Name:_______________________

Advanced Higher Physics

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	Symbol	Value	Quantity	Symbol	Value
Gravitational acceleration on Earth	g	$9{\cdot}8\ \mathrm{m\,s^{-2}}$	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}\ \mathrm{kg}$
Radius of Earth	R_E	$6{\cdot}4 \times 10^{6}\ \mathrm{m}$	Charge on electron	e	$-1{\cdot}60 \times 10^{-19}\ \mathrm{C}$
Mass of Earth	M_E	$6{\cdot}0 \times 10^{24}\ \mathrm{kg}$	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}\ \mathrm{kg}$
Mass of Moon	M_M	$7{\cdot}3 \times 10^{22}\ \mathrm{kg}$	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}\ \mathrm{kg}$
Radius of Moon	R_M	$1{\cdot}7 \times 10^{6}\ \mathrm{m}$	Mass of alpha particle	m_a	$6{\cdot}645 \times 10^{-27}\ \mathrm{kg}$
Mean Radius of Moon Orbit		$3{\cdot}84 \times 10^{8}\ \mathrm{m}$	Charge on alpha particle		$3{\cdot}20 \times 10^{-19}\ \mathrm{C}$
Solar radius		$6{\cdot}955 \times 10^{8}\ \mathrm{m}$	Planck's constant	h	$6{\cdot}63 \times 10^{-34}\ \mathrm{J\,s}$
Mass of Sun		$2{\cdot}0 \times 10^{30}\ \mathrm{kg}$	Permittivity of free space	ε_0	$8{\cdot}85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
1 AU		$1{\cdot}5 \times 10^{11}\ \mathrm{m}$	Permeability of free space	μ_0	$4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
Stefan-Boltzmann constant	σ	$5{\cdot}67 \times 10^{-8}\ \mathrm{W\ m^{-2}K^{-4}}$	Speed of light in vacuum	c	$3{\cdot}0 \times 10^{8}\ \mathrm{m\,s^{-1}}$
Universal constant of gravitation	G	$6{\cdot}67 \times 10^{-11}\ \mathrm{m^3\,kg^{-1}\,s^{-2}}$	Speed of sound in air	v	$3{\cdot}4 \times 10^{2}\ \mathrm{m\,s^{-1}}$

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	Glycerol	1·47
Glass	1·51	Water	1·33
Ice	1·31	Air	1·00
Perspex	1·49	Magnesium Fluoride	1·38

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	Specific Heat Capacity/ $\mathrm{J\,kg^{-1}\,K^{-1}}$	Specific Latent Heat of Fusion/ $\mathrm{J\,kg^{-1}}$	Specific Latent Heat of Vaporisation/ $\mathrm{J\,kg^{-1}}$
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623	$9{\cdot}02 \times 10^{2}$	$3{\cdot}95 \times 10^{5}$	....
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853	$3{\cdot}86 \times 10^{2}$	$2{\cdot}05 \times 10^{5}$	....
Glass	$2{\cdot}60 \times 10^{3}$	1400	....	$6{\cdot}70 \times 10^{2}$	....	....
Ice	$9{\cdot}20 \times 10^{2}$	273	....	$2{\cdot}10 \times 10^{3}$	$3{\cdot}34 \times 10^{5}$	....
Glycerol	$1{\cdot}26 \times 10^{3}$	291	563	$2{\cdot}43 \times 10^{3}$	$1{\cdot}81 \times 10^{5}$	$8{\cdot}30 \times 10^{5}$
Methanol	$7{\cdot}91 \times 10^{2}$	175	338	$2{\cdot}52 \times 10^{3}$	$9{\cdot}9 \times 10^{4}$	$1{\cdot}12 \times 10^{6}$
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377	$3{\cdot}93 \times 10^{3}$	....	....
Water	$1{\cdot}00 \times 10^{3}$	273	373	$4{\cdot}19 \times 10^{3}$	$3{\cdot}34 \times 10^{5}$	$2{\cdot}26 \times 10^{6}$
Air	1·29	....	....	....	....	....
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20	$1{\cdot}43 \times 10^{4}$	....	$4{\cdot}50 \times 10^{5}$
Nitrogen	1·25	63	77	$1{\cdot}04 \times 10^{3}$	....	$2{\cdot}00 \times 10^{5}$
Oxygen	1·43	55	90	$9{\cdot}18 \times 10^{2}$	....	$2{\cdot}40 \times 10^{4}$

Relationships Required For Higher Physics

$d = \bar{v}t$

$s = \bar{v}t$

$v = u + at$

$s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

$s = \frac{1}{2}(u+v)t$

$W = mg$

$F = ma$

$E_w = Fd$

$E_p = mgh$

$E_k = \frac{1}{2}mv^2$

$P = \frac{E}{t}$

$p = mv$

$Ft = mv - mu$

$F = G\frac{m_1 m_2}{r^2}$

$t' = \frac{t}{\sqrt{1 - \frac{v^2}{c^2}}}$

$l' = l\sqrt{1 - \left(\frac{v}{c}\right)^2}$

$f_o = f_s\left(\frac{v}{v \pm v_s}\right)$

$z = \frac{v}{c}$

$v = H_0 d$

$W = QV$

$E = mc^2$

$I = \frac{P}{A}$

$I = \frac{k}{d^2}$

$I_1 d_1^2 = I_2 d_2^2$

$E = hf$

$E_k = hf - hf_0$

$v = f\lambda$

$E_2 - E_1 = hf$

$d\sin\theta = m\lambda$

$n = \frac{\sin\theta_1}{\sin\theta_2}$

$\frac{\sin\theta_1}{\sin\theta_2} = \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$

$\sin\theta_c = \frac{1}{n}$

Path difference= $m\lambda$ or $(m+ ½)\lambda$ where m = 0,1,2 …..

$\text{random uncertainty} = \frac{\text{max. value - min. value}}{\text{number of values}}$

$V_{rms} = \frac{V_{peak}}{\sqrt{2}}$

$I_{rms} = \frac{I_{peak}}{\sqrt{2}}$

$T = \frac{1}{f}$

$V = IR$

$P = IV = I^2R = \frac{V^2}{R}$

$R_T = R_1 + R_2 + \ldots.$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots.$

$V_1 = \left(\frac{R_1}{R_1 + R_2}\right)V_S$

$\frac{V_1}{V_2} = \frac{R_1}{R_2}$

$E = V + Ir$

$C = \frac{Q}{V}$

Q=It

$E = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$

Relationships required for Physics Advanced Higher

$$v = \frac{ds}{dt}$$

$$a = \frac{dv}{dt} = \frac{d^2s}{dt^2}$$

$$v = u + at$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

$$\omega = \frac{d\theta}{dt}$$

$$\alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$$

$$\omega = \omega_o + \alpha t$$

$$\omega^2 = \omega_o{}^2 + 2\alpha\theta$$

$$\theta = \omega_o t + \frac{1}{2}\alpha t^2$$

$$s = r\theta$$

$$v = r\omega$$

$$a_t = r\alpha$$

$$\omega = \frac{2\pi}{T}$$

$$\omega = 2\pi f$$

$$a_r = \frac{v^2}{r} = r\omega^2$$

$$F = \frac{mv^2}{r} = mr\omega^2$$

$$I = \sum mr^2$$

$$\tau = Fr$$

$$\tau = I\alpha$$

$$L = mvr = mr^2\omega$$

$$L = I\omega$$

$$E_{k(rotational)} = \frac{1}{2}I\omega^2$$

$$E_P = E_{k(translational)} + E_{k(rotational)}$$

$$F = \frac{GMm}{r^2}$$

$$F = \frac{GMm}{r^2} = \frac{mv^2}{r} = mr\omega^2 = mr\left(\frac{2\pi}{T}\right)^2$$

$$V = -\frac{GM}{r}$$

$$E_P = Vm = -\frac{GMm}{r}$$

$$v_{esc} = \sqrt{\frac{2GM}{r}}$$

$$r_{Schwarzschild} = \frac{2GM}{c^2}$$

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

$$\frac{P}{A} = \sigma T^4$$

$$L = 4\pi r^2 \sigma T^4$$

$$E = hf$$

$$mvr = \frac{nh}{2\pi}$$

$$\lambda = \frac{h}{p}$$

$$\Delta x \, \Delta p_x \geq \frac{h}{4\pi}$$

$$\Delta E \, \Delta t \geq \frac{h}{4\pi}$$

$$F = qvB$$

$$F = \frac{mv^2}{r}$$

$$F = -ky$$

$$\omega = 2\pi f = \frac{2\pi}{T}$$

$$a = \frac{d^2y}{dt^2} = -\omega^2 y$$

$$y = A\cos\omega t \quad \text{or} \quad y = A\sin\omega t$$

$$v = \pm\omega\sqrt{\left(A^2 - y^2\right)}$$

$$E_k = \frac{1}{2}m\omega^2\left(A^2 - y^2\right)$$

$$E_P = \frac{1}{2}m\omega^2 y^2$$

$$E = kA^2$$

$$y = A\sin 2\pi\left(ft - \frac{x}{\lambda}\right)$$

$$\phi = \frac{2\pi x}{\lambda}$$

$$opd = n \times gpd$$

$$opd = m\lambda \text{ or } \left(m + \frac{1}{2}\right)\lambda \text{ where } m = 0,1,2\ldots$$

$$\Delta x = \frac{\lambda l}{2d}$$

$$d = \frac{\lambda}{4n}$$

$$\Delta x = \frac{\lambda D}{d}$$

$$n = \tan i_P$$

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_o r^2}$$

$$V = \frac{Q}{4\pi\varepsilon_o r}$$

$$E = \frac{Q}{4\pi\varepsilon_o r^2}$$

$$F = QE$$

$$V = Ed$$

$$W = QV$$

$$E_k = \frac{1}{2}mv^2$$

$$B = \frac{\mu_o I}{2\pi r}$$

$$F = IlB\sin\theta$$

$$F = qvB$$

$$\tau = RC$$

$$X_C = \frac{V}{I}$$

$$X_C = \frac{1}{2\pi fC}$$

$$\varepsilon = -L\frac{dI}{dt}$$

$$E = \frac{1}{2}LI^2$$

$$X_L = \frac{V}{I}$$

$$X_L = 2\pi fL$$

$$c = \frac{1}{\sqrt{\varepsilon_o \mu_o}}$$

$$\Delta W = \sqrt{\Delta X^2 + \Delta Y^2 + \Delta Z^2}$$

$$\frac{\Delta W}{W} = \sqrt{\left(\frac{\Delta X}{X}\right)^2 + \left(\frac{\Delta Y}{Y}\right)^2 + \left(\frac{\Delta Z}{Z}\right)^2}$$

$$\left(\frac{\Delta W^n}{W^n}\right) = n\left(\frac{\Delta W}{W}\right)$$

Additional relationships

Circle

circumference $= 2\pi r$

area $= \pi r^2$

Sphere

area $= 4\pi r^2$

volume $= \frac{4}{3}\pi r^3$

Trigonometry

$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}}$

$\cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}}$

$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$

$\sin^2\theta + \cos^2\theta = 1$

Moment of inertia

point mass
$I = mr^2$

rod about centre
$I = \frac{1}{12}ml^2$

rod about end
$I = \frac{1}{3}ml^2$

disc about centre
$I = \frac{1}{2}mr^2$

sphere about centre
$I = \frac{2}{5}mr^2$

Table of standard derivatives

$f(x)$	$f'(x)$
$\sin ax$	$a\cos ax$
$\cos ax$	$-a\sin ax$

Table of standard integrals

$f(x)$	$\int f(x)dx$
$\sin ax$	$-\frac{1}{a}\cos ax + C$
$\cos ax$	$\frac{1}{a}\sin ax + C$

The Berwickshire High School

Periodic Table

Electron Arrangements of Elements

Key

Key
Atomic number Symbol Electron arrangement Name

Transition Elements

Group 1 (1)	Group 2 (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	Group 3 (13)	Group 4 (14)	Group 5 (15)	Group 6 (16)	Group 7 (17)	Group 0 (18)
1 **H** 1 Hydrogen																	2 **He** 2 Helium
3 **Li** 2,1 Lithium	4 **Be** 2,2 Beryllium											5 **B** 2,3 Boron	6 **C** 2,4 Carbon	7 **N** 2,5 Nitrogen	8 **O** 2,6 Oxygen	9 **F** 2,7 Fluorine	10 **Ne** 2,8 Neon
11 **Na** 2,8,1 Sodium	12 **Mg** 2,8,2 Magnesium											13 **Al** 2,8,3 Aluminium	14 **Si** 2,8,4 Silicon	15 **P** 2,8,5 Phosphorus	16 **S** 2,8,6 Sulfur	17 **Cl** 2,8,7 Chlorine	18 **Ar** 2,8,8 Argon
19 **K** 2,8,8,1 Potassium	20 **Ca** 2,8,8,2 Calcium	21 **Sc** 2,8,9,2 Scandium	22 **Ti** 2,8,10,2 Titanium	23 **V** 2,8,11,2 Vanadium	24 **Cr** 2,8,13,1 Chromium	25 **Mn** 2,8,13,2 Manganese	26 **Fe** 2,8,14,2 Iron	27 **Co** 2,8,15,2 Cobalt	28 **Ni** 2,8,16,2 Nickel	29 **Cu** 2,8,18,1 Copper	30 **Zn** 2,8,18,2 Zinc	31 **Ga** 2,8,18,3 Gallium	32 **Ge** 2,8,18,4 Germanium	33 **As** 2,8,18,5 Arsenic	34 **Se** 2,8,18,6 Selenium	35 **Br** 2,8,18,7 Bromine	36 **Kr** 2,8,18,8 Krypton
37 **Rb** 2,8,18,8,1 Rubidium	38 **Sr** 2,8,18,8,2 Strontium	39 **Y** 2,8,18,9,2 Yttrium	40 **Zr** 2,8,18, 10,2 Zirconium	41 **Nb** 2,8,18, 12,1 Niobium	42 **Mo** 2,8,18,13, 1 Molybdenum	43 **Tc** 2,8,18,13, 2 Technetium	44 **Ru** 2,8,18,15, 1 Ruthenium	45 **Rh** 2,8,18,16, 1 Rhodium	46 **Pd** 2,8,18, 18,0 Palladium	47 **Ag** 2,8,18, 18,1 Silver	48 **Cd** 2,8,18, 18,2 Cadmium	49 **In** 2,8,18, 18,3 Indium	50 **Sn** 2,8,18, 18,4 Tin	51 **Sb** 2,8,18, 18,5 Antimony	52 **Te** 2,8,18, 18,6 Tellurium	53 **I** 2,8,18, 18,7 Iodine	54 **Xe** 2,8,18, 18,8 Xenon
55 **Cs** 2,8,18,18, 8,1 Caesium	56 **Ba** 2,8,18,18, 8,2 Barium	57 **La** 2,8,18,18, 9,2 Lanthanum	72 **Hf** 2,8,18,32, 10,2 Hafnium	73 **Ta** 2,8,18, 32,11,2 Tantalum	74 **W** 2,8,18,32, 12,2 Tungsten	75 **Re** 2,8,18,32, 13,2 Rhenium	76 **Os** 2,8,18,32, 14,2 Osmium	77 **Ir** 2,8,18,32, 15,2 Iridium	78 **Pt** 2,8,18,32, 17,1 Platinum	79 **Au** 2,8,18, 32,18,1 Gold	80 **Hg** 2,8,18, 32,18,2 Mercury	81 **Tl** 2,8,18, 32,18,3 Thallium	82 **Pb** 2,8,18, 32,18,4 Lead	83 **Bi** 2,8,18, 32,18,5 Bismuth	84 **Po** 2,8,18, 32,18,6 Polonium	85 **At** 2,8,18, 32,18,7 Astatine	86 **Rn** 2,8,18, 32,18,8 Radon
87 **Fr** 2,8,18,32, 18,8,1 Francium	88 **Ra** 2,8,18,32, 18,8,2 Radium	89 **Ac** 2,8,18,32, 18,9,2 Actinium	104 **Rf** 2,8,18,32, 32,10,2 Rutherfordium	105 **Db** 2,8,18,32, 32,11,2 Dubnium	106 **Sg** 2,8,18,32, 32,12,2 Seaborgium	107 **Bh** 2,8,18,32, 32,13,2 Bohrium	108 **Hs** 2,8,18,32, 32,14,2 Hassium	109 **Mt** 2,8,18,32, 32,15,2 Meitnerium	110 **Ds** 2,8,18,32, 32,17,1 Darmstadtium	111 **Rg** 2,8,18,32, 32,18,1 Roentgenium	112 **Cn** 2,8,18,32, 32,18,2 Copernicium						

Lanthanides	57 **La** 2,8,18, 18,9,2 Lanthanum	58 **Ce** 2,8,18, 20,8,2 Cerium	59 **Pr** 2,8,18,21, 8,2 Praseodymium	60 **Nd** 2,8,18,22, 8,2 Neodymium	61 **Pm** 2,8,18,23, 8,2 Promethium	62 **Sm** 2,8,18,24, 8,2 Samarium	63 **Eu** 2,8,18,25, 8,2 Europium	64 **Gd** 2,8,18,25, 9,2 Gadolinium	65 **Tb** 2,8,18,27, 8,2 Terbium	66 **Dy** 2,8,18,28, 8,2 Dysprosium	67 **Ho** 2,8,18,29, 8,2 Holmium	68 **Er** 2,8,18,30, 8,2 Erbium	69 **Tm** 2,8,18,31, 8,2 Thulium	70 **Yb** 2,8,18,32, 8,2 Ytterbium	71 **Lu** 2,8,18,32, 9,2 Lutetium
Actinides	89 **Ac** 2,8,18,32, 18,9,2 Actinium	90 **Th** 2,8,18,32, 18,10,2 Thorium	91 **Pa** 2,8,18,32, 20,9,2 Protactinium	92 **U** 2,8,18,32, 21,9,2 Uranium	93 **Np** 2,8,18,32, 22,9,2 Neptunium	94 **Pu** 2,8,18,32, 24,8,2 Plutonium	95 **Am** 2,8,18,32, 25,8,2 Americium	96 **Cm** 2,8,18,32, 25,9,2 Curium	97 **Bk** 2,8,18,32, 27,8,2 Berkelium	98 **Cf** 2,8,18,32, 28,8,2 Californium	99 **Es** 2,8,18,32, 29,8,2 Einsteinium	100 **Fm** 2,8,18,32, 30,8,2 Fermium	101 **Md** 2,8,18,32, 31,8,2 Mendelevium	102 **No** 2,8,18,32, 32,8,2 Nobelium	103 **Lr** 2,8,18,32, 32,9,2 Lawrencium

Success Criteria	Test	Prelim	Exam
0.1 Units, Prefixes and Uncertainties			
Units, Prefixes, and Scientific Notation			
0.1.0 I use SI units correctly for all physical quantities.			
0.1.1 I know and correctly use non-SI units such as electronvolt (eV), light-year (ly), and astronomical unit (AU).			
0.1.2 I can convert between units when needed.			
0.1.3 I correctly apply prefixes: $\boldsymbol{femto(f)} = 10^{-15}$ $\boldsymbol{pico(p)} = 10^{-12}$ $\boldsymbol{nano(n)} = 10^{-9}$ $\boldsymbol{micro(\mu)} = 10^{-6}$ $\boldsymbol{milli(m)} = 10^{-3}$ $\boldsymbol{kilo(k)} = 10^{3}$ $\boldsymbol{mega(M)} = 10^{6}$ $\boldsymbol{giga(G)} = 10^{9}$ $\boldsymbol{tera(T)} = 10^{12}$ $\boldsymbol{peta(P)} = 10^{15}$			
0.1.4 I use the correct number of significant figures in final answers.			
0.1.5 I use scientific notation where appropriate (e.g. 3.2×10^{-6}).			
Uncertainties			
0.1.6 I understand the different types of uncertainty: systematic (e.g., all measurements too high/low due to calibration or method), scale reading (linked to instrument precision), random (small variations in repeated measurements), and calibration (accuracy of the measuring instrument vs standard).			
0.1.7 I know how to state absolute uncertainty (e.g. ±0.1 V), convert to percentage/fractional uncertainty and vice versa, and round uncertainty to 1 significant figure (2 if appropriate).			
Combining Uncertainties			
0.1.8 Knowledge and use of the relationship to calculate total uncertainty in a single measurement: $\Delta W = \sqrt{(\Delta X)^2 + (\Delta Y)^2 + (\Delta Z)^2}$			
0.1.9 Knowledge and use of the relationship to calculate total percentage/fractional uncertainty in calculated values: $\frac{\Delta W}{W} = \sqrt{\left(\frac{\Delta X}{X}\right)^2 + \left(\frac{\Delta Y}{Y}\right)^2 + \left(\frac{\Delta Z}{Z}\right)^2}$			
0.1.10 Knowledge and use of the relationship for values raised to a power: $\frac{\Delta W}{W} = \lvert n \rvert \cdot \frac{\Delta X}{X}$			
0.1.11 I ignore small uncertainties if they are less than 1/3 of another larger uncertainty in the calculation.			

Success Criteria	Test	Prelim	Exam
Graphs and Data Analysis			
0.1.12 I correctly draw and interpret error bars for uncertainties on graphs.			
0.1.13 I can estimate uncertainty in the gradient and intercept of a best-fit line.			
0.1.14 I can identify dominant uncertainties in experiments and suggest ways to reduce them.			
Accuracy vs Precision			
0.1.15 I understand that accuracy means closeness to the true value, and precision refers to how consistent or repeatable results are (related to uncertainty).			
0.1.16 I use these terms correctly when evaluating experimental results.			

Success Criteria	Test	Prelim	Exam
1.1 Kinematic Relationships			
Understanding Concepts			
1.1.0 I can explain what is meant by rate of change using calculus notation.			
1.1.1 I can describe how velocity is the rate of change of displacement, and acceleration is the rate of change of velocity.			
1.1.2 I can explain that acceleration is the second derivative of displacement with respect to time.			
Using Calculus in Motion			
1.1.3 Knowledge and use of the relationships (derived using differentiation and integration): $v = u + at$ $s = ut + \frac{1}{2}at^2$			
1.1.4 I can use calculus to find instantaneous displacement, velocity, and acceleration for straight-line motion with constant or changing acceleration.			
Applying Equations of Motion			
1.1.5 I can use the correct equations to solve problems involving displacement, velocity, acceleration, and time for straight-line motion.			

Success Criteria	Test	Prelim	Exam
1.1.6 Knowledge and use of the relationships and choosing the appropriate equation: $v = u + at$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$ $v = \frac{ds}{dt}$ $a = \frac{dv}{dt}$ $a = \frac{d^2s}{dt^2}$			
Working with Graphs			
1.1.7 I can find the gradient of a motion graph to determine velocity or acceleration.			
1.1.8 I can explain that the gradient of a displacement-time graph gives velocity, and the gradient of a velocity-time graph gives acceleration.			
1.1.9 I can explain that the area under a velocity-time graph gives displacement, and the area under an acceleration-time graph gives change in velocity.			
Solving Graph-Based Problems			
1.1.10 I can calculate displacement, velocity, or acceleration from the gradient of a graph.			
1.1.11 I can calculate displacement or change in velocity from the area under a graph between two time values.			

Success Criteria	Test	Prelim	Exam
1.2 Angular Motion			
Understanding Angular Quantities			
1.2.0 I can explain what a radian is and use it as a measure of angular displacement.			
1.2.1 I can convert between degrees and radians accurately.			
Using Angular Kinematic Equations			
1.2.2 I can identify and use the correct equations to solve problems involving angular displacement, angular velocity, angular acceleration, and time.			
1.2.3 Knowledge and use of the relationships (for constant angular acceleration): $\omega = \omega_o + \alpha t$ $\theta = \omega_o t + \frac{1}{2}\alpha t^2$ $\omega^2 = \omega_o^2 + 2\alpha$			

Success Criteria	Test	Prelim	Exam
1.2.4 Knowledge and use of the relationships (using calculus to relate angular quantities): $$\omega = \frac{d\theta}{dt}$$ $$\alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$$			
Relating Angular and Tangential Quantities			
1.2.5 Knowledge and use of the relationships between angular and tangential motion: $$s = r\theta (arclength)$$ $$v = r\omega (tangentialvelocity)$$ $$a_t = r\alpha (tangentialacceleration)$$			
Period, Frequency, and Angular Velocity			
1.2.6 Knowledge and use of the relationships to calculate angular velocity: $$\omega = \frac{2\pi}{T} (fromperiod)$$ $$\omega = 2\pi f (fromfrequency)$$			
Centripetal Acceleration and Force			
1.2.7 I can explain why a centripetal (radial) force is needed for circular motion.			
1.2.8 I understand that this force causes centripetal acceleration, directed towards the centre of the circle.			
1.2.9 Knowledge and use of the relationships to calculate centripetal acceleration: $$a_r = \frac{v^2}{r}$$ $$a_r = \omega^2 r$$			
1.2.10 Knowledge and use of the relationships to calculate centripetal force: $$F = \frac{mv^2}{r}$$ $$F = m\omega^2 r$$			

Success Criteria	Test	Prelim	Exam
1.3 Rotational Dynamics			
Forces and Motion in Rotation			
1.3.0 I can explain that an unbalanced torque causes a change in an object's rotational motion.			
1.3.1 I can define the moment of inertia as a measure of how much an object resists angular acceleration.			
1.3.2 I can describe how the moment of inertia depends on the mass of the object and how the mass is distributed about the axis of rotation.			

Success Criteria	Test	Prelim	Exam
Calculating Moment of Inertia			
1.3.3 Knowledge and use of the relationship for a point mass: $$I = mr^2$$			
1.3.4 Knowledge and use of the relationship for a system of discrete masses: $$= \sum mr^2$$			
1.3.5 I can use the correct formulas for standard shapes (thin rod about centre, thin rod about end, solid disc about centre, solid sphere about centre): $$I = \frac{1}{12}ml^2$$ $$I = \frac{1}{3}ml^2$$ $$I = \frac{1}{2}mr^2$$ $$I = \frac{2}{5}mr^2$$			
Torque and Angular Acceleration			
1.3.6 Knowledge and use of the relationships to calculate torque (perpendicular force × distance from axis; moment of inertia × angular acceleration): $$\tau = Fr$$ $$\tau = I\alpha$$			
Angular Momentum			
1.3.7 Knowledge and use of the relationships to calculate angular momentum (for a point mass; for rotating objects): $$L = mvr$$ $$L = I\omega$$			
1.3.8 I can explain and apply the principle of conservation of angular momentum: if no external torque acts, the total angular momentum of a system remains constant.			
1.3.9 I can solve problems using conservation of angular momentum in closed systems.			
Rotational and Translational Energy			
1.3.10 Knowledge and use of the relationship for rotational kinetic energy: $$E_k = \frac{1}{2}I\omega^2$$			
1.3.11 Knowledge and use of the relationship for translational kinetic energy: $$E_k = \frac{1}{2}mv^2$$			
1.3.12 Knowledge and use of the relationship for total energy in a system with both rotational and translational motion: $$E = E_{k\,(translational)} + E_{k\,(rotational)}$$			
1.3.13 I can include potential energy when solving problems involving energy conservation.			

Success Criteria	Test	Prelim	Exam
1.4 Gravitation			
Gravitational Quantities and Units			
1.4.0 I can convert between Astronomical Units (AU) and metres (m), and between light-years (ly) and metres (m).			
Gravitational Fields			
1.4.1 I can define gravitational field strength as the gravitational force on a unit mass.			
1.4.2 I can sketch gravitational field lines around a single object (e.g. a planet or star) and around two-object systems (e.g. planet-moon or binary stars).			
Gravitational Force and Motion			
1.4.3 Knowledge and use of the relationship to calculate gravitational force between two masses: $$F = \frac{GMm}{r^2}$$			
1.4.4 Knowledge and use of the relationships to calculate the orbital period, orbital radius, mass, or orbital speed of a satellite: $$F = \frac{mv^2}{r} = \frac{GMm}{r^2}$$ $$T = \frac{2\pi r}{v}$$ $$v = \sqrt{\frac{GM}{r}}$$			
Gravitational Potential and Energy			
1.4.5 I can define gravitational potential as the work done to bring unit mass from infinity to a point in space.			
1.4.6 I understand that gravitational energy changes are independent of the path taken.			
1.4.7 Knowledge and use of the relationship to calculate gravitational potential: $$V = -\frac{GM}{r}$$			
1.4.8 Knowledge and use of the relationships to calculate gravitational potential energy: $$E_p = -\frac{GMm}{r}$$ $$E_p = Vm$$			

Success Criteria	Test	Prelim	Exam
Escape Velocity			
1.4.9 I can define escape velocity as the minimum speed needed for an object to escape a gravitational field, reaching zero kinetic energy at infinity.			
1.4.10 Knowledge and use of the relationship for escape velocity: $v_{esc} = \sqrt{\frac{2GM}{r}}$			
1.4.11 I can calculate escape velocity for a given mass and distance from the centre of the object.			

Success Criteria	Test	Prelim	Exam
1.5 General Relativity			
Inertial and Non-Inertial Frames			
1.5.0 I can describe the difference between special relativity (which applies to motion in inertial, non-accelerating frames) and general relativity (which applies to motion in non-inertial, accelerating frames).			
Equivalence Principle			
1.5.1 I can state the equivalence principle: it is not possible to distinguish between the effects of a uniform gravitational field and a constant acceleration.			
1.5.2 I can explain what the equivalence principle means for how we understand gravity.			
Spacetime and Curvature			
1.5.3 I can describe spacetime as the combination of three dimensions of space and one of time.			
1.5.4 I understand that mass causes spacetime to curve, and that this curvature is what we experience as gravity.			
1.5.5 I know that light and objects in freefall follow paths called geodesics (the “straightest” possible paths in curved spacetime).			
World Lines in Spacetime			
1.5.6 I can sketch or interpret world lines for a stationary object (vertical line), an object moving at constant speed (diagonal straight line), and an accelerating object (curved line).			
Black Holes and Event Horizons			
1.5.7 I know that the escape velocity at the event horizon of a black hole is equal to the speed of light.			
1.5.8 I understand that, from a distant observer’s point of view, time appears to freeze at the event horizon of a black hole.			

Success Criteria	Test	Prelim	Exam
1.5.9 I can define the Schwarzschild radius as the radius of the event horizon of a black hole – the point beyond which nothing can escape.			
Calculations Involving Black Holes			
1.5.10 Knowledge and use of the relationship to calculate the Schwarzschild radius: $$r_s = \frac{2GM}{c^2}$$			

Success Criteria	Test	Prelim	Exam
1.6 Stellar Physics			
Luminosity and Star Properties			
1.6.0 Knowledge and use of the relationship between luminosity, apparent brightness, and distance: $$b = \frac{L}{4\pi d^2}$$			
1.6.1 Knowledge and use of the Stefan-Boltzmann law to relate power per unit area to temperature, and luminosity to radius and temperature: $$P = \sigma T^4$$ $$L = 4\pi r^2 \sigma T^4$$			
1.6.2 I can apply these formulas to solve problems involving stellar radius, stellar surface temperature, and distance, brightness, and luminosity.			
Star Formation and Life Cycle			
1.6.3 I can describe how stars form in interstellar clouds when gravity overcomes thermal pressure, causing collapse and heating.			
1.6.4 I understand that when the core is hot enough for fusion, a star is born, and fusion provides the thermal pressure to balance gravity.			
Fusion Reactions			
1.6.5 I can describe the proton-proton chain (p-p chain) for nuclear fusion in stars: $${}^1_1H + {}^1_1H \rightarrow {}^2_1H + e^+ + v_e$$ $${}^2_1H + {}^1_1H \rightarrow {}^3_2He + \gamma$$ $${}^3_2He + {}^3_2He \rightarrow {}^4_2He + 2{}^1_1H$$			
Hertzsprung-Russell (H-R) Diagram			
1.6.6 I can identify the position of main sequence, giants, supergiants, and white dwarfs on the H-R diagram.			
1.6.7 I can use the H-R diagram to predict the colour of a star and to determine its temperature, luminosity, and stage of life.			
1.6.8 I understand that stars in the main sequence are fusing hydrogen in their cores.			

Success Criteria	Test	Prelim	Exam
Star Evolution and Fate			
1.6.9 I know that core hydrogen fusion supports the star against gravitational collapse.			
1.6.10 I understand what happens when core hydrogen is depleted: fusion stops in the core, the core contracts, shell hydrogen begins fusing, and increased pressure causes the outer layers to expand and cool, forming a giant or supergiant.			
1.6.11 I know that the core may get hot enough for helium fusion.			
1.6.12 I understand that a star's mass determines its lifetime and final fate: low-mass stars become white dwarfs, while massive stars become neutron stars or black holes.			

Success Criteria	Test	Prelim	Exam
2.1 Introduction to Quantum Theory			
Limitations of Classical Physics			
2.1.0 I can identify and explain experiments that cannot be explained using classical physics: black-body radiation and the ultraviolet catastrophe, emission and absorption spectra, and the photoelectric effect.			
2.1.1 I understand how quantum theory explains these observations.			
Photon Energy			
2.1.2 Knowledge and use of the relationship to calculate the energy of a photon from its frequency, or the frequency of a photon from its energy: $E = hf$			
Bohr Model of the Atom			
2.1.3 I understand the Bohr model and how it explains the quantisation of electron energy levels and the appearance of atomic spectra.			
2.1.4 I can describe how electrons move in discrete orbits with quantised angular momentum.			
2.1.5 Knowledge and use of the relationship to calculate the angular momentum of an electron in a Bohr orbit: $mvr = \frac{nh}{2\pi}$			
Wave-Particle Duality			
2.1.6 I can describe experiments that show waves behaving like particles (e.g. photoelectric effect) and particles behaving like waves (e.g. electron diffraction).			
2.1.7 Knowledge and use of the de Broglie equation to calculate the wavelength of a particle given its momentum, or the momentum of a particle from its wavelength: $\lambda = h/p$			

Success Criteria	Test	Prelim	Exam
Heisenberg Uncertainty Principle			
2.1.8 I know that it is impossible to know both the position and momentum of a quantum particle exactly at the same time.			
2.1.9 I know that it is impossible to know both the energy change and lifetime of a quantum particle exactly at the same time.			
2.1.10 Knowledge and use of the uncertainty relationships: $\Delta x \Delta p_x \geq \frac{h}{4\pi}$ $\Delta E \Delta t \geq \frac{h}{4\pi}$			
Quantum Tunnelling			
2.1.11 I understand the concept of quantum tunnelling: a quantum particle can appear in a region where it does not have enough energy to be found, according to classical physics.			
2.1.12 I can explain quantum tunnelling as an implication of the uncertainty principle.			

Success Criteria	Test	Prelim	Exam
2.2 Particles from Space			
Cosmic Rays			
2.2.0 I can describe what cosmic rays are and where they come from (e.g. the Sun, supernovae).			
2.2.1 I know that cosmic rays are made up of high-energy particles, mostly protons and atomic nuclei.			
2.2.2 I can explain how cosmic rays interact with Earth's atmosphere to produce secondary particles (e.g. muons, neutrinos).			
Solar Wind			
2.2.3 I know that the solar wind is a stream of charged particles (plasma) released from the Sun.			
2.2.4 I understand that the solar wind includes protons, electrons, and alpha particles.			
Motion of Charged Particles in Magnetic Fields			
2.2.5 I can explain why charged particles follow a helical path when they enter Earth's magnetic field at an angle.			
2.2.6 I know that the magnetic force acts perpendicularly to the particle's velocity, creating circular or spiral motion.			
Calculations with Magnetic Fields			
2.2.7 Knowledge and use of the relationship to calculate the force on a charged particle moving through a magnetic field: $F = qvB$			

Success Criteria	Test	Prelim	Exam
2.2.8 Knowledge and use of the relationship to link the radius of the particle's path to its mass, speed, and magnetic force: $$F = \frac{mv^2}{r}$$			
2.2.9 I can combine the two formulas to solve problems involving the radius of curvature of the particle's path, the magnetic field strength, and the velocity, mass, and charge of the particle.			

Success Criteria	Test	Prelim	Exam
2.3 Simple Harmonic Motion			
Understanding the Nature of SHM			
2.3.0 I can define simple harmonic motion (SHM) as when the acceleration (and restoring force) is directly proportional to the displacement from the rest position, and directed towards it.			
2.3.1 I understand that SHM is a type of oscillatory motion that occurs in many physical systems.			
Mathematical Description of SHM			
2.3.2 I can use calculus to show that y = A cos(ωt) or y = A sin(ωt) leads to a = $-\omega^2 y$, proving SHM.			
2.3.3 Knowledge and use of the relationship for velocity in SHM: $$v = \pm\omega\sqrt{A^2 - y^2}$$			
2.3.4 Knowledge and use of the expression for kinetic energy in SHM: $$E_k = \frac{1}{2}m\omega^2(A^2 - y^2)$$			
2.3.5 I understand how total energy is shared between kinetic and potential energy during SHM.			
Solving SHM Problems			
2.3.6 Knowledge and use of the equation of motion for displacement: $y = A\cos(\omega t)$ or $y = A\sin(\omega t)$			
2.3.7 I can calculate displacement y, velocity v, acceleration a = $-\omega^2 y$, and restoring force F = -ky.			
2.3.8 Knowledge and use of the relationship relating angular frequency, period, and frequency: $$\omega = 2\pi f = \frac{2\pi}{T}$$			
2.3.9 Knowledge and use of the energy relationships (kinetic, potential, total mechanical energy): $$E_k = \frac{1}{2}mv^2$$ $$E_p = \frac{1}{2}m\omega^2 y^2$$ $$Total mechanical energy E = \frac{1}{2}m\omega^2 A^2$$			

Success Criteria	Test	Prelim	Exam
Damping in SHM			
2.3.10 I understand and can describe the effects of damping on SHM: underdamping (oscillations continue with gradually decreasing amplitude), critical damping (system returns to rest in the shortest possible time without oscillating), and overdamping (system returns to rest slowly without oscillating).			

Success Criteria	Test	Prelim	Exam
2.4 Waves			
Wave Energy			
2.4.0 Knowledge and use of the relationship to explain and calculate how wave energy depends on amplitude: $E \propto A^2$			
Travelling Waves			
2.4.1 Knowledge and use of the relationship describing the mathematical form of a travelling wave: $y = A\sin\left(2\pi\left(\frac{x}{\lambda} - ft\right)\right)$			
Phase and Phase Difference			
2.4.2 Knowledge and use of the relationship to explain and calculate the phase difference: $\phi = \frac{2\pi x}{\lambda}$			
2.4.3 I can relate phase difference to positions on a wave (e.g., peak to trough = π radians).			
Stationary Waves			
2.4.4 I understand that stationary waves are formed when two waves of the same frequency and amplitude travel in opposite directions and interfere.			
2.4.5 I can describe nodes (points of zero displacement) and antinodes (points of maximum displacement).			
2.4.6 I can explain the formation of stationary waves using superposition and interference principles.			

Success Criteria	Test	Prelim	Exam
2.5 Interference			
Coherence and Phase			
2.5.0 I can explain that coherent waves have a constant phase difference.			
2.5.1 I know the conditions for constructive interference (phase difference is a multiple of 2π) and destructive interference (phase difference is an odd multiple of π).			
Path Differences			
2.5.2 I understand the difference between geometrical path difference (gpd – actual distance difference) and optical path difference (opd – accounts for refractive index).			
2.5.3 Knowledge and use of the relationship between optical and geometrical path difference: $\text{opd} = \text{gpd} \times n$			
Phase Change on Reflection			
2.5.4 I know that a wave gains a phase change of π (inverts) when it reflects from a more dense medium.			
2.5.5 I know there is no phase change when reflecting from a less dense medium.			
Division of Amplitude (Thin Film Interference)			
2.5.6 I can explain interference by division of amplitude using geometrical path length, optical path difference (opd), and phase change.			
2.5.7 Knowledge and use of the relationship to calculate optical path difference in thin films: $\text{opd} = 2nt$			
2.5.8 Knowledge and use of the relationship for constructive interference (bright fringe): $\text{opd} = m$			
2.5.9 Knowledge and use of the relationship for destructive interference (dark fringe): $\text{opd} = \left(m + \frac{1}{2}\right)$			
2.5.10 I can explain wedge fringes and how they form due to varying film thickness.			
Anti-Reflective Coating			
2.5.11 Knowledge and use of the relationship to make a lens non-reflective for a specific wavelength: $t = \frac{\lambda}{4n}$			
Interference by Division of Wavefront (Young's Slits)			
2.5.12 I can explain how Young's double-slit experiment demonstrates interference.			

Success Criteria	Test	Prelim	Exam
2.5.13 Knowledge and use of the relationship for fringe spacing: $$\Delta x = \frac{\lambda D}{d}$$			

Success Criteria	Test	Prelim	Exam
2.6 Polarisation			
Understanding Polarisation			
2.6.0 I can describe what is meant by a plane-polarised wave: a wave where the electric field oscillates in only one plane.			
2.6.1 I know that transverse waves, like light, can be polarised, but longitudinal waves cannot.			
Polarisers and Analysers			
2.6.2 I can explain the effect of a polariser: it only allows vibrations in one direction to pass through.			
2.6.3 I can describe the function of an analyser: it is a second polariser used to detect polarisation.			
2.6.4 I understand that if the analyser is at 90° to the polariser, no light is transmitted.			
Brewster's Angle			
2.6.5 I know that when unpolarised light hits the surface of a transparent insulator (e.g. glass) at Brewster's angle, the reflected light is completely plane-polarised.			
2.6.6 I can define Brewster's angle as the angle of incidence at which this occurs.			
Brewster's Angle Calculation			
2.6.7 Knowledge and use of the relationship for Brewster's angle: $$n = \tan i_p$$			

Success Criteria	Test	Prelim	Exam
3.1 Fields			
Electric Fields			
3.1.0 I know that an electric field is the region around a charged particle where other charges feel a force.			
3.1.1 Knowledge and use of the relationship defining electric field strength (E) as the force per unit positive charge: $$E = \frac{F}{Q}$$			

Success Criteria	Test	Prelim	Exam
3.1.2 I can sketch electric field patterns around a positive point charge (radially outward), around a negative point charge (radially inward), between opposite charges (curved lines between them), and in a uniform field (parallel, equally spaced straight lines).			
Electric Potential			
3.1.3 I can define electric potential (V) at a point as the work done in moving a unit positive charge from infinity to that point.			
3.1.4 I understand that energy transferred when moving a charge between two points is path independent.			
3.1.5 Knowledge and use of the relationships: $V = \frac{Q}{4\pi\varepsilon_0 r}$ and $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ and $F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$			
Millikan's Experiment			
3.1.6 I can describe Millikan's oil drop experiment and explain how it determined the charge of the electron.			
3.1.7 Knowledge and use of the relationships to carry out calculations using uniform electric fields: $F = QE, \quad V = Ed, \quad W = QV$			
Energy and Electronvolts			
3.1.8 I understand that 1 electronvolt (eV) is the energy gained by one electron when it moves through 1 volt.			
3.1.9 Knowledge and use of the conversion between electronvolts and joules: $1\text{ eV} = 1.6 \times 10^{-19}\text{ J}$			
Magnetic Fields			
3.1.10 I know that electrons moving around nuclei produce magnetic effects.			
3.1.11 I can explain ferromagnetism, where magnetic dipoles in materials like iron, cobalt, and nickel align.			
Magnetic Field Patterns			
3.1.12 I can sketch magnetic field patterns between magnetic poles, around a solenoid, and around Earth.			
Forces and Motion in Fields			
3.1.13 I can compare gravitational, electrostatic, magnetic, and nuclear forces in terms of strength and range.			
Magnetic Fields and Currents			
3.1.14 Knowledge and use of the relationship to calculate the magnetic field strength around a current-carrying wire: $B = \frac{\mu_0 I}{2\pi r}$			
3.1.15 I can explain why a charged particle moves in a helical path in a magnetic field.			

Success Criteria	Test	Prelim	Exam
Force in Magnetic Fields			
3.1.16 Knowledge and use of the relationships for force in magnetic fields (on a wire, on a charge, and for circular motion in a magnetic field): $F = IlB\sin$ $F = qvB$ $\frac{mv^2}{r} = qvB$			

Success Criteria	Test	Prelim	Exam
3.2 Circuits			
RC Circuits (Resistor-Capacitor Circuits)			
3.2.0 I know how current and voltage vary over time in charging and discharging capacitors.			
3.2.1 I can define the time constant τ = RC as: time to reach 63% of the difference between initial and final charge during charging, and time to fall to 37% of initial charge during discharging.			
3.2.2 I understand that after 5 time constants (5τ), a capacitor is fully charged (≈99%) during charging and fully discharged (≈1%) during discharging.			
3.2.3 I can determine the time constant graphically from charging/discharging curves.			
Capacitive Reactance Xc			
3.2.4 I know that capacitive reactance is the opposition a capacitor offers to a changing current.			
3.2.5 Knowledge and use of the relationships to solve problems involving AC circuits with capacitors: $X_C = \frac{1}{2\pi f C}$ and $V = IX_C$			
3.2.6 I understand how frequency affects capacitive reactance: $As frequency \uparrow, X_C \downarrow$			
Inductors in DC Circuits			
3.2.7 I can describe the growth and decay of current in an inductor-resistor (LR) DC circuit.			
3.2.8 I understand self-inductance: an inductor resists changes in current by producing a back EMF.			
3.2.9 I can state Lenz's law: the direction of induced EMF is such that it opposes the change that caused it.			
Inductors in AC Circuits			
3.2.10 I know that an inductor stores energy in its magnetic field when current flows.			

Success Criteria	Test	Prelim	Exam
3.2.11 I know how the current varies with frequency in an AC circuit containing an inductor.			
3.2.12 I know that inductive reactance XL is the opposition of an inductor to changing current.			
3.2.13 Knowledge and use of the relationships for inductive reactance: $X_L = 2\pi fL$ and $V = IX_L$			
3.2.14 Knowledge and use of the back EMF equation: $\varepsilon = -L\frac{dI}{dt}$			
3.2.15 Knowledge and use of the relationship for the energy stored in an inductor: $E = \frac{1}{2}LI^2$			

Success Criteria	Test	Prelim	Exam
3.3 Electromagnetic Radiation			
Unification of Electricity and Magnetism			
3.3.0 I understand that electricity and magnetism are part of the same force: the electromagnetic interaction.			
3.3.1 I know that changing electric fields produce magnetic fields, and changing magnetic fields produce electric fields – forming electromagnetic waves.			
Wave Properties of Electromagnetic Radiation			
3.3.2 I know that electromagnetic radiation transfers energy through space, and has electric and magnetic field components that oscillate in phase, are perpendicular to each other, and are both perpendicular to the direction of wave propagation (i.e. it is a transverse wave).			
3.3.3 I can describe and sketch the orientation of electric and magnetic fields in an EM wave.			
Speed of Light and Physical Constants			
3.3.4 Knowledge and use of the relationship for the speed of light: $c = \frac{1}{\sqrt{\varepsilon_0\mu_0}}$			
3.3.5 I understand how this equation shows that the speed of light is determined by the properties of space itself.			