18. Electric Fields

18.5 Electric potential

Paper 4

Question Paper

1 **(a)** Define electric potential at a point.

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..... [2]

(b) Two isolated charged metal spheres X and Y are near to each other in a vacuum. The centres of the spheres are 1.2 m apart, as shown in Fig. 5.1.

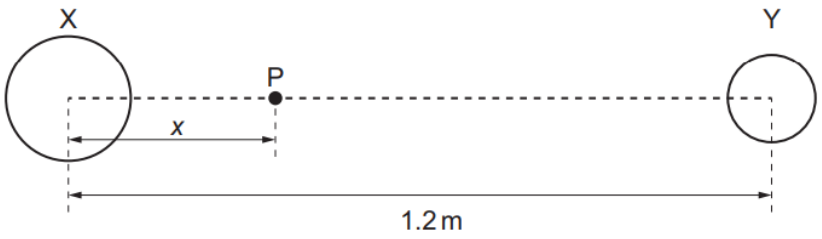


Fig. 5.1 (not to scale)

Point P is on the line joining the centres of spheres X and Y and is at a variable distance *x* from the centre of X.

Fig. 5.2 shows the variation with *x* of the total electric potential *V* due to the two spheres.

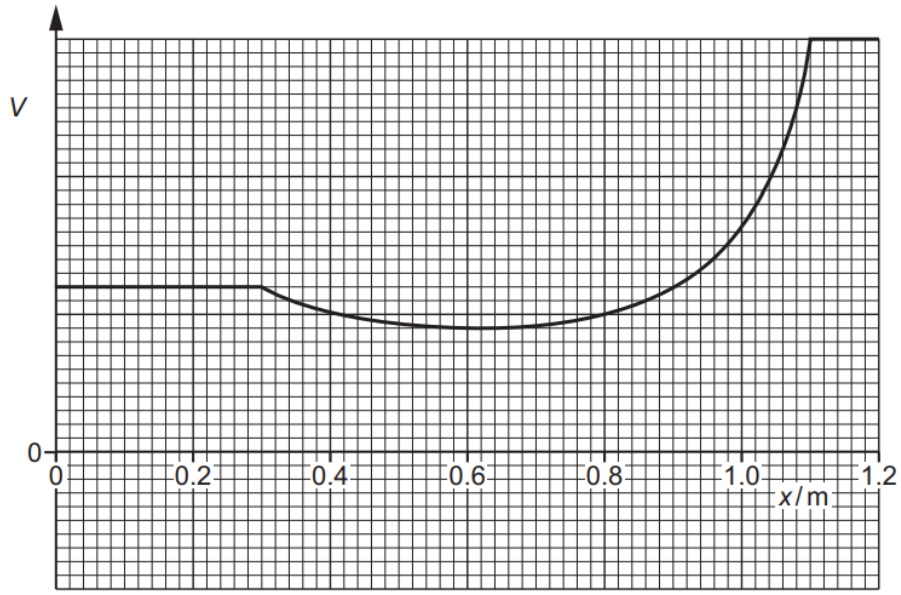


Fig. 5.2

State **three** conclusions that may be drawn about the spheres from Fig. 5.2. The conclusions may be qualitative or quantitative.

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[3]

(c) A proton is held at rest on the line joining the centres of the spheres in **(b)** at the position where $x = 0.60\,\text{m}$.

The proton is released.

Describe and explain, without calculation, the subsequent motion of the proton.

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..... [2]

2 **(a)** State the relationship between electric field and electric potential.

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(b) Two charged isolated insulating spheres X and Y are near to each other, as shown in Fig. 5.1.



Fig. 5.1

P is a point on the line joining the centres of the spheres.

Explain why it is **not** possible for the total electric potential and the resultant electric field to simultaneously be zero at point P.

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(c) The magnitudes of the charges on spheres X and Y in Fig. 5.1 are Q and $2Q$ respectively. The spheres may be considered as point charges at their centres.

Point P is a distance x from the centre of sphere X.

The electric potential at point P is zero.

(i) Show that the distance y of point P from the centre of sphere Y is equal to $2x$.

[2]

3 **(a)** Define electric potential at a point.

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(b) Two isolated charged metal spheres X and Y are situated near to each other in a vacuum with their centres a distance of 24 m apart. Point P is at a variable distance *x* from the centre of sphere X on the line joining the centres of the spheres.

Fig. 5.1 shows the variation with *x* of the electric potential *V* due to the spheres at point P.

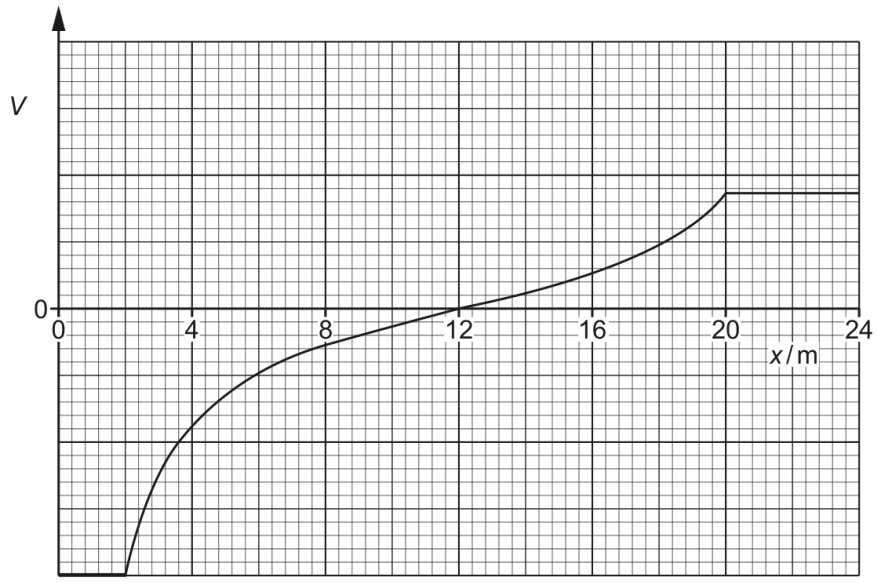


Fig. 5.1

State **three** conclusions that can be drawn about the spheres from Fig. 5.1. The conclusions may be qualitative or quantitative.

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[3]

(c) A positively charged particle is placed at point P in **(b)**, such that $x = 12\,\text{m}$.
The particle is released.

Describe and explain the subsequent motion of the particle.

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..... [3]

4 **(a)** Define electric potential at a point.

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(b) An isolated conducting sphere is charged. Fig. 5.1 shows the variation of the potential V due to the sphere with displacement x from its centre.

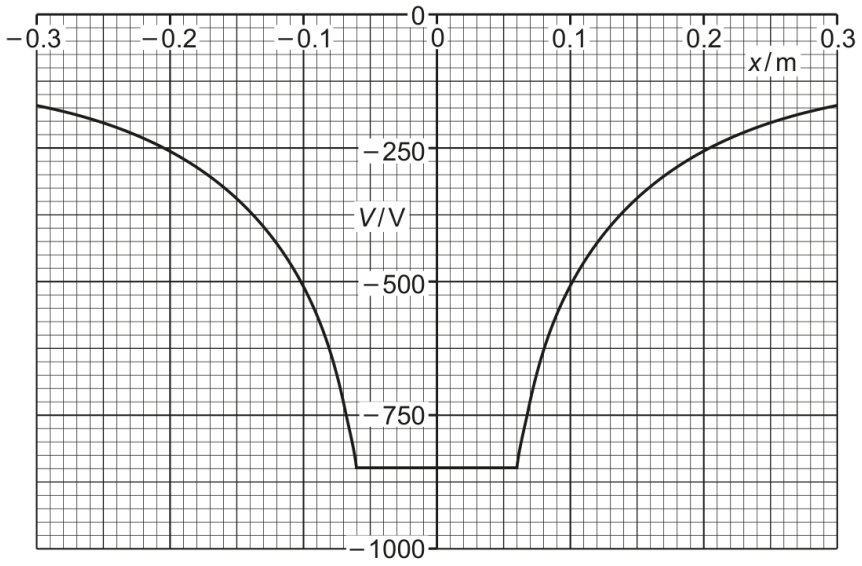


Fig. 5.1

Use Fig. 5.1 to determine:

(i) the radius of the sphere

radius = ... m [1]

(ii) the charge on the sphere.

charge = ... C [2]

(c) Two spheres are identical to the sphere in **(b)**. Each sphere has the same charge as the sphere in **(b)**.

The spheres are held in a vacuum so that their centres are separated by a distance of 0.46 m. Assume that the charge on each sphere is a point charge at the centre of the sphere.

(i) Calculate the electric potential energy E_P of the two spheres.

E_P = ... J [2]

(ii) The two spheres are now released simultaneously so that they are free to move.

Describe and explain the subsequent motion of the spheres.

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..... [3]

5 **(a)** An isolated metal sphere of radius r is charged so that the electric potential at its surface is V_0.

On Fig. 5.1, sketch the variation with distance x from the centre of the sphere of the electric potential. Your graph should extend from $x = 0$ to $x = 3r$.

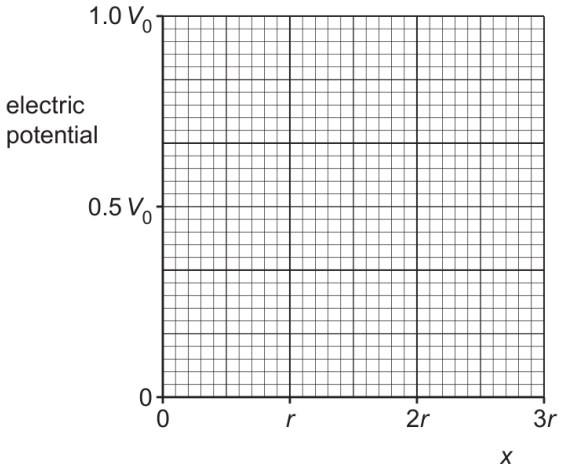


Fig. 5.1

[3]

6 **(b)** Electrons, each of mass m and charge q, are accelerated from rest in a vacuum through a potential difference V.

Derive an expression, in terms of m, q and V, for the final speed v of the electrons. Explain your working.

[2]

7 **(c)** Electrons are accelerated from rest through a potential difference (p.d.) of 4.8 kV.

(i) Show that the final speed of the electrons is $4.1 \times 10^7\,\text{m s}^{-1}$.

[2]

8 **(a)** Define *electric potential*.

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9 **(a)** Define *electric potential* at a point.

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(b) Two point charges A and B are separated by a distance of 12.0 cm in a vacuum, as illustrated in Fig. 5.1.

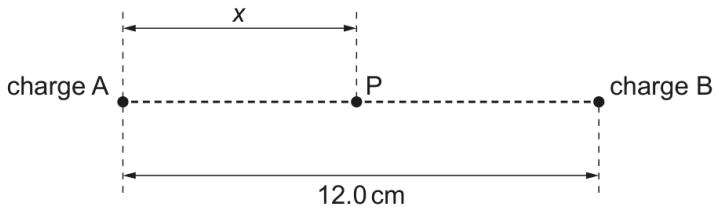


Fig. 5.1

The charge of A is $+2.0 \times 10^{-9}$ C.

A point P lies on the line joining charges A and B. Its distance from charge A is *x*.

The variation with distance *x* of the electric potential *V* at point P is shown in Fig. 5.2.

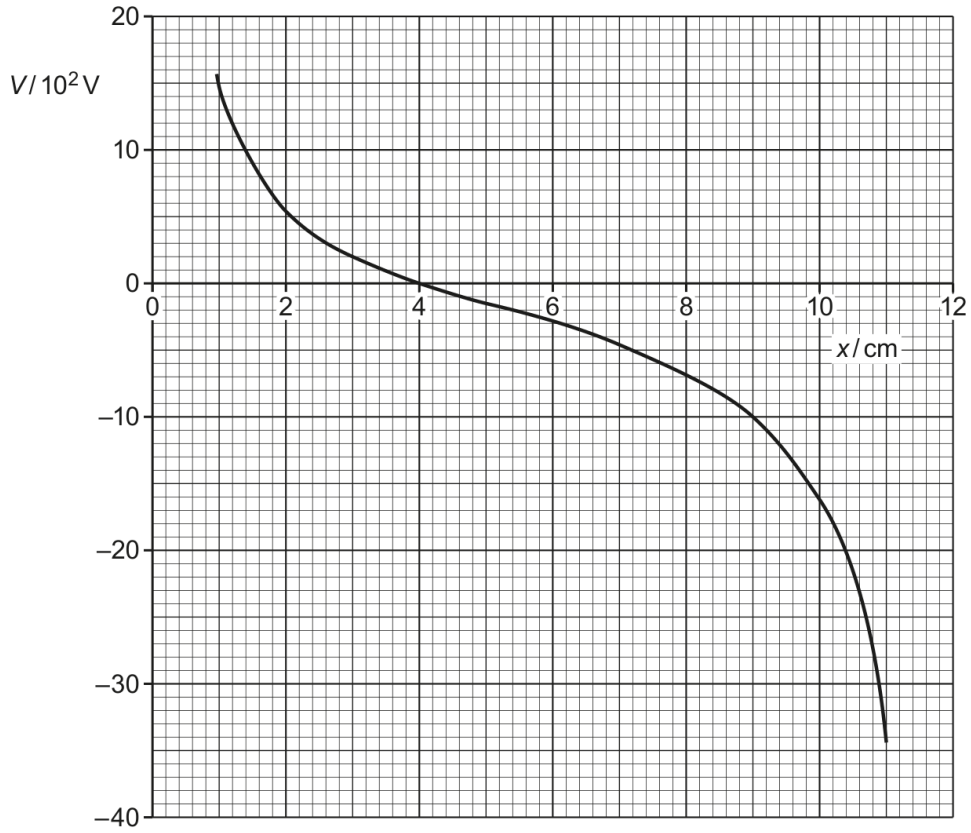


Fig. 5.2

Use Fig. 5.2 to determine:

(i) the charge of B

charge = ... C [3]

(ii) the change in electric potential when point P moves from the position where $x = 9.0\,\text{cm}$ to the position where $x = 3.0\,\text{cm}$.

change = ... V [1]

(c) An α-particle moves along the line joining point charges A and B in Fig. 5.1.

The α-particle moves from the position where $x = 9.0\,\text{cm}$ and just reaches the position where $x = 3.0\,\text{cm}$.

Use your answer in **(b)(ii)** to calculate the speed v of the α-particle at the position where $x = 9.0\,\text{cm}$.

v = ... m s^{-1} [3]

10 (a) State what is meant by *electric potential* at a point.

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.....[2]

(b) Two parallel metal plates A and B are held a distance *d* apart in a vacuum, as illustrated in Fig. 6.1.

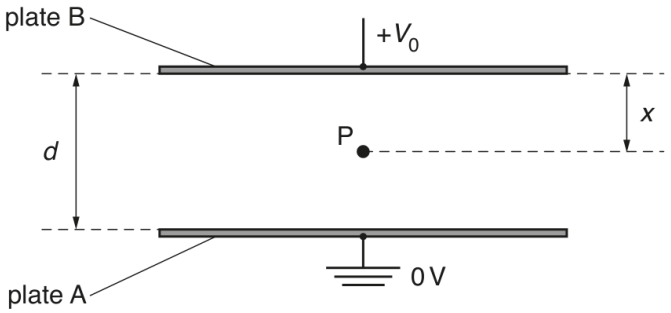


Fig. 6.1

Plate A is earthed and plate B is at a potential of +V_0.

Point P is situated in the centre region between the plates at a distance *x* from plate B. The potential at point P is *V*.

On Fig. 6.2, show the variation with *x* of the potential *V* for values of *x* from *x* = 0 to *x* = *d*.

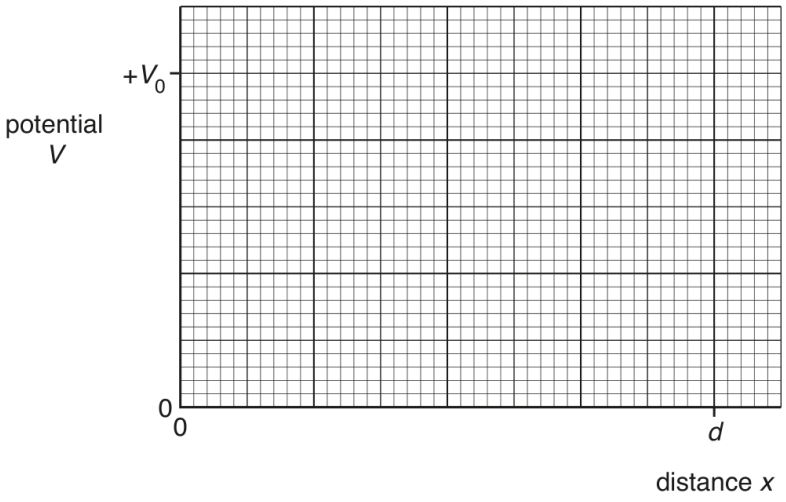


Fig. 6.2

[3]

(c) Two isolated solid metal spheres M and N, each of radius *R*, are situated in a vacuum. Their centres are a distance *D* apart, as illustrated in Fig. 6.3.

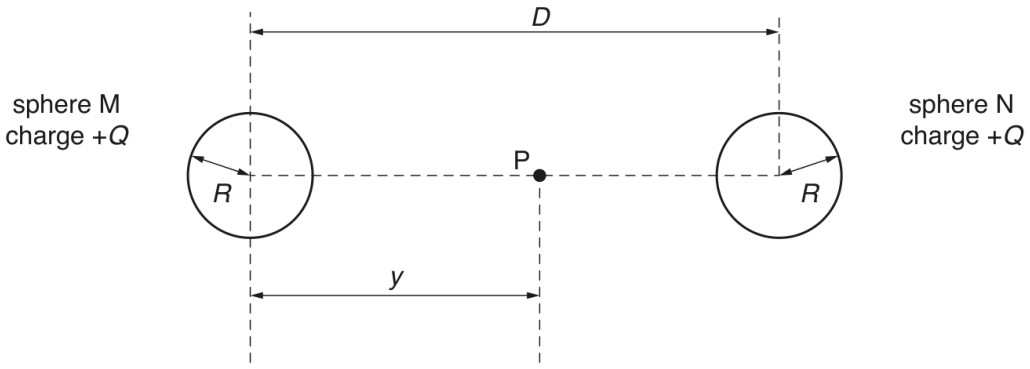


Fig. 6.3

Each sphere has charge +*Q*.

Point P lies on the line joining the centres of the two spheres, and is a distance *y* from the centre of sphere M.

On Fig. 6.4, show the variation with distance *y* of the electric potential at point P, for values of *y* from *y* = 0 to *y* = *D*.

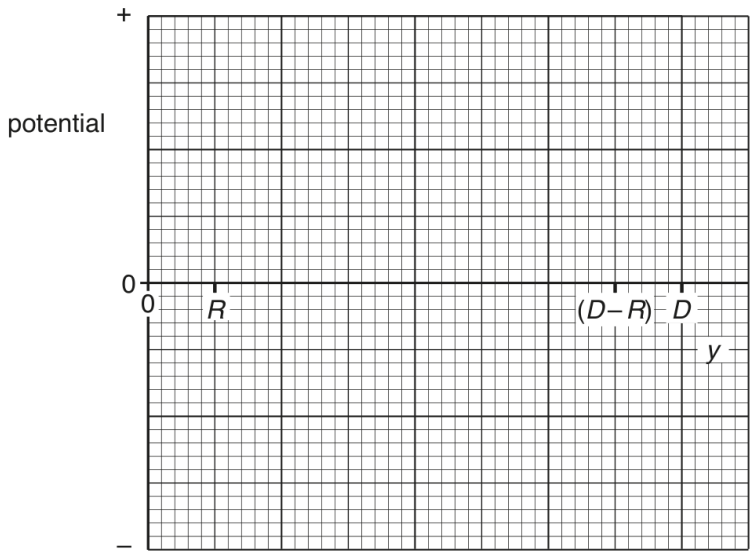


Fig. 6.4

[4]

11 (a) Define what is meant by *electric potential* at a point.

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(b) In an α-particle scattering experiment, α-particles are directed towards a thin film of gold, as illustrated in Fig. 9.1.

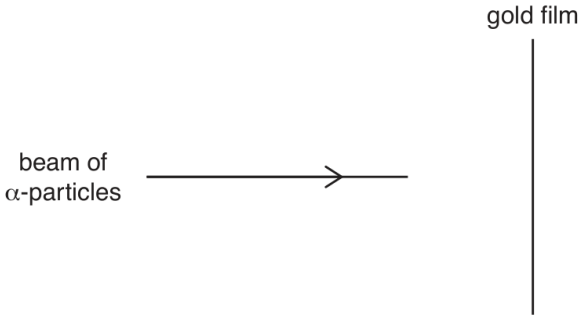


Fig. 9.1

The apparatus is in a vacuum.

The gold-197 ($^{197}_{79}$Au) nuclei in the film may be considered to be fixed point charges.

The α-particles emitted from the source each have an energy of 4.8 MeV.

Calculate:

(i) the initial kinetic energy E_K, in J, of an α-particle emitted from the source

E_K = ... J [1]

(ii) the distance d of closest approach of an α-particle to a gold nucleus.

d = ... m [4]

(c) Use your answer in **(b)(ii)** to comment on the possible diameter of a gold nucleus.

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..... [1]

12 (a) (i) Define *electric potential* at a point.

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.....[2]

(ii) State the relationship between electric potential and electric field strength at a point.

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(b) Two parallel metal plates A and B are situated a distance 1.2 cm apart in a vacuum, as shown in Fig. 6.1.

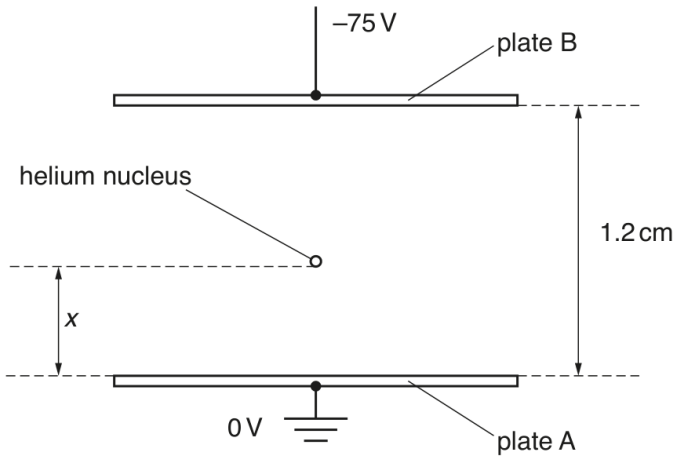


Fig. 6.1

Plate A is earthed and plate B is at a potential of –75 V.

A helium nucleus is situated between the plates, a distance x from plate A.

Initially, the helium nucleus is at rest on plate A where $x = 0$.

(i) The helium nucleus is free to move between the plates. By considering energy changes of the helium nucleus, explain why the speed at which it reaches plate B is independent of the separation of the plates.

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(ii) As the helium nucleus ($^4_2$He) moves from plate A towards plate B, its distance x from plate A increases.

Calculate the speed of the nucleus after it has moved a distance $x = 0.40$ cm from plate A.

speed = ... $m\,s^{-1}$ [3]

13 (a) State

(i) what is meant by the *electric potential* at a point,

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.....[2]

(ii) the relationship between electric potential at a point and electric field strength at the point.

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(b) Two similar solid metal spheres A and B, each of radius *R*, are situated in a vacuum such that the separation of their centres is *D*, as shown in Fig. 6.1.

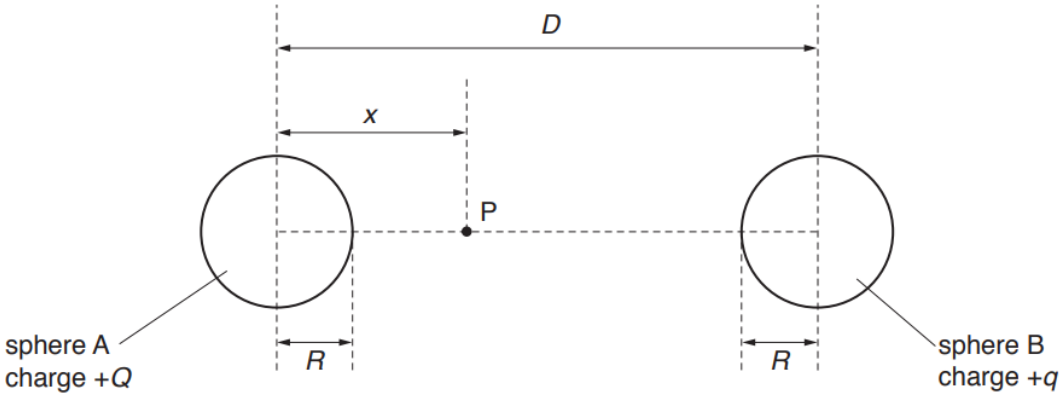


Fig. 6.1

The charge +*Q* on sphere A is larger than the charge +*q* on sphere B.

A movable point P is located on the line joining the centres of the two spheres.
The point P is a distance *x* from the centre of sphere A.

On Fig. 6.2, sketch a graph to show the variation with x of the electric potential V between the centres of the two spheres.

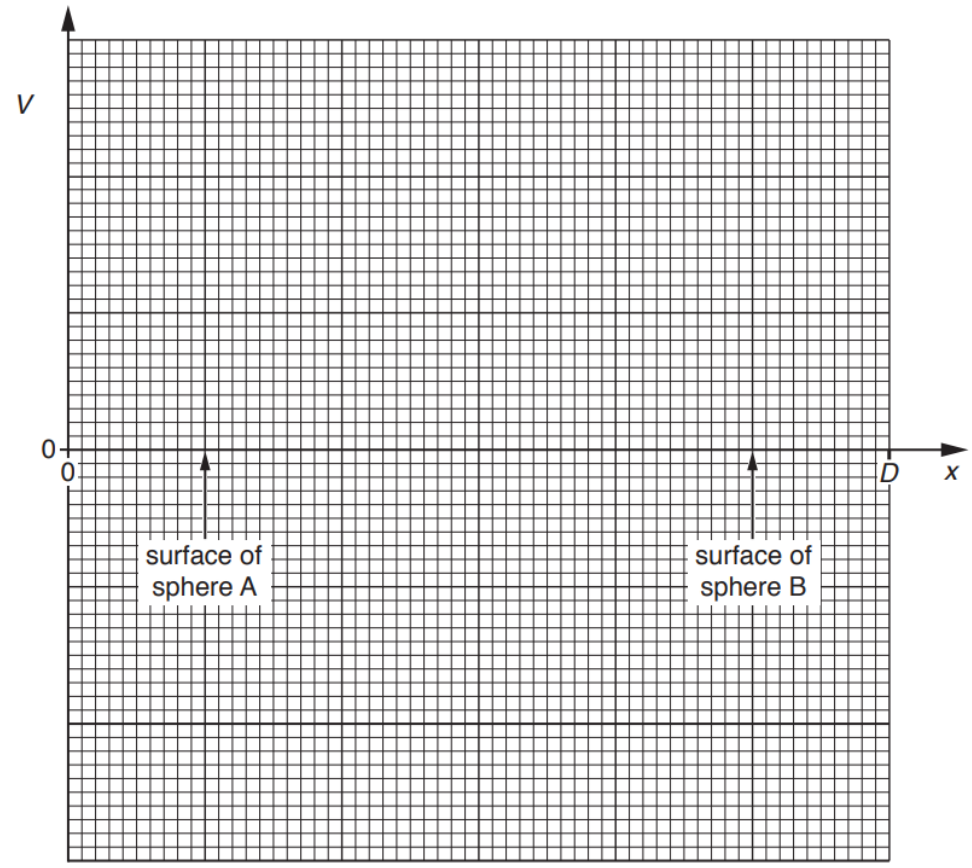


Fig. 6.2

[4]