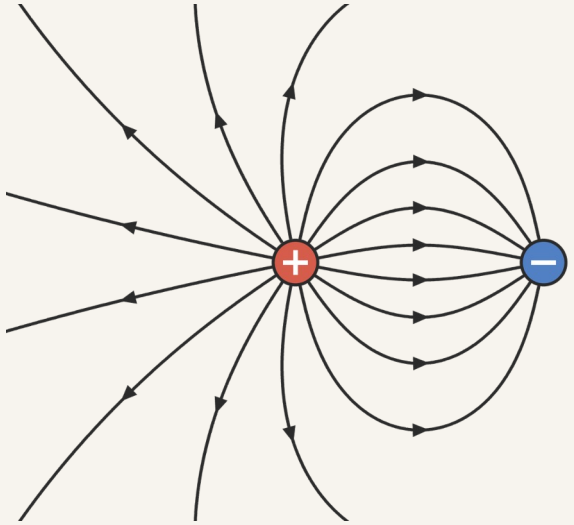
Electric Fields 1: Point Charges



Every charge pushes or pulls on every other — across empty space.

Advanced Higher Physics

By the end of this deck…

1. I can **sketch** the electric field around point charges.
2. I can use $F = Q_1Q_2/4\pi\varepsilon_0 r^2$ for a system of charges.
3. I can **state** what is meant by **electric field strength**.
4. I can use $E = Q/4\pi\varepsilon_0 r^2$, adding fields as **vectors**.
5. I can use $V = Q/4\pi\varepsilon_0 r$, adding potentials as **scalars**.

Recap — from Higher

Charges

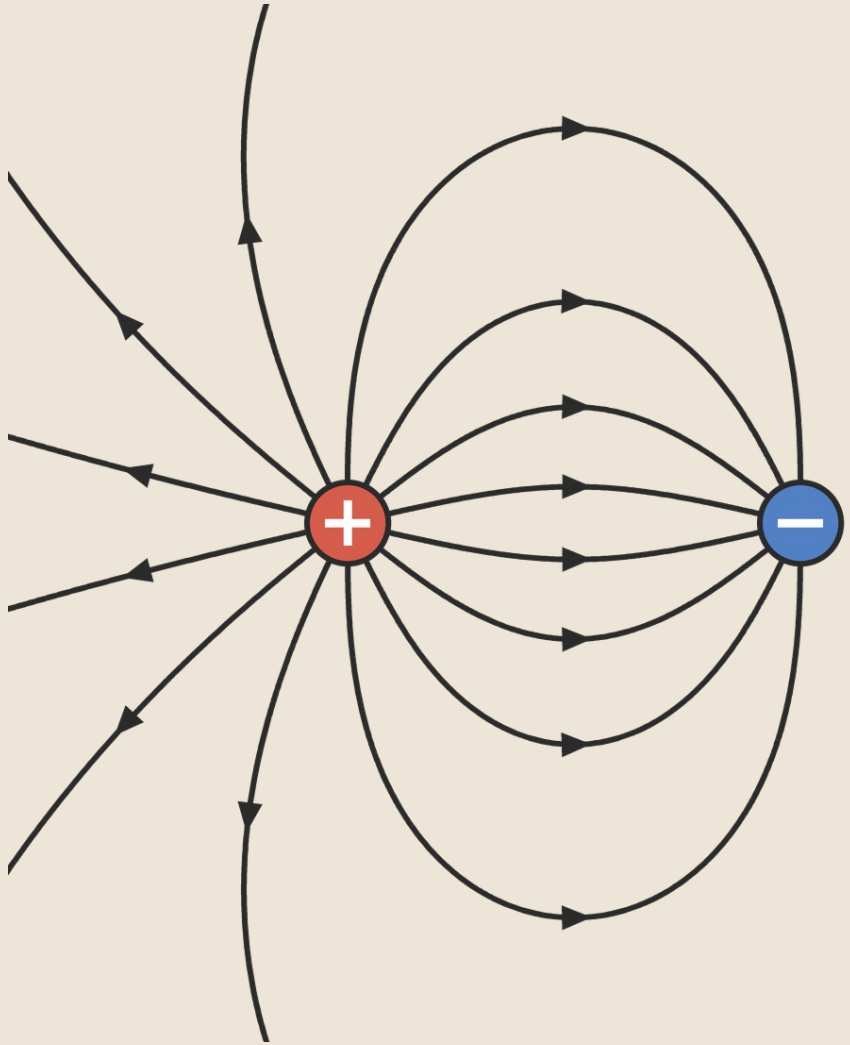
Like repel. Unlike attract.

Field lines

Show the force on a + charge.

Direction

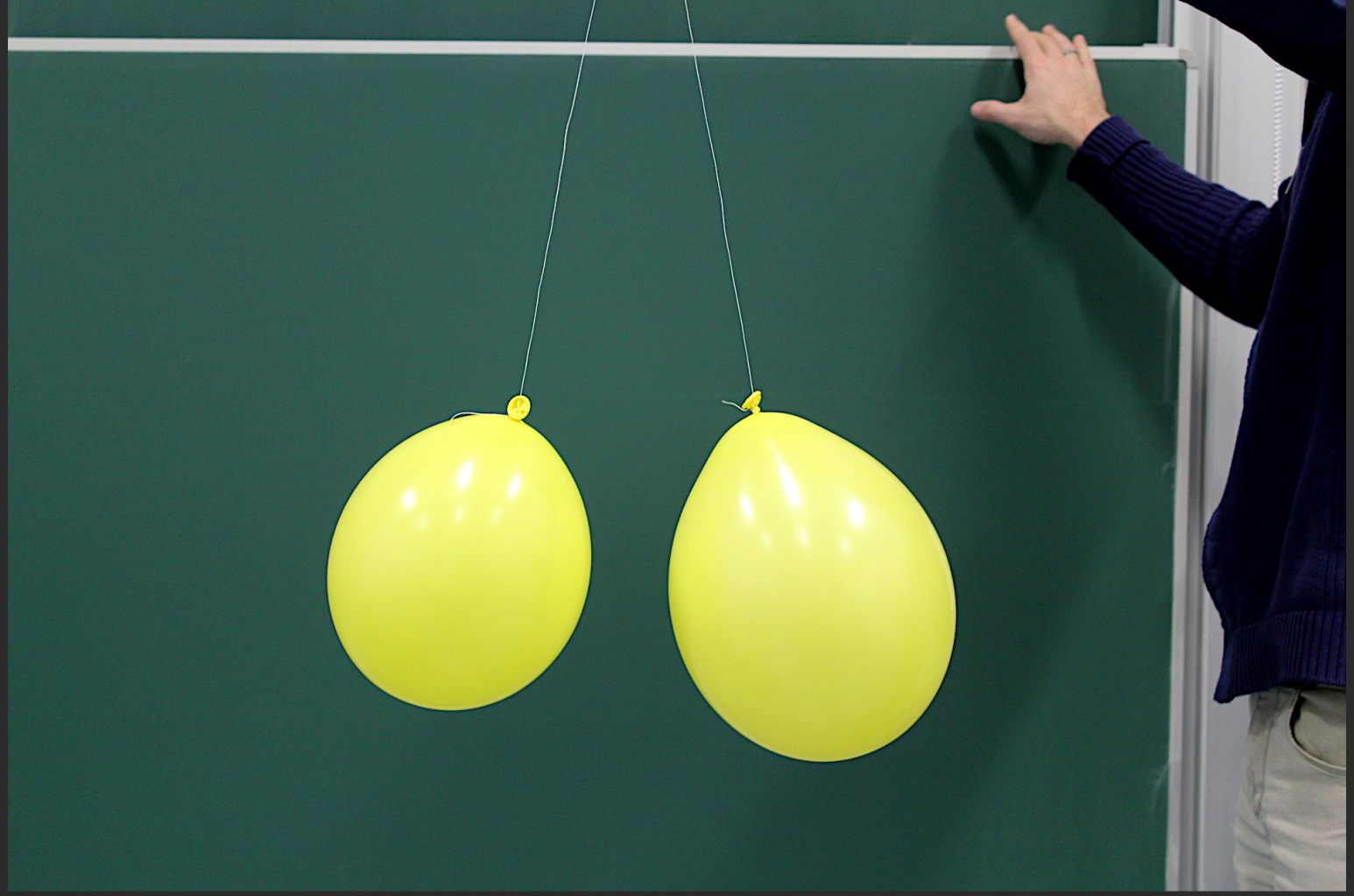
Away from +, towards −.



Starter — from memory, notes closed



1. **State** what is meant by **gravitational field strength**.
2. **State** what is meant by the **gravitational potential** at a point.
3. **Write** the relationship for the force between two masses.
4. **State** how the force changes if the distance **doubles**.
5. **State** the direction of a **field line** around a mass.



Two charged balloons hang apart. What sets how hard they push?

PART 1

How hard do two charges push?

Coulomb's law: it is an inverse square law, like gravity.

By the end of this part…

1. I can **describe** what an electric field is.
2. I can **sketch** the field around point charges.
3. I can use $F = Q_1Q_2/4\pi\varepsilon_0 r^2$ for one or more charges.

What an electric field is

Electric field

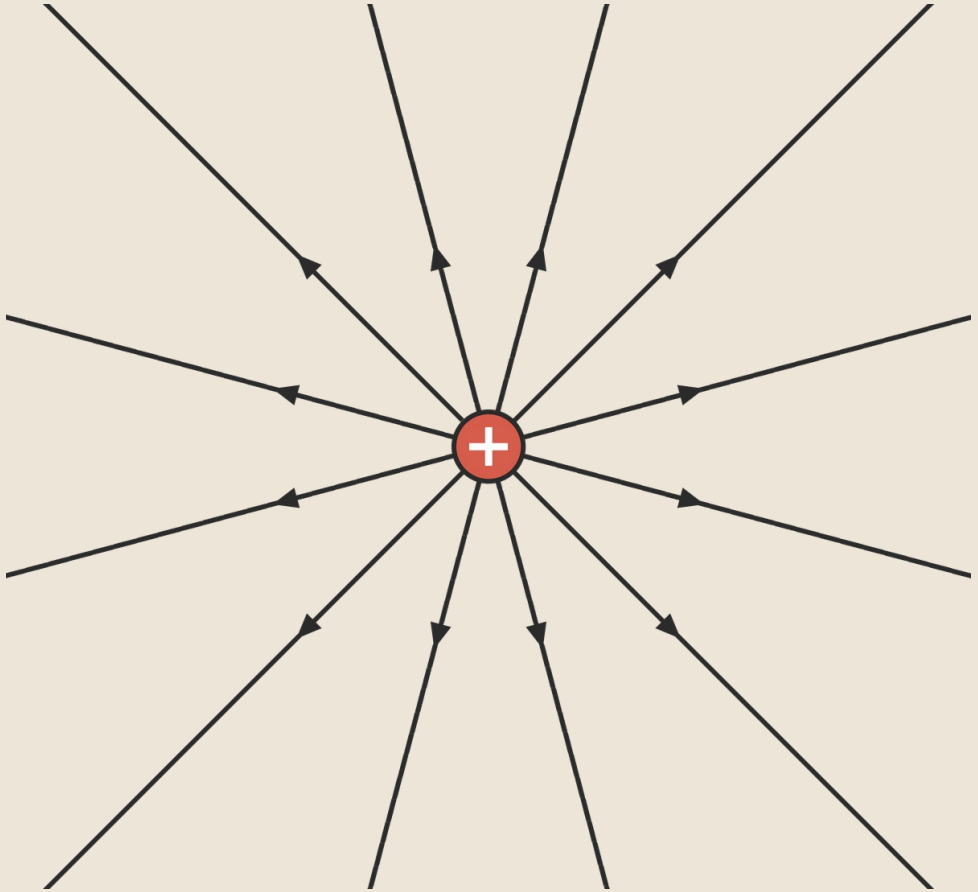
Region round a charge.

In it

Charges feel a force.

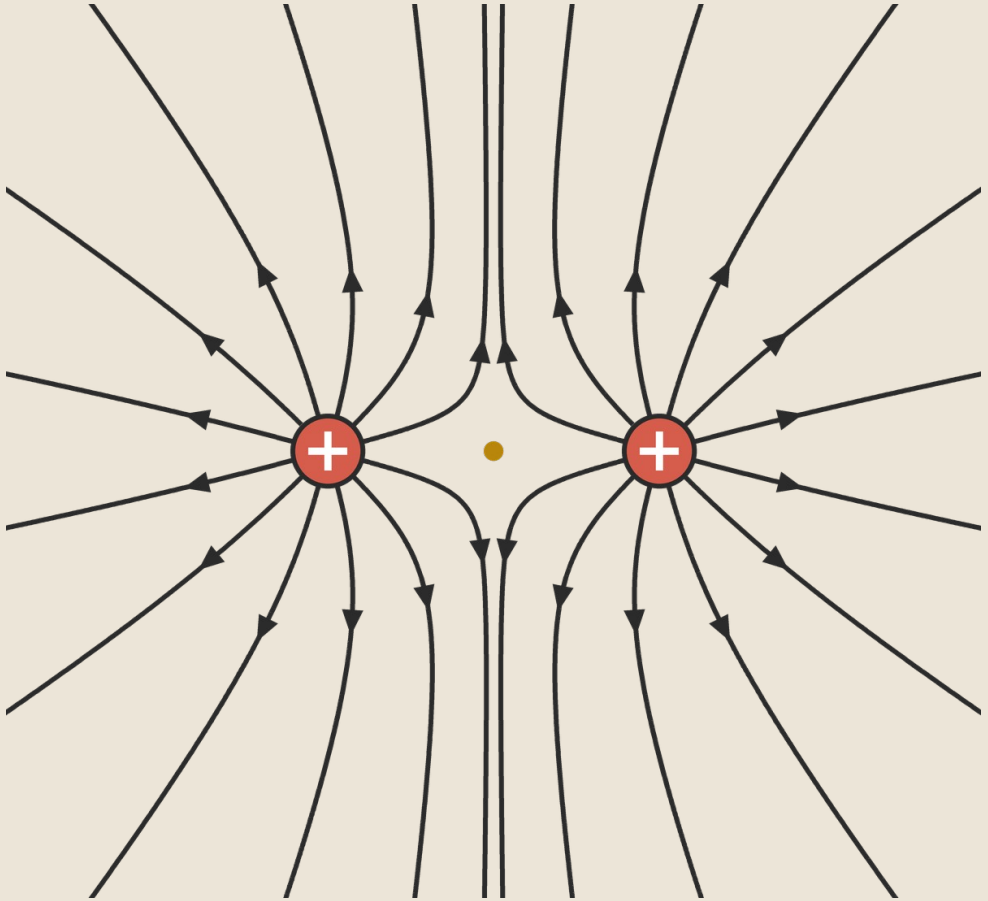
Lines

Closer: stronger field.

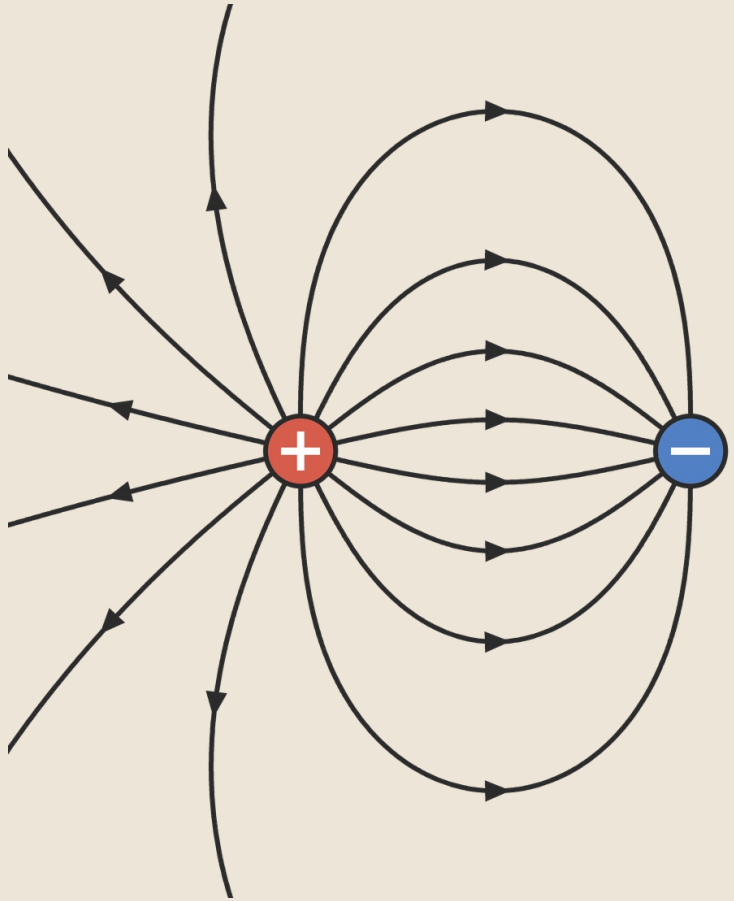


Positive charge: lines point away.

Field patterns — systems of charges



Like: neutral point



Unlike: + to –

How to sketch a field pattern

Touching

Lines start on the charge.

Even

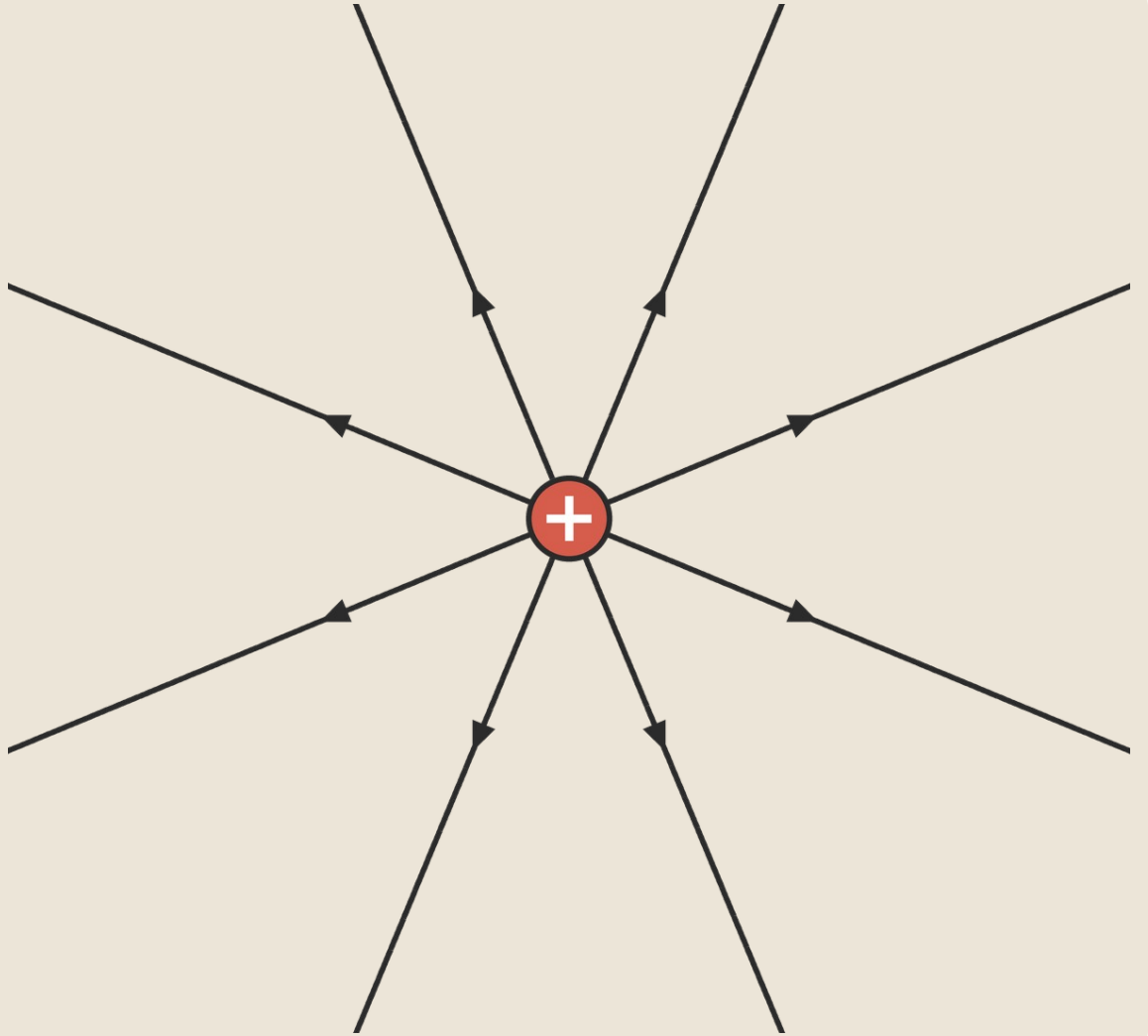
Evenly spaced, at least five.

Arrows

Away from +, towards −.

Never cross

Lines never cross or touch.



Example answer — 2023 Q13(b)

13. A polar molecule is positively charged at one side and negatively charged at the other side. It can be modelled as two point charges.

(b) The charges in this model of the polar molecule produce an electric field. On Figure 13C, **sketch** the electric field pattern of this model. **2**

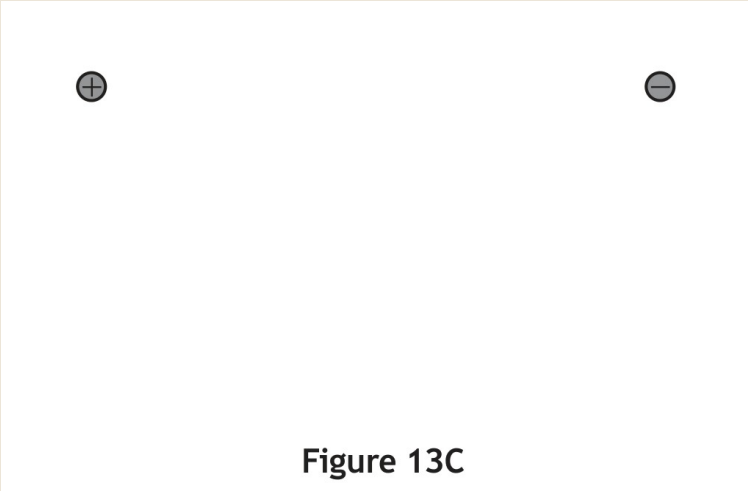


Figure 13C

Marking: 2023 Q13(b)

Question	Expected response	Max mark	Additional guidance
13 (b)	Arrows from + to − (1 mark) Pattern with no field lines crossing (1 mark)	2	If no attempt at an attractive field pattern, zero marks.

Coulomb's law

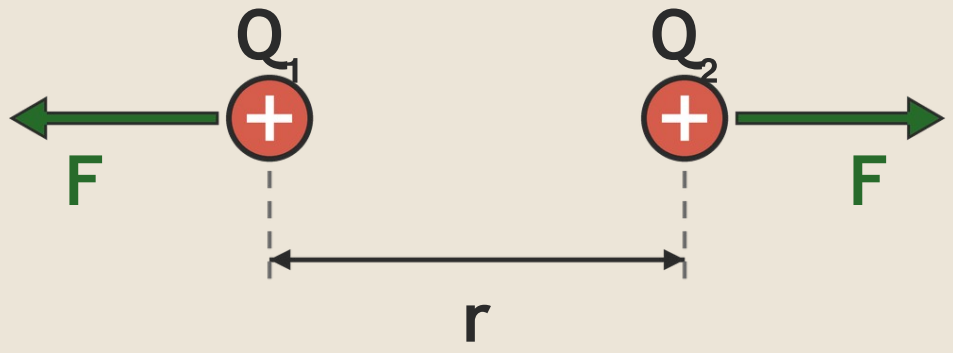
$$F = Q_1 Q_2 / 4\pi\varepsilon_0 r^2$$

F: electrical force (N)

Q_1, Q_2: the charges (C)

r: distance between them (m)

ε_0: 8.85×10^{-12} F m^{-1} (data sheet)



Equal and opposite forces.

Compare — Newton's law of gravitation

Same shape

Both inverse square.

Gravity

Masses: always attract.

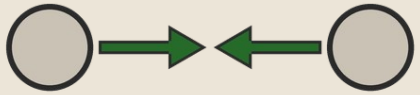
Electric

Like repel, unlike attract.

Constant

G becomes $1/4\pi\varepsilon_0$.

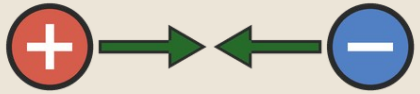
Masses: always attract



Like charges: repel



Unlike charges: attract



For interest — electric against gravity

Two protons

Electric ÷ gravity ≈ 10^{36}.

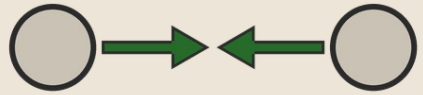
Distance

Cancels: both inverse square.

Planets

Neutral, so gravity wins.

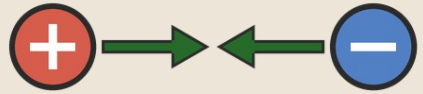
Masses: always attract



Like charges: repel



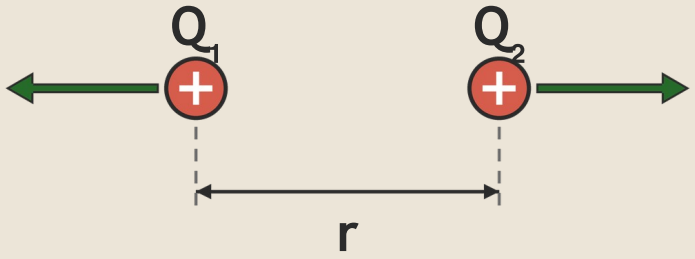
Unlike charges: attract



Worked example 1 — Coulomb's law

Two point charges of **+3.0 nC** and **+5.0 nC** are **0.040 m** apart.

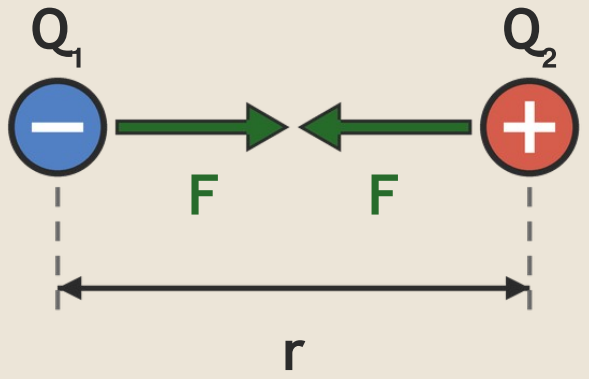
Calculate the electrical force between them. **3**



Marking: Worked example 1

Question	Expected response	Max mark	Additional guidance
	$F = Q_1Q_2 / 4\pi\varepsilon_0 r^2$ (1 mark) $F = (3.0 \times 10^{-9} \times 5.0 \times 10^{-9}) / (4\pi \times 8.85 \times 10^{-12} \times 0.040^2)$ (1 mark) $F = 8.4 \times 10^{-5}$ N (1 mark)	3	No value for ε_0 substituted: max 1 mark. Accept 9×10^9 for $1/4\pi\varepsilon_0$.

Calculate the size of the force between charges of **−2.0 nC** and **+6.0 nC** that are **25 mm** apart.



$F = 1.7 \times 10^{-4}$ N (attractive)

Systems of charges — forces add as vectors

One at a time

Force from each charge.

Direction

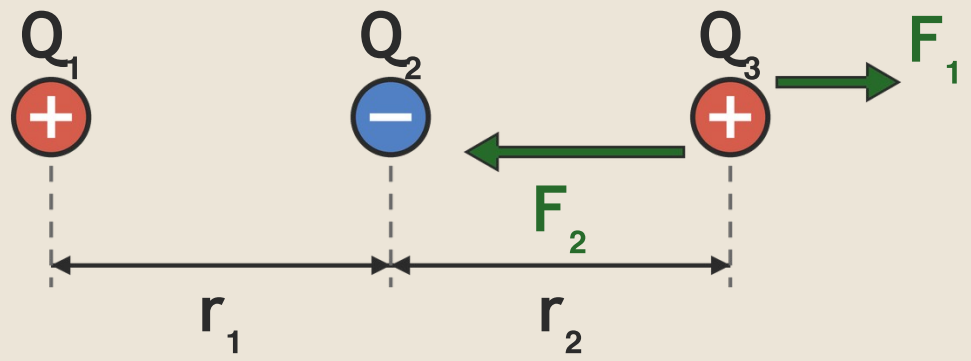
Draw each arrow first.

In a line

Add or subtract.

At right angles

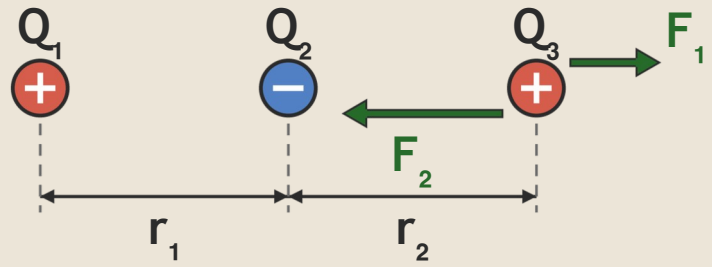
Pythagoras, then angle.



Worked example 2 — charges in a line

Q_1 = **+4.0 nC**, Q_2 = **−2.0 nC** and Q_3 = **+3.0 nC** are in a line. r_1 = **0.10 m** and r_2 = **0.050 m**.

Determine the resultant force on Q_3. 4



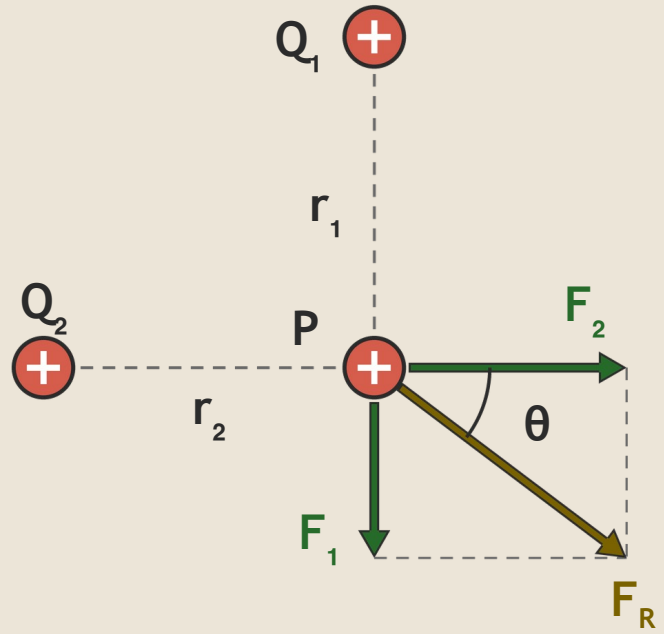
Marking: Worked example 2

Question	Expected response	Max mark	Additional guidance
	$F = Q_1Q_2 / 4\pi\varepsilon_0 r^2$ (1 mark) $F_1 = (4.0 \times 10^{-9} \times 3.0 \times 10^{-9}) / (4\pi \times 8.85 \times 10^{-12} \times 0.15^2) = 4.8 \times 10^{-6}$ N and $F_2 = 2.16 \times 10^{-5}$ N (1 mark) $F = 2.16 \times 10^{-5} - 4.8 \times 10^{-6}$ (1 mark) $F = 1.7 \times 10^{-5}$ N to the left, towards Q_2 (1 mark)	4	Distance from Q_1 is 0.15 m. Direction needed.

Worked example 3 — forces at right angles

A **+3.0 nC** charge sits at P. Q_1 = **+6.0 nC** is **0.25 m** above P. Q_2 = **+15 nC** is **0.35 m** to the left of P.

Determine the size and direction of the resultant force on the charge at P. **4**



Marking: Worked example 3

Question	Expected response	Max mark	Additional guidance
	$F_1 = 2.59 \times 10^{-6}$ N and $F_2 = 3.30 \times 10^{-6}$ N (1 mark) $F = \sqrt{((2.59 \times 10^{-6})^2 + (3.30 \times 10^{-6})^2)}$ (1 mark) $F = 4.2 \times 10^{-6}$ N (1 mark) $\tan \theta = 2.59 \div 3.30$, $\theta = 38^\circ$ below the horizontal, to the right (1 mark)	4	Accept a bearing or angle to the vertical (52°) if stated.

Suspended charged spheres

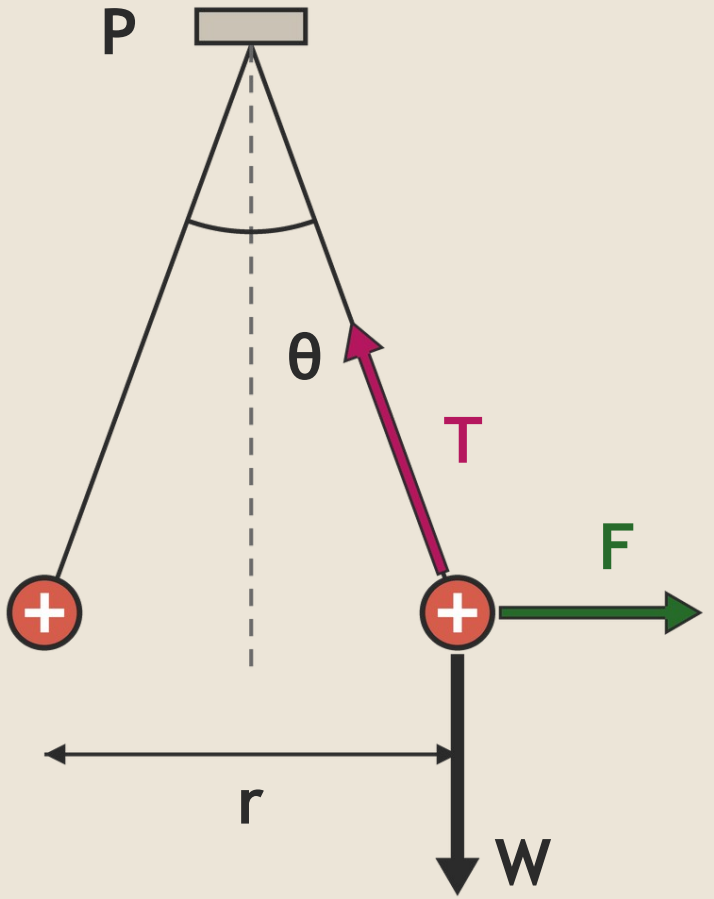
$$tan\ \theta = F/W$$

The sphere is in equilibrium.

Three forces: W, T and F.

W: weight, mg (N)

F: electrical force (N)

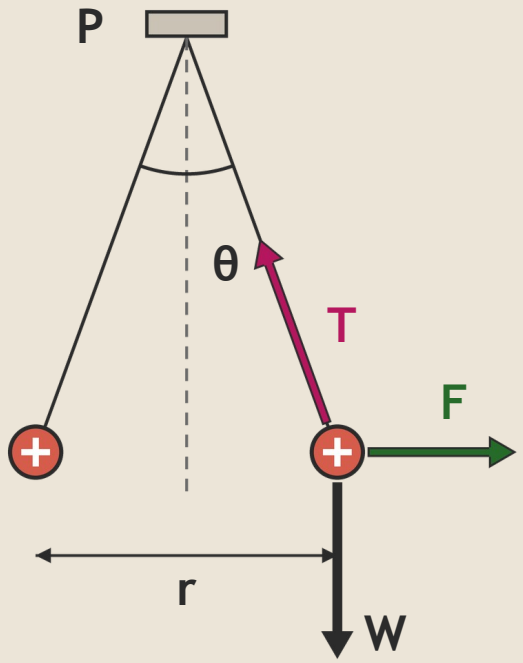


Worked example 4 — suspended spheres

Two identical spheres, each of mass **1.5 g** and charge **+40 nC**, hang from P. Each thread is at **12°** to the vertical.

(a) **Show** that the electrical force on one sphere is 3.1×10^{-3} N. **2**

(b) **Calculate** the distance between the centres of the spheres. **3**



Marking: Worked example 4

Question	Expected response	Max mark	Additional guidance
(a)	$F = W \tan \theta$ (1 mark) $F = 1.5 \times 10^{-3} \times 9.8 \times \tan 12^\circ = 3.1 \times 10^{-3}$ N (1 mark)	2	Final line must be shown.
(b)	$F = Q_1 Q_2 / 4\pi\varepsilon_0 r^2$ (1 mark) $3.1 \times 10^{-3} = (40 \times 10^{-9})^2 / (4\pi \times 8.85 \times 10^{-12} \times r^2)$ (1 mark) $r = 0.068$ m (1 mark)	3	Accept 0.07, 0.0679.

How it's marked — 2018 Q13(b)

(b) Two identical spheres, each with a charge of +22 nC, are suspended from point P by two equal lengths of light insulating thread.

The spheres repel and come to rest in the positions shown in Figure 13A.

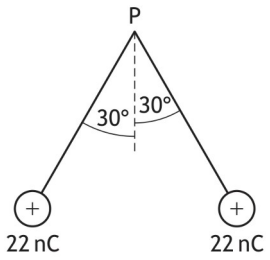


Figure 13A

(i) Each sphere has a weight of $9{\cdot}80 \times 10^{-4}$ N.

By considering the forces acting on one of the spheres, show that the electric force between the charges is $5{\cdot}66 \times 10^{-4}$ N. **2**

Space for working and answer

(ii) By considering the electric force between the charges, calculate the distance between the centres of the spheres. **3**

Space for working and answer

Question			Answer	Max mark	Additional guidance
	(b)	(i)	$F_e = W \tan\theta$ **(1)** $F_e = 9{\cdot}80\times10^{-4}\times\tan 30$ **(1)** $F_e = 5{\cdot}66 \times10^{-4}$ N	2	NOT A STANDARD SHOW QUESTION $\tan\theta = \frac{opposite}{adjacent}$ is an acceptable starting point
		(ii)	$F = \frac{Q_1Q_2}{4\pi\varepsilon_0 r^2}$ **(1)** $5{\cdot}66\times10^{-4} = \frac{(22\times10^{-9})^2}{4\pi\times8{\cdot}85\times10^{-12}r^2}$ **(1)** $r = 0{\cdot}088$ m **(1)**	3	Accept 0·09, 0·0877, 0·08769 Accept 0·08773 if 9×10^9 used.

Exam question — 2025 Q13(a)

13. A small, positively charged sphere is fixed to an insulated stand, as shown in **Figure 13A**.

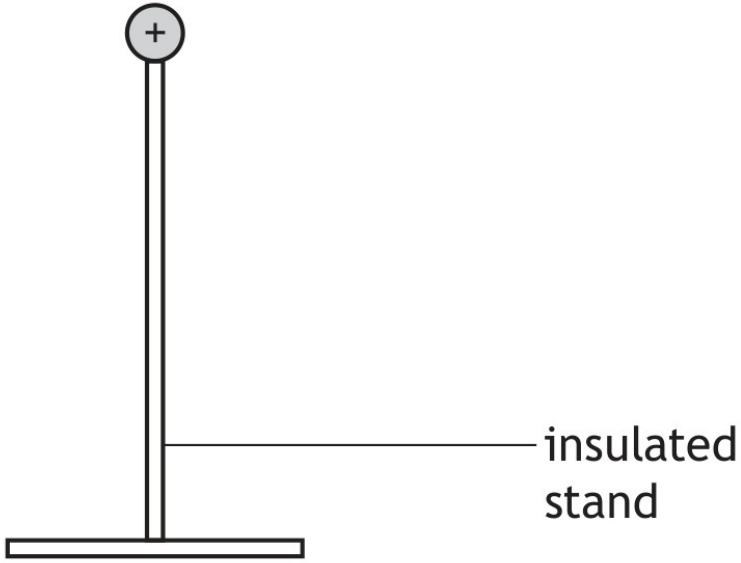
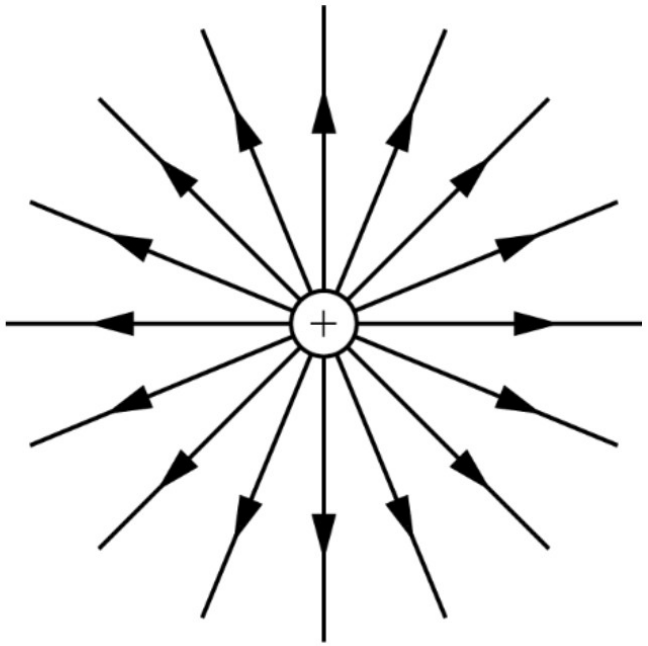


Figure 13A

(a) On **Figure 13A**, sketch the electric field pattern around the charged sphere. **1**

(An additional diagram, if required, can be found on *page 54*.)

Marking — 2025 Q13(a)

Question			Expected response	Max mark	Additional guidance
13.	(a)			1	Field lines should be evenly spaced around the charge. Field lines should be passably straight. Field lines should be touching the charge. Minimum number of field lines is five.

Exam question — 2025 Q13(c)(i)

13. A small, positively charged sphere is fixed to an insulated stand, as shown in **Figure 13A**.

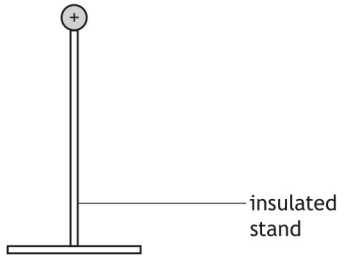


Figure 13A

(c) Another charged sphere of mass 16 g is suspended by a thin, insulating cord.

This suspended sphere is moved towards the fixed sphere. When the distance between the two spheres is 0.15 m the deflection of the cord is 5.0° from the vertical.

This is shown in **Figure 13B**.

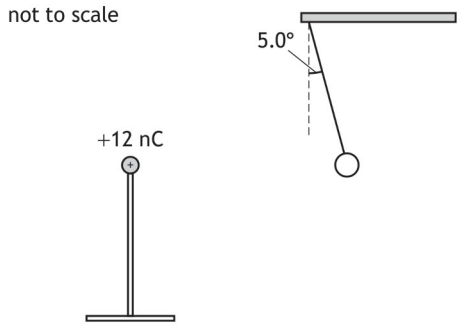


Figure 13B

(i) Determine the magnitude of the electrostatic force acting on the suspended sphere. **3**

Space for working and answer

Marking — 2025 Q13(c)(i)

Question			Expected response		Max mark	Additional guidance
	(c)	(i)	$F = mg\tan\theta$ $F = 16\times10^{-3}\times9.8\times\tan 5.0$ $F = 1.4\times10^{-2}$ N	(1) (1) (1)	3	Accept 1, 1.37, 1.372

Look back — by the end of this part…



1. I can **describe** what an electric field is.
2. I can **sketch** the field around point charges.
3. I can use $F = Q_1Q_2/4\pi\varepsilon_0 r^2$ for one or more charges.

Starter — from memory, notes closed



1. **State** what is meant by an **electric field**.
2. **Write** Coulomb's law.
3. **State** the value of ε_0, with its unit.
4. **Sketch** the field between a + and a − charge.
5. **State** how F changes if both charges **double**.



Under a storm cloud the air breaks down. How strong is the field?

PART 2

How strong is the field at a point?

Field strength: the force on one coulomb of positive charge.

By the end of this part…

1. I can **state** what is meant by **electric field strength**.
2. I can use $E = Q/4\pi\varepsilon_0 r^2$.
3. I can **determine** E from two charges, size and direction.

Electric field strength



LEARN THIS WORD FOR WORD

Electric field strength is the **electrical force acting on unit positive charge.**

Example answer — 2017 Q11(a)

11. (a) **State** what is meant by the term **electric field strength.** **1**

Marking: 2017 Q11(a)

Question	Expected response	Max mark	Additional guidance
11 (a)	Force acting per unit positive charge (in an electric field) (1 mark)	1	

Field strength from force

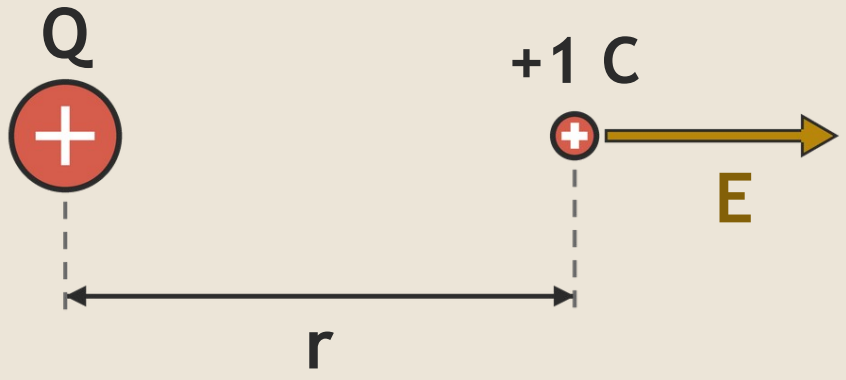
$$E = F/Q$$

E: electric field strength (N C^{-1})

F: force on the charge (N)

Q: charge placed there (C)

Direction of E: force on a + charge.



Field strength around a point charge

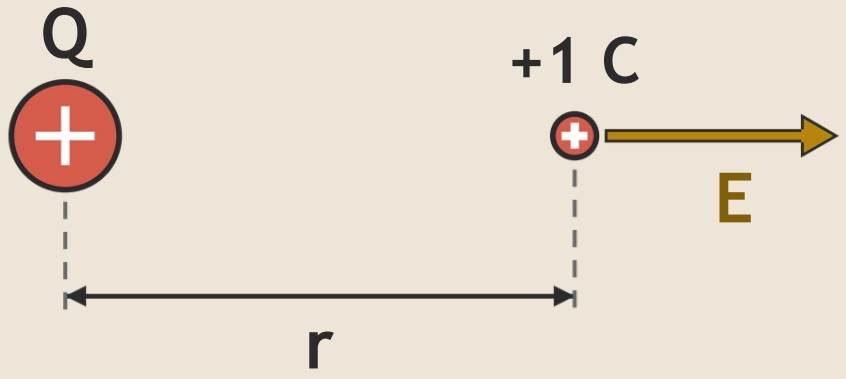
$$E = Q/4\pi\varepsilon_0 r^2$$

E: electric field strength (N C^{-1})

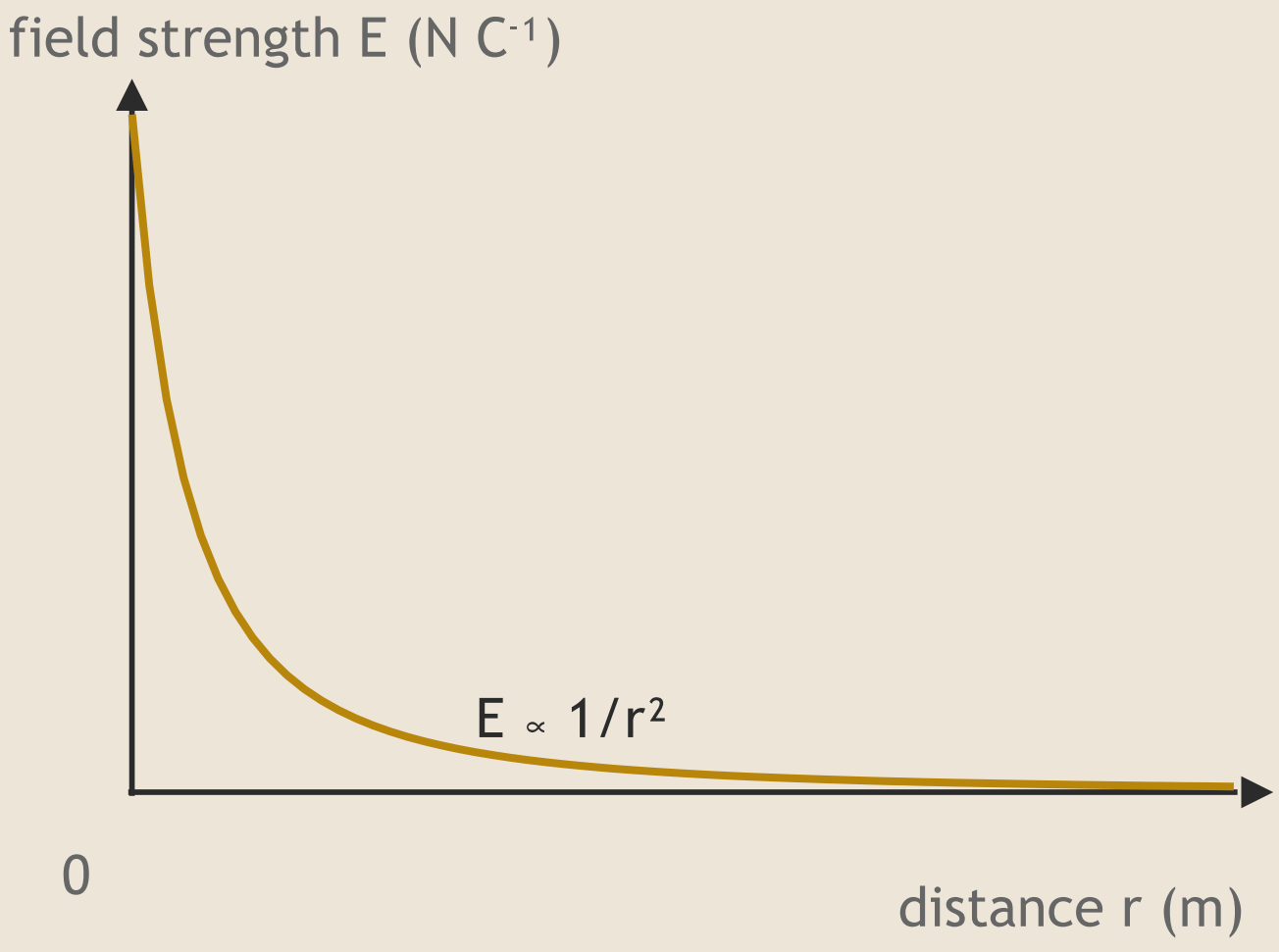
Q: the charge making the field (C)

r: distance from it (m)

Inverse square: 2r gives E/4.



Field strength against distance



Close

Very strong field.

Double r

E is a quarter.

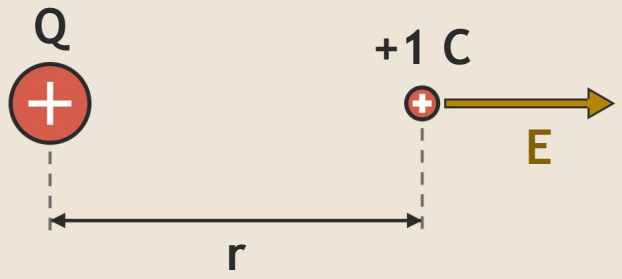
Far away

E tends to zero.

Worked example 5 — field strength

A point charge of **+7.5 nC** is in air.

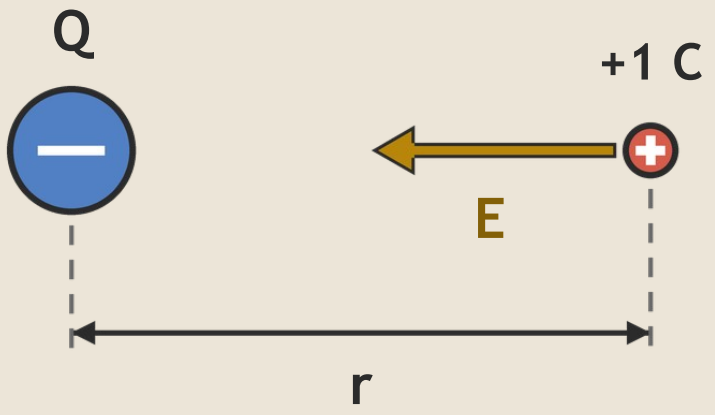
Calculate the electric field strength at a distance of **0.20 m** from the charge. **3**



Marking: Worked example 5

Question	Expected response	Max mark	Additional guidance
	$E = Q / 4\pi\varepsilon_0 r^2$ (1 mark) $E = 7.5 \times 10^{-9} / (4\pi \times 8.85 \times 10^{-12} \times 0.20^2)$ (1 mark) $E = 1.7 \times 10^3$ N C^{-1} (1 mark)	3	Accept 2×10^3, 1.69×10^3, 1.686×10^3.

Calculate the electric field strength **0.050 m** from a **−2.5 nC** point charge.



$E = 9.0 \times 10^{3}$ N C^{-1}, towards the charge

Two or more charges — add E as vectors

Each charge

Its own E at the point.

Direction

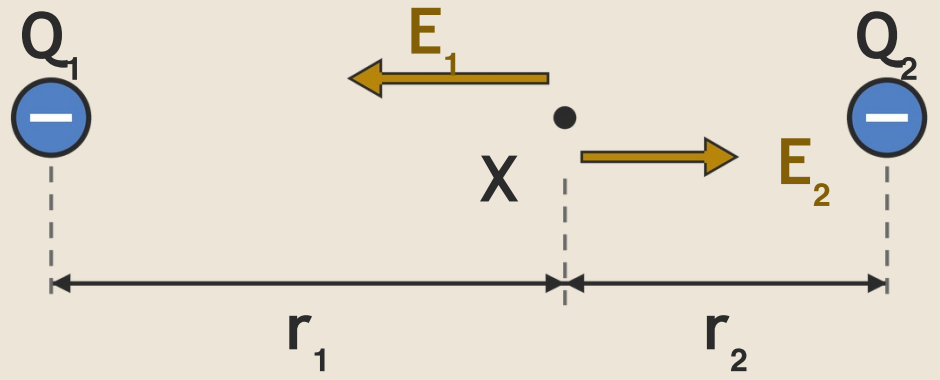
Away from +, towards −.

In a line

Add or subtract.

At right angles

Pythagoras, then angle.

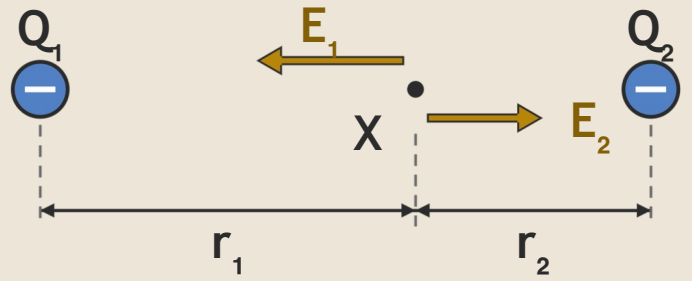


Worked example 6 — field strength in a line

Q_1 = **−8.0 nC** and Q_2 = **−2.0 nC**. Point X is between them: r_1 = **0.30 m** and r_2 = **0.20 m**.

Determine the size and direction of the resultant electric field strength at X.

4



Marking: Worked example 6

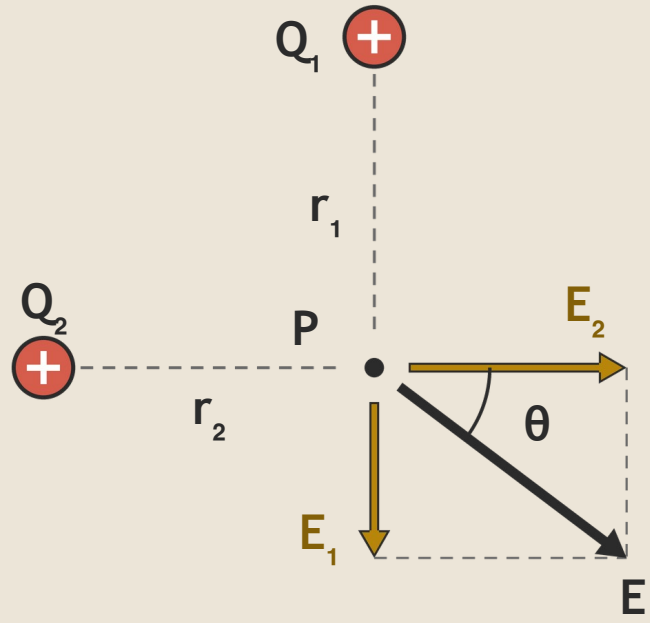
Question	Expected response	Max mark	Additional guidance
	$E_1 = 8.0 \times 10^{-9} / (4\pi \times 8.85 \times 10^{-12} \times 0.30^2) = 799$ N C^{-1} (1 mark) $E_2 = 2.0 \times 10^{-9} / (4\pi \times 8.85 \times 10^{-12} \times 0.20^2) = 450$ N C^{-1} (1 mark) E = 799 – 450 (1 mark) E = 350 N C^{-1} towards Q_1 (1 mark)	4	Direction needed for the last mark.

Worked example 7 — field strength at right angles

Q_1 = **+5.0 nC** is **0.30 m** above point P. Q_2 = **+12 nC** is **0.40 m** to the left of P.

Determine the size and direction of the resultant electric field strength at P.

4



Marking: Worked example 7

Question	Expected response	Max mark	Additional guidance
	E_1 = 500 N C^{-1} (down) and E_2 = 674 N C^{-1} (right) (1 mark) $E = \sqrt{(500^2 + 674^2)}$ (1 mark) E = 839 N C^{-1} (1 mark) θ = 37° below the horizontal, to the right (1 mark)	4	Accept 840, 839.2. Trigonometry also accepted.

Watch Out — state a direction in full

Write

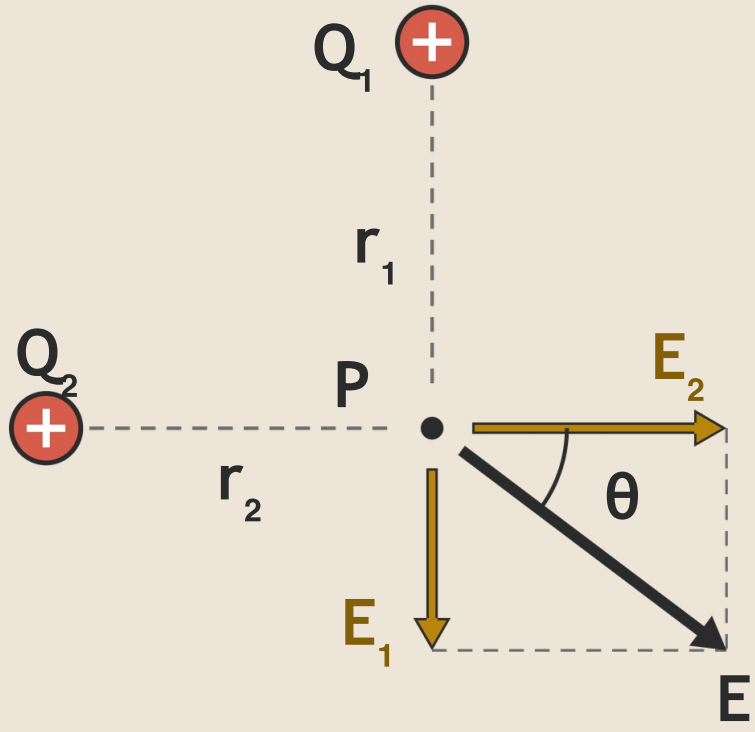
"Vertically down the page".

Or

"Away from Q_1", "towards Q_2".

Not

"Down" on its own.



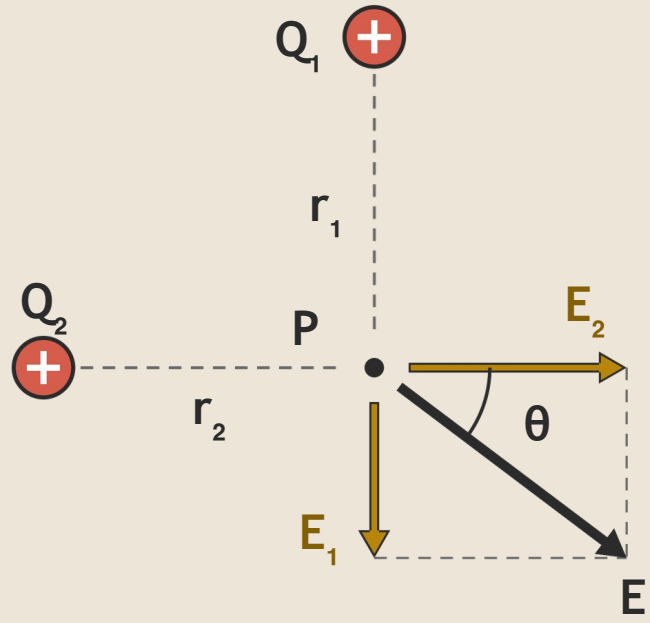
2024 Q13(b)(ii): facility 0.18.

Worked example 8 — a charge placed at the point

A **−1.5 nC** charge is now placed at P, where E = **839 N C^{-1}**.

(a) **Calculate** the size of the force on this charge. **3**

(b) **State** the direction of this force. **1**



Marking: Worked example 8

Question	Expected response	Max mark	Additional guidance
(a)	F = QE (1 mark) F = $1.5 \times 10^{-9} \times 839$ (1 mark) F = 1.3×10^{-6} N (1 mark)	3	Accept 1, 1.26, 1.259.
(b)	37° above the horizontal, to the left - opposite to E (1 mark)	1	

How it's marked — 2017 Q11(b)(i)

(b) A, B, C and D are the vertices of a square of side 0·12 m.

Two +4·0 nC point charges are placed at positions B and D as shown in Figure 11A.

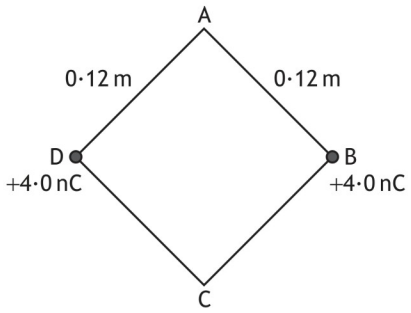


Figure 11A

(i) Show that the magnitude of the electric field strength at position A is $3{\cdot}5 \times 10^3\ \text{N C}^{-1}$. **3**

Space for working and answer

Question			Answer	Max mark	Additional guidance
	(b)	(i)	$E = \frac{Q}{4\pi\varepsilon_0 r^2}$ 1 $E = \frac{4{\cdot}0 \times 10^{-9}}{4\pi \times 8{\cdot}85 \times 10^{-12} \times 0{\cdot}12^2}$ 1 $E_{total} = \sqrt{2 \times \left[\frac{4{\cdot}0 \times 10^{-9}}{4\pi \times 8{\cdot}85 \times 10^{-12} \times 0{\cdot}12^2}\right]^2}$ 1 $E_{total} = 3{\cdot}5 \times 10^3\ \text{N C}^{-1}$	3	If value for ε_0 not substituted, max 1 mark. third line can be done by trigonometry rather than Pythagoras. $E_{total} = 2 \times \left[\frac{4{\cdot}0 \times 10^{-9}}{4\pi \times 8{\cdot}85 \times 10^{-12} \times 0{\cdot}12^2}\right] \times \sin 45$ 1 If the final line is not shown then maximum 2 marks can be awarded.

Exam question — 2025 Q13(b)

13. A small, positively charged sphere is fixed to an insulated stand, as shown in **Figure 13A**.

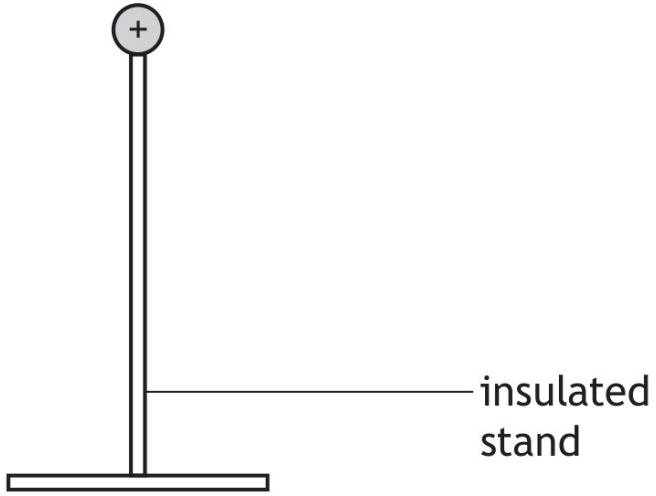


Figure 13A

(b) The charge on the sphere is +12 nC.

Show that the electric field strength at a distance of 0.15 m from the centre of the charged sphere is 4800 N C^{-1}. **2**

Space for working and answer

Marking — 2025 Q13(b)

Question	Expected response	Max mark	Additional guidance
(b)	$E = \frac{Q}{4\pi\varepsilon_0 r^2}$ (1) $E = \frac{12\times10^{-9}}{4\pi\times8.85\times10^{-12}\times0.15^2}$ (1) $E = 4800\ \text{NC}^{-1}$	2	SHOW question $E = k\frac{Q}{r^2}$ (1) $E = 9\times10^{9}\times\frac{12\times10^{-9}}{0.15^2}$ (1) $E = 4800\ \text{NC}^{-1}$ Final line must be shown or max 1 mark.

Exam question — 2024 Q13(a)(ii)

13. (a) An electric field exists around a point charge Q_1.

The charge of Q_1 is −4.5 nC.

(ii) Calculate the electric field strength at a distance of 0.088 m from Q_1. **3**

Space for working and answer

Marking — 2024 Q13(a)(ii)

Question			Expected response	Max mark	Additional guidance
		(ii)	$E = \frac{Q}{4\pi\varepsilon_0 r^2}$ (1) $E = \frac{-4.5\times10^{-9}}{4\pi\times8.85\times10^{-12}\times0.088^2}$ (1) $E = -5.2\times10^{3}\ \text{NC}^{-1}$ (1)	3	Accept: -5, -5.23, -5.225 Using 9×10^9 gives -5.230

Exam question — 2024 Q13(b)(i)

(b) Point S is at a distance of 0.088 m from charge Q_1.

A second identical charge Q_2 is now placed at a distance of 0.088 m from point S as shown in **Figure 13A**.

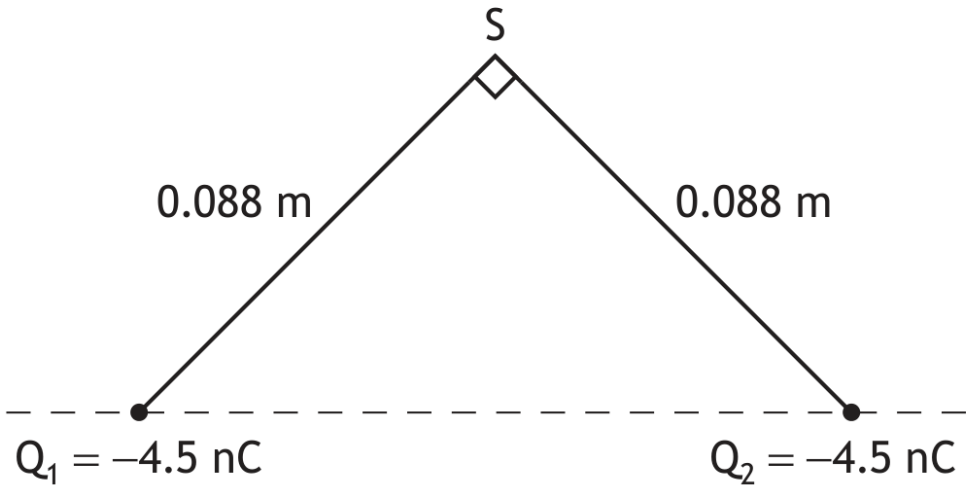


Figure 13A

(i) Determine the magnitude of the resultant electric field strength at point S due to both charges. **2**

Space for working and answer

Marking — 2024 Q13(b)(i)

Question			Expected response	Max mark	Additional guidance
	(b)	(i)	$\left(E_T = \sqrt{E_1^2 + E_2^2}\right)$ $E_T = \sqrt{\left(-5.2\times10^3\right)^2 + \left(-5.2\times10^3\right)^2}$ **(1)** $E_T = 7.4\times10^3 \text{ NC}^{-1}$ **(1)**	**2**	Accept: 7, 7.35, 7.354 Or consistent with (a)(ii) Accept alternative methods using trigonometry.

Look back — by the end of this part…

1. I can **state** what is meant by **electric field strength**.
2. I can use $E = Q/4\pi\varepsilon_0 r^2$.
3. I can **determine** E from two charges, size and direction.

Starter — from memory, notes closed



1. **State** what is meant by **electric field strength**.
2. **Write** the relationship for E around a point charge.
3. **State** the unit of electric field strength.
4. **State** why E from two charges is added as a vector.
5. **State** what is meant by **gravitational potential**.



These birds sit on a high-voltage line. Why are they safe?

PART 3

How much work to bring a charge in?

Potential: work done per coulomb, from infinity.

By the end of this part…

1. I can **state** what is meant by **electrical potential**.
2. I can use $V = Q/4\pi\varepsilon_0 r$, adding potentials as scalars.
3. I can **calculate** the work done to move a charge.

Electrical potential



LEARN THIS WORD FOR WORD

The electrical potential at a point is the **work done in moving unit positive charge from infinity to that point.**

Compare — gravitational potential

Both

Zero at infinity.

Gravity

Always negative.

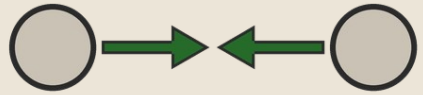
+Q

V positive: work to push in.

−Q

V negative: it pulls in.

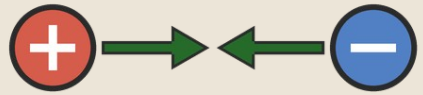
Masses: always attract



Like charges: repel



Unlike charges: attract



Potential around a point charge

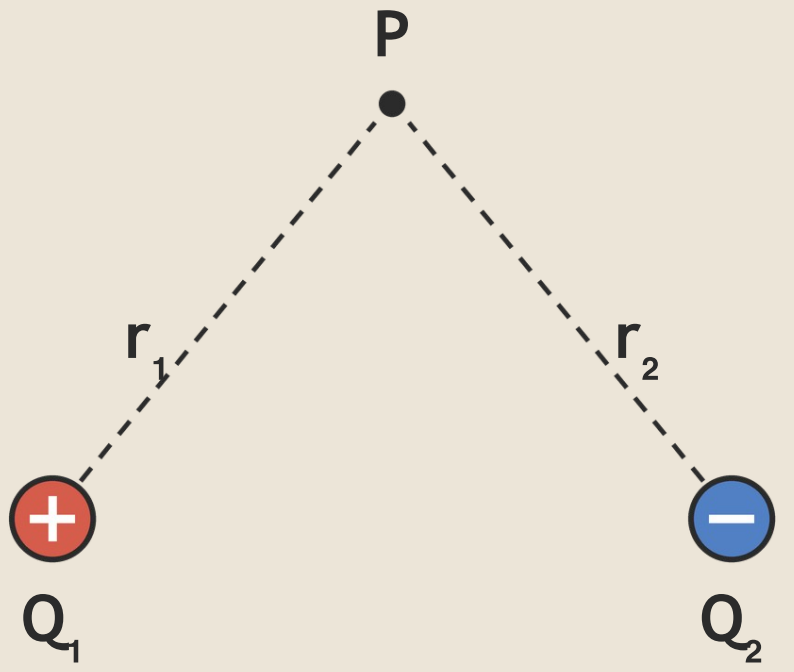
$$V = Q/4\pi\varepsilon_0 r$$

V: electrical potential (V)

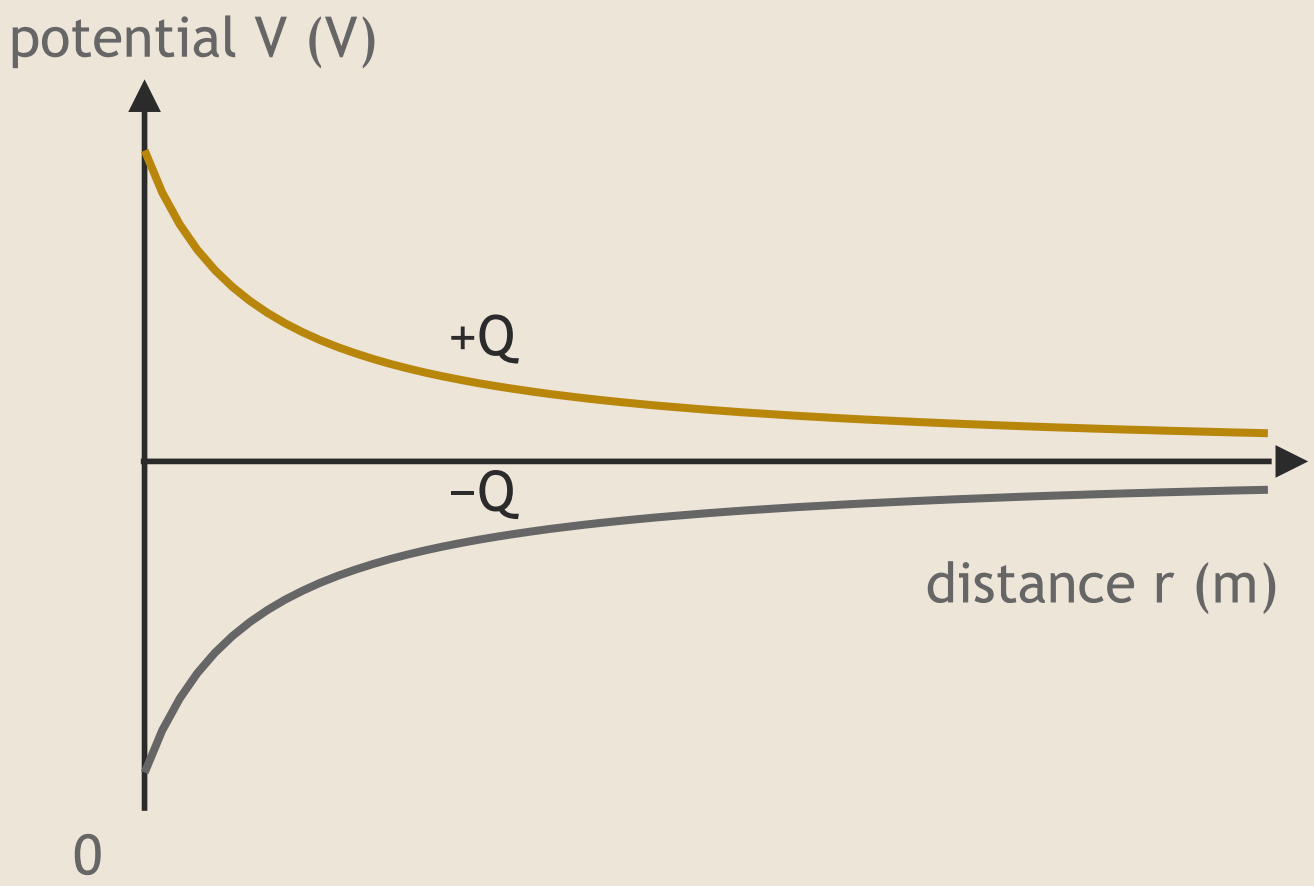
Q: the charge (C) — keep its sign

r: distance from it (m)

1/r, not $1/r^2$.



Potential against distance



+Q

V positive, falls to 0.

−Q

V negative, rises to 0.

Shape

$V \propto 1/r$.

E is a vector, V is a scalar

E

Size and direction.

Add E

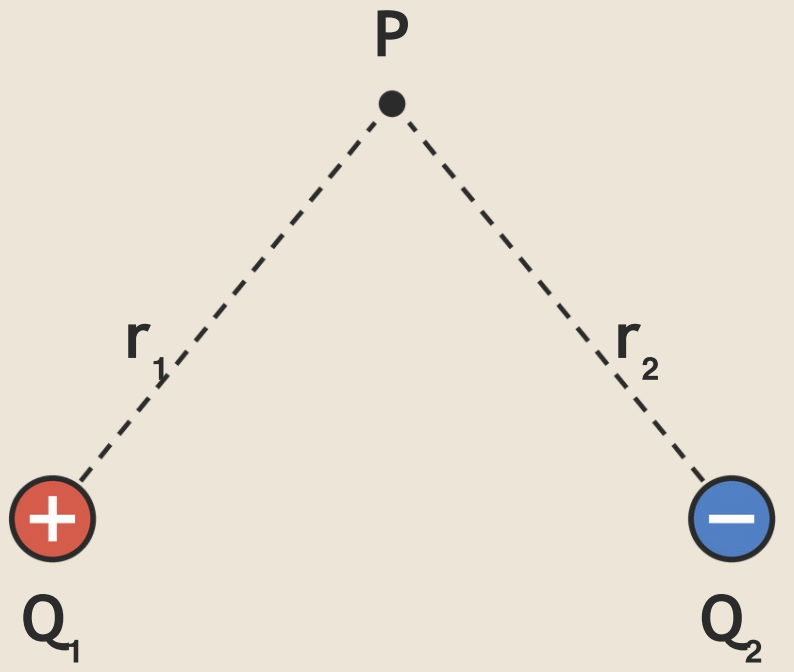
Vectors: arrows.

V

Size and sign only.

Add V

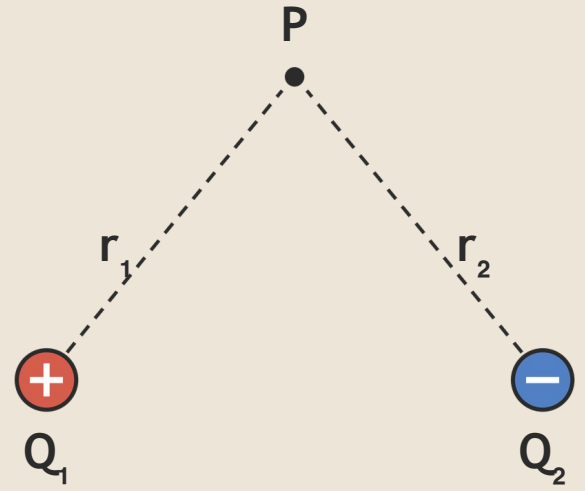
Just add, with signs.



Worked example 9 — potential from two charges

Q_1 = **+4.0 nC** is **0.20 m** from P. Q_2 = **−6.0 nC** is **0.50 m** from P.

Determine the electrical potential at P due to both charges. **4**



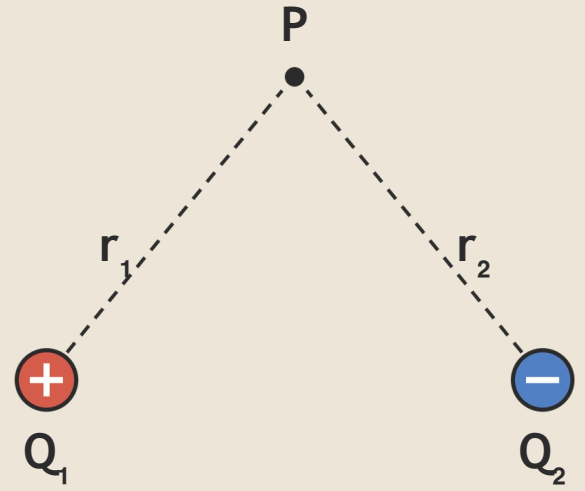
Marking: Worked example 9

Question	Expected response	Max mark	Additional guidance
	$V = Q / 4\pi\varepsilon_0 r$ (1 mark) $V_1 = 4.0 \times 10^{-9} / (4\pi \times 8.85 \times 10^{-12} \times 0.20) = 180$ V (1 mark) $V_2 = -6.0 \times 10^{-9} / (4\pi \times 8.85 \times 10^{-12} \times 0.50) = -108$ V (1 mark) $V = 180 + (-108) = 72$ V (1 mark)	4	Accept 70, 71.9, 71.93.

Worked example 10 — where the potential is zero

Q_1 = **+9.0 nC** is **0.25 m** from point Y. A second charge Q_2 is placed **0.35 m** from Y. The potential at Y is now **zero**.

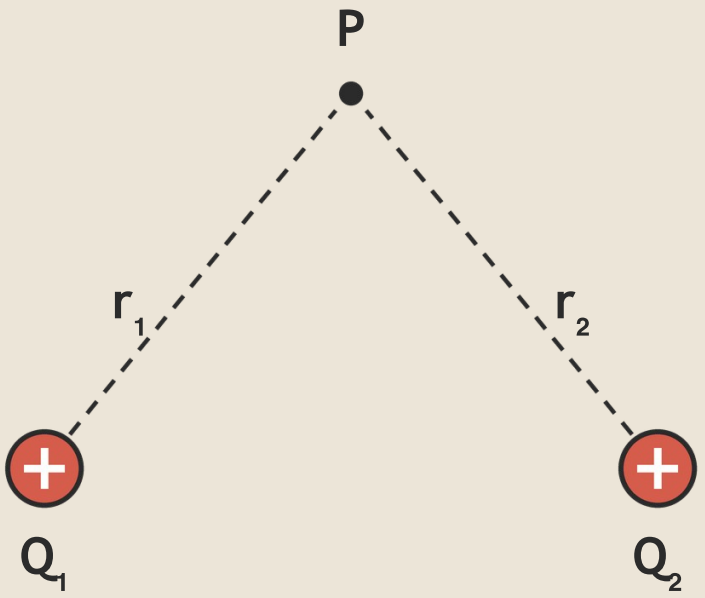
Determine the charge Q_2. **3**



Marking: Worked example 10

Question	Expected response	Max mark	Additional guidance
	$V_1 = 9.0 \times 10^{-9} / (4\pi \times 8.85 \times 10^{-12} \times 0.25) = 324$ V, so $V_2 = -324$ V (1 mark) $-324 = Q_2 / (4\pi \times 8.85 \times 10^{-12} \times 0.35)$ (1 mark) $Q_2 = -1.3 \times 10^{-8}$ C (1 mark)	3	Accept −13 nC, -1.26×10^{-8} C.

Determine the potential at a point **0.10 m** from **+2.0 nC** and **0.30 m** from **+3.0 nC**.



$$V = 180 + 90 = 270\ V$$

The path does not matter

X to Y

Same work, any path.

Why

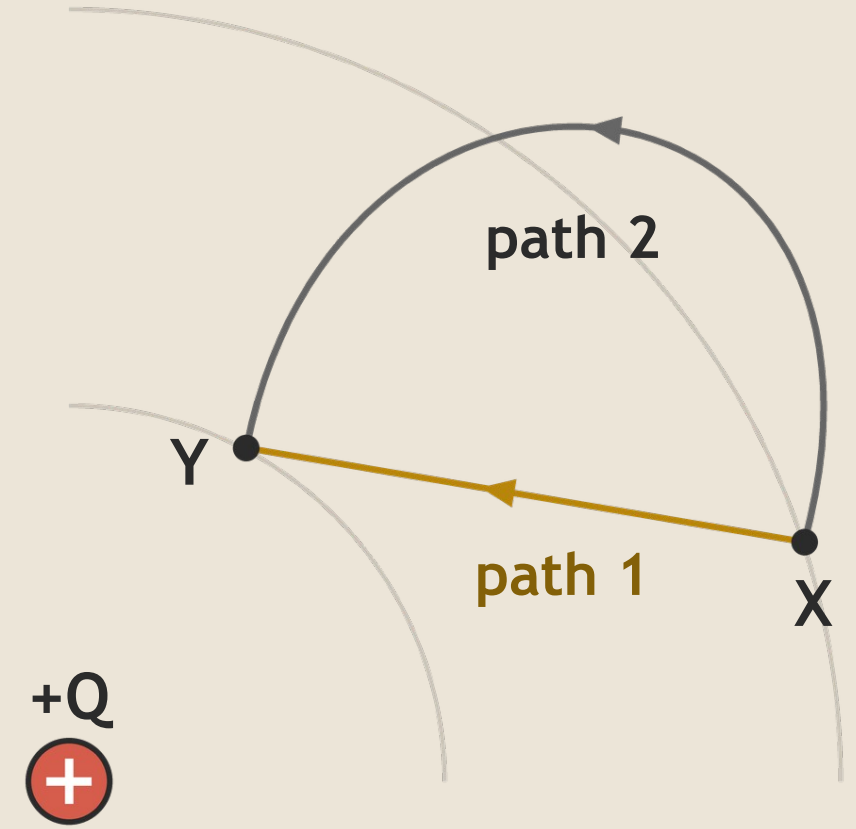
Only start and end V count.

Work done

$W = Q(V_Y - V_X)$.

Same as

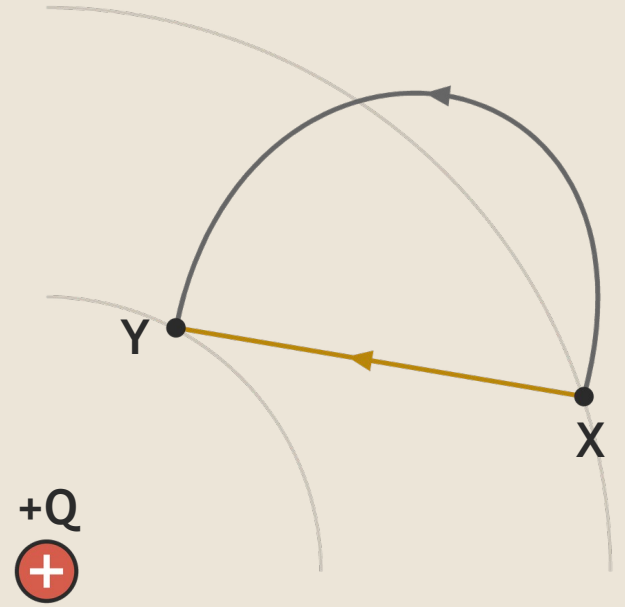
Gravity: path independent.



Worked example 11 — work done moving a charge

A fixed charge of **+5.0 nC**. Point X is **0.60 m** from it and point Y is **0.20 m** from it.

Determine the work done in moving a **+2.0 × 10^{-12} C** charge from X to Y. **4**



Marking: Worked example 11

Question	Expected response	Max mark	Additional guidance
	$V_X = 5.0 \times 10^{-9} / (4\pi \times 8.85 \times 10^{-12} \times 0.60) = 74.9$ V and $V_Y = 225$ V (1 mark) $\Delta V = 225 - 74.9 = 150$ V (1 mark) $W = QV = 2.0 \times 10^{-12} \times 150$ (1 mark) $W = 3.0 \times 10^{-10}$ J (1 mark)	4	Accept 3, 2.99, 2.997.

How it's marked — 2016 Q13(a)

13. (a) Q_1 is a point charge of +12 nC. Point Y is 0·30 m from Q_1 as shown in Figure 13A.

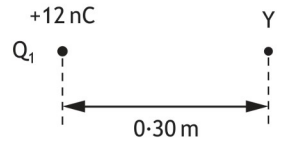


Figure 13A

Show that the electrical potential at point Y is +360 V. **2**

Space for working and answer

Question			Answer	Max Mark	Additional Guidance
13	(a)		SHOW QUESTION	2	$V = k\frac{Q_1}{r}$ **1**
			$V = \frac{1}{4\pi\varepsilon_o}\frac{Q_1}{r}$ **1**		$V = \frac{9\times10^{9}\times12\times10^{-9}}{0\cdot30}$ **1**
			$V = \frac{1}{4\pi\times8\cdot85\times10^{-12}}\frac{12\times10^{-9}}{0\cdot30}$ **1**		**OR**
			$V = (+)360$ V		$V = \frac{12\times10^{-9}}{1\cdot1\times10^{-10}\times0\cdot30}$
					$V = (+)360$ V
					If either a value for k or ε_0 is not given, then a maximum of 1 mark can be awarded.
					If the final line is missing then a maximum of 1 mark can be awarded

Exam question — 2019 Q14(a)

14. (a) (i) A point charge of $+1{\cdot}3 \times 10^{-14}$ C is placed 48 mm from point P.

Show that the electrical potential at P due to this charge is $2{\cdot}4 \times 10^{-3}$ V. **2**

Space for working and answer.

(ii) A second point charge, of $-1{\cdot}3 \times 10^{-14}$ C, is now placed 52 mm from P.

This is shown in Figure 14A.

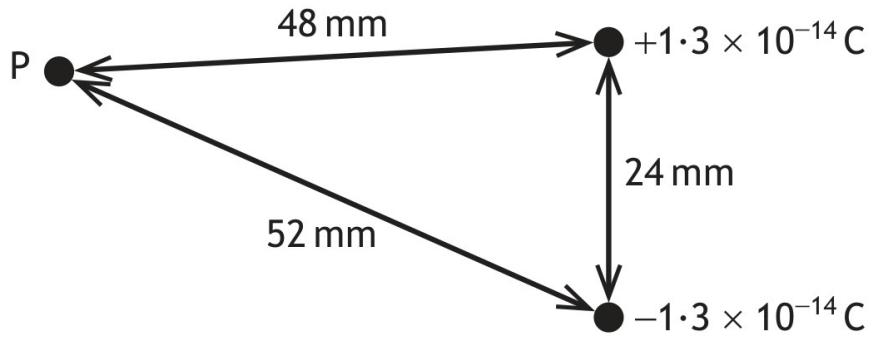


Figure 14A

Determine the electrical potential at P due to both charges. **3**

Space for working and answer.

Marking — 2019 Q14(a)

Question			Expected response	Max mark	Additional guidance
14.	(a)	(i)	$V = \frac{Q}{4\pi\varepsilon_0 r}$ (1) $V = \frac{1{\cdot}3\times10^{-14}}{4\pi\times8{\cdot}85\times10^{-12}\times48\times10^{-3}}$ (1) $V = 2{\cdot}4\times10^{-3}$ V	2	SHOW QUESTION $V = k\frac{Q}{r}$ (1 $V = 9\times10^{9}\times\frac{1{\cdot}3\times10^{-14}}{48\times10^{-3}}$ (1 $V = 2{\cdot}4\times10^{-3}$ V Final answer must be show or max **(1 mark).**
		(ii)	$\left(V = \frac{Q}{4\pi\varepsilon_0 r}\right)$ $V_{(-)} = \frac{-1{\cdot}3\times10^{-14}}{4\pi\times8{\cdot}85\times10^{-12}\times52\times10^{-3}}$ (1) $(V_{(P)} = V_{(+)} + V_{(-)})$ $V_{(P)} = 2\cdot4\times10^{-3} + \frac{-1{\cdot}3\times10^{-14}}{4\pi\times8{\cdot}85\times10^{-12}\times52\times10^{-3}}$ (1) $V_{(P)} = 1{\cdot}5\times10^{-4}$ V (1)	3	Method using k as above acceptable. Accept: 2, 1·52, 1·520 (ϵ_0) Accept: 2, 1·50, 1·500 (k)

Exam question — 2023 Q13(a)

13. A polar molecule is positively charged at one side and negatively charged at the other side.

One polar molecule can be modelled as two point charges connected together and separated by a fixed distance of 1.33×10^{-10} m. This is shown in **Figure 13A**.

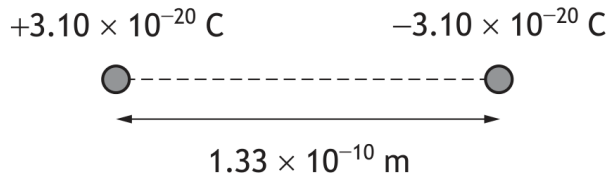


Figure 13A

(a) Point P is 2.10×10^{-10} m to the right of the negative charge as shown in **Figure 13B**.

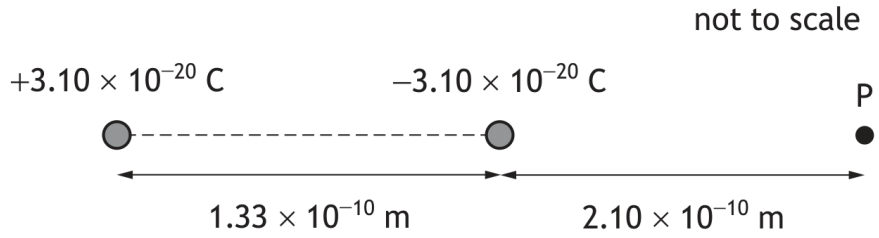


Figure 13B

Determine the electric potential at point P due to both charges. **4**

Space for working and answer

Marking — 2023 Q13(a)

Question			Expected response		Max mark	Additional guidance
13.	(a)		$V = \frac{Q}{4\pi\varepsilon_0 r}$	1	4	Accept: 0.51, 0.5147, 0.51469 For 9×10^9: Accept: 0.52, 0.5152, 0.51516
			$V_1 = \frac{3.10\times10^{-20}}{4\pi\times8.85\times10^{-12}\times(1.33\times10^{-10}+2.10\times10^{-10})}$	1		
			$V_2 = \frac{-3.10\times10^{-20}}{4\pi\times8.85\times10^{-12}\times2.10\times10^{-10}}$	1		
			$(V = V_1 + V_2)$			
			$V = -0.515$ V	1		

Look back — by the end of this part…



1. I can **state** what is meant by **electrical potential**.
2. I can use $V = Q/4\pi\varepsilon_0 r$, adding potentials as scalars.
3. I can **calculate** the work done to move a charge.

Point charges in the exam

Year	Question	Marks
2025	Q13 (a) to (d)	11
2024	Q13 (a) to (c)	12
2023	Q13 (a) to (c)(i)	9
2019	Q14 (a) to (b)	7
2018	Q13 (a) to (b)	11
2017	Q11 (a) to (b)	12
2016	Q13 (a) to (b)	11

Past paper finder

Point charges in the exam — the figures

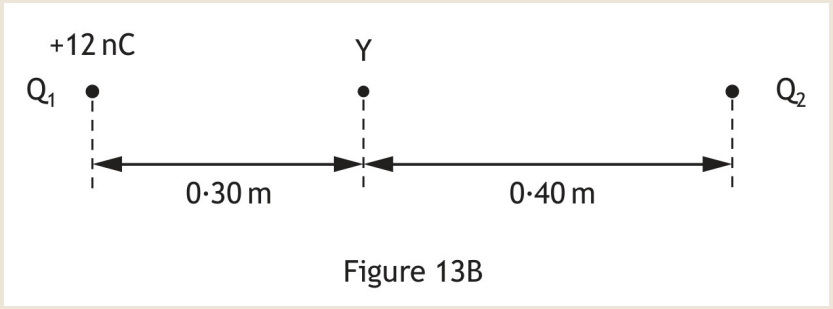


Figure 13B

2016 Q13

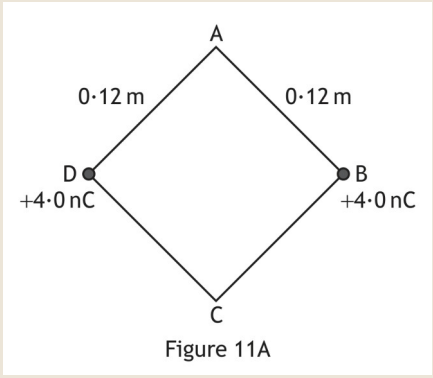


Figure 11A

2017 Q11

Past paper finder

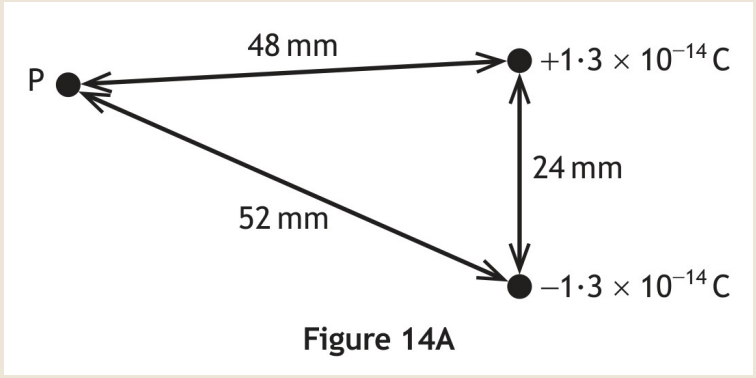


Figure 14A

2019 Q14

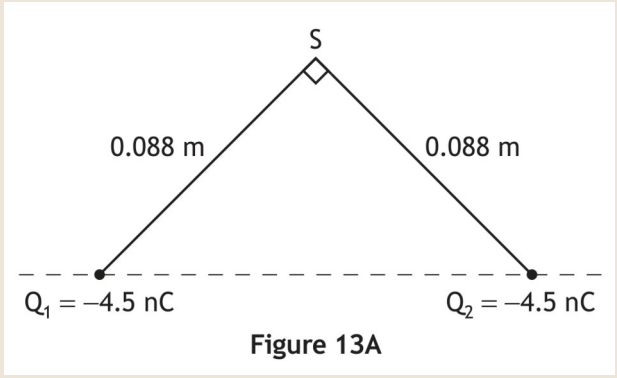


Figure 13A

2024 Q13

Reading and homework

Scholar Topics 1-2

Scholar — Unit 3, Topic 1 Electric force and field
Scholar — Unit 3, Topic 2 Electric potential
BrightRed Study Guide pages 94-95
Past papers — the questions on the last slide

Scholar

Errors that cost marks

- "Per unit charge" scores 0 — say "unit **positive** charge".
- No number for ε_0 substituted: 1 mark at most.
- E has r^2, V has r. Do not mix them up.
- Add E as vectors; add V with signs only.
- Change nC to $\times 10^{-9}$ C and mm to m first.

Check yourself

1. **Sketch** the field round two like, then two unlike, charges.
2. **Calculate** a Coulomb force, then a resultant at right angles.
3. **State** what is meant by electric field strength.
4. **Determine** E from two charges, size and full direction.
5. **State** what is meant by electrical potential.

Experiments you could try

- PhET "Charges and Fields": place charges, read E and V anywhere.
- Two balloons on threads: charge them and measure the angle.
- Rub a balloon: watch it pull a thin stream of tap water.
- Phone video of the hanging balloons: measure θ, find $F = W \tan \theta$.

Course specification — 1 of 3

- Knowledge that an electric field is the region that surrounds electrically charged particles in which a force is exerted on other electrically charged particles.
- Definition of electric field strength as the electrical force acting on unit positive charge.
- Sketch of electric field patterns around single point charges, a system of charges and in a uniform electric field.



Course spec, pages 17-18

Course specification — 2 of 3

- Definition of electrical potential at a point as the work done in moving unit positive charge from infinity to that point.
- Knowledge that the energy required to move charge between two points in an electric field is independent of the path taken.



Course spec, pages 17-18

Course specification — 3 of 3

- Use of appropriate relationships to solve problems involving electrical force, electrical potential and electric field strength around a point charge and a system of charges.
- $F = Q_1Q_2/4\pi\varepsilon_0 r^2$ $V = Q/4\pi\varepsilon_0 r$ $E = Q/4\pi\varepsilon_0 r^2$

Course spec, pages 17-18

Credits (1 of 3)

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Credits (2 of 3)

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Point charges in the exam — the figures: © Qualifications Scotland (SQA). AH Physics 2016, 2017, 2019, 2024.

Reading and homework: SCHOLAR AH Physics © Heriot-Watt University. BrightRed AH Physics Study Guide

Credits (3 of 3)

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R Stewart - November 2026