m.

Determine the elastic potential energy stored when the spring extension is 22 mm. **2**

Space for working and answer

[END OF QUESTION PAPER]

Question			Expected response	Max mark	Additional guidance
16.	(a)	(i)	Axes appropriately labelled (quantity and units) and axes linearly scaled **(1)** [Allow for axes starting at zero or broken axes or an appropriate value] Data points plotted accurately **(1)** Appropriate line of best-fit **(1)**	**3**	If the origin is shown the scale must either be continuous, or the axis must be 'broken'. Otherwise, maximum 2 marks. If non-linear scale is used over the range of the data on either axis eg values from the table are used as the scale points, (0) marks. Do not penalise if candidates plot e against F. Accuracy of plotting should be easily checkable with the scale chosen. An appropriate scale to allow the accuracy of plotting to be checked must be linear over the range of the data.

Question			Expected response	Max mark	Additional guidance
16.	(a)	(ii)	$(gradient = k)$ $gradient = \dfrac{5.9 - 2.6}{24\times10^{-3} - 10\times10^{-3}}$ **(1)** $k = 240\ \text{Nm}^{-1}$ **(1)**	2	**<u>Must be</u>** consistent with (a)(i). If relationship to calculate gradient is stated incorrectly (0) marks, eg $\dfrac{y^2 - y^1}{x^2 - x^1}$ Tolerance required depending upon best fit line drawn by the candidate. If candidates use values from the table, these points must lie on **<u>their line</u>**. If ($\times10^{-3}$) is not accounted for in the final answer, maximum 1 mark unless this being omitted is consistent with the graph drawn in (a)(i). If the candidate has drawn a straight line through the origin, then any point on the line can be used to calculate the spring constant using $F = ke$ If the line drawn (or extrapolated line) does NOT pass through the origin, the gradient of the line must be used and not one single point selected, otherwise 0 marks. If the candidate uses a broken scale on either axis, or does not start their scale at zero, they must use the gradient in their calculation of k, otherwise 0 marks. If candidate has plotted e against F, then any implication of k = gradient, 0 marks, as in this case: $k = \dfrac{1}{gradient}$

Question			Expected response	Max mark	Additional guidance
16.	(a)	(iii)	Repeat the measurements and calculate the mean **OR** Use a greater range of masses/forces	**1**	Accept: 'Average' for 'mean' Accept: use smaller increments Do not accept: 'Repeat the **experiment** and take the mean' on its own. **OR** 'Take more measurements' on its own. **OR** Answers addressing precision of measuring instruments. **OR** Answers addressing a systematic uncertainty.
	(b)		$E_e = \frac{ke^2}{2}$ $E_e = \frac{240 \times \left(22 \times 10^{-3}\right)^2}{2}$ **(1)** $E_e = 5.8 \times 10^{-2}$ J **(1)**	**2**	Must be consistent with (a)(ii)

[END OF MARKING INSTRUCTIONS]

H

National Qualifications 2025

X857/76/12

Physics
Paper 1 — Multiple choice

THURSDAY, 15 MAY

9:00 AM – 9:45 AM

Total marks — 25

Attempt ALL questions.

You may use a calculator.

Instructions for the completion of Paper 1 are given on *page 02* of your answer booklet X857/76/02.

Record your answers on the answer grid on *page 03* of your answer booklet.

Reference may be made to the data sheet on *page 02* of this question paper and to the relationships sheet X857/76/22.

Space for rough work is provided at the end of this booklet.

Before leaving the examination room you must give your answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	Symbol	Value	Quantity	Symbol	Value
Speed of light in vacuum	c	3.00×10^{8} m s^{-1}	Planck's constant	h	6.63×10^{-34} J s
Magnitude of the charge on an electron	e	1.60×10^{-19} C	Mass of electron	m_e	9.11×10^{-31} kg
Universal Constant of Gravitation	G	6.67×10^{-11} m^{3} kg^{-1} s^{-2}	Mass of neutron	m_n	1.675×10^{-27} kg
Gravitational acceleration on Earth	g	9.8 m s^{-2}	Mass of proton	m_p	1.673×10^{-27} kg
Hubble's constant	H_0	2.3×10^{-18} s^{-1}	Speed of sound in air	v_{air}	3.40×10^{2} m s^{-1}

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	Refractive index	Substance	Refractive index
Diamond	2.42	Water	1.33
Crown glass	1.50	Air	1.00

SPECTRAL LINES

Element	Wavelength (nm)	Colour	Element	Wavelength (nm)	Colour
Hydrogen	656	Red	Cadmium	644	Red
	486	Blue-green		509	Green
	434	Blue-violet		480	Blue
	410	Violet	Lasers		
	397	Ultraviolet	Element	Wavelength (nm)	Colour
	389	Ultraviolet	Carbon dioxide	9550 10 590	Infrared
Sodium	589	Yellow	Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	Density (kg m^{-3})	Melting point (K)	Boiling point (K)
Aluminium	2.70×10^{3}	933	2623
Copper	8.96×10^{3}	1357	2853
Ice	9.20×10^{2}	273	. . . .
Sea Water	1.02×10^{3}	264	377
Water	1.00×10^{3}	273	373
Air	1.29	. . . .	. . . .
Hydrogen	9.0×10^{-2}	14	20

The gas densities refer to a temperature of 273 K and a pressure of 1.01×10^{5} Pa.

Total marks — 25

Attempt ALL questions

1. A car accelerates uniformly from rest and travels a distance of 18 m in 3.0 seconds.

The speed of the car at 3.0 seconds is

A 4.0 $m\,s^{-1}$

B 6.0 $m\,s^{-1}$

C 12 $m\,s^{-1}$

D 36 $m\,s^{-1}$

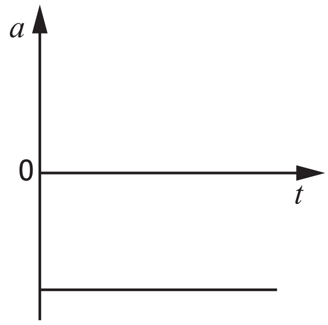
E 54 $m\,s^{-1}$.

[Turn over

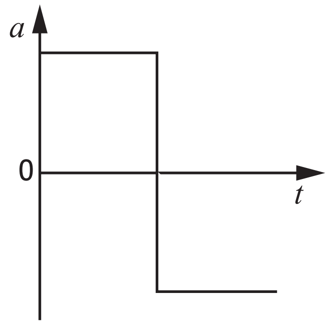
2. A ball is thrown vertically upwards and then falls back to its starting position.

Which of the following acceleration-time graphs represents the motion of the ball?

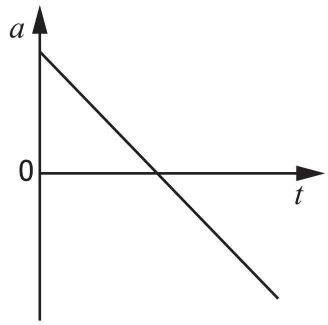
A



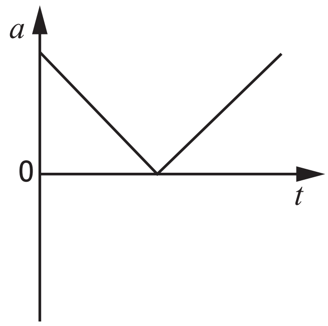
B



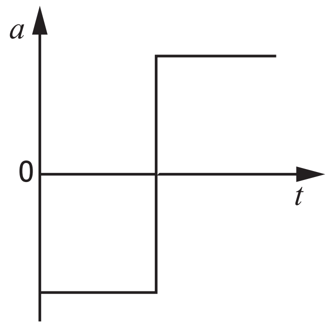
C



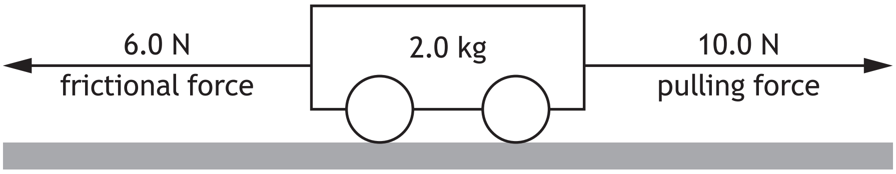
D



E



3. A force of 10.0 N pulls a trolley of mass 2.0 kg along a horizontal surface.



The total frictional force acting on the trolley is 6.0 N.

The acceleration of the trolley is

A 2.0 $m\,s^{-2}$

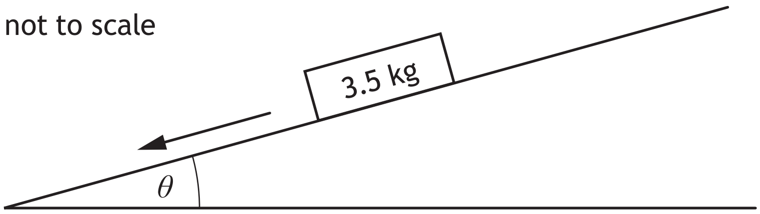
B 3.0 $m\,s^{-2}$

C 5.0 $m\,s^{-2}$

D 8.0 $m\,s^{-2}$

E 10.0 $m\,s^{-2}$.

4. A block of wood of mass 3.5 kg slides down a slope. The block of wood has a constant acceleration of 2.3 $m\,s^{-2}$ down the slope.



The force of friction acting on the block is 6.4 N.

The angle of the slope θ is

A 2.8°

B 11°

C 14°

D 25°

E 65°.

[Turn over

5. An object is released from rest at a height of 1.6 m above the ground.

The mass of the object is 0.20 kg.

The maximum speed of the object just before it hits the ground is

A $4.0\ \text{m s}^{-1}$

B $5.6\ \text{m s}^{-1}$

C $13\ \text{m s}^{-1}$

D $16\ \text{m s}^{-1}$

E $31\ \text{m s}^{-1}$.

6. A ball of mass 0.164 kg is dropped from rest and falls towards the ground.

The ball collides with the ground and rebounds upwards.

The speed of the ball just before it hits the ground is $4.85\ \text{m s}^{-1}$.

The ball is in contact with the ground for 0.180 s.

The speed of the ball immediately after it rebounds from the ground is $3.96\ \text{m s}^{-1}$.

The mean force exerted by the ball on the ground during the collision is

A 0.146 N

B 0.811 N

C 0.645 N

D 1.44 N

E 8.03 N.

7. Two samples of modelling clay, X and Y, have the same shape and mass.

Sample X is made of a softer clay than sample Y.

The samples are both released from the same height and fall towards the ground.

Both samples come to rest when they collide with the ground.

A student makes the following statements about the samples colliding with the ground.

I Sample X comes to rest in less time than sample Y.

II The mean force exerted by the ground on sample X is less than the mean force exerted by the ground on sample Y.

III The change in momentum of sample X is less than the change in momentum of sample Y.

Which of these statements is/are correct?

A I only

B II only

C I and II only

D I and III only

E II and III only

8. The Large Hadron Collider (LHC) is contained in a circular tunnel.

A technician working at the LHC measures the length of the tunnel to be 26.7 km.

Protons in the tunnel are accelerated to a speed of $0.999c$.

The length of the tunnel in the frame of reference of the protons is

A 0.844 km

B 1.19 km

C 26.7 km

D 597 km

E 844 km.

[Turn over

9. A student makes the following statements about cosmic microwave background radiation.

I Cosmic microwave background radiation provides evidence for the Big Bang theory.

II Cosmic microwave background radiation reaches the Earth from all directions.

III Measurements of the peak wavelength of cosmic microwave background radiation indicate that the average temperature of the Universe was lower in the past than it is now.

Which of these statements is/are correct?

A I only

B II only

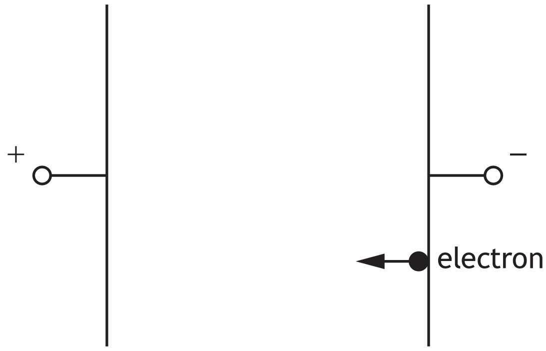
C I and II only

D II and III only

E I, II and III

10. A potential difference of 1.2 kV is applied across two parallel metal plates in a vacuum.

An electron is released from rest at the negative plate as shown.



The speed of the electron just before it reaches the positive plate is

A 1.9×10^{-16} m s^{-1}

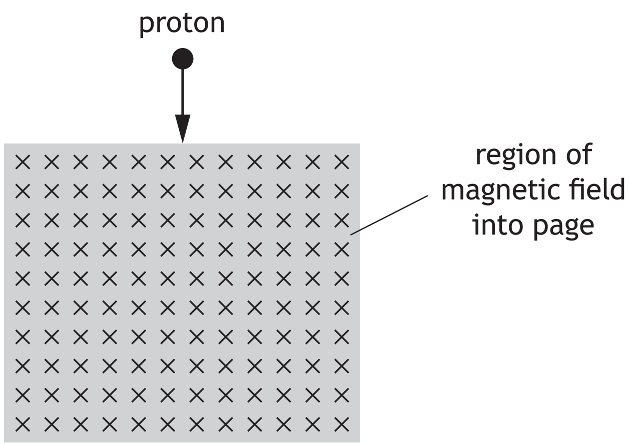
B 6.5×10^{5} m s^{-1}

C 2.1×10^{7} m s^{-1}

D 4.2×10^{11} m s^{-1}

E 4.2×10^{14} m s^{-1}.

11. A proton enters a region of magnetic field as shown.



The direction of the force exerted by the magnetic field on the proton as it enters the field is

A into the page

B out of the page

C towards the left of the page

D towards the bottom of the page

E towards the right of the page.

12. The following statement represents a nuclear reaction.

$$^{226}_{88}\mathrm{Ra} \rightarrow {}^{222}_{86}\mathrm{Rn} + \mathrm{X}$$

X represents

A an alpha particle

B a beta particle

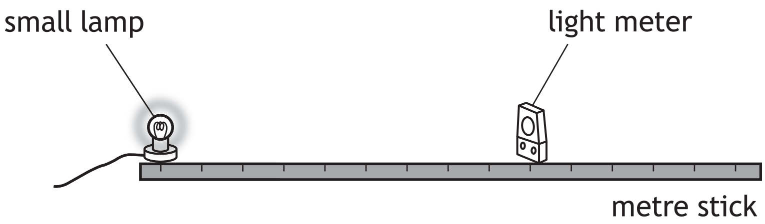
C a neutrino

D a neutron

E a proton.

[Turn over

13. A small lamp is placed 0.40 m from a light meter in a darkened room.



The irradiance of the light from the lamp is measured using the light meter.

The irradiance at this distance is 20 mW m^{-2}.

The light meter is now moved until the irradiance is 80 mW m^{2}.

The distance between the lamp and the light meter is now

A 0.04 m

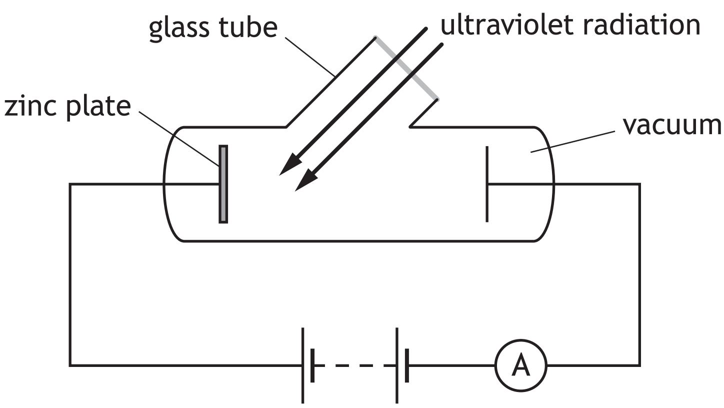
B 0.10 m

C 0.20 m

D 0.80 m

E 1.60 m.

14. A student sets up the following apparatus to investigate photoemission from a zinc plate.



The reading on the ammeter can be increased by

A replacing the ultraviolet radiation with visible light

B replacing the ultraviolet radiation with infrared radiation

C decreasing the irradiance at the zinc plate

D reversing the connections to the battery

E allowing air into the glass tube.

15. Ultraviolet radiation of wavelength 250 nm is incident on a metal surface.

The work function of the metal is 3.1×10^{-19} J.

The energy of each photon of the ultraviolet radiation is

A 1.7×10^{-40} J

B 3.1×10^{-19} J

C 4.9×10^{-19} J

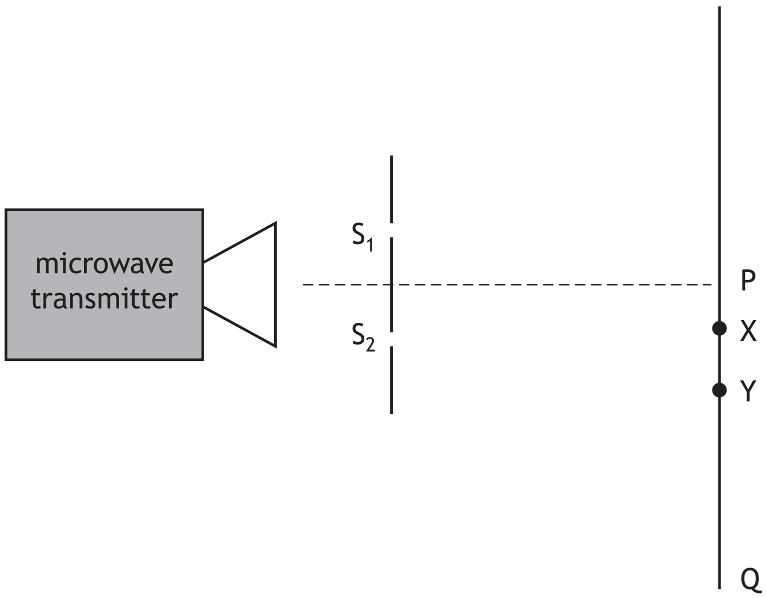
D 8.0×10^{-19} J

E 1.1×10^{-18} J.

[Turn over

16. A student sets up the apparatus shown to produce an interference pattern.

S_1 and S_2 provide coherent sources of microwave radiation.



A radiation detector is moved along the line from P to Q.

The first minimum is detected at point X.

The distance from S_1 to X is 300 mm.

The distance from S_2 to X is 250 mm.

The second minimum is detected at Y.

The path difference $S_1Y - S_2Y$ is

A 25 mm

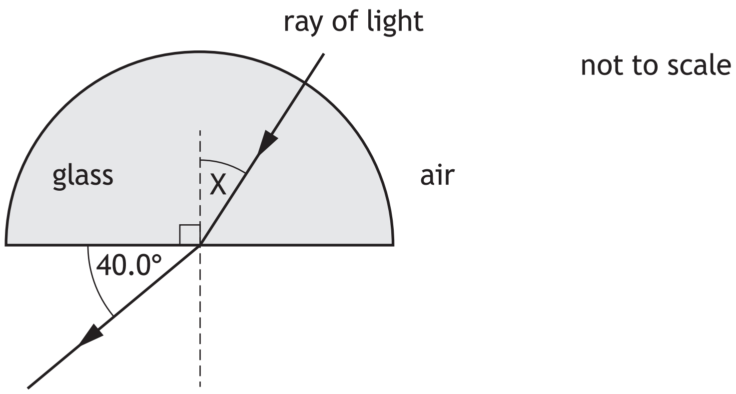
B 75 mm

C 100 mm

D 150 mm

E 250 mm.

17. A ray of monochromatic light passes through a glass block into air as shown.



The critical angle for the glass block is 37.0° for this light.

Angle X is

A 22.8°

B 27.5°

C 30.7°

D 62.5°

E 67.2°.

18. A ray of monochromatic light in air has speed c, wavelength λ, and frequency f.

The ray of light passes from air into a substance.

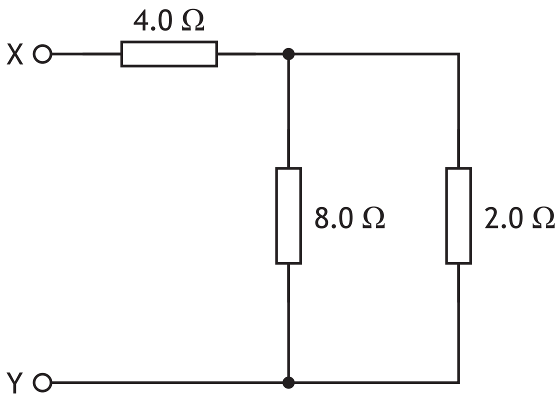
The refractive index of the substance is 2.0 for this light.

Which row in the table shows the speed, wavelength, and frequency of the light in the substance?

	Speed	Wavelength	Frequency
A	c	λ	f
B	c	2λ	$0.5f$
C	$0.5c$	2λ	f
D	$0.5c$	0.5λ	$0.5f$
E	$0.5c$	0.5λ	f

[Turn over

19. A circuit is set up as shown.



The total resistance between X and Y is

A 1.1 Ω

B 1.7 Ω

C 4.6 Ω

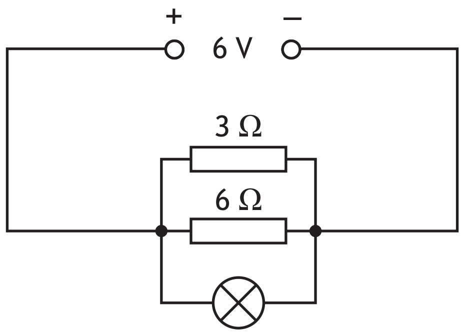
D 5.6 Ω

E 14 Ω.

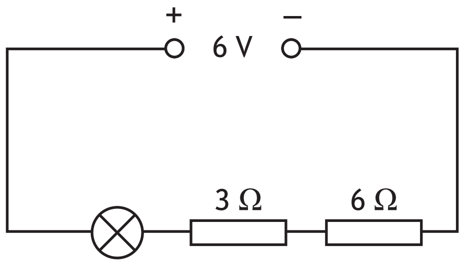
20. In the circuits shown below, the lamps are identical. The power supply has negligible internal resistance.

In which circuit is the greatest power dissipated in the lamp?

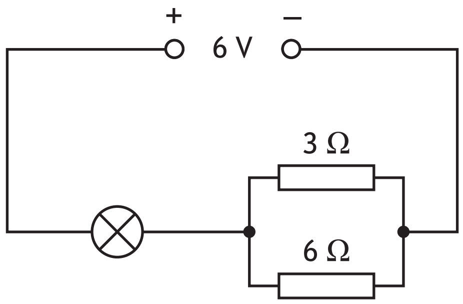
A



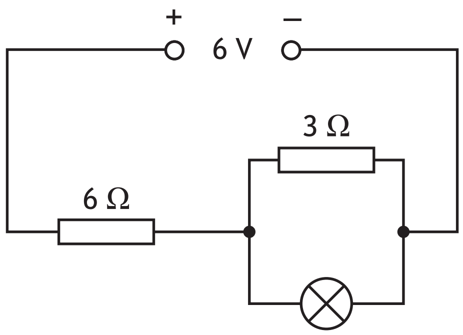
B



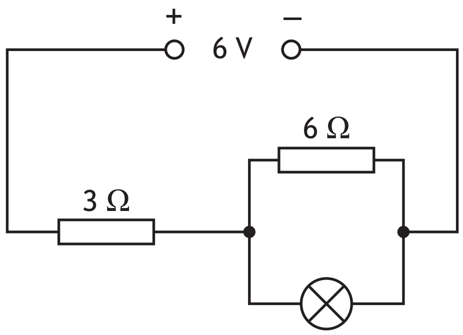
C



D

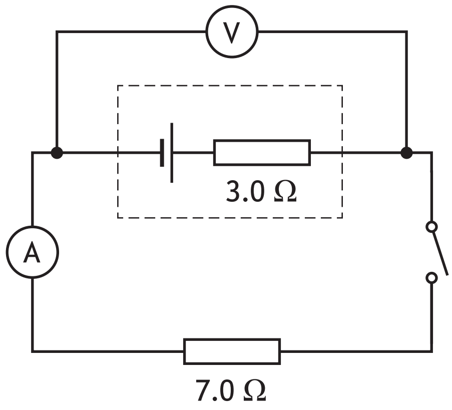


E



[Turn over

21. A 7.0 Ω resistor is connected to a cell as shown.



The internal resistance of the cell is 3.0 Ω.

The switch is now closed.

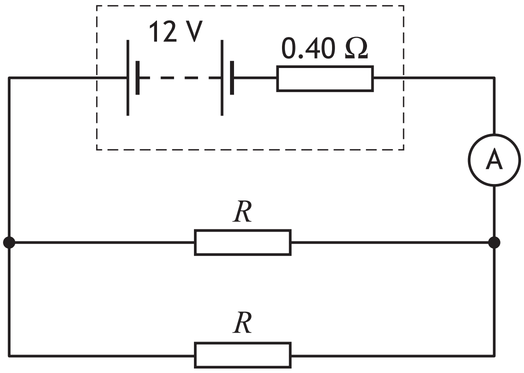
The reading on the ammeter is 0.15 A.

Which row in the table shows the EMF of the cell and the reading on the voltmeter?

	EMF (V)	Reading on voltmeter (V)
A	0.45	1.05
B	1.05	0.45
C	0.60	0.45
D	1.50	1.05
E	1.50	0.45

22. A battery has an EMF of 12 V and an internal resistance of 0.40 Ω.

Two identical resistors each of resistance R are connected to the battery as shown.



The reading on the ammeter is 4.0 A.

The resistance R is

A 0.77 Ω

B 2.6 Ω

C 3.0 Ω

D 3.4 Ω

E 5.2 Ω.

23. A student makes the following statements about red and blue LEDs.

I The gap between the valence band and the conduction band is larger for red LEDs than blue LEDs.

II Red LEDs emit photons of longer wavelength than blue LEDs.

III The potential difference across an LED determines the wavelength of the photons emitted.

Which of these statements is/are correct?

A I only

B II only

C III only

D I and II only

E I, II and III

[Turn over

24. A student measures the acceleration of a toy car down a slope.

The experiment is repeated and the following values for the acceleration are recorded.

$0.28\ \mathrm{m\,s^{-2}}$ $0.29\ \mathrm{m\,s^{-2}}$ $0.34\ \mathrm{m\,s^{-2}}$ $0.30\ \mathrm{m\,s^{-2}}$ $0.29\ \mathrm{m\,s^{-2}}$

Which row in the table shows the mean value of the acceleration and the approximate random uncertainty in the mean value of the acceleration?

	Mean value of the acceleration ($\mathrm{m\,s^{-2}}$)	Approximate random uncertainty ($\mathrm{m\,s^{-2}}$)
A	0.29	0.01
B	0.29	0.06
C	0.30	0.01
D	0.30	0.06
E	0.34	0.06

25. A black hole can be formed from a star which has become so massive it collapses under its own gravitational force.

The radius r of a black hole is calculated using the relationship

$$r = \frac{2GM}{c^2}$$

where: G is the Universal Constant of Gravitation

M is the mass of the star

c is the speed of light.

A star of mass 1.99×10^{31} kg collapses to form a black hole.

The radius of this black hole is

A 7.37×10^{3} m

B 1.47×10^{4} m

C 2.95×10^{4} m

D 8.85×10^{12} m

E 4.33×10^{15} m.

[END OF QUESTION PAPER]

Marking Instructions for each question

Question	Answer	Mark
1.	C	1
2.	A	1
3.	A	1
4.	D	1
5.	B	1
6.	E	1
7.	B	1
8.	B	1
9.	C	1
10.	C	1
11.	E	1
12.	A	1
13.	C	1
14.	D	1
15.	D	1
16.	D	1
17.	B	1
18.	E	1
19.	D	1
20.	A	1
21.	D	1
22.	E	1
23.	B	1
24.	C	1
25.	C	1

[END OF MARKING INSTRUCTIONS]

FOR OFFICIAL USE

H

National Qualifications 2025

Mark

X857/76/01

Physics Paper 2

THURSDAY, 15 MAY

10:15 AM – 12:30 PM

* X 8 5 7 7 6 0 1 *

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth

Day Month Year

Scottish candidate number

Total marks — 130

Attempt ALL questions.

You may use a calculator.

Reference may be made to the data sheet on *page 02* of this booklet and to the relationships sheet X857/76/11.

Care should be taken to give an appropriate number of significant figures in the final answers to calculations.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. Score through your rough work when you have written your final copy.

Use **blue** or **black** ink.

Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	Symbol	Value	Quantity	Symbol	Value
Speed of light in vacuum	c	3.00×10^{8} m s^{-1}	Planck's constant	h	6.63×10^{-34} J s
Magnitude of the charge on an electron	e	1.60×10^{-19} C	Mass of electron	m_e	9.11×10^{-31} kg
Universal Constant of Gravitation	G	6.67×10^{-11} m^{3} kg^{-1} s^{-2}	Mass of neutron	m_n	1.675×10^{-27} kg
Gravitational acceleration on Earth	g	9.8 m s^{-2}	Mass of proton	m_p	1.673×10^{-27} kg
Hubble's constant	H_0	2.3×10^{-18} s^{-1}	Speed of sound in air	v_{air}	3.40×10^{2} m s^{-1}

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	Refractive index	Substance	Refractive index
Diamond	2.42	Water	1.33
Crown glass	1.50	Air	1.00

SPECTRAL LINES

Element	Wavelength (nm)	Colour
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	Wavelength (nm)	Colour
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	Wavelength (nm)	Colour
Carbon dioxide	9550, 10 590	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	Density (kg m^{-3})	Melting point (K)	Boiling point (K)
Aluminium	2.70×10^{3}	933	2623
Copper	8.96×10^{3}	1357	2853
Ice	9.20×10^{2}	273	. . . .
Sea Water	1.02×10^{3}	264	377
Water	1.00×10^{3}	273	373
Air	1.29	. . . .	. . . .
Hydrogen	9.0×10^{-2}	14	20

The gas densities refer to a temperature of 273 K and a pressure of 1.01×10^{5} Pa.

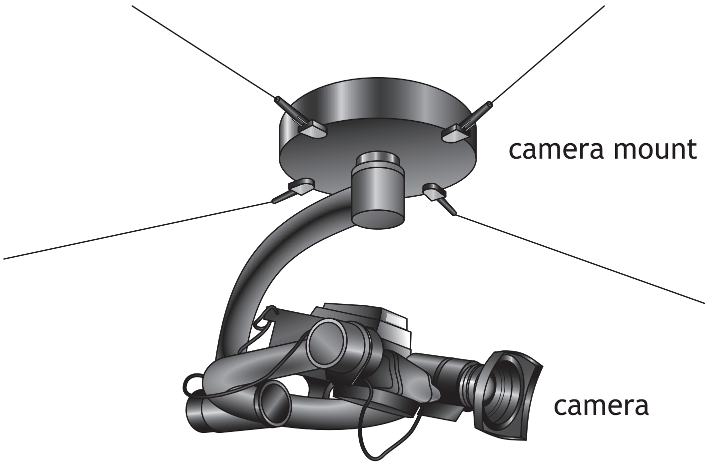
* X 8 5 7 7 6 0 1 0 2 *

DO NOT WRITE IN THIS MARGIN

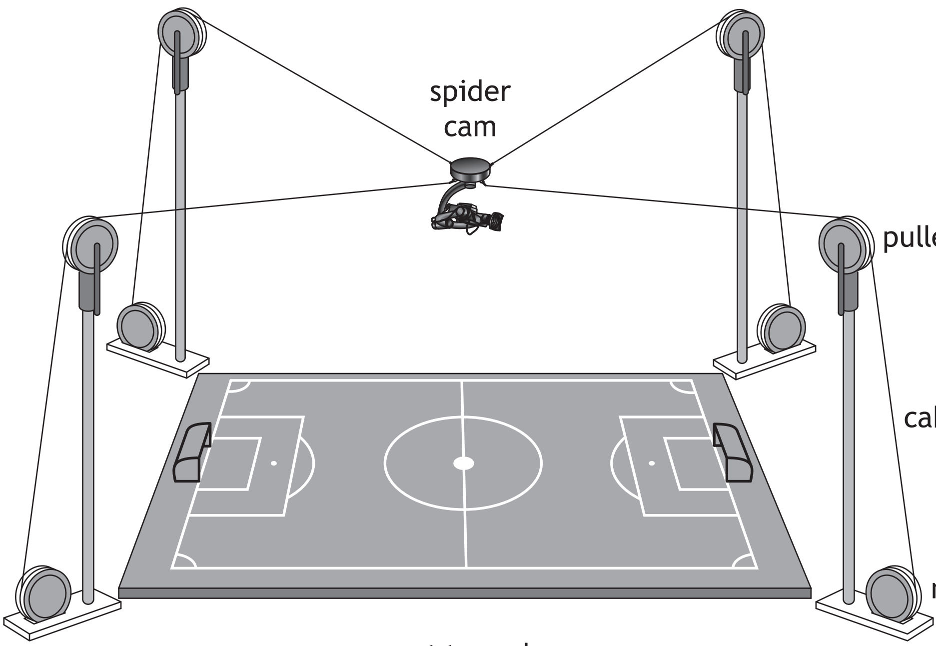
Total marks — 130

Attempt ALL questions

1. A television company uses a 'spider cam' to film a sporting event. A 'spider cam' is made up of a camera mount that carries a camera.



The camera mount is suspended from four cables. The length of the cables can be changed using a motor attached to each cable. This allows the height and position of the camera over the pitch to be changed.



not to scale

MARKS DO NOT WRITE IN THIS MARGIN

1. **(continued)**

The camera mount and camera have a maximum acceleration of 1.45 $m\,s^{-2}$ and a maximum velocity of 8.86 $m\,s^{-1}$.

(a) (i) State what is meant by an *acceleration of 1.45* $m\,s^{-2}$. **1**

(ii) Calculate the distance travelled by the camera mount and camera as they accelerate at 1.45 $m\,s^{-2}$ from rest to the maximum velocity. **3**

Space for working and answer

[Turn over

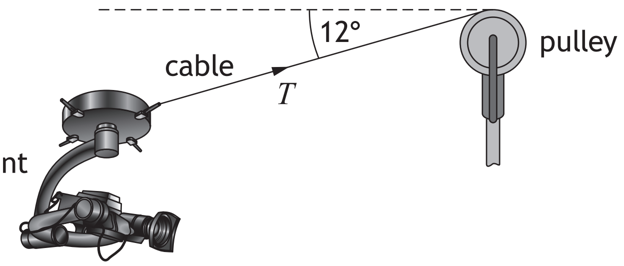
MARKS DO NOT WRITE IN THIS MARGIN

1. **(continued)**

(b) During a test of the system, the camera mount and camera are held stationary at a constant maximum height above the centre of the pitch.

The total mass of the camera mount and camera is 31 kg.

At the maximum height, the angle that **each** cable makes to the horizontal is 12°.



not to scale

Determine the tension T in each of the four cables. **4**

Space for working and answer

* X 8 5 7 7 6 0 1 0 6 *

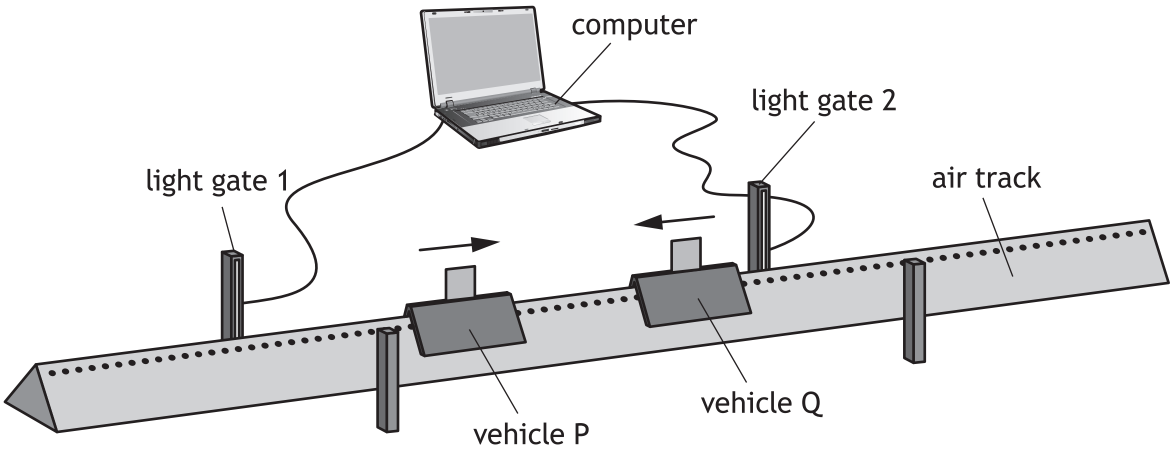
Marking instructions for each question

Question			Expected response	Max mark	Additional guidance
1.	(a)	(i)	The velocity increases by 1.45 m s^{-1} every second	1	Accept: Speed increases by 1.45 m s^{-1} every second. Velocity/speed changes by 1.45 m s^{-1} every second. Rate of change of velocity/speed is 1.45 m s^{-1} every second.
		(ii)	$v^2 = u^2 + 2as$ (1) $8.86^2 = 0^2 + (2 \times 1.45 \times s)$ (1) $s = 27.1$ m (1)	3	Accept: 27, 27.07, 27.069 Alternative methods using two relationships: 1 mark for both relationships. 1 mark for both substitutions. 1 mark for final answer.

Question			Expected response	Max mark	Additional guidance
1.	(b)		$(W = mg)$ $W = 31 \times 9.8$ (1) Each cable supports $\frac{31 \times 9.8}{4}$ (1) $T \sin 12 = \frac{31 \times 9.8}{4}$ (1) $T = 370$ N (1)	4	Accept: 400, 365, 365.3 1 mark for quartering mass/weight/tension/force anywhere. Alternative methods: Each cable supports $\frac{31}{4}$ (1) $(W = mg)$ $W = \frac{31}{4} \times 9.8$ (1) $T \sin 12 = \frac{31}{4} \times 9.8$ (1) $T = 370$ N (1) **OR** $(W = mg)$ $W = 31 \times 9.8$ (1) $T \sin 12 = 31 \times 9.8$ (1) $\left(T = \frac{31 \times 9.8}{\sin 12}\right)$ Tension in each cable $\frac{\left(\frac{31 \times 9.8}{\sin 12}\right)}{4}$ (1) $T = 370$ N (1) Accept methods using $\cos 78$ Do not accept: $F = ma$ $F = mg \sin \theta$ Max 1 mark for quartering.

MARKS DO NOT WRITE IN THIS MARGIN

2. A technician sets up the apparatus shown to demonstrate the law of conservation of linear momentum.



The mass of vehicle P is 0.18 kg and the mass of vehicle Q is 0.24 kg.

The effects of friction are negligible.

In one experiment, vehicle P is moving at $1.20\ m\,s^{-1}$ to the right and vehicle Q is moving at $0.64\ m\,s^{-1}$ to the left.

The vehicles collide and move off separately.

Vehicle P rebounds with a velocity of $0.76\ m\,s^{-1}$ to the left.

(a) State the law of conservation of linear momentum. **1**

(b) Calculate the velocity of vehicle Q immediately after the collision. **3**

Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

2. (continued)

(c) Show by calculation whether the collision is elastic or inelastic. **4**

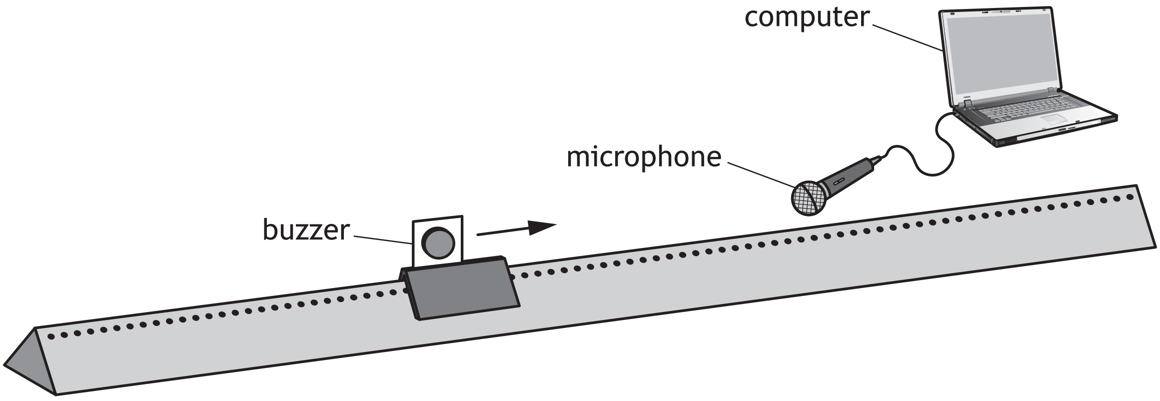
Space for working and answer

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

2. (continued)

(d) The technician now sets up the linear air track to demonstrate the Doppler effect.



The vehicle is fitted with a buzzer. A microphone is connected to a computer.

The vehicle is held stationary and the buzzer is switched on.

The buzzer emits sound with a frequency of 845 Hz.

The vehicle now travels at a constant speed towards the microphone.

The frequency of sound measured by the computer is 849 Hz.

(i) Calculate the speed of the vehicle along the linear air track. **3**

Space for working and answer

X857760110

MARKS DO NOT WRITE IN THIS MARGIN

2. (d) (continued)

(ii) Explain, in terms of wavefronts, why the frequency of the sound detected by the microphone is greater than the frequency of the sound emitted by the buzzer.

You may wish to use a diagram. **1**

(iii) A student standing at the end of the linear air track, near the microphone, states that they did not hear this small change in frequency.

Using the same apparatus, describe one way the Doppler effect could be made more obvious for the student. **1**

[Turn over

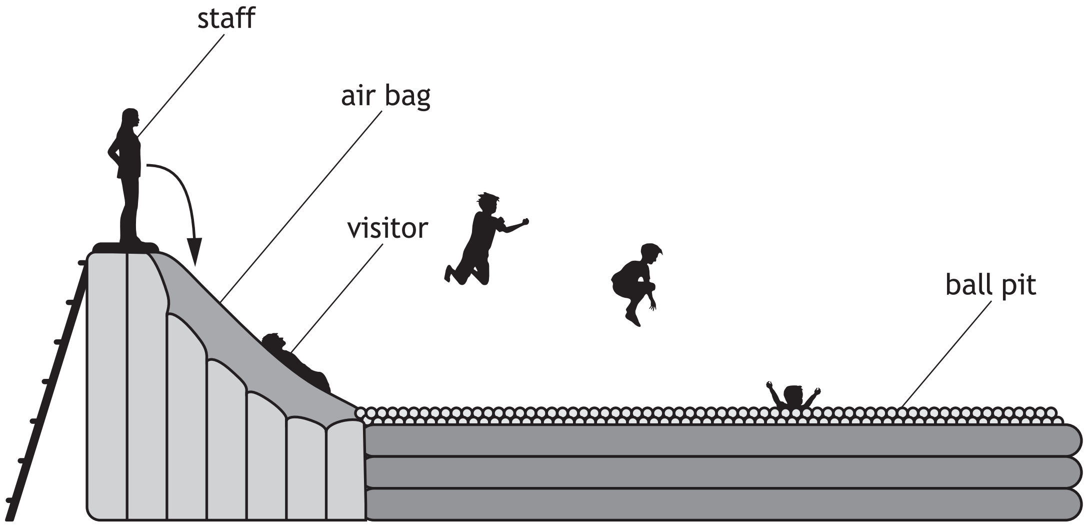
Question			Expected response	Max mark	Additional guidance
2.	(a)		Total momentum before (a collision) is equal to the total momentum after (a collision) in the absence of external forces.	1	Do not accept: TMB = TMA. 'An isolated system' is equivalent to the absence of external forces.
	(b)		(total momentum before = total momentum after) $m_P u_P + m_Q u_Q = m_P v_P + m_Q v_Q$ (1) $(0.18 \times 1.20) + (0.24 \times -0.64) = (0.18 \times -0.76) + (0.24 \times v_Q)$ (1) $v_Q = 0.83 \text{ m s}^{-1}$ (1)	3	Accept 0.8, 0.830, 0.8300 Equating the total momenta before and after. (1) All substitutions. (1) Final answer. (1) If a direction is stated it must be 'to the right' otherwise MAX 2 marks.
	(c)		$E_k = \frac{1}{2}mv^2$ *before* $E_{k_{before}} = \left(\frac{1}{2} \times 0.18 \times 1.20^2\right) + \left(\frac{1}{2} \times 0.24 \times 0.64^2\right)$ $E_{k_{before}} = 0.18 \text{ J}$ *after* $E_{k_{after}} = \left(\frac{1}{2} \times 0.18 \times 0.76^2\right) + \left(\frac{1}{2} \times 0.24 \times 0.83^2\right)$ $E_{k_{after}} = 0.13 \text{ J}$ The collision is inelastic.	4	Or consistent with (b). 1 mark for relationship anywhere. 1 mark for **all** substitutions. 1 mark for **both** total kinetic Energies. 1 mark for correct final statement. Suspend significant figure rule for calculated values of total kinetic energies in this question. Final statement mark only available if calculation for total E_k is attempted.

Question			Expected response	Max mark	Additional guidance
2.	(d)	(i)	$f_o = f_s\left(\frac{v}{v \pm v_s}\right)$ (1) $849 = 845 \times \left(\frac{3.40 \times 10^2}{3.40 \times 10^2 - v_s}\right)$ (1) $v_s = 1.60\ \text{m s}^{-1}$ (1)	3	Accept: 1.6, 1.602, 1.6019 Accept: $f_o = f_s\left(\frac{v}{v - v_s}\right)$
		(ii)	Statement that there are more wavefronts per second (arriving at the microphone). **OR** The wavefronts (arriving at the microphone) are closer together. **OR** Diagram showing wavefronts closer together ahead of the vehicle and further apart behind it. Or any similar response.	1	Look for reference to wavefronts/ wavelengths/waves/crests first, otherwise 0 marks. The wavefronts in front of the vehicle/buzzer are closer together. Do not accept: Any answer that implies that the frequency/wavelength of the sound produced by the buzzer itself is changing. **OR** wavelengths are decreas<u>ing</u> on its own.
		(iii)	Move the vehicle/buzzer with a greater speed (towards the student). **OR** Student stands at the middle of the air track (so the vehicle passes the student).	1	Do not accept: Moving the microphone. **OR** Changing the frequency of the buzzer. **OR** Visual interpretations e.g. use computer software.

MARKS DO NOT WRITE IN THIS MARGIN

3. An activity at an inflatable park involves a visitor lying on a large air bag.

A member of staff jumps down onto the air bag. This causes the visitor to 'fly' through the air and land in a ball pit.



Using your knowledge of physics, comment on the principles of how the activity works. **3**

MARKS DO NOT WRITE IN THIS MARGIN

4. The Theory of Special Relativity states that the measurement of time for an observer moving at high speed is changed relative to a stationary observer.

(a) State the name of this effect. **1**

(b) A spacecraft is travelling at a constant speed of 2.29×10^8 m s^{-1} relative to a nearby planet.

A technician on the spacecraft measures a time interval to be 245 s.

Calculate the time interval as measured by an observer on the nearby planet. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

4. (continued)

(c) A student makes the following statement regarding special relativity:

'Train drivers who travel at speeds of $80\ \text{m s}^{-1}$ over large distances will have to reset their watches frequently, as they spend so many hours travelling at high speeds.'

State whether the student is correct.

Justify your answer. **2**

[Turn over

Question			Expected response	Max mark	Additional guidance
4.	(a)		Time dilation	1	
	(b)		$t' = \dfrac{t}{\sqrt{1-\left(\dfrac{v}{c}\right)^2}}$ (1) $t' = \dfrac{245}{\sqrt{1-\left(\dfrac{2.29\times10^8}{3.00\times10^8}\right)^2}}$ (1) $t' = 379\text{ s}$ (1)	3	Accept: 380, 379.3, 379.25 Accept: $t' = \dfrac{245}{\sqrt{1-\left(\dfrac{2.29}{3.00}\right)^2}}$
	(c)		The student is incorrect. **(1)** The train does not travel at relativistic speeds. **(1)**	2	**JUSTIFY** Accept: Time dilation is negligible/ insignificant. **OR** No time dilation takes place. Accept: The train is not travelling at a speed close to the speed of light. The effects of special relativity only become significant when the speed $\geq 0.1c$. The train will not reach speeds of this magnitude. Can be justified by calculation. Allow for responses that identify that time dilation does take place but is insignificant, so statement is correct in one aspect.

MARKS DO NOT WRITE IN THIS MARGIN

5. The table contains information about three stars in the Milky Way galaxy.

Star	Surface temperature (K)	Radius (m)	Mass (kg)
star 1	2290	8.14×10^{7}	1.77×10^{29}
Sun	5800	6.96×10^{8}	1.99×10^{30}
star 2	210 000	5.57×10^{8}	5.69×10^{31}

(a) Compare the surface temperature of star 2 with the surface temperature of star 1 in terms of orders of magnitude. **2**

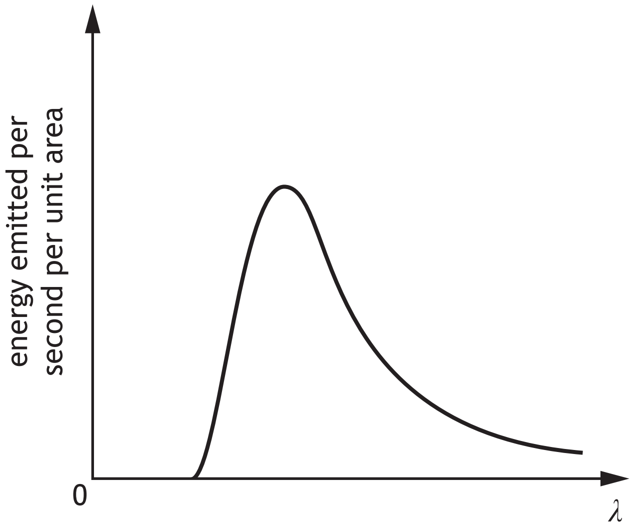
Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

5. **(continued)**

(b) Stars emit radiation with a range of wavelengths.

The graph shows how the energy emitted per second per unit area varies with the wavelength λ of emitted radiation from the Sun.



(i) On the graph above, add a line to show how the energy emitted per second per unit area varies with the wavelength of emitted radiation λ from star 2. **2**

(An additional graph, if required, can be found on *page 51*.)

(ii) Explain why star 1 appears more red than the Sun. **1**

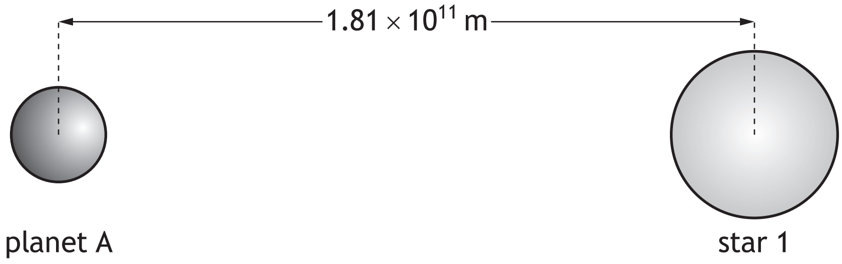
[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

5. (continued)

(c) (i) Exoplanets are planets that are outside our Solar System. Star 1 is orbited by a number of exoplanets.

One exoplanet, planet A, has a mean orbital radius of 1.81×10^{11} m and a mass of 6.09×10^{24} kg.



not to scale

The mass of star 1 is 1.77×10^{29} kg.

Calculate the gravitational force between planet A and star 1. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

5. (c) (continued)

(ii) A second exoplanet, planet B, has three times the mass of planet A.

The mean orbital radius of planet B is double the mean orbital radius of planet A.

State how the gravitational force of attraction between planet B and star 1 compares to the gravitational force of attraction between planet A and star 1.

Justify your answer. **3**

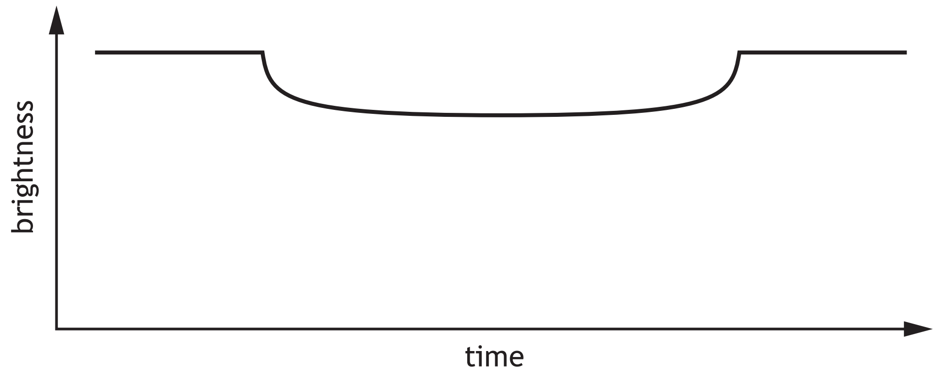
(iii) The exoplanets orbiting star 1 were discovered using the 'transit method'. The brightness of the light from the star is recorded. A dip in brightness is recorded during the time it takes the exoplanet to pass between the star and an observer.

The table gives information about the exoplanets, planet A and planet B.

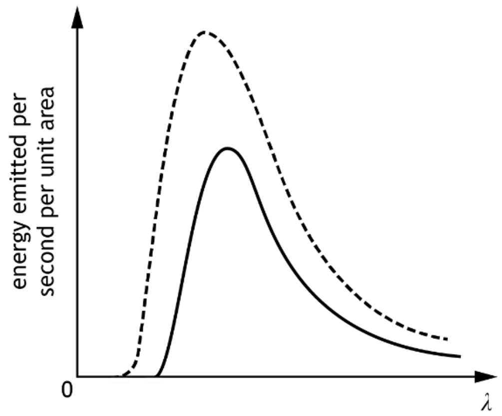
Exoplanet	Radius of exoplanet (m)	Mean orbital radius (m)	Orbital period (s)
planet A	7.1×10^6	1.81×10^{11}	1.4×10^8
planet B	5.0×10^6	3.62×10^{11}	4.0×10^8

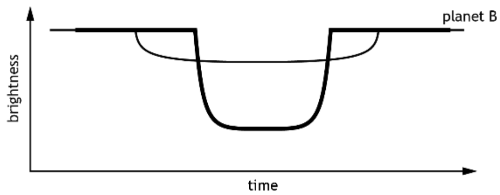
The graph shows how the brightness varies with time as planet B passes between the star and the observer.

Add a line to the graph to show how the brightness varies with time as planet A passes between the star and the observer. **2**



(An additional graph, if required, can be found on *page 51*.)

Question			Expected response	Max mark	Additional guidance
5.	(a)		$\left(\dfrac{210000}{2290}\right)=92$ (1) (Surface temperature of Star 2 is) 2 (orders of magnitude) greater. **OR** Surface temperature of Star 1 is 2 orders of magnitude smaller. **(1)**	**2**	Accept: $\left(\dfrac{2.1\times10^5}{2.29\times10^3}\right)=92$ **OR** $\left(\dfrac{10^5}{10^3}\right)=10^2$ (1) Accept: '2 greater' on its own. (2) Do not accept: '2 <u>times</u> greater' on its own. (0) Care should be taken where candidates answer by the reciprocal method - 2 marks are still available. $\left(\dfrac{2.29\times10^3}{2.1\times10^5}\right)=0.011$ (1) Comparison statement. (1)
	(b)	(i)		**2**	Peak wavelength less. (1) Line added should always be above original line. (1)
		(ii)	Lower (surface) temperature. **OR** (The radiation from star 1) has a longer <u>peak</u> wavelength (than the Sun).	**1**	Accept: Less hot or cooler. Accept: A <u>peak</u> wavelength closer to red.

Question			Expected response	Max mark	Additional guidance
5.	(c)	(i)	$F = G\frac{m_1 m_2}{r^2}$ (1) $F = 6.67\times10^{-11}\times\frac{6.09\times10^{24}\times1.77\times10^{29}}{(1.81\times10^{11})^2}$ (1) $F = 2.19\times10^{21}$ N (1)	3	Accept: 2.2, 2.195, 2.1946
		(ii)	Force is less/ $\frac{3}{4}$ **(1)** Three times the mass gives three times the force. **(1)** Doubling the distance gives quarter of the force. **(1)**	3	**JUSTIFY** Look for this statement first - if incorrect or missing then 0 marks. Correct statement. (1) Do not accept: decrease by $\frac{3}{4}$ Numerator three times bigger. (1) Denominator four times bigger. (1) Can justify by calculation Correct substitution. (1) Correct numerical final answer (1) $(1.65\times10^{21}\text{ N})$ Accept: 1.6, 1.646, 1.6460
		(iii)		2	**INDEPENDENT MARKS** Drop from same initial brightness is greater. (1) Transit time is shorter. (1) Accept "double or multiple dips"; however if multiple dips are shown, transit times and dips must look consistent.

MARKS DO NOT WRITE IN THIS MARGIN

6. (a) The following statement represents a nuclear decay in which an alpha particle is emitted.

$$^{241}_{95}\text{Am} \rightarrow {}^{237}_{93}\text{Np} + {}^{4}_{2}\text{He}$$

(i) Explain why energy is released in this decay. **1**

(ii) The mass of the particles involved in this decay are shown in the table.

Particle	Mass (kg)
$^{241}_{95}\text{Am}$	4.0028×10^{-25}
$^{237}_{93}\text{Np}$	3.9363×10^{-25}
$^{4}_{2}\text{He}$	6.6447×10^{-27}

Determine the energy released in this decay. **4**

Space for working and answer

* X 8 5 7 7 6 0 1 2 0 *

MARKS DO NOT WRITE IN THIS MARGIN

6. (continued)

(b) Carbon-14 undergoes nuclear decay by releasing a beta particle ${}^{0}_{-1}e$.

The following statement represents this decay.

$${}^{14}_{6}\mathrm{C} \rightarrow \mathrm{X} + {}^{0}_{-1}e$$

(i) Identify the element represented by X. **1**

(ii) An explanation for beta decay is that a neutron decays into a proton and an electron. The electron is emitted as a beta particle.

However, studies of beta decay show that the mass-energy equivalence of carbon-14 is greater than the total mass-energy equivalence of element X and the beta particle.

State the conclusion that particle physicists have drawn from this evidence about what happens during beta decay. **1**

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

6. (continued)

(c) Quarks are fundamental particles that do not exist by themselves but make up other particles called hadrons.

There are six types of quark: up, down, charm, strange, top, and bottom.

(i) Explain what is meant by the term *fundamental particle*. **1**

(ii) Hadrons can be further classified according to the number of quarks they contain.

State the type of particles that contain three quarks. **1**

X857760122

MARKS DO NOT WRITE IN THIS MARGIN

6. (c) (continued)

(iii) Scientists have discovered a type of particle called pentaquarks.

Pentaquarks contain 4 quarks and 1 antiquark.

Recently scientists at CERN reported the discovery of a pentaquark containing 1 up, 1 down, 1 strange, 1 charm, and 1 anticharm quark.

The table contains information about the charge of some of the quarks that make up this pentaquark.

Type of quark	Charge
Up	$+\frac{2}{3}e$
Down	$-\frac{1}{3}e$
Charm	$+\frac{2}{3}e$

The overall charge on the pentaquark is 0.

Determine the charge of a strange quark. **2**

Space for working and answer

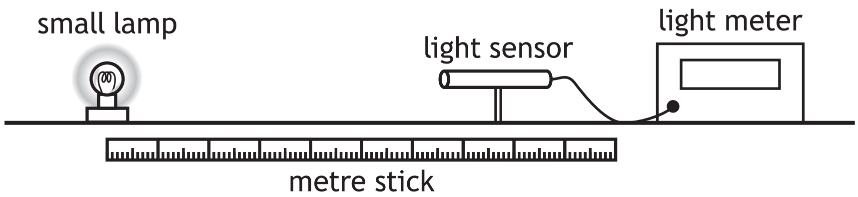
[Turn over

Question			Expected response	Max mark	Additional guidance
6.	(a)	(i)	(Some) mass (is lost and) converted to energy.	**1**	There must be an indication of mass being converted (or an equivalent term) to energy eg transformed, becomes, changed to. Do not accept: transferred. Mass is lost on its own (0) Mass defect is wrong physics (0)
		(ii)	Mass before $= 4.0028 \times 10^{-25}$ (kg) Mass after $= 3.9363 \times 10^{-25} + 6.6447 \times 10^{-27}$ Mass after $= 4.002747 \times 10^{-25}$ (kg) Mass lost $= 5.3 \times 10^{-30}$ (kg) (1) $E = mc^2$ (1) $E = 5.3 \times 10^{-30} \times (3.00 \times 10^8)^2$ (1) $E = 4.77 \times 10^{-13}$ J (1)	**4**	Accept: 4.8, 4.770, 4.7700 Check for correct substitutions of values in calculation of mass lost. If values are incorrect, maximum 1 mark for relationship, even if final answer is correct. $E = mc^2$ anywhere, 1 mark. If masses before and after not substituted to full significant figures as given in the table, then maximum 1 mark for relationship. Ignore inappropriate reference to mass defect. Arithmetic mistake can be carried forward through the response.
	(b)	(i)	Nitrogen	**1**	Accept: N or $^{14}_{7}N$
		(ii)	An (anti)neutrino is emitted. **OR** An extra particle is emitted.	**1**	Accept: Beta decay is evidence for (the existence of) the neutrino.

Question			Expected response	Max mark	Additional guidance
6.	(c)	(i)	Fundamental particles are not composed of other particles.	1	Accept: Fundamental particles cannot be 'broken down' into other/smaller particles. **OR** Fundamental particles cannot be 'broken down' any further.
		(ii)	Baryon(s)	1	
		(iii)	$+\frac{2}{3}(e)-\frac{1}{3}(e)+\left(\frac{2}{3}(e)-\frac{2}{3}(e)\right)+s=0$ (1) $s=-\frac{1}{3}e$ (1) $\left(+\frac{2}{3}(e)\right)+\left(-\frac{1}{3}(e)\right)+\left[\left(+\frac{2}{3}(e)\right)+\left(-\frac{2}{3}(e)\right)\right]+s=0$ (1) $s=-\frac{1}{3}e$ (1)	2	Accept: 5.33×10^{-20} C $-\frac{1}{3}$ on its own, maximum 1 mark. Allow imprecise working leading to a correct final answer for this question.

MARKS DO NOT WRITE IN THIS MARGIN

7. A student sets up an experiment, in a darkened room, to investigate the relationship between irradiance I and distance d from a point source of light. The apparatus used is shown.



The distance between the lamp and the light sensor is measured with a metre stick. The irradiance is measured with a light meter.

The results obtained are shown in the table.

d (m)	0.200	0.400	0.600	0.800
I ($W\,m^{-2}$)	198.4	49.6	22.0	12.4

(a) State what is meant by the term *irradiance*. **1**

(b) Use **all** the data to establish the relationship between irradiance I and distance d. **3**

Space for working and answer

* X 8 5 7 7 6 0 1 2 4 *

MARKS | DO NOT WRITE IN THIS MARGIN

7. (continued)

(c) Other than repeating each measurement and calculating the mean, suggest **two** improvements that could be made to the student's experimental procedure. **2**

(d) A second student carries out the experiment using a laser instead of a lamp.

(i) The laser beam is initially shone onto the light sensor from a distance of 0.20 m.

The beam produces a uniformly lit circle of diameter 1.00×10^{-3} m on the light sensor.

The irradiance of the circle of light is 1.51×10^{3} W m^{-2}.

Determine the power of the laser beam. **4**

Space for working and answer

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

7. (d) (continued)

(ii) The student moves the laser to a distance of 0.40 m from the sensor.

The reading on the light meter does not change.

Suggest why the reading does not change. **1**

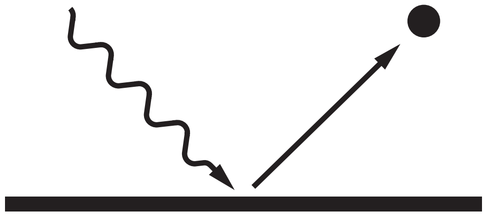
Question			Expected response	Max mark	Additional guidance
7.	(a)		The power per unit area (incident on a surface).	1	Accept: power per square metre. power per metre squared. power per m^2. Do not accept: watts per square metre.
	(b)		$\left.\begin{array}{r} 198.4\times0.200^2=7.94 \\ 49.6\times0.400^2=7.94 \\ 22.0\times0.600^2=7.92 \\ 12.4\times0.800^2=7.94 \end{array}\right\}$ (2) statement of $I\times d^2=\text{constant}$ **OR** $I\propto\frac{1}{d^2}$ (1)	3	If only 3 sets of data used correctly then maximum 2 marks. If only 2 sets of data used correctly then maximum 1 mark (for relationship). If only 1 set of data used correctly, award 0 marks. Must be clear how the candidate has used the data to obtain the relationship. Suspend significant figure rule for calculated values of constant in this question. Accept: $I\times d^2=7.9$ Unit is not required but if stated needs to be correct. In this case watts, W. The 'statement' mark is only available if consistent with the calculations shown. $I_1d_1^2=I_2d_2^2$ is insufficient on its own for statement of relationship. $I\times d^2=k$ is insufficient on its own for statement of relationship. Graphical method: Graph drawn correctly. (1) Line of best fit through origin. (1) Statement of relationship. (1) A sketch graph is not acceptable.

Question			Expected response	Max mark	Additional guidance
7.	(c)		Any two from: Smaller lamp / use point source. Black cloth on bench / wear black clothing. Greater range of distances. Smaller increments of distance. Account for background light level eg Subtract background light level, Tare/zero the light meter.	2	Do not accept: 'repeat measurements and calculate the mean'. Do not accept: do it in a darkened room. **OR** any suggestion about making the room darker. ± rule applies for surplus responses (GMP 21).
	(d)	(i)	$\left(r = 5.00\times10^{-4}\right)$ $(A = \pi r^2)$ $A = \pi\times(5.00\times10^{-4})^2$ (1) $I = \frac{P}{A}$ (1) $1.51\times10^3 = \frac{P}{\pi\times(5.00\times10^{-4})^2}$ (1) $P = 1.19\times10^{-3}$ W (1)	4	Accept: 1.2, 1.186, 1.1860 The use of 3.14 is acceptable for π. For use of 3.14, accept: P = 1.185, 1.1854 $I = \frac{P}{A}$ anywhere, 1 mark. If no attempt to calculate area, maximum 1 mark for irradiance relationship.
		(ii)	Laser is not a point source. **OR** Light from the laser does not conform to the inverse square law. **OR** Laser beam does not diverge.	1	Accept: The beam of light does not spread out. **OR** The beam of light covers same area. Do not accept: 'irradiance doesn't change with distance' on its own.

MARKS DO NOT WRITE IN THIS MARGIN

8. Radiation of frequency 1.30×10^{15} Hz from an ultraviolet lamp is incident on a clean metal plate.

This causes electrons to be emitted from the surface of the metal plate.



This is an example of the photoelectric effect.

(a) Explain why the photoelectric effect provides evidence supporting the particle model of light. **1**

(b) The work function of the metal plate is 5.89×10^{-19} J.

(i) State what is meant by the term *work function*. **1**

(ii) Calculate the maximum kinetic energy of an electron emitted from the surface of the metal plate. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

8. (b) (continued)

(iii) The ultraviolet lamp is now moved further away from the metal plate. This reduces the irradiance of the ultraviolet radiation incident on the metal plate.

State what effect, if any, this has on the maximum kinetic energy of an electron emitted from the surface of the metal plate.

You must justify your answer. **2**

[Turn over

Question			Expected response	Max mark	Additional guidance
8.	(a)		Each photon has a fixed/discrete amount of energy. **OR** Each photon removes one electron.	**1**	Some indication of quantisation of energy.
	(b)	(i)	The minimum energy required for (photo)electron(s) to be emitted/ejected.	**1**	Accept: The minimum energy required for photoemission (of electrons). Accept: least/lowest/smallest. Do not accept: minimum energy of light without mention of photon.
		(ii)	$E_k = hf - hf_0$ (1) $E_k = (6.63\times10^{-34}\times1.30\times10^{15}) - 5.89\times10^{-19}$ (1) $E_k = 2.73\times10^{-19}$ J (1)	**3**	Accept: 2.7, 2.729, 2.7290 Alternative method: $E = hf$ (1) $E = 6.63\times10^{-34}\times1.30\times10^{15}$ $E_k = (6.63\times10^{-34}\times1.30\times10^{15}) - 5.89\times10^{-19}$ (1) $E_k = 2.73\times10^{-19}$ J (1) $E = hf$ on its own (0) marks.
		(iii)	No effect (on the maximum kinetic energy). **(1)** Each photon incident on the metal plate has the same energy as before. **(1)**	**2**	**MUST JUSTIFY** Accept: no change (to the maximum kinetic energy). Accept: $E = hf$ is unchanged.

MARKS DO NOT WRITE IN THIS MARGIN

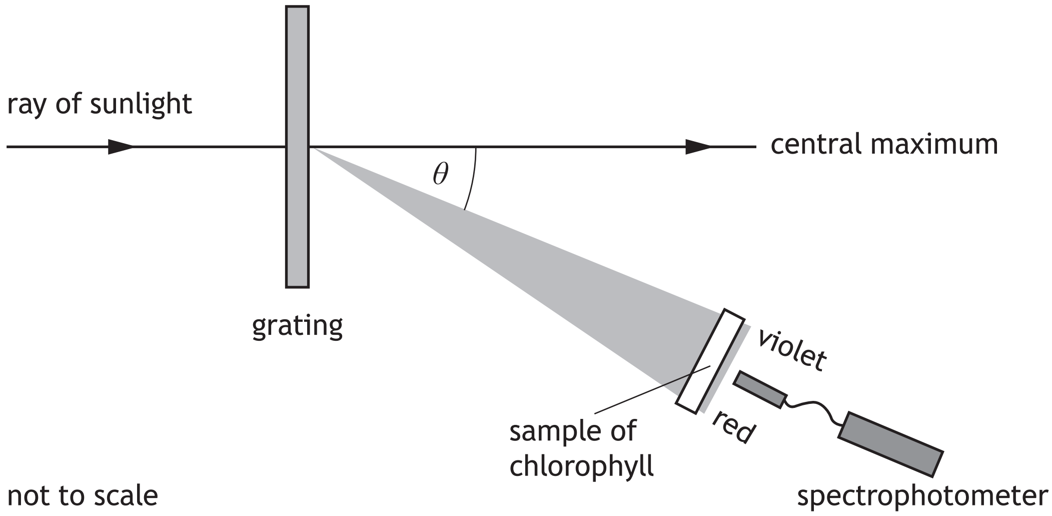
9. A student studies the effect of different wavelengths of light on a sample of chlorophyll.

Chlorophyll is a green pigment, present in all green plants, which is responsible for the absorption of light to provide energy for photosynthesis.

The student sets up the apparatus shown, using a grating with 1000 lines per millimetre to produce an interference pattern.

The interference pattern consists of a central white maximum and a series of spectra on either side of the central maximum.

The student uses the first order spectrum to study the absorption of different wavelengths of light by chlorophyll. The percentage absorption of the different wavelengths of light is measured using a spectrophotometer.



(a) Explain why the central maximum is white. **2**

MARKS DO NOT WRITE IN THIS MARGIN

9. (continued)

(b) The wavelength of light at the violet end of the first order spectrum is 412 nm.

Calculate the angle θ between the central maximum and the violet end of the spectrum. **3**

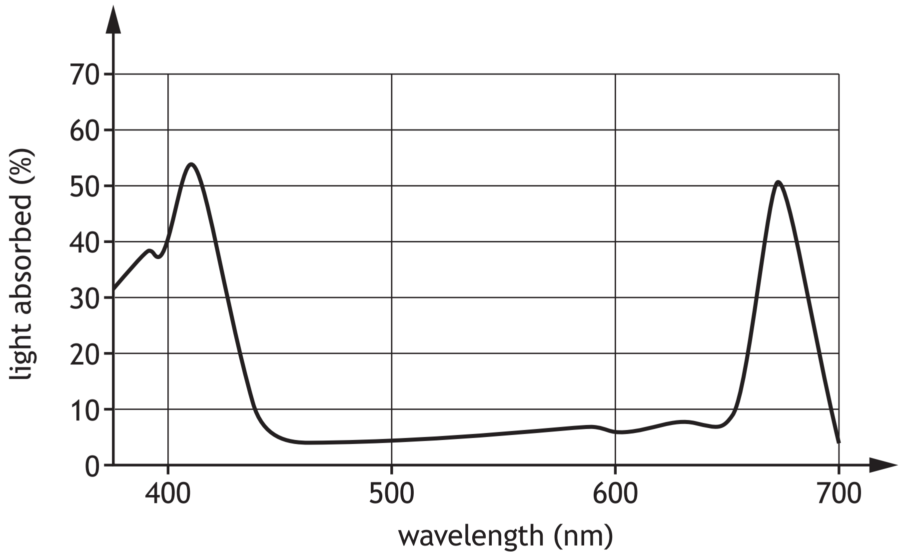
Space for working and answer

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

9. (continued)

(c) The graph shows how the percentage of light absorbed by the chlorophyll varies with wavelength of light.



Using information from the graph, suggest why the light passing through the chlorophyll sample appears green. **2**

MARKS DO NOT WRITE IN THIS MARGIN

9. (continued)

(d) Another student suggests using a grating with 250 lines per millimetre. The student claims that this will allow them to more accurately determine which wavelengths of light are absorbed by the chlorophyll.

Explain why the student's suggestion is incorrect. **2**

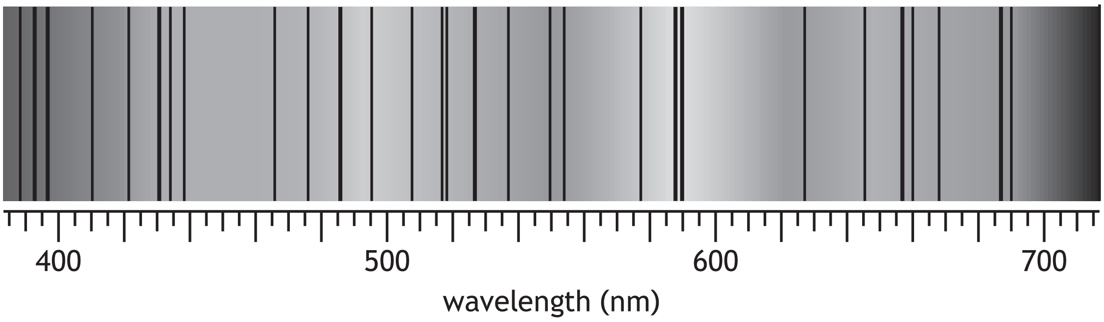
[Turn over

Question			Expected response	Max mark	Additional guidance
9.	(a)		Path difference (at the central maximum) is zero for each wavelength. **(1)** All wavelengths combine (to give white light). **OR** Constructive interference occurs for each wavelength. **(1)**	2	**INDEPENDENT MARKS** Accept: Path difference (at the central maximum) is the same for all wavelengths. Accept: frequency/colour for wavelength, for this question.
	(b)		$d\sin\theta = m\lambda$ (1) $\frac{1}{1000000}\times\sin\theta = 1\times 412\times 10^{-9}$ (1) $\theta = 24.3°$ (1)	3	Accept: 24, 24.33, 24.331 Accept: $d\sin\theta = m\lambda$ (1) $\frac{1\times 10^{-3}}{1000}\times\sin\theta = 1\times 412\times 10^{-9}$ (1) $\theta = 24.3°$ (1)
	(c)		Greater (%) absorption at red and blue/violet ends of the spectrum. **(1)** Smaller (%) absorption of green light. **(1)**	2	**INDEPENDENT MARKS** Smaller (%) transmission at red and blue/violet ends of the spectrum. **(1)** Greater (%) green light is transmitted/passes through. **(1)** Effect on red and blue light. **(1)** Effect on green light. **(1)** Do not accept: any discussion of appearing green due to reflection, on its own. The question is asking about the transmitted light. Do not accept: any implication of total absorption or total transmission.

Question			Expected response	Max mark	Additional guidance
9.	(d)		Slit separation d of new grating is greater than the previous grating. **(1)** Spectrum is narrower. **OR** Colours in the spectrum are closer together. **OR** It is more difficult to place the spectrophotometer in one colour of light. **(1)**	2	**INDEPENDENT MARKS** Do not accept: fewer lines per millimetre on its own. Accept: angle of dispersion is smaller. Do not accept: $\sin\theta$ or θ is smaller on its own. **OR** maxima less spaced out on its own. May be answered with the aid of a labelled diagram.

MARKS DO NOT WRITE IN THIS MARGIN

10. Light from the Sun is a continuous spectrum containing dark lines as shown.



(a) Explain how these dark lines in the spectrum of sunlight are produced. **2**

(b) One of the dark lines corresponds to the blue-green line in the hydrogen spectrum.

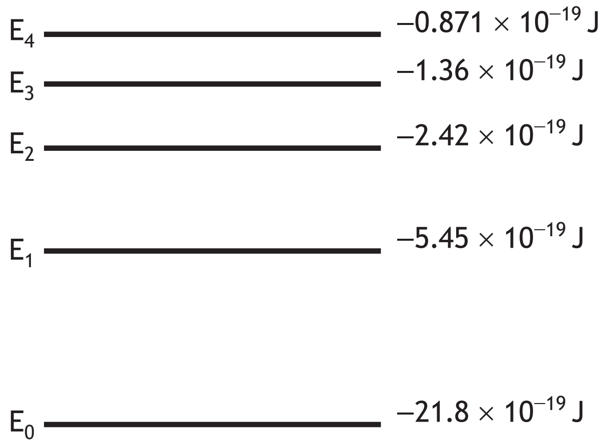
(i) State the wavelength of this blue-green spectral line. **1**

(ii) Calculate the frequency of this spectral line. **3**

Space for working and answer

10. (b) (continued) MARKS DO NOT WRITE IN THIS MARGIN

(iii) Some of the energy levels of the hydrogen atom are shown.



The dark line corresponding to the blue-green line in the hydrogen spectrum is produced due to an electron transition between E_1 and one of the other energy levels.

(A) Calculate the energy of the photon involved in this transition. **3**

Space for working and answer

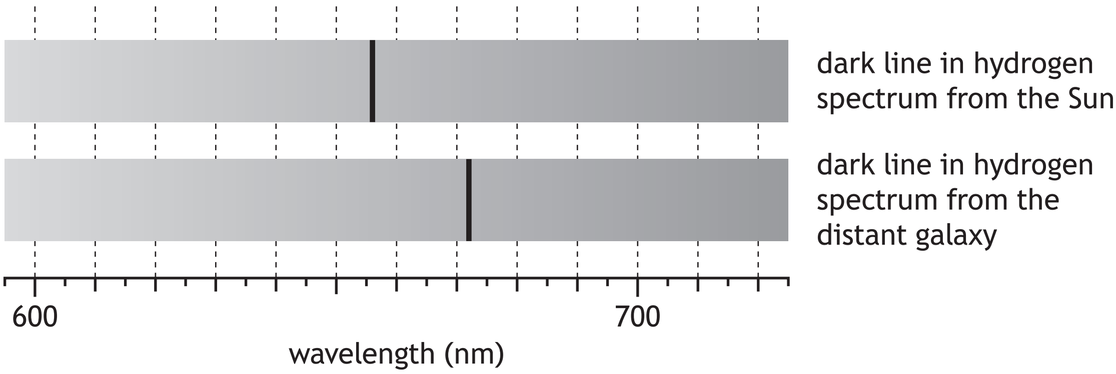
(B) Identify the electron transition that produces this dark line. **1**

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

10. (continued)

(c) One of the other dark lines in the spectrum of the Sun corresponds to a wavelength of 656 nm in the hydrogen spectrum. In the spectrum of light from a distant galaxy, the corresponding dark line is observed at 672 nm.



(i) Determine the recessional velocity of this galaxy. **5**

Space for working and answer

MARKS | DO NOT WRITE IN THIS MARGIN

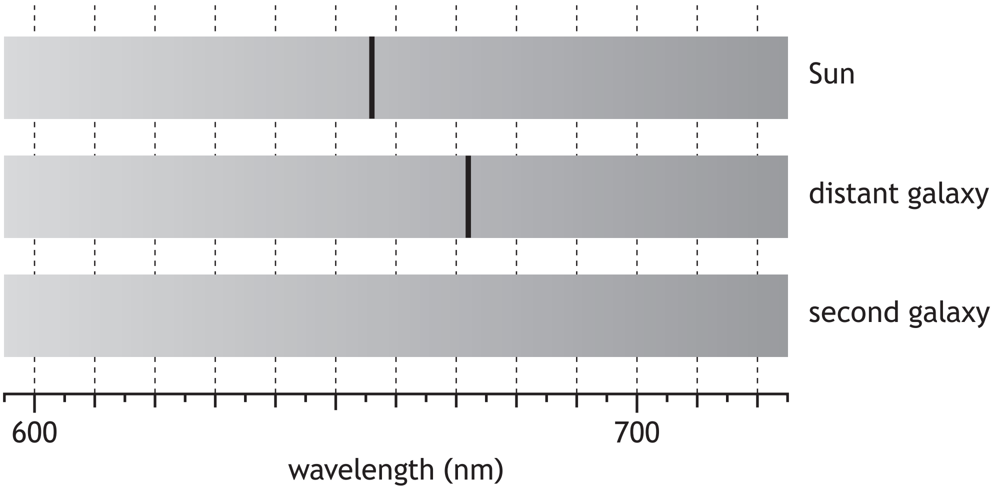
10. (c) (continued)

(ii) A second galaxy produces a spectrum where the corresponding dark line is observed in a different position. This galaxy has a recessional velocity of 4.88×10^6 m s^{-1}.

On the diagram below, add a line to show where this dark line would be observed on the spectrum of the second galaxy.

A numerical value is not required. **1**

(An additional diagram, if required, can be found on *page 52*.)

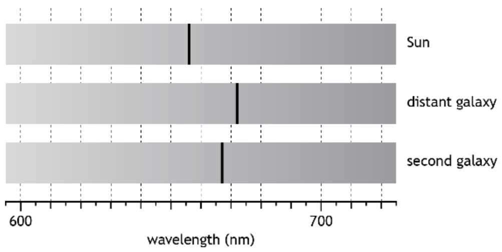


(d) Through observation of distant galaxies, it has been observed that the Universe is expanding at an accelerating rate.

State what physicists think is responsible for this accelerating rate of expansion. **1**

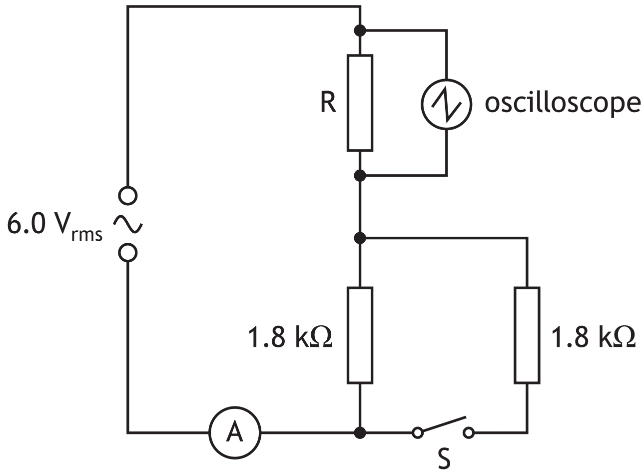
[Turn over

Question			Expected response	Max mark	Additional guidance
10.	(a)		Photons of particular/some/certain energies/frequencies/wavelengths are absorbed. **(1)** in its/the <u>Sun's</u> (upper/outer) atmosphere/outer layers. **(1)**	2	Accept: Particular/some/certain frequencies/wavelengths of light/radiation are absorbed. Accept: gases or suitable named gases in place of atmosphere, but not elements or atoms on their own. Do not accept: 'in the atmosphere' - it is too vague.
	(b)	(i)	486 nm	1	Accept: 4.86×10^{-7} m 486×10^{-9} m
		(ii)	$v = f\lambda$ (1) $3.00 \times 10^{8} = f \times 486 \times 10^{-9}$ (1) $f = 6.17 \times 10^{14}$ Hz (1)	3	Or consistent with b(i) Accept: 6.2, 6.173, 6.1728
		(iii) (A)	$E = hf$ (1) $E = 6.63 \times 10^{-34} \times 6.17 \times 10^{14}$ (1) $E = 4.09 \times 10^{-19}$ J (1)	3	Or consistent with b(ii) Accept: 4.1, 4.091, 4.0907 Accept: $E_2 - E_1 = hf$ $\Delta E = hf$
		(iii) (B)	E_1 to E_3	1	Or consistent with (b)(iii)(A). Accept: (Electron transition) to E_3 Accept: $E_1 \rightarrow E_3$ Between E_1 and E_3 Direction must be correct. Accept: correct transition indicated on energy level diagram. Do not accept: E_1 - E_3 'E_1 and E_3' on its own. Between E_3 and E_1

Question			Expected response	Max mark	Additional guidance
10.	(c)	(i)	$z = \frac{\lambda_o - \lambda_r}{\lambda_r}$ (1) $z = \frac{672\times10^{-9} - 656\times10^{-9}}{656\times10^{-9}}$ (1) $z = \frac{v}{c}$ (1) $\frac{672\times10^{-9} - 656\times10^{-9}}{656\times10^{-9}} = \frac{v}{3.00\times10^{8}}$ (1) $v = 7.32\times10^{6}\ \text{ms}^{-1}$ (1)	5	Accept: 7.3, 7.317, 7.3171 $z = \frac{\lambda_o - \lambda_r}{\lambda_r}$ anywhere, 1 mark. Accept: 672 and 656 $z = \frac{v}{c}$ anywhere, 1 mark substitution of 3.00×10^8 **(1)** Alternative method: $\frac{\lambda_o - \lambda_r}{\lambda_r} = \frac{v}{c}$ $\frac{672 - 656}{656} = \frac{v}{3.00\times10^{8}}$ $v = 7.32\times10^{6}\ \text{ms}^{-1}$ Equating formula, **(2)** Substitution of λ_r and λ_o **(1)** Substitution of c **(1)** Final answer **(1)**
		(ii)		1	Or consistent with (c)(i). Line drawn should be between the Sun and distant galaxy lines. (667 nm). Note: If value to (c)(i) is less than 4.88×10^6 m s^{-1} then line can be anywhere to the right of distant galaxy line.
	(d)		Dark energy	1	

MARKS DO NOT WRITE IN THIS MARGIN

11. A student sets up a circuit using an AC supply of negligible internal resistance as shown.



(a) Switch S is open.

The ammeter displays the rms current. The reading on the ammeter is 2.0 mA.

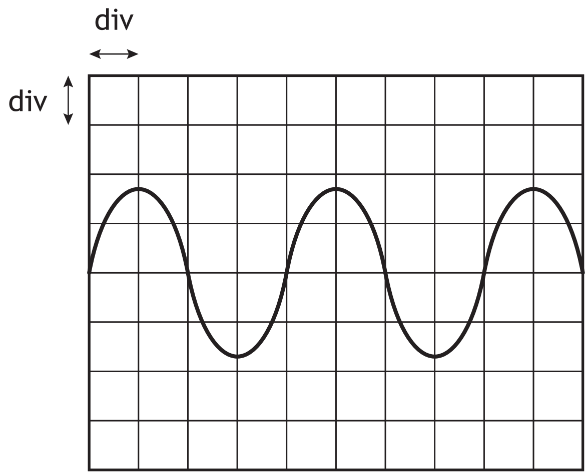
Determine the resistance of resistor R. **4**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

11. (continued)

(b) The oscilloscope screen is shown.



The timebase setting on the oscilloscope is 5.0 ms/div.

Show that the frequency of the AC supply is 50 Hz. **3**

Space for working and answer

(c) Switch S is now closed. The settings on the AC supply and the oscilloscope are unchanged.

State whether the amplitude of the trace on the oscilloscope increases, stays the same, or decreases.

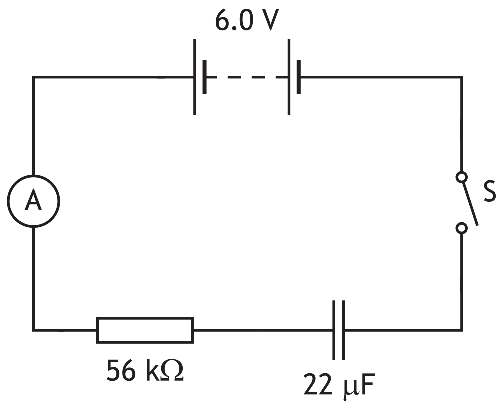
You must justify your answer. **3**

[Turn over

Question			Expected response	Max mark	Additional guidance
11.	(a)		$V = IR$ (1) $6.0 = 2.0\times10^{-3}\times R_T$ (1) $R = \left(\dfrac{6.0}{2.0\times10^{-3}}\right) - 1.8\times10^{3}$ (1) $R = 1.2\times10^{3}\ \Omega$ (1)	4	Accept: 1, 1.20, 1.200 Alternative method using $V = IR$ twice: Relationship **(1)** Substitution to find voltage across 1.8 kΩ **(1)** Substitution to find R **(1)** Correct final answer **(1)**
	(b)		$T = 4\times5.0\times10^{-3}$ (s) (1) $T = \dfrac{1}{f}$ (1) $4\times5.0\times10^{-3} = \dfrac{1}{f}$ (1) $f = 50$ Hz	3	**SHOW question** Accept: $f = \dfrac{N}{t}$ Accept: $T = \dfrac{1}{f}$ (1) $4\times5.0\times10^{-3} = \dfrac{1}{f}$ (2) $f = 50$ Hz
	(c)		(Amplitude) increases **(1)** Total resistance of the circuit decreases. **OR** Current (in R) increases. **(1)** Voltage across R increases. **(1)**	3	**MUST JUSTIFY.** Resistance of parallel part of circuit decreases. **OR** voltage across parallel part of circuit decreases. Do not accept: Voltage through/in … Current across … 0 marks

MARKS DO NOT WRITE IN THIS MARGIN

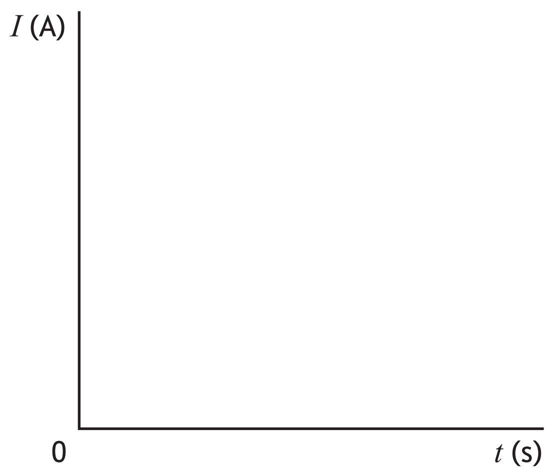
12. (a) A student sets up a circuit to investigate the charging of a capacitor.



The capacitor is initially uncharged. The student closes the switch and the capacitor takes 6.2 s to fully charge.

On the axes below, sketch a graph of current I against time t for the capacitor to fully charge.

Numerical values are required on both axes. **3**



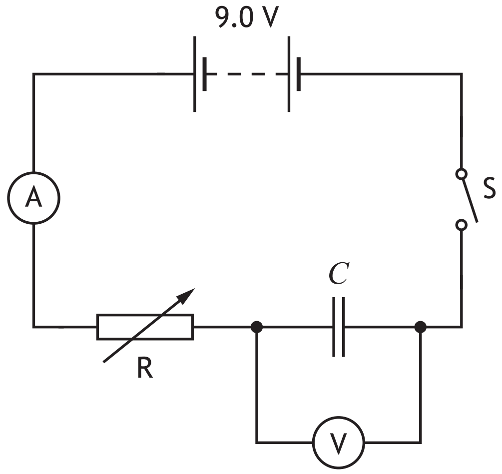
(An additional graph, if required, can be found on *page 52*.)

[Turn over

12. (continued)

MARKS DO NOT WRITE IN THIS MARGIN

(b) In a second experiment, the student sets up a circuit to determine the capacitance C of a different capacitor.



The resistance of the variable resistor can be adjusted to maintain a constant charging current.

Initially, the capacitor is uncharged.

Switch S is closed and the capacitor begins to charge.

(i) State whether the student should be increasing or decreasing the resistance of the variable resistor R to maintain a constant charging current.

Justify your answer. **2**

(ii) During the experiment, there is a constant charging current of 15 μA.

The capacitor takes 28 s to fully charge.

Calculate the charge stored on the capacitor when it is fully charged. **3**

Space for working and answer

* X 8 5 7 7 6 0 1 4 2 *

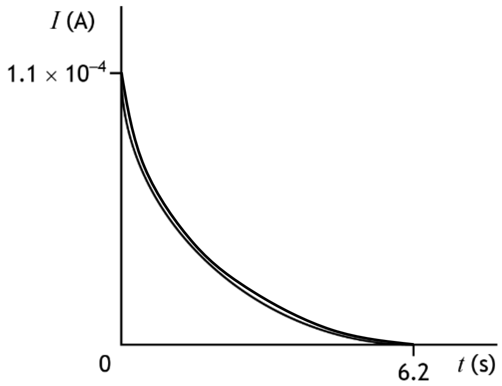
MARKS DO NOT WRITE IN THIS MARGIN

12. (b) (continued)

(iii) Calculate the capacitance C of the capacitor. **3**

Space for working and answer

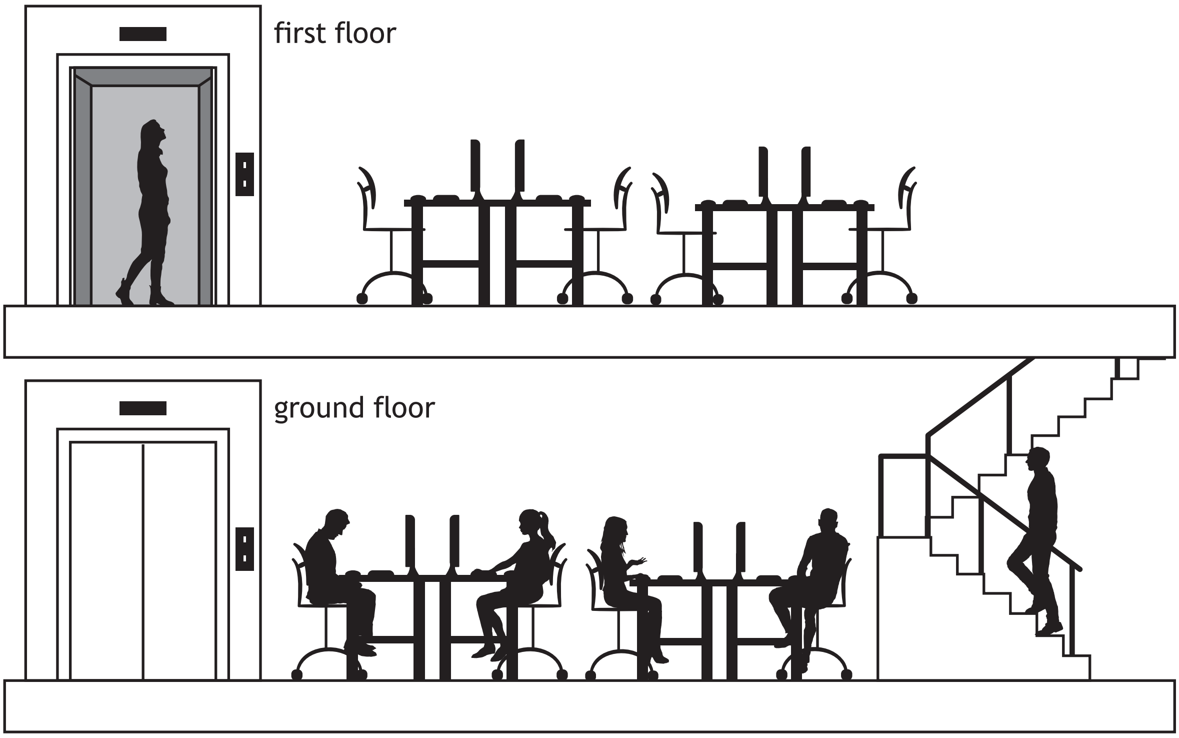
[Turn over

Question			Expected response	Max mark	Additional guidance
12.	(a)		1.1×10^{-4} on the y-axis **(1)** Graph shape **(1)** Reaches zero at 6.2 **(1)** 	**3**	Accept: 1, 1.07, 1.071 Line crossing x-axis - maximum **(2)** Line crossing y-axis - maximum **(2)** Line must be a curve to award the second mark. __If__ an acceptable value for initial current is shown, then the line must start at this value to be awarded the 'graph shape' mark. Line must tend towards the time axis to gain the second mark.
	(b)	(i)	Decreasing (the resistance). **(1)** The current would decrease during charging so the resistance must be decreased to compensate. **(1)**	**2**	**JUSTIFY** Accept: The voltage across R would decrease during charging so the resistance must be decreased to compensate. 2nd mark is for indicating what would happen if you didn't adjust the resistance. eg to prevent the current from decreasing
		(ii)	$Q = It$ (1) $Q = 15 \times 10^{-6} \times 28$ (1) $Q = 4.2 \times 10^{-4}$ C (1)	**3**	Accept: 4, 4.20, 4.200
		(iii)	$C = \frac{Q}{V}$ (1) $C = \frac{4.2 \times 10^{-4}}{9.0}$ (1) $C = 4.7 \times 10^{-5}$ F (1)	**3**	Or consistent with (b)(ii) Accept: 5, 4.67, 4.667

MARKS DO NOT WRITE IN THIS MARGIN

13. The use of analogies from everyday life can help improve the understanding of physics concepts.

A student describes how an office building with two floors can be used as an analogy for band theory in solid materials.



The student states:

'All the desks on the ground floor of the office must be occupied before workers can occupy a desk on the first floor. This represents an insulator.

'The first floor is only unlocked when the ground floor is full.

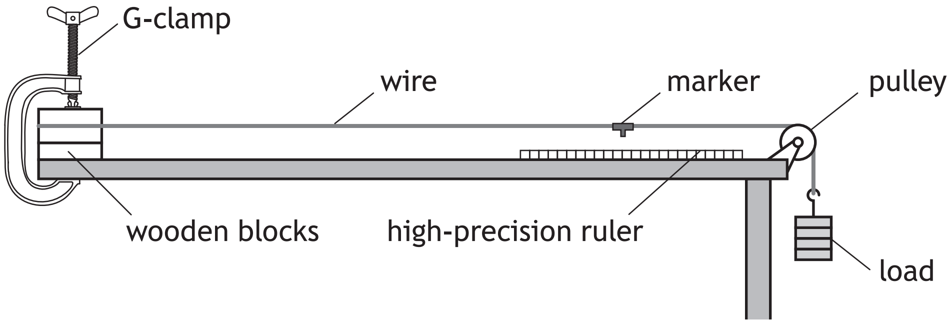
'When the whole office is full, no worker can change the desk that they are working at. This represents no current.'

Using your knowledge of physics, comment on this analogy. **3**

MARKS DO NOT WRITE IN THIS MARGIN

14. Young's modulus E of a material is a measure of its stiffness.

A student sets up an experiment to determine Young's modulus of a copper wire.



The student applies a force to the wire, which causes the wire to stretch.

The extension of the wire is the difference between its new length and its original length.

The student varies the force F applied to the wire and measures the corresponding extension e of the wire.

The student records the following information.

F (N)	e ($\times 10^{-3}$ m)
2.0	0.5
3.9	1.0
5.9	1.6
7.8	2.1
9.8	2.7
10.8	3.2

(a) (i) Using the square-ruled paper on *page 48*, draw a graph of F against e. **3**

(The table of results is also shown on *page 49*, opposite the square-ruled paper.)

(ii) Calculate the gradient of the line of best fit on your graph. **2**

Space for working and answer

X857760146

MARKS DO NOT WRITE IN THIS MARGIN

14. (a) (continued)

(iii) Young's modulus can be determined using the relationship

$$F = \frac{EA}{L}e$$

where: E is Young's modulus in Pa

F is the force applied to the wire by the load in N

L is the original length of the wire in m

A is the cross-sectional area of the wire in m^2

e is the extension of the wire in m.

The original length of the copper wire is 1.500 m and the cross-sectional area is 5.9×10^{-8} m^2.

Using the gradient of your line of best fit, determine Young's modulus of the copper wire. **2**

Space for working and answer

(b) The student plots a graph of the data and concludes that there is a systematic uncertainty associated with this data.

Suggest why the student reached this conclusion. **1**

[END OF QUESTION PAPER]

* X 8 5 7 7 6 0 1 4 7 *

Question			Expected response	Max mark	Additional guidance
14.	(a)	(i)	Axes appropriately labelled (quantity and units) and axes linearly scaled. **(1)** [Allow for axes starting at zero or broken axes or an appropriate value]. Data points plotted accurately. **(1)** Appropriate line of best-fit. **(1)**	**3**	If the origin is shown the scale must either be continuous, or the axis must be 'broken'. Otherwise, maximum 2 marks. If non-linear scale is used over the range of the data on either axis eg values from the table are used as the scale points, (0) marks. Do not penalise if candidates plot e against F. Accuracy of plotting should be easily checkable with the scale chosen. An appropriate scale to allow the accuracy of plotting to be checked must be linear over the range of the data.

Question			Expected response	Max mark	Additional guidance
14.	(a)	(ii)	Choosing 2 points on their line. **(1)** Calculate gradient. **(1)** (min 1 sig fig, max 4 sig figs). (Gradient works out as approx. 3.3×10^3).	2	<u>**Must**</u> be consistent with graph drawn for (a)(i). Candidates are asked to calculate the gradient of <u>**their line of best fit**</u>. If relationship to calculate gradient is stated incorrectly (0) marks, eg $\frac{y^2 - y^1}{x^2 - x^1}$. If candidates use values from the table, these points must lie on <u>**their line**</u>. If ($\times 10^{-3}$) is not accounted for in the final answer, maximum 1 mark unless this being omitted is consistent with the graph drawn in (a)(i). A unit is not required in the final answer, but if stated it must be correct. If candidate has a non-linear scale over the range of the values used in the substitution, **(0)** marks. If candidate has drawn a 'dot to dot' graph or no line, **(0)** marks.

Question			Expected response	Max mark	Additional guidance
14.	(a)	(iii)	$\left(gradient = \frac{EA}{L}\right)$ $3.3 \times 10^{3} = \frac{E \times 5.9 \times 10^{-8}}{1.500}$ (1) $E = 8.4 \times 10^{10}$ Pa (1)	**2**	**<u>Must be</u>** consistent with (a)(ii). **<u>Must</u>** substitute the gradient of **<u>their line of best fit</u>**, and not a single data point. If a single data point is substituted into in the calculation, award (0) marks. Accept: correct alternative units. If candidate has plotted extension against force, the formula becomes $\left(gradient = \frac{L}{EA}\right)$ $3.3 \times 10^{-4} = \frac{1.500}{E \times 5.9 \times 10^{-8}}$ (1) $E = 8.4 \times 10^{10}$ Pa (1)
	(b)		There is (a non-zero) y-intercept. **OR** the line of best fit does not go through the origin.	**1**	

[END OF MARKING INSTRUCTIONS]