

ELECTRIC FIELD

Challenging **MCQ** questions by The Physics Cafe

Compiled and selected by The Physics Cafe



1 (a) Define *electric field strength* at a point.

.....

[2]

(b) Fig. 4.1 shows two identical conducting spheres, **A** and **B**, placed in a vacuum. Sphere **A** carries a charge of $+2Q$ while sphere **B** carries a charge of $+Q$.

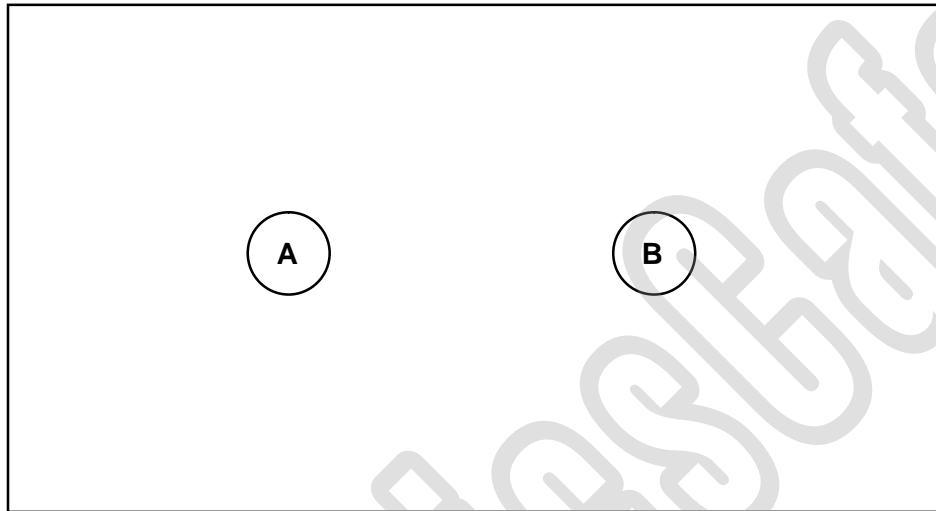


Fig. 4.1

On Fig. 4.1, sketch electric field lines to represent the electric field around the two spheres.

[3]

Ans (a) Electric field strength at a point is defined as the **electric force per unit charge** acting on a **unit positive test charge** placed at that point.

(b)

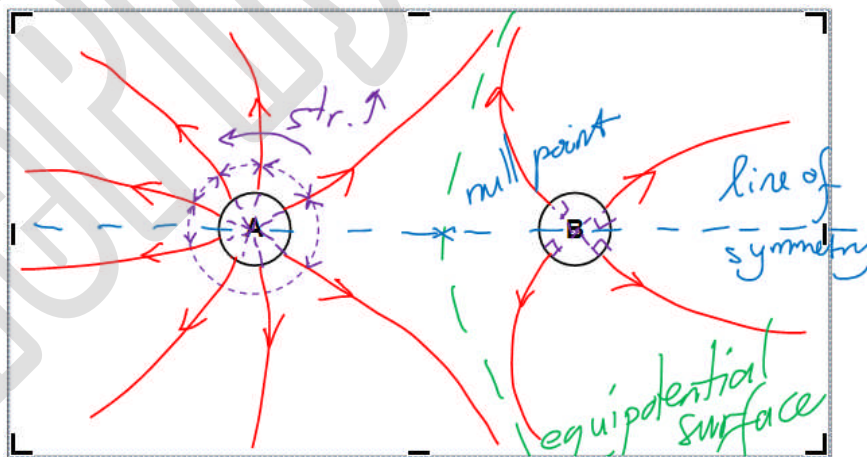


Fig. 4.1

The field lines have to reasonably indicate the **strength of the field** at points in the region of electric field. (notice the **purple dashed arrows** that indicates strength). The field lines have to show **symmetry about the axis connecting the centres** of the sphere AND the **direction** of the field lines has to be **radiating out** of the spheres. null point is shown clearly, whereby the distance between the null point from the centre of **A** is $\sqrt{2}$ times the distance between the null point and centre of **B**. Any point mentioned is worth 1 mark. Maximum 3 marks to be awarded.

- 2 (a) Define *electric field strength*.

[1]
- (b) Two point charges P and Q are separated by a distance of **60 mm** as shown in Fig. 3.1. They both have a charge of **+40 μC** .

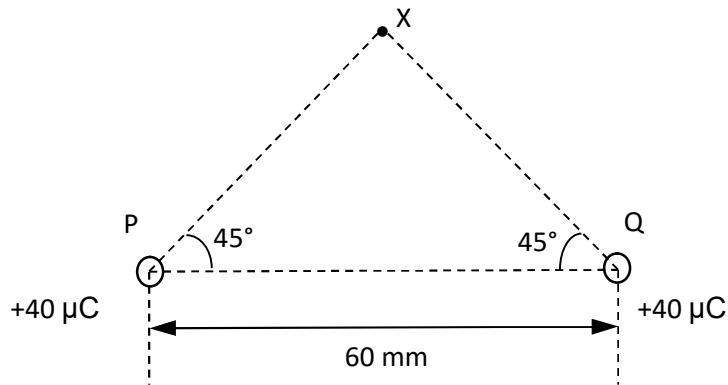


Fig. 3.1

Calculate the magnitude of the resultant electric field strength at point X.

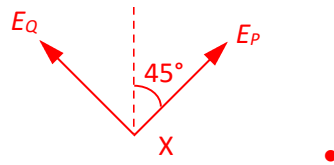
field strength = N C^{-1} [3]

- (c) Another **-10 μC** point charge is placed in the vicinity of P and Q so that the resultant electric field strength at X is zero.

- (i) Indicate in Fig. 3.1, the position for this charge. Label it Z. [1]
- (ii) Determine the separation distance XZ.

XZ = mm [2]

Ans (a) Electric field strength at a point is the electric force acting per unit positive charge placed at that point.
[B1]



Since PX and QX has the same separation distance and P and Q have the same charge,

$$E_P = E_Q$$

Resultant electric field strength at X

$$= 2E_P \cos 45^\circ$$

[C1]

$$= 2 \left(\frac{Q_P}{4\pi\epsilon_0 [(\sqrt{2})(0.03)]^2} \right) \left(\frac{1}{\sqrt{2}} \right)$$

[M1]

$$= (9 \times 10^9) \frac{(40 \times 10^{-6})}{9 \times 10^{-4}} \left(\frac{1}{\sqrt{2}} \right)$$

$$= 2.83 \times 10^8 \text{ N C}^{-1}$$

[A1]

(c)(i) In Fig. 3.1, point Z is directly below X but above line PQ
[B1]

(c)(ii) For resultant electric field strength at X to be zero,
E due to Z = $2.83 \times 10^8 \text{ N C}^{-1}$

$$E_Z = \frac{Q_Z}{4\pi\epsilon_0 r_{XZ}^2}$$

$$2.83 \times 10^8 = (9 \times 10^9) \frac{10 \times 10^{-6}}{r_{XZ}^2}$$

[M1]

$$r_{XZ} = 1.78 \times 10^{-2} \text{ m}$$

$$r_{XZ} = 17.8 \text{ mm}$$

[A1]

- 3 (a) An electric field may be produced in the region between two charged parallel plates. Fig.4.1 shows two such plates, which are nearer in separation at the bottom ends. On Fig 4.1, sketch the pattern of field lines between the plates. [2]

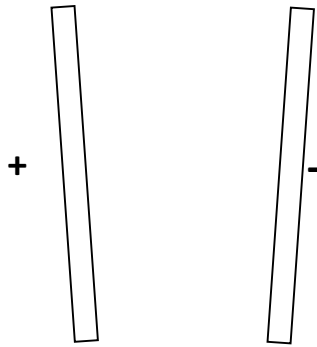


Fig. 4.1

- (b) An isolated point charge Q is situated in a vacuum. At a distance of $1.0 \times 10^{-10} \text{ m}$ from this charge, the electric potential is $+14.4 \text{ J C}^{-1}$.

- (i) Explain what is meant by *electrical potential* at a point in an electric field.

.....

...[1]

- (ii) Determine the charge Q .

charge = C [1]

- (iii) An electron is moved from a distance of $3.0 \times 10^{-10} \text{ m}$ to a distance of $1.0 \times 10^{-10} \text{ m}$ from charge Q . Determine the work done in moving the electron.

work done = J [3]

(iv) State and explain whether the work done in **b(iii)** is positive or negative.

.....

 [2]

- Ans (a) field lines starting from + to -, starting perpendicularly at surface of plates B1
 field lines closer at bottom, and more spaced out near top B1
- (b) (i) Electrical potential at a point in a field is the work done per unit positive B1
 charge in moving it from infinity to that point in the field.
- (ii) $V = \frac{Q}{4\pi\epsilon_0(1 \times 10^{-10})} = +14.4$ A1
 $Q = +1.6 \times 10^{-19} \text{ C (with +ve sign)}$
- (iii) $V_{3m} = \frac{+1.6 \times 10^{-19}}{4\pi\epsilon_0(3 \times 10^{-10})} = +4.79 \text{ JC}^{-1}$ C1
 $WD = q \Delta V = q(V_{1m} - V_{3m}) = (-1.6 \times 10^{-19}) [+14.4 - (+4.79)]$ M1
 $= -1.54 \times 10^{-18} \text{ J} = -1.5 \times 10^{-18} \text{ J}$ A1
- (iv) Negative work done A1
 as force between the 2 charges is attractive, and as the electron comes B1
 nearer to charge Q, it loses potential energy. Work done is really by the
 e-field of charge Q.

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

.....

.....

..... [1]

(b) Two charged spheres of radius **2.0 mm** are held **4.00 cm** apart (centre-to-centre). Fig. 3.1 shows the variation with displacement x , of the electric potential V , between the two charged spheres.

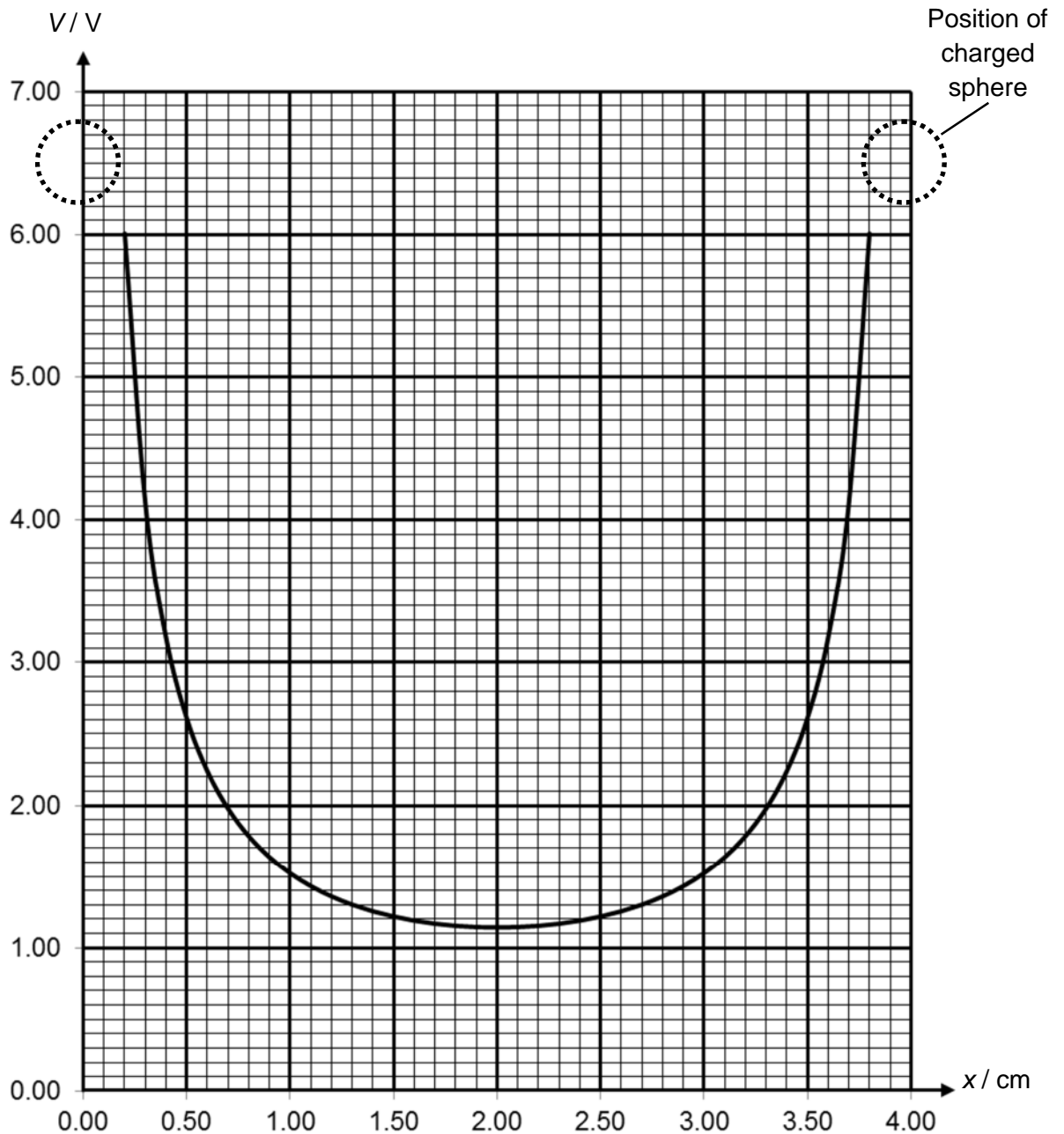


Fig. 3.1

- (i) Using Fig. 3.1, determine the magnitude of the electric field strength at $x = 1.00 \text{ cm}$ and state its direction.

electric field strength = N C^{-1} [2]

direction: [1]

- (ii) Using Fig. 3.1, determine the charge on each sphere.

charge = C [2]

(iii) State an assumption made for the calculation in part **(ii)**.

.....

..... [1]

(c) The scenario in part **(b)** can be used as a one-dimensional potential well. A potential well is a region which can be used to “trap” particles.

(i) Suggest one type of particle which can be “trapped” within such a well and explain briefly how the well “traps” the particle.

Type of particle:

How it works:

.....

.....

..... [2]

(ii) “Trapped” particles can escape the well if it possesses sufficient energy. However it is found that some particles which do not have sufficient energy can still escape from the well. State the phenomenon associated with this.

..... [1]

Ans (a) The electric potential at a point in an electric field is defined as the work done per unit positive charge by an external agent in bringing a positive test charge from infinity to that point without acceleration. [B1]

(b) (i)
$$E = -\frac{dV}{dr}$$

$$|E| = \text{gradient of graph}$$

$$= \left| \frac{(2.50 - 0.00)}{(0.00 - 2.50) \times 10^{-2}} \right| \quad \text{[M1]}$$

$$= 100 \text{ N C}^{-1} \quad \text{[A1]}$$

Acceptable range: $90 \leq E \leq 110$

Direction: in positive x-direction / towards right / from left to right / \rightarrow [B1]

(ii) At $x = 0.20 \text{ cm}$,

$$V = \frac{Q}{4\pi\epsilon_0 x} + \frac{Q}{4\pi\epsilon_0 (0.040 - x)}$$

$$6.00 = \frac{Q}{4\pi\epsilon_0} \left[\frac{1}{0.002} + \frac{1}{(0.040 - 0.002)} \right]$$

$$Q = 1.27 \times 10^{-12} \text{ C}$$

Accept also if student used other suitable points for substitution.

(iii) Charge is evenly distributed over the sphere
 OR
 Charged sphere is taken to be a point charge
 OR
No other surrounding charges
 OR
Centre of charge is taken to be at centre of sphere [B1]

(c) (i) Type of particle: Any positively charged particle / proton / positive ion / cation [B1]

The two ends of the well form a potential barrier such that particles without sufficient energy will not be able to overcome it to escape

OR

The force on the particle always points to the centre and hence keeps the particle trapped between the two charged spheres. [B1]

(ii) Quantum tunneling [B1]