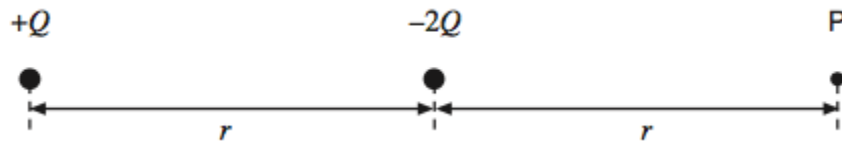


1

The diagram shows two point charges of magnitude $+Q$ and $-2Q$ placed a distance r apart.



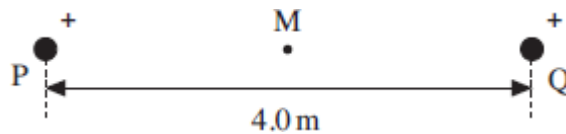
What is the electric potential at point P, a distance r to the right of the $-2Q$ charge?

- A $-\frac{3Q}{8\pi\epsilon_0 r}$
- B $-\frac{Q}{2\pi\epsilon_0 r}$
- C $+\frac{Q}{8\pi\epsilon_0 r}$
- D $+\frac{5Q}{8\pi\epsilon_0 r}$

(Total 1 mark)

2

Two identical positive point charges, P and Q, are separated by a distance of 4.0 m. The resultant electric potential at point M, which is mid-way between the charges, is 25.0 V.



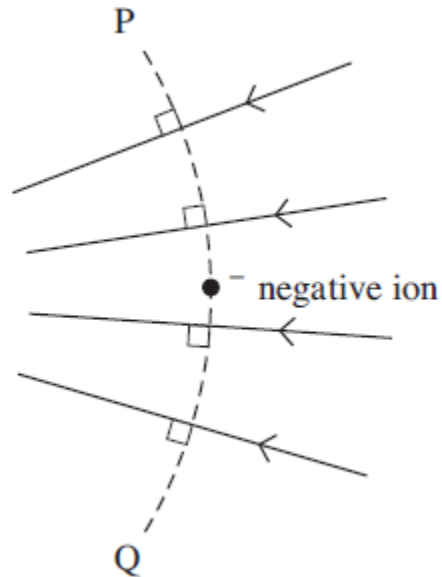
What would be the resultant electrical potential at a point 1.0 m closer to P?

- A 8.3 V
- B 12.5 V
- C 33.3 V
- D 37.5 V

(Total 1 mark)

3

The diagram shows a negative ion at a point in an electric field, which is represented by the arrowed field lines.



Which one of the following statements correctly describes what happens when the ion is displaced?

When the negative ion is displaced

- A to the left the magnitude of the electric force on it decreases.
- B to the right its potential energy increases.
- C along the line PQ towards Q its potential energy decreases.
- D along the line PQ towards P the magnitude of the electric force on it is unchanged.

(Total 1 mark)

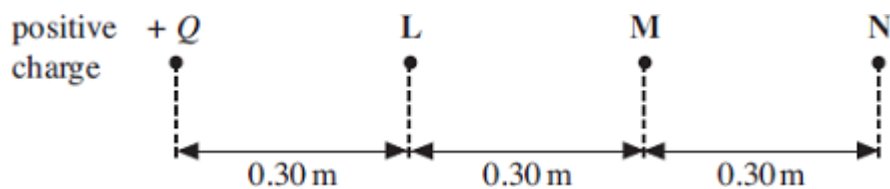
4

(a) Define the electric potential at a point in an electric field.

(3)

- (b) **Figure 1** shows part of the region around a small positive charge.

Figure 1



- (b) (i) The electric potential at point **L** due to this charge is + 3.0 V. Calculate the magnitude Q of the charge. Express your answer to an appropriate number of significant figures.

answer = _____ C

(3)

- (ii) Show that the electric potential at point **N**, due to the charge, is +1.0 V.

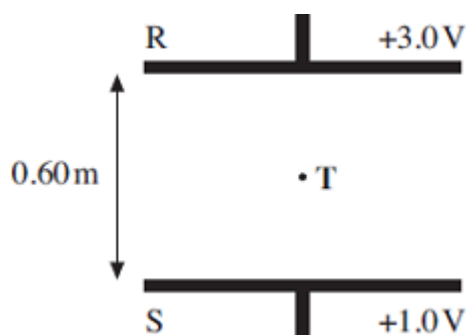
(1)

- (iii) Show that the electric field strength at point **M**, which is mid-way between **L** and **N**, is 2.5 Vm^{-1} .

(1)

- (c) **R** and **S** are two charged parallel plates, 0.60 m apart, as shown in **Figure 2**. They are at potentials of + 3.0 V and + 1.0 V respectively.

Figure 2



- (i) On **Figure 2**, sketch the electric field between **R** and **S**, showing its direction.

(2)

- (ii) Point **T** is mid-way between R and S.
Calculate the electric field strength at **T**.

answer = _____ Vm^{-1}

(1)

- (iii) Parts (b)(iii) and (c)(ii) both involve the electric field strength at a point mid-way between potentials of + 1.0 V and + 3.0 V. Explain why the magnitudes of these electric field strengths are different.

(1)

(Total 12 marks)

5

An electron and a proton are 1.0×10^{-10} m apart. In the absence of any other charges, what is the electric potential energy of the electron?

- A $+2.3 \times 10^{-18}\text{J}$
B $-2.3 \times 10^{-18}\text{J}$
C $+2.3 \times 10^{-8}\text{J}$
D $-2.3 \times 10^{-8}\text{J}$

(Total 1 mark)

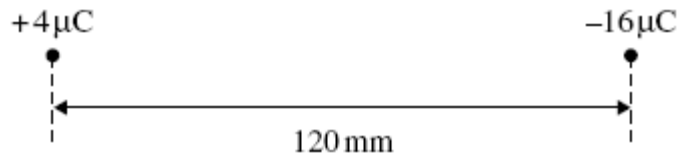
6

The electric potential at a distance r from a positive point charge is 45 V. The potential increases to 50 V when the distance from the charge decreases by 1.5 m. What is the value of r ?

- A 1.3 m
B 1.5 m
C 7.9 m
D 15 m

(Total 1 mark)

7



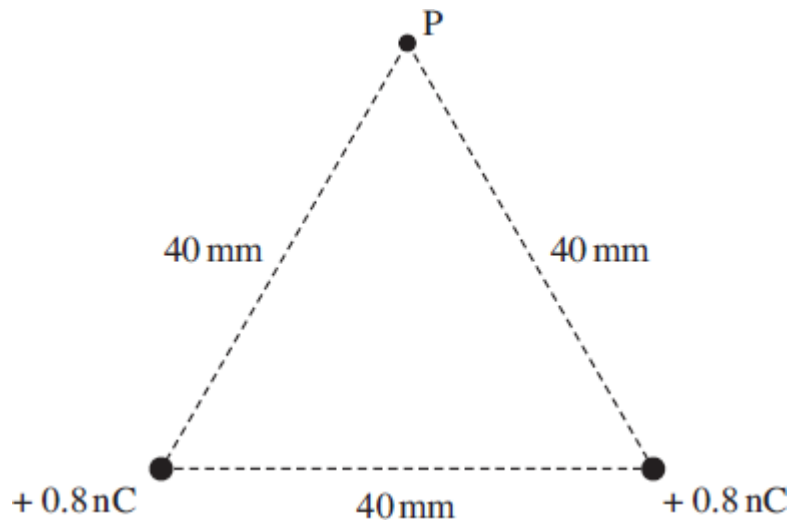
The diagram shows two charges, $+4 \mu\text{C}$ and $-16 \mu\text{C}$, 120 mm apart. What is the distance from the $+4 \mu\text{C}$ charge to the point between the two charges where the resultant electric potential is zero?

- A 24 mm
- B 40 mm
- C 80 mm
- D 96 mm

(Total 1 mark)

8

Two charges, each of $+0.8 \text{ nC}$, are 40 mm apart. Point P is 40 mm from each of the charges.



What is the electric potential at P?

- A zero
- B 180 V
- C 360 V
- D 4500 V

(Total 1 mark)

9

Which one of the following statements about *electric field strength* and *electric potential* is **incorrect**?

- A Electric potential is a scalar quantity.
- B Electric field strength is a vector quantity.
- C Electric potential is zero whenever the electric field strength is zero.
- D The potential gradient is proportional to the electric field strength.

(Total 1 mark)

10



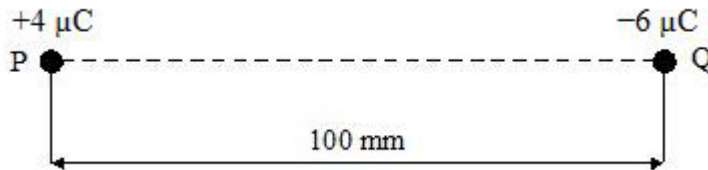
The diagram shows two charges, $+4 \mu\text{C}$ and $-16 \mu\text{C}$, 120 mm apart. What is the distance from the $+4 \mu\text{C}$ charge to the point between the two charges, where the resultant electric potential is zero?

- A 24 mm
- B 40 mm
- C 80 mm
- D 96 mm

(Total 1 mark)

11

Two charges, P and Q, are 100 mm apart.



X is a point on the line between P and Q. If the potential at X is 0 V, what is the distance from P to X?

- A 40 mm
- B 45 mm
- C 50 mm
- D 60 mm

(Total 1 mark)

12

Two horizontal parallel plate conductors are separated by a distance of 5.0 mm in air. The lower plate is earthed and the potential of the upper plate is + 50 V.

Which line, **A** to **D**, gives correctly the electric field strength, E , and the potential, V , at a point midway between the plates?

	<i>electric field strength $E/V\text{ m}^{-1}$</i>	<i>potential V/V</i>
A	1×10^4 upwards	25
B	1×10^4 downwards	25
C	1×10^4 upwards	50
D	1×10^4 downwards	50

(Total 1 mark)

13

Which one of the following statements about *electric field strength* and *electric potential* is **incorrect**?

- A** Electric potential is a scalar quantity.
- B** Electric field strength is a vector quantity.
- C** Electric potential is zero whenever the electric field strength is zero.
- D** The potential gradient is proportional to the electric field strength.

(Total 1 mark)

14

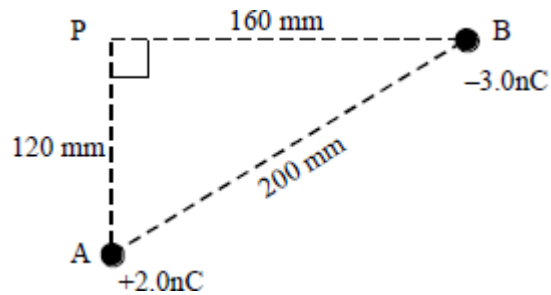
- (a) (i) Define *electric field strength*, and state whether it is a scalar quantity or a vector quantity.

- (ii) Complete the diagram below to show the electric field lines in the region around two equal positive point charges. Mark with a letter N the position of any point where the field strength is zero.



(6)

- (b) Point charges A, of $+2.0 \text{ nC}$, and B, of -3.0 nC , are 200 mm apart in a vacuum, as shown by the figure. The point P is 120 mm from A and 160 mm from B.



- (i) Calculate the component of the electric field at P in the direction AP.

- (ii) Calculate the component of the electric field at P in the direction PB.

(iii) Hence calculate the magnitude and direction of the resultant field at P.

(6)

(c) (i) Explain why there is a point X on the line AB in part (b) at which the **electric potential** is zero.

(ii) Calculate the distance of the point X from A.

(4)

(Total 16 marks)

15

Which one of the following statements about electric potential and electric field strength is correct?

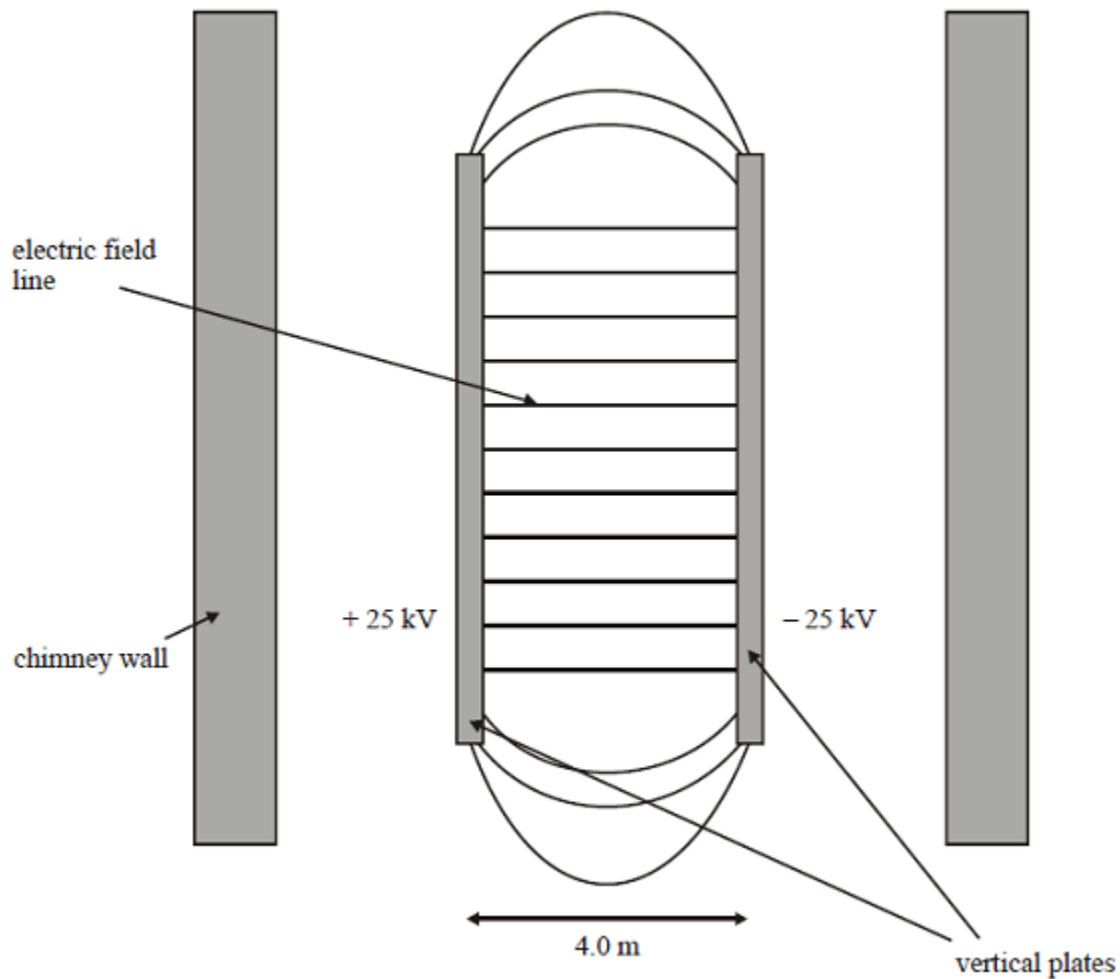
- A Electric potential is zero whenever the electric field strength is zero.
- B Electric field strength is a scalar quantity.
- C Electric potential is a vector quantity.
- D Electric potential due to a point charge varies as $\frac{1}{r}$ where r is the distance from the point charge.

(Total 1 mark)

16

- (a) The diagram below shows part of a precipitation system used to collect dust particles in a chimney. It consists of two large parallel vertical plates maintained at potentials of $+25\text{ kV}$ and -25 kV .

The diagram below also shows the electric field lines between the plates.



- (i) Add arrows to the diagram to show the direction of the electric field.

(1)

- (ii) Explain what is meant by an *equipotential surface*.

(1)

- (iii) Draw and label on the diagram equipotentials that correspond to potentials of -12.5 kV , 0 V , and $+12.5\text{ kV}$.

(2)

(b) A small dust particle moves vertically up the centre of the chimney, midway between the plates.

- (i) The charge on the dust particle is $+5.5 \text{ nC}$. Show that there is an electrostatic force on the particle of about 0.07 mN .

(2)

- (ii) The mass of the dust particle is $1.2 \times 10^{-4} \text{ kg}$ and it moves up the centre of the chimney at a constant vertical speed of 0.80 m s^{-1} .

Calculate the minimum length of the plates necessary for this particle to strike one of them. Ignore air resistance.

(4)

(Total 10 marks)

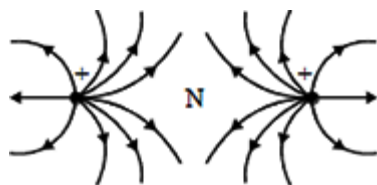
1	A		[1]
2	C		[1]
3	D		[1]
4	(a) work done [or energy needed] per unit charge [or (change in) electric pe per unit charge] ✓ on [or of] a (small) positive (test) charge ✓ in moving the charge from infinity (to the point) ✓ [not from the point to infinity] ✓	3	
	(b) (i) $V = \frac{Q}{4\pi\epsilon_0 r}$ gives $Q (= 4\pi\epsilon_0 rV) = 4\pi \times 8.85 \times 10^{-12} \times 0.30 \times 3.0$ ✓ $= 1.0 \times 10^{-10} \text{ (C)}$ ✓ to 2 sf only ✓	3	
	(ii) use of $V \propto \frac{1}{r}$ gives $V_M = \frac{V_L}{3}$ ✓ (= (+) 1.0 V)	1	
	(iii) $E \left(= \frac{Q}{4\pi\epsilon_0 r^2} \right) = \frac{1.0 \times 10^{-10}}{4\pi \times 8.85 \times 10^{-12} \times 0.60^2}$ ✓ (= 2.50 V m ⁻¹)	1	
	(c) (i) uniformly spaced vertical parallel lines which start and end on plates ✓ relevant lines with arrow(s) pointing only downwards ✓	2	
	(ii) = 3.3(3) (V m ⁻¹) ✓	1	
	(iii) part (b) is a radial field whilst part (c) is a uniform field ✓ [or field lines become further apart between L and M but are equally spaced between R and S]	1	
5	B		[12]

[1]

6	D	[1]
7	A	[1]
8	C	[1]
9	C	[1]
10	A	[1]
11	A	[1]
12	B	[1]
13	C	[1]

- 14 (a) (i) force per unit positive charge **(1)(1)**
[force on a unit charge **(1)** only]
vector **(1)**

(ii)



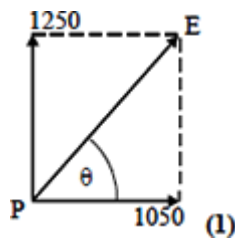
overall correct symmetrical shape **(1)**
outward directions of lines **(1)**
spacing of lines on appropriate diagram **(1)**
neutral point, N, shown midway between charges **(1)**

(b) (i)
$$E_{AP} \left(= \frac{Q}{4\pi\epsilon_0 r^2} \right) = \frac{2 \times 10^{-19}}{4\pi \times 8.85 \times 10^{-12} \times (0.12)^2} \quad (1)$$

$$= 1250 \text{ V m}^{-1} \quad (1)$$

(ii)
$$E_{PB} = \frac{3.0 \times 10^{-9}}{4\pi \times 8.85 \times 10^{-12} \times (0.16)^2} = 1050 \text{ Vm}^{-1} \quad (1)$$

(iii)



allow e.c.f. from wrong numbers in (i) and (ii)

$$E = \sqrt{1250^2 + 1050^2} \text{ (1) } 1630 \text{Vm}^{-1} \text{ (1)}$$

$$\theta = \tan^{-1} \left(\frac{1250}{1050} \right) = 50.0^\circ \text{ to line PB and in correct direction (1)}$$

max 6

- (c) (i) potential due to A is positive, potential due to B is negative (1)
at X sum of potentials is zero (1)

$$(ii) \frac{2 \times 10^{-9}}{4\pi\epsilon_0(x)} + \frac{-3 \times 10^{-9}}{4\pi\epsilon_0(0.20-x)} = 0 \text{ (1)}$$

gives AX (= x) = 0.080m (1) (only from satisfactory use of potentials)

4

[16]

15

D

[1]

16

- (a) (i) shows arrows from + to –

BI

- (ii) surface of constant potential / no work done in moving charge
on surface OWTTE

BI

- (iii) 3 correct lines between plates, straight, labelled, +12.5 kV on left

BI

outwards curvature at edge of plates

BI

- (b) (i) $F = Vq / d$ or $50000 \times 5.5 \times 10^{-9} / 4$

BI

$$= 0.0690 \text{ [mN]} \quad [0.0688]$$

BI

(ii) $a = F / m = 0.069 \times 10^{-3} / 0.12 \times 10^{-3}$

$$= 0.575 / 0.573 \text{ m s}^{-2}$$

CI

use of appropriate kinematic equation

CI

$$t = \sqrt{2 \times 2 / 0.575} = (2.63) \text{ s}$$

CI

so length must be $0.8 \times 2.63 = 2.11 \text{ m}$ [gets mark ecf from third mark if number quoted]

allow alternative energy approach

BI

[10]