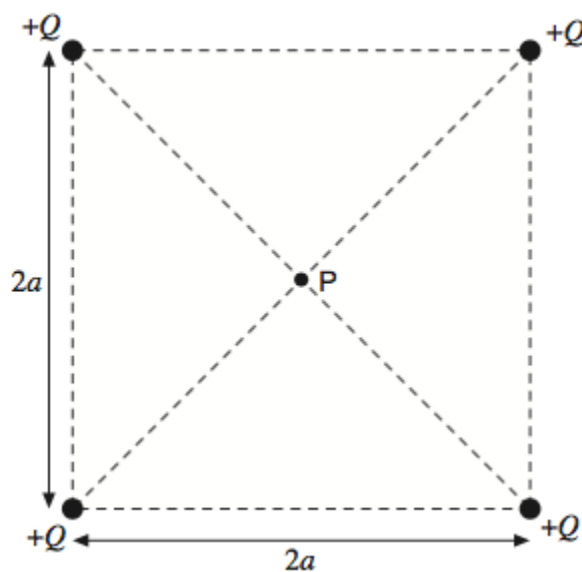


1

The diagram shows four point charges, each $+Q$, at the corners of a square of side $2a$.



What is the electric field strength at P, the centre of the square?

- A zero
- B $\frac{Q}{4\pi\epsilon_0 a^2}$
- C $\frac{Q}{2\pi\epsilon_0 a^2}$
- D $\frac{Q}{\pi\epsilon_0 a^2}$

(Total 1 mark)

2

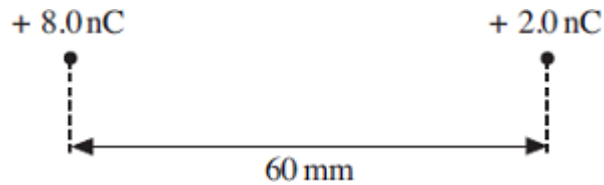
Which one of the following **cannot** be used as a unit for electric field strength?

- A $\text{J m}^{-1} \text{C}^{-1}$
- B $\text{J A}^{-1} \text{s}^{-1} \text{m}^{-1}$
- C $\text{N A}^{-1} \text{s}^{-1}$
- D J C m^{-1}

(Total 1 mark)

3

The distance between two point charges of $+ 8.0 \text{ nC}$ and $+ 2.0 \text{ nC}$ is 60 mm .



At a point between the charges, on the line joining them, the resultant electric field strength is zero. How far is this point from the $+ 8.0 \text{ nC}$ charge?

- A 20 mm
- B 25 mm
- C 40 mm
- D 45 mm

(Total 1 mark)

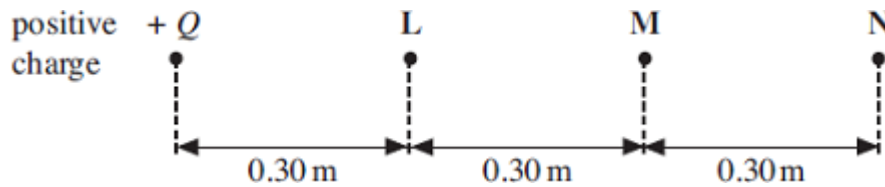
4

- (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 $+ 3.0 \text{ V}$. Calculate the magnitude Q of the charge. Express your answer to an appropriate number of significant figures.

answer = _____ C

(3)

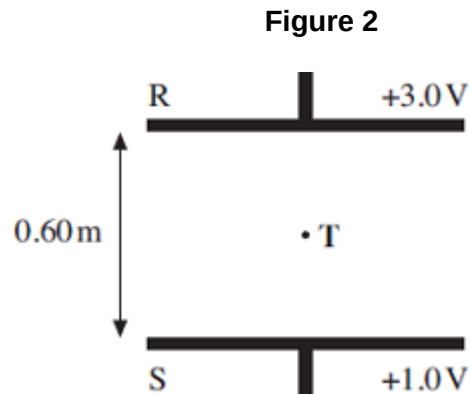
(ii) Show that the electric potential at point **N**, due to the charge, is +1.0 V.

(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.



- (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 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)

6 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 $E/V\ m^{-1}$</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)

7 If the potential difference between a pair of identical, parallel, conducting plates is known, what is the only additional knowledge required to determine the electric field strength between the plates?

- A the permittivity of the medium between the plates
- B the separation and area of the plates
- C the separation and area of the plates and the permittivity of the medium between the plates
- D the separation of the plates

(Total 1 mark)

8

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)

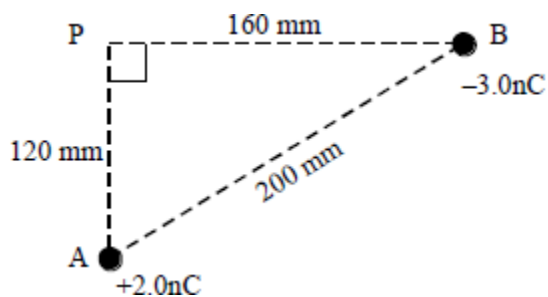
9

- (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.



- (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)

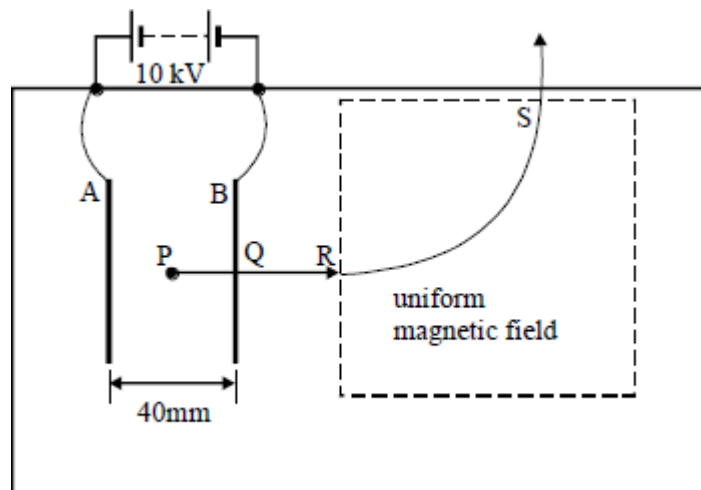
10

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)

11



A positive ion with a mass of 3.4×10^{-26} kg and a charge of 3.2×10^{-19} C is initially at rest at a point P, midway between two parallel conducting plates, A and B which are separated by 40 mm. The ion is accelerated and passes through a hole Q in plate B. It enters a magnetic field of uniform flux density 0.10 T at R. After following a circular path the ion leaves the field at S. Assume that the magnetic field is uniform everywhere within the dotted rectangle and that the space within the solid rectangle is evacuated.

- (a) (i) Calculate the electric field strength between the plates AB.

- (ii) Calculate the force on the ion due to the electric field.

- (iii) Show that the speed of the ion just after it has passed through the hole at Q is $3.1 \times 10^5 \text{ m s}^{-1}$.

(5)

- (b) (i) State the direction of the magnetic field.

- (ii) Explain why the ion follows a circular path in the magnetic field.

- (iii) Show that the radius of the circular path is proportional to the momentum of the ion and calculate the value of the radius.

(6)

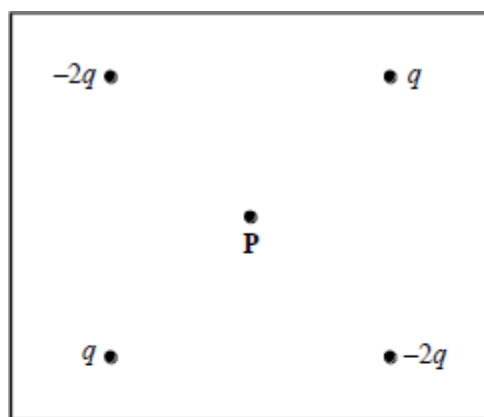
- (c) Explain how, if at all, the trajectory would be different for an ion with a slightly greater mass but carrying the same charge.

(2)

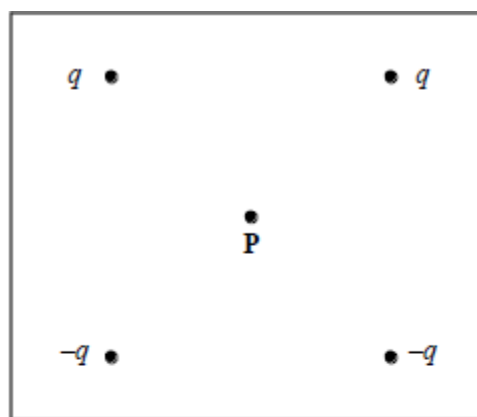
(Total 13 marks)

12

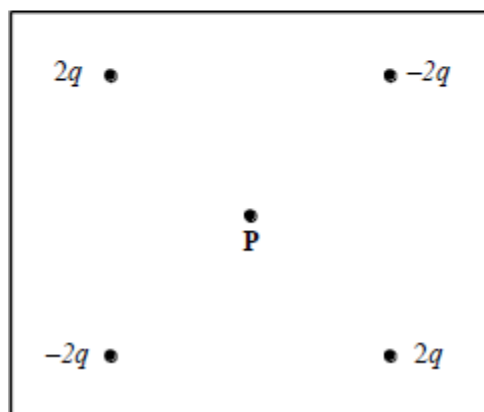
Which one of the following arrangements of charge will produce zero electric field strength and zero electric potential at the point labelled P?



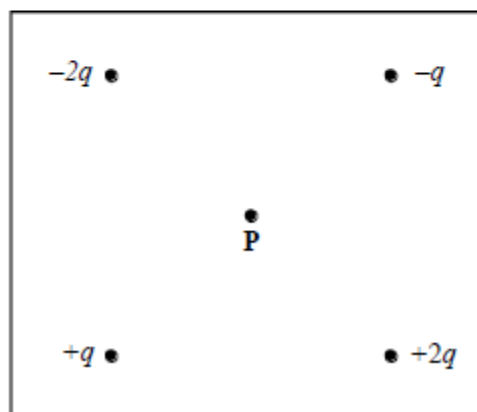
A



B



C



D

(Total 1 mark)

1	A		[1]
2	D		[1]
3	C		[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 $Q (= 4\pi\epsilon_0 rV) = 4\pi \times 8.85 \times 10^{-12} \times 0.30 \times 3.0$ ✓ $= 1.0 \times 10^{-10}$ (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	C		[12]
			[1]

[1]

6

B

[1]

7

D

[1]

8

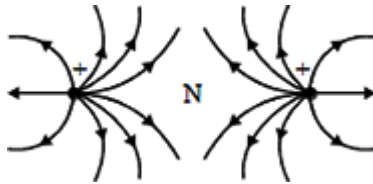
C

[1]

9

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

(ii)



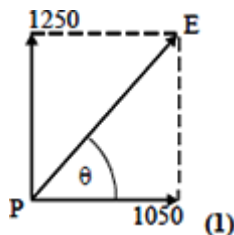
- overall correct symmetrical shape **(1)**
outward directions of lines **(1)**
spacing of lines on appropriate diagram **(1)**
neutral point, N, shown midway between charges **(1)**

6

(b) (i) $E_{AP} \left(= \frac{Q}{4\pi\epsilon_0 r^2} \right) = \frac{2 \times 10^{-19}}{4\pi \times 8.85 \times 10^{-12} \times (0.12)^2}$ **(1)**
= 1250 V m⁻¹ **(1)**

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

(iii)



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

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

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

- (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]

10

D

11

(a) (i) $E = \frac{V}{d} = \frac{10000}{40 \times 10^{-3}} \text{ (1)} = 2.5 \times 10^5 \text{ V m}^{-1} \text{ (1)}$

(ii) $F = Eq = 2.5 \times 10^5 \times 3.2 \times 10^{-19} \text{ (1)} = 8.0 \times 10^{-14} \text{ N (1)}$

(iii) $qV = \frac{1}{2}mv^2 \text{ or } v = \sqrt{\frac{2qV}{m}} = \sqrt{\frac{2 \times 3.2 \times 10^{-19} \times 5000}{3.4 \times 10^{-26}}} \text{ (1)}$

$$(\text{= } 3.1 \times 10^5 \text{ m s}^{-1})$$

(max 5)

- (b) (i) field into paper **(1)**
(ii) force $\perp$ motion in B-field **(1)**
 $\therefore$ directed towards centre of a *circular* path **(1)**

(iii) $\frac{mv^2}{r} = Bqvr = \frac{mv}{Bq} \text{ (1)}$

for B, q constant $r \propto mv$, momentum **(1)**

$$r = \frac{3.4 \times 10^{-26} \times 3.1 \times 10^5}{0.10 \times 3.2 \times 10^{-19}} = 0.33 \text{ m (1)}$$

(6)

- (c) greater mass, so smaller speed at Q **(1)**

greater momentum justified e.g. $E = \frac{p^2}{2m}$ (E const) **(1)**

$\therefore$ greater radius **(1)**

(max 2)

[13]

12

C

[1]