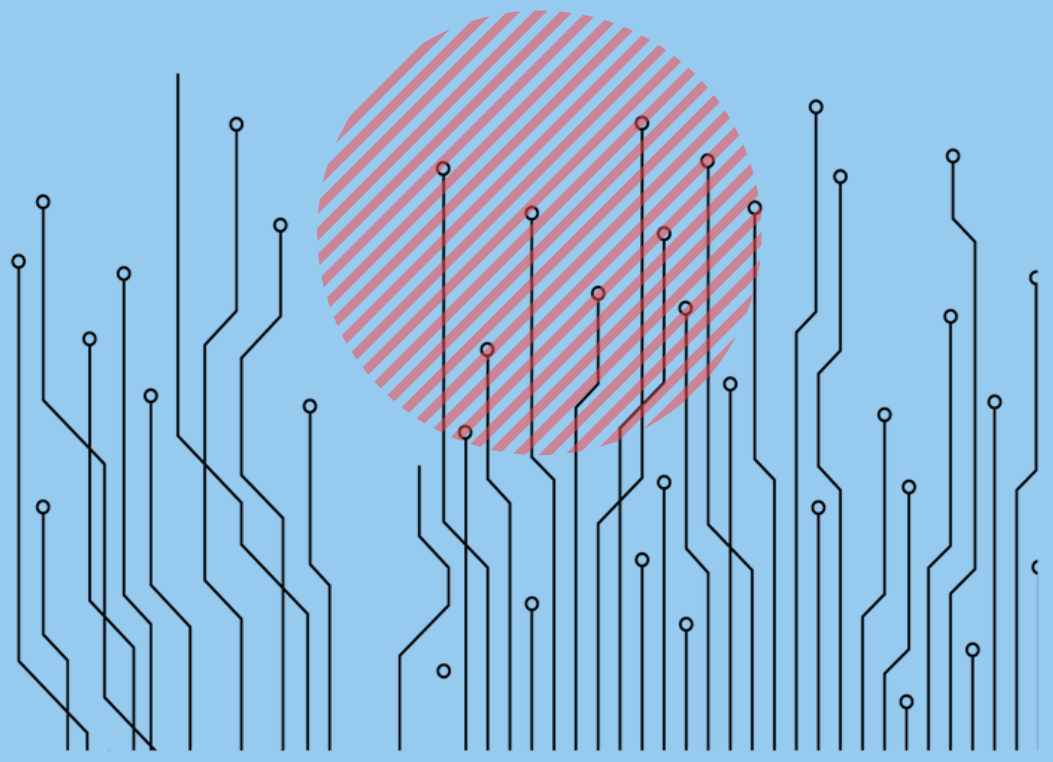
Cambridge International AS & A Level

PHYSICS

Paper 4

Topical Past Paper Questions
+ Answer Scheme

2016 - 2021



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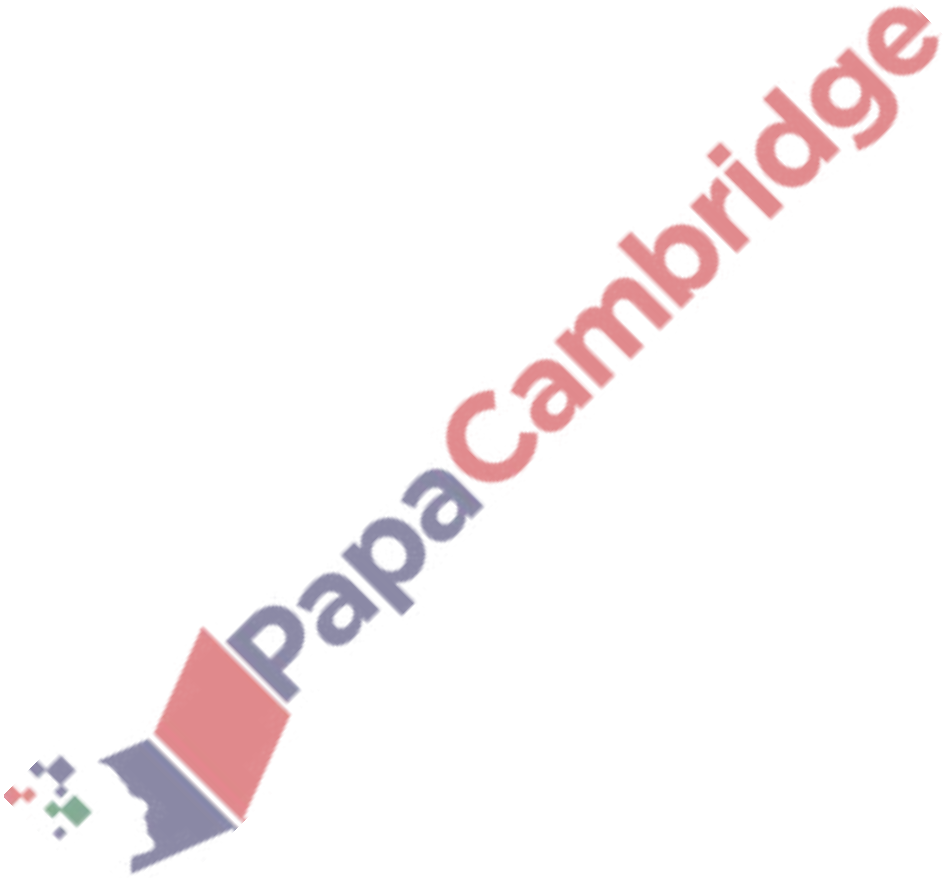
Chapter 8

Electric fields



172. 9702_s17_qp_41 Q: 5

An α-particle is travelling in a vacuum towards the centre of a gold nucleus, as illustrated in Fig. 5.1.

Fig. 5.1

The gold nucleus has charge $79e$.
The gold nucleus and the α-particle may be assumed to behave as point charges.
At a large distance from the gold nucleus, the α-particle has energy 7.7×10^{-13} J.

(a) The α-particle does not collide with the gold nucleus. Show that the radius of the gold nucleus must be less than 4.7×10^{-14} m.

[3]

(b) Determine the acceleration of the α-particle for a separation of 4.7×10^{-14} m between the centres of the gold nucleus and of the α-particle.

acceleration = ... $m\,s^{-2}$ [3]

(c) In an α-particle scattering experiment, the beam of α-particles is incident on a very thin gold foil.
Suggest why the gold foil must be very thin.

.....

.....[1]

[Total: 7]

173. 9702_s20_qp_41 Q: 5

(a) State **one** similarity and **one** difference between the fields of force produced by an isolated point charge and by an isolated point mass.

similarity: .....

.....

difference: .....

.....

[2]

(b) An isolated solid metal sphere A of radius R has charge $+Q$, as illustrated in Fig. 5.1.

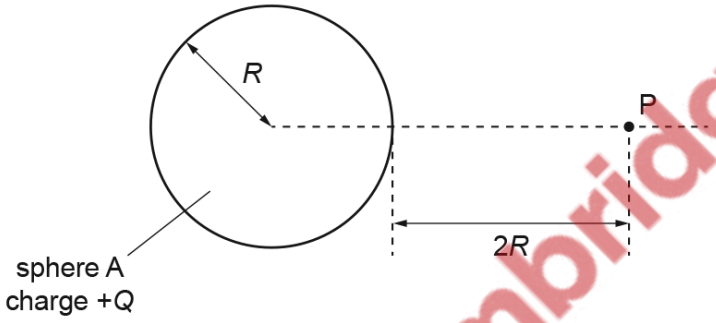


Fig. 5.1

A point P is distance $2R$ from the surface of the sphere.

Determine an expression that includes the terms R and Q for the electric field strength E at point P.

E = ... [2]

(c) A second identical solid metal sphere B is now placed near sphere A. The centres of the spheres are separated by a distance 6*R*, as shown in Fig. 5.2.

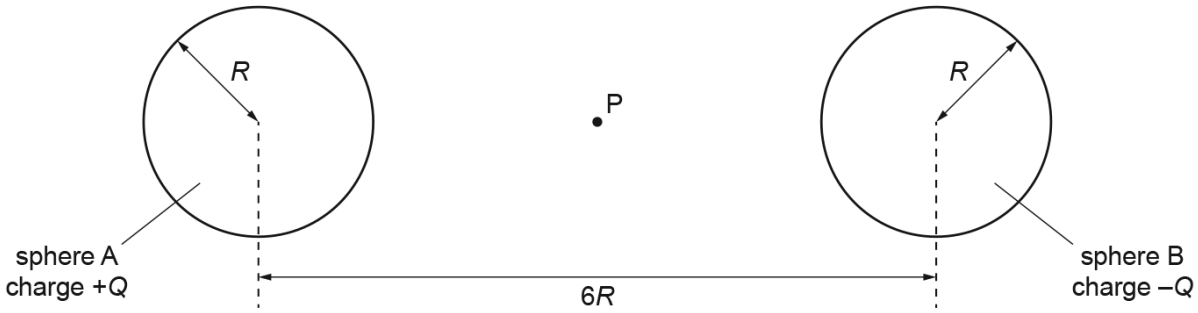


Fig. 5.2

Point P lies midway between spheres A and B.

Sphere B has charge –*Q*.

Explain why:

(i) the magnitude of the electric field strength at P is given by the sum of the magnitudes of the field strengths due to each sphere

.....

..... [1]

(ii) the electric field strength at point P due to the charged metal spheres is not, in practice, equal to 2*E*, where *E* is the electric field strength determined in **(b)**.

.....

.....

..... [2]

[Total: 7]

174. 9702_s20_qp_42 Q: 7

A metal sphere of radius *R* is isolated in space.

Point P is a distance *x* from the centre of the sphere, as illustrated in Fig. 7.1.

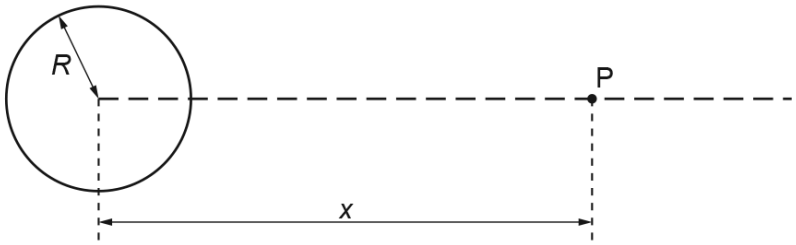


Fig. 7.1

The variation with distance *x* of the electric field strength *E* due to the charge on the sphere is shown in Fig. 7.2.

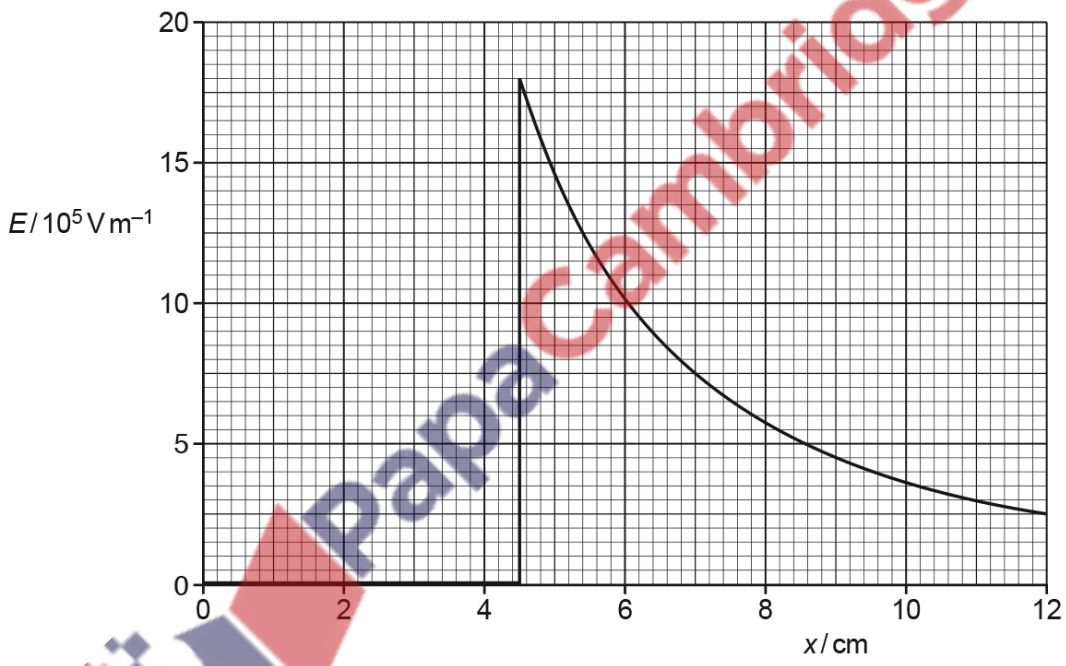


Fig. 7.2

(a) State what is meant by *electric field strength*.

.....

.....

..... [2]

(b) **(i)** Use Fig. 7.2 to determine the radius R of the sphere. Explain your working.

R = ... cm [2]

(ii) Use Fig. 7.2 to determine the charge Q on the sphere.

Q = ... C [3]

(c) An α-particle is situated a distance 8.0 cm from the centre of the sphere.

Calculate the acceleration of the α-particle.

acceleration = ... $m\,s^{-2}$ [3]

[Total: 10]

(a) State **one** similarity and **one** difference between the fields of force produced by an isolated point charge and by an isolated point mass.

similarity: .....

.....

difference: .....

.....

[2]

(b) An isolated solid metal sphere A of radius *R* has charge +*Q*, as illustrated in Fig. 5.1.

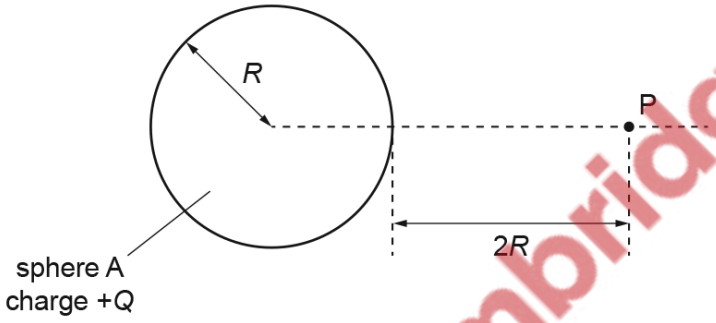


Fig. 5.1

A point P is distance 2*R* from the surface of the sphere.

Determine an expression that includes the terms *R* and *Q* for the electric field strength *E* at point P.

E = ... [2]

(c) A second identical solid metal sphere B is now placed near sphere A. The centres of the spheres are separated by a distance 6*R*, as shown in Fig. 5.2.

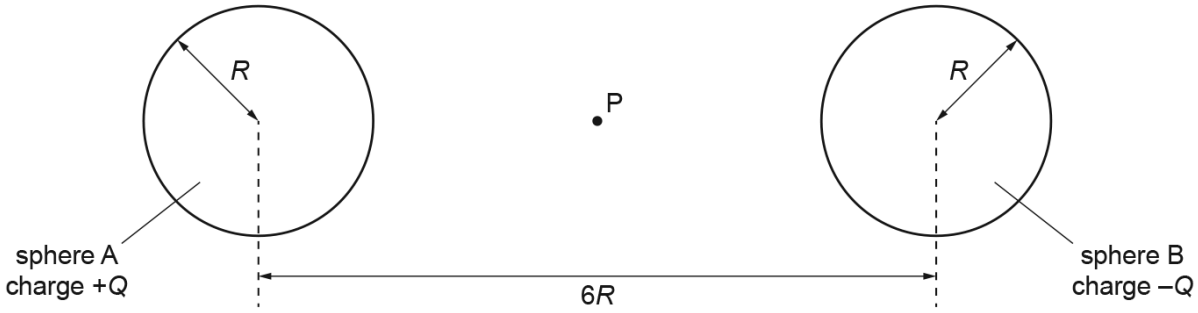


Fig. 5.2

Point P lies midway between spheres A and B.

Sphere B has charge –*Q*.

Explain why:

(i) the magnitude of the electric field strength at P is given by the sum of the magnitudes of the field strengths due to each sphere

.....

..... [1]

(ii) the electric field strength at point P due to the charged metal spheres is not, in practice, equal to 2*E*, where *E* is the electric field strength determined in **(b)**.

.....

.....

..... [2]

[Total: 7]

176. 9702_m19_qp_42 Q: 5

(a) State what is meant by an *electric field*.

.....

..... [1]

(b) An isolated solid metal sphere has radius R. The charge on the sphere is $+Q$ and the electric field strength at its surface is E.

On Fig. 5.1, draw a line to show the variation of the electric field strength with distance x from the centre of the solid sphere for values of x from $x = 0$ to $x = 3R$.

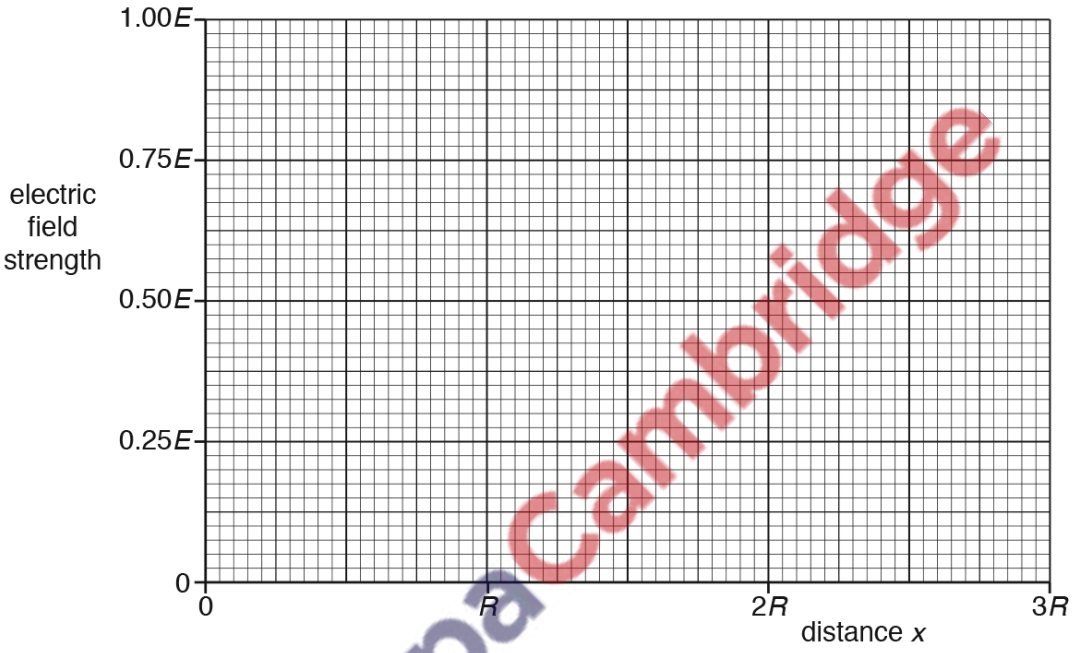


Fig. 5.1

[4]

(c) The sphere in **(b)** has radius $R = 0.26\,\text{m}$.

Electrical breakdown (a spark) occurs when the electric field strength at the surface of the sphere exceeds $2.0 \times 10^6\,\text{V m}^{-1}$.

Determine the maximum charge that can be stored on the sphere before electrical breakdown occurs.

charge = ... C [3]

[Total: 8]

177. 9702_s19_qp_41 Q: 5

(a) State what is meant by *electric field strength*.

.....

.....

..... [2]

(b) Two point charges A and B are situated a distance 15 cm apart in a vacuum, as illustrated in Fig. 5.1.

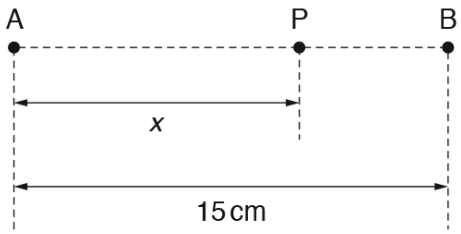


Fig. 5.1

Point P lies on the line joining the charges and is a distance x from charge A.

The variation with distance x of the electric field strength E at point P is shown in Fig. 5.2.

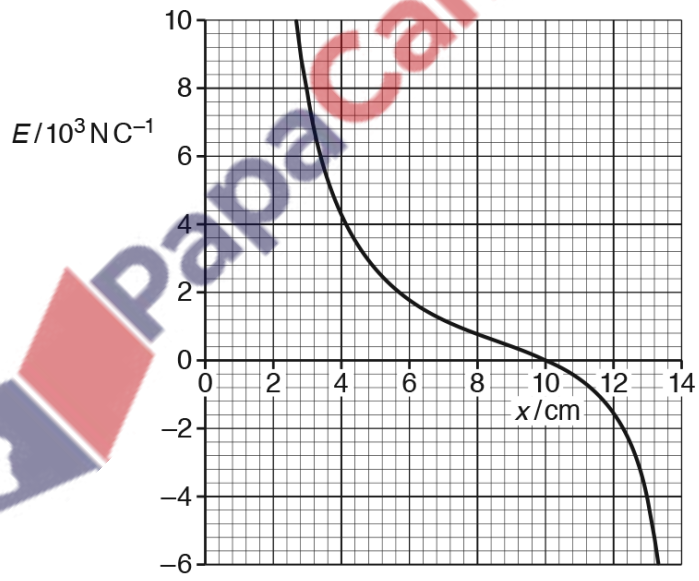


Fig. 5.2

(i) By reference to the direction of the electric field, state and explain whether the charges A and B have the same, or opposite, signs.

.....

.....

..... [2]

(ii) State why, although charge A is a point charge, the electric field strength between $x = 3\,\text{cm}$ and $x = 7\,\text{cm}$ does not obey an inverse-square law.

.....

..... [1]

(iii) Use Fig. 5.2 to determine the ratio

$$\frac{\text{magnitude of charge A}}{\text{magnitude of charge B}}.$$

ratio = ... [3]

[Total: 8]

178. 9702_s19_qp_43 Q: 5

(a) State what is meant by *electric field strength*.

.....

.....

..... [2]

(b) Two point charges A and B are situated a distance 15 cm apart in a vacuum, as illustrated in Fig. 5.1.

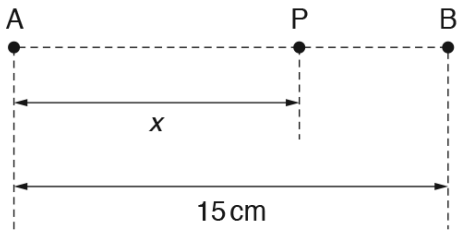


Fig. 5.1

Point P lies on the line joining the charges and is a distance x from charge A.

The variation with distance x of the electric field strength E at point P is shown in Fig. 5.2.

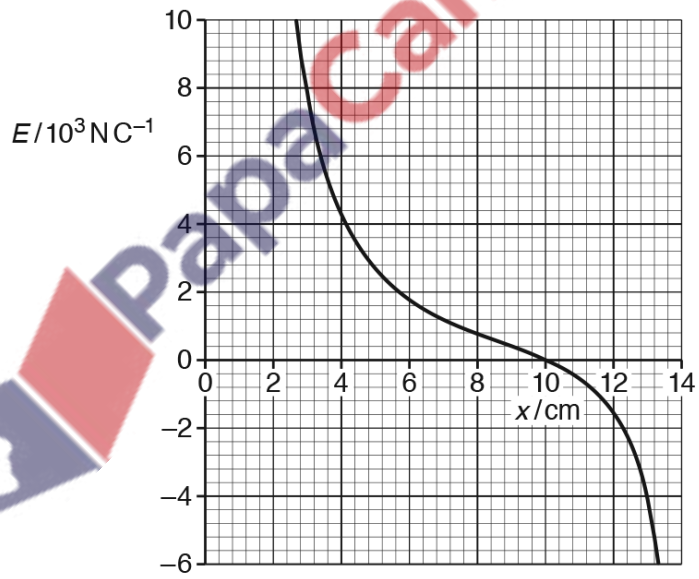


Fig. 5.2

(i) By reference to the direction of the electric field, state and explain whether the charges A and B have the same, or opposite, signs.

.....

.....

..... [2]

(ii) State why, although charge A is a point charge, the electric field strength between $x = 3\,\text{cm}$ and $x = 7\,\text{cm}$ does not obey an inverse-square law.

.....

..... [1]

(iii) Use Fig. 5.2 to determine the ratio

$$\frac{\text{magnitude of charge A}}{\text{magnitude of charge B}}.$$

ratio = ... [3]

[Total: 8]

179. 9702_w19_qp_41 Q: 6

(a) State an expression for the electric field strength E at a distance r from a point charge Q in a vacuum.
State the name of any other symbol used.

.....

.....

..... [2]

(b) Two point charges A and B are situated a distance 10.0 cm apart in a vacuum, as illustrated in Fig. 6.1.

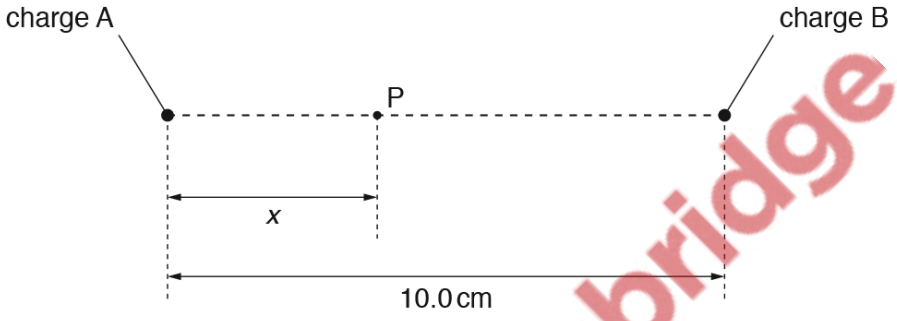


Fig. 6.1

A point P lies on the line joining the charges A and B. Point P is a distance x from A.

The variation with distance x of the electric field strength E at point P is shown in Fig. 6.2.

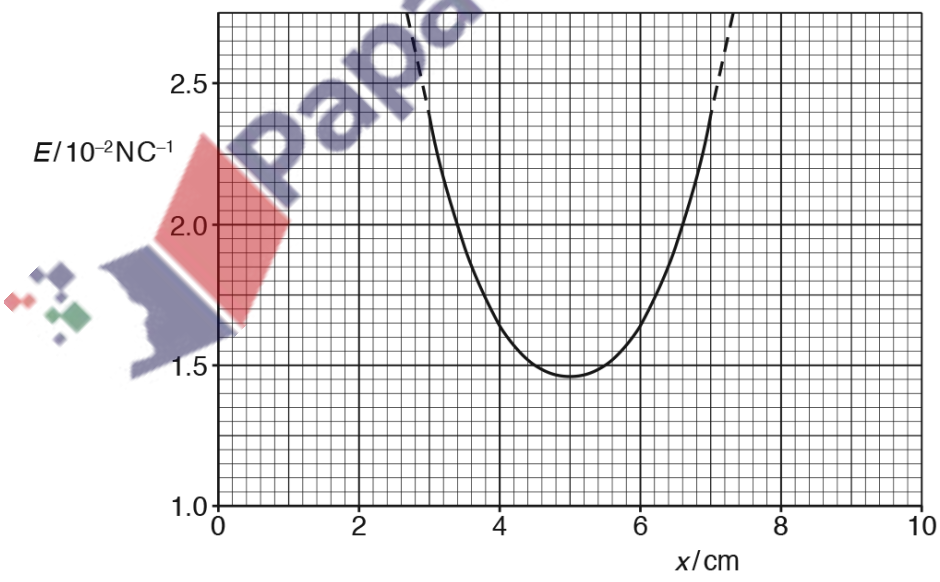


Fig. 6.2

State and explain whether the charges A and B:

(i) have the same, or opposite, signs

.....

.....

..... [2]

(ii) have the same, or different, magnitudes.

.....

.....

..... [2]

(c) An electron is situated at point P.

Without calculation, state and explain the variation in the magnitude of the acceleration of the electron as it moves from the position where $x = 3\,\text{cm}$ to the position where $x = 7\,\text{cm}$.

.....

.....

.....

.....

.....

..... [4]

[Total: 10]

180. 9702_w19_qp_43 Q: 6

(a) State an expression for the electric field strength E at a distance r from a point charge Q in a vacuum.
State the name of any other symbol used.

.....

.....

..... [2]

(b) Two point charges A and B are situated a distance 10.0 cm apart in a vacuum, as illustrated in Fig. 6.1.

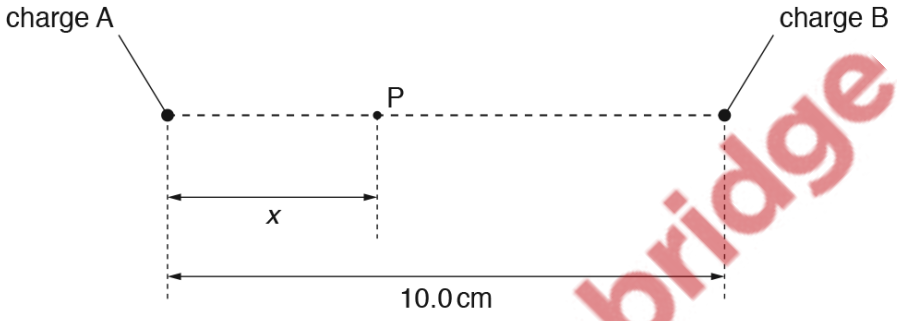


Fig. 6.1

A point P lies on the line joining the charges A and B. Point P is a distance x from A.

The variation with distance x of the electric field strength E at point P is shown in Fig. 6.2.

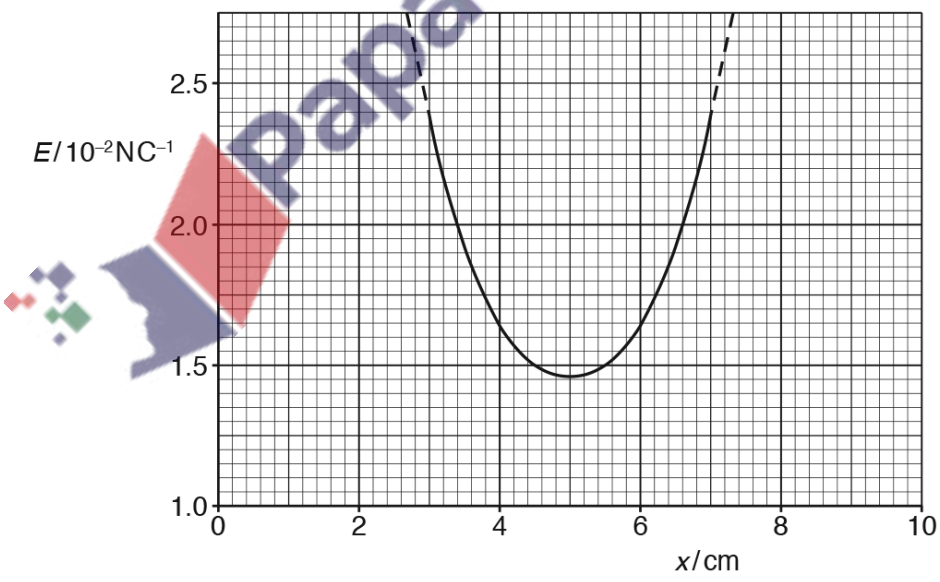


Fig. 6.2

State and explain whether the charges A and B:

(i) have the same, or opposite, signs

.....

.....

..... [2]

(ii) have the same, or different, magnitudes.

.....

.....

..... [2]

(c) An electron is situated at point P.

Without calculation, state and explain the variation in the magnitude of the acceleration of the electron as it moves from the position where $x = 3\,\text{cm}$ to the position where $x = 7\,\text{cm}$.

.....

.....

.....

.....

.....

..... [4]

[Total: 10]

181. 9702_s18_qp_41 Q: 6

(a) State what is meant by *electric field strength*.

.....

.....[1]

(b) An isolated metal sphere A of radius 26 cm is positively charged. Sphere A is shown in Fig. 6.1.

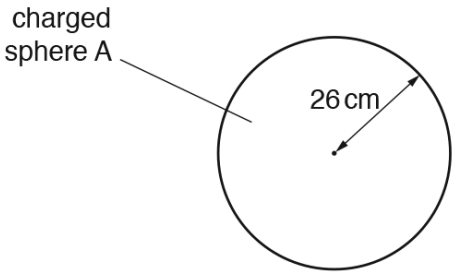


Fig. 6.1

Electrical breakdown (a spark) occurs when the electric field strength at the surface of the sphere exceeds $2.0 \times 10^4\,\text{V m}^{-1}$.

Calculate the maximum charge Q that can be stored on the sphere.

Q = ... C [2]

(c) A second isolated metal sphere B, also with charge $+Q$, has a radius of 52 cm.

Calculate the additional charge, in terms of Q, that may be stored on this sphere before electrical breakdown occurs.

additional charge = ...[2]

[Total: 5]

182. 9702_s18_qp_43 Q: 6

(a) State what is meant by *electric field strength*.

.....

.....[1]

(b) An isolated metal sphere A of radius 26 cm is positively charged. Sphere A is shown in Fig. 6.1.

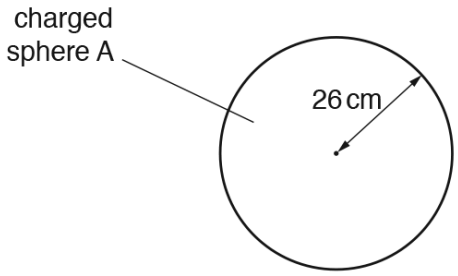


Fig. 6.1

Electrical breakdown (a spark) occurs when the electric field strength at the surface of the sphere exceeds $2.0 \times 10^4\,\text{V m}^{-1}$.

Calculate the maximum charge Q that can be stored on the sphere.

Q = ... C [2]

(c) A second isolated metal sphere B, also with charge $+Q$, has a radius of 52 cm.

Calculate the additional charge, in terms of Q, that may be stored on this sphere before electrical breakdown occurs.

additional charge = ...[2]

[Total: 5]

183. 9702_m17_qp_42 Q: 6

(a) State **one** similarity and **one** difference between the electric field lines and the gravitational field lines around an isolated positively charged metal sphere.

similarity .....

.....

difference .....

.....

[2]

(b) A positive point charge $+Q$ is positioned at a fixed point X and an identical positive point charge is positioned at a fixed point Y, as shown in Fig. 6.1.

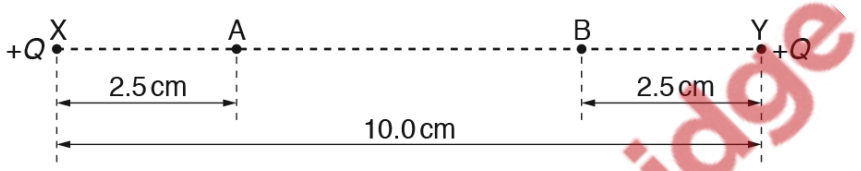


Fig. 6.1

The charges are separated in a vacuum by a distance of 10.0 cm.

Points A and B are on the line XY. Point A is a distance of 2.5 cm from X and point B is a distance of 2.5 cm from Y. The electric field strength at point A is 4.1×10^{-5} V m^{-1}.

(i) Calculate charge $+Q$.

$+Q$ = ...C [3]

(ii) On Fig. 6.2, sketch the variation of the electric field strength E with distance d from A to B, along the line AB.

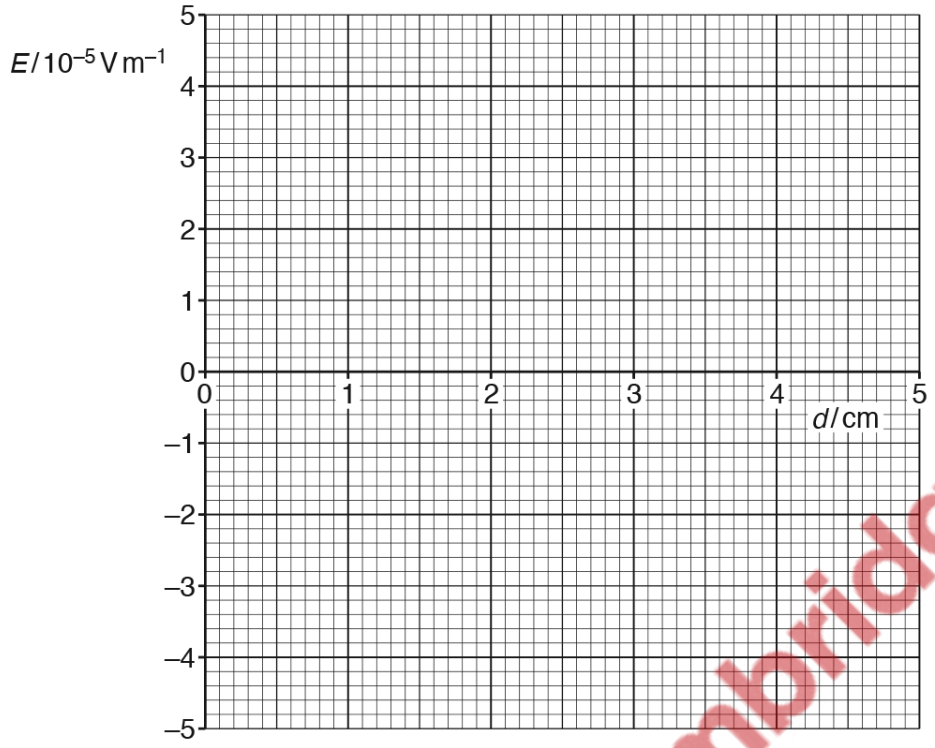


Fig. 6.2

[2]

(iii) A small positive charge is placed at A. The electric field causes this charge to move from rest along the line AB.

Describe the acceleration of the charge as it moves from A to B.

.....

.....

.....

.....[2]

[Total: 9]

184. 9702_s19_qp_42 Q: 6

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

.....

.....

.....[2]

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

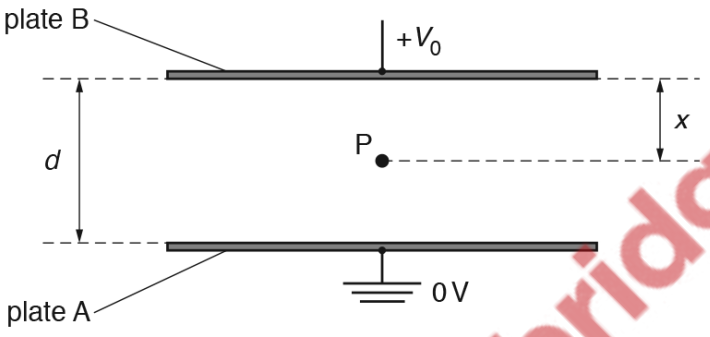


Fig. 6.1

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*.

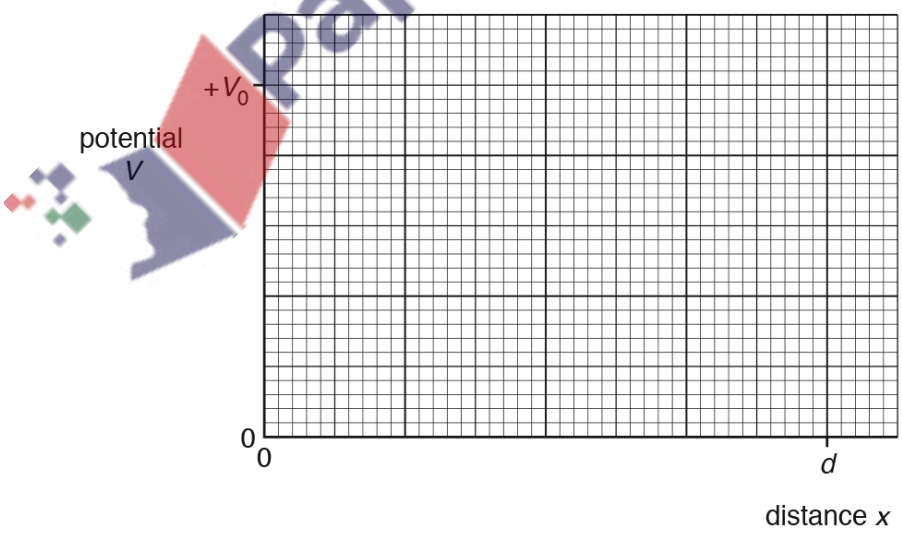


Fig. 6.2

[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.

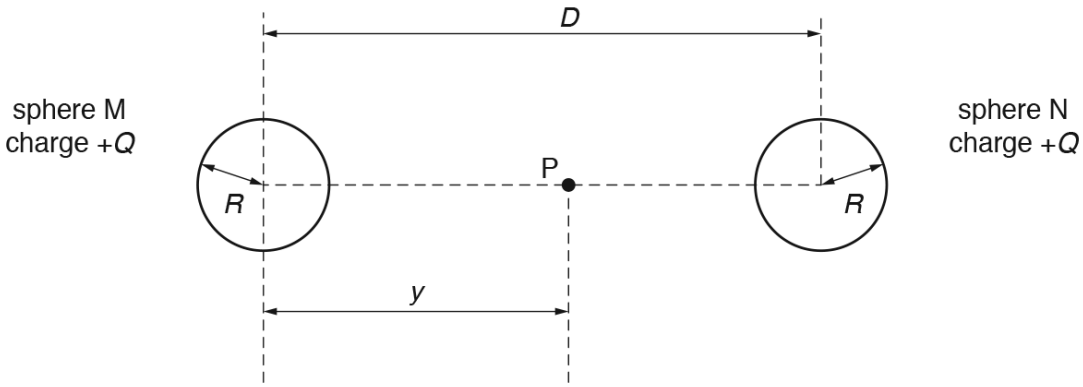


Fig. 6.3

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*.

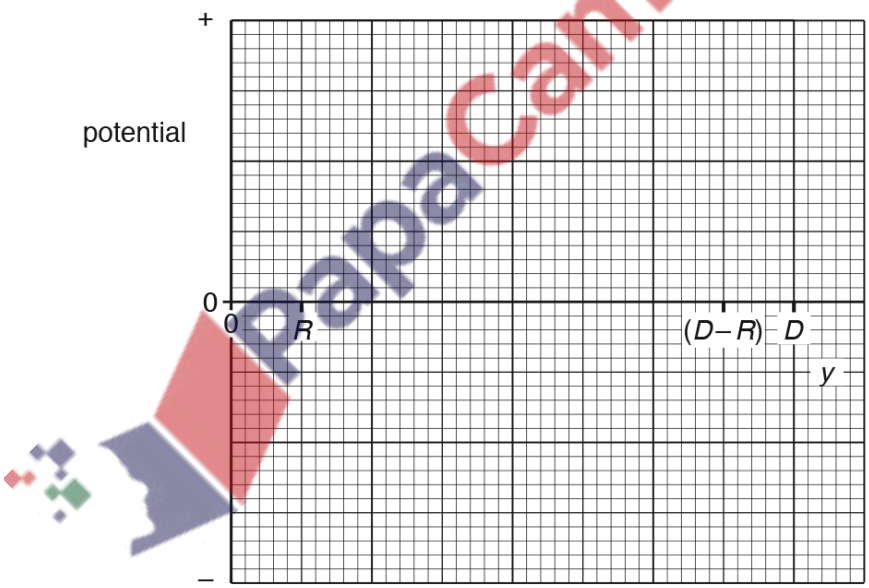


Fig. 6.4

[4]

[Total: 9]

185. 9702_w19_qp_42 Q: 9

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

.....

.....

..... [2]

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

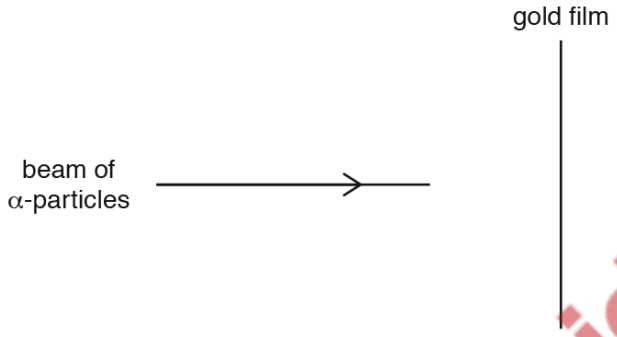


Fig. 9.1

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.

.....

..... [1]

[Total: 8]

186. 9702_m18_qp_42 Q: 7

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

.....

.....

.....[2]

(b) The centres of two charged metal spheres A and B are separated by a distance of 44.0 cm, as shown in Fig. 7.1.

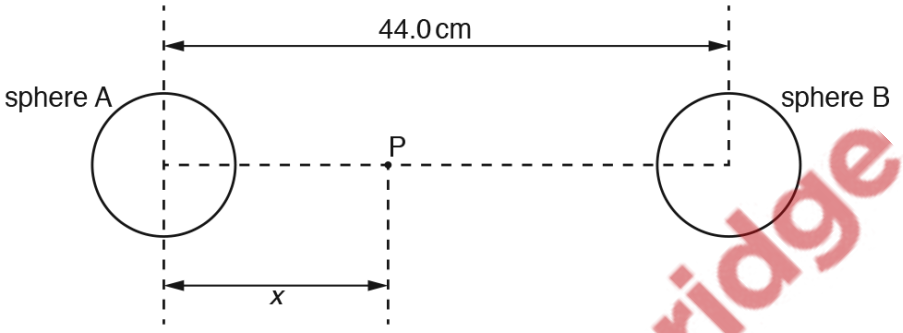


Fig. 7.1 (not to scale)

A moveable point P lies on the line joining the centres of the two spheres. Point P is a distance *x* from the centre of sphere A. The variation with distance *x* of the electric potential *V* at point P is shown in Fig. 7.2.

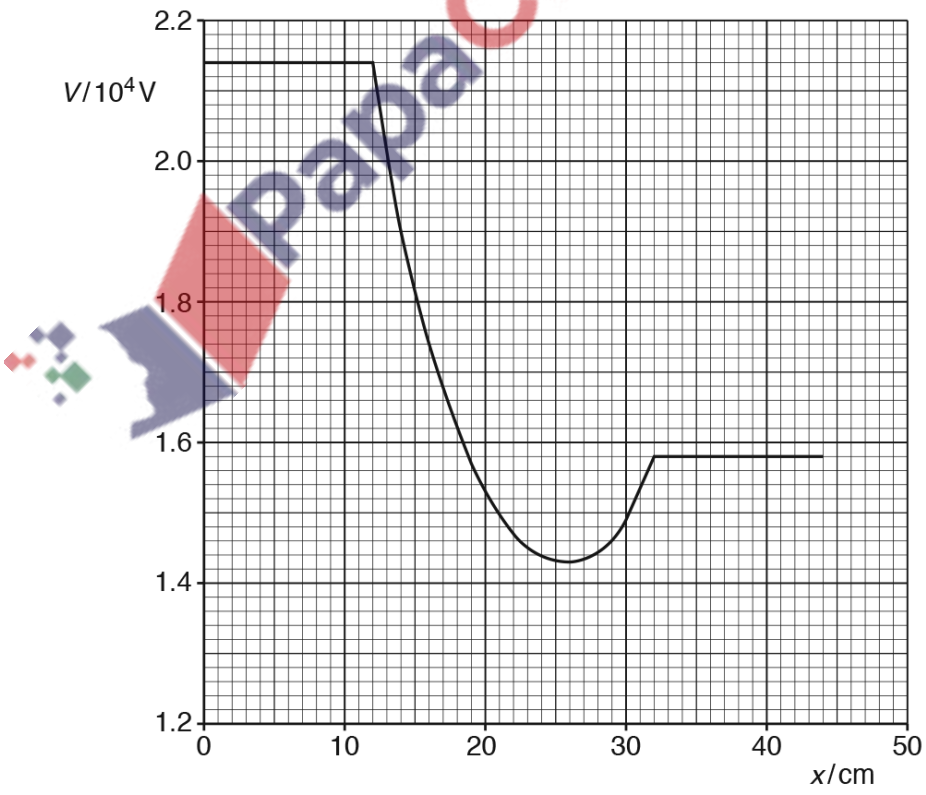


Fig. 7.2

(i) Use Fig. 7.2 to state and explain whether the two spheres have charges of the same, or opposite, sign.

.....

.....

.....[1]

(ii) A positively-charged particle is at rest on the surface of sphere A.

The particle moves freely from the surface of sphere A to the surface of sphere B.

1. Describe qualitatively the variation, if any, with distance x of the speed of the particle as it

moves from $x = 12\,\text{cm}$ to $x = 25\,\text{cm}$ .....

.....

passes through $x = 26\,\text{cm}$ .....

.....

moves from $x = 27\,\text{cm}$ to $x = 31\,\text{cm}$ .....

.....

reaches $x = 32\,\text{cm}$ .....

.....[4]

2. The particle has charge $3.2 \times 10^{-19}\,\text{C}$ and mass $6.6 \times 10^{-27}\,\text{kg}$.

Calculate the maximum speed of the particle.

speed = ... m s^{-1} [2]

[Total: 9]

187. 9702_w18_qp_41 Q: 6

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

.....

.....

.....[2]

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

.....

.....

.....[2]

(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.

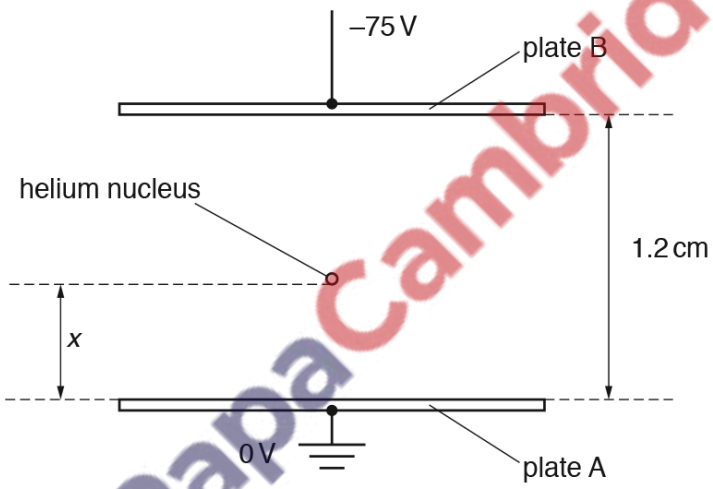


Fig. 6.1

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.

.....

.....

.....

.....[2]

(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 $x = 0.40\,\text{cm}$ from plate A.

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

[Total: 9]

188. 9702_w18_qp_42 Q: 6

(a) State

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

.....

.....

.....[2]

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

.....

.....

.....[2]

(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.

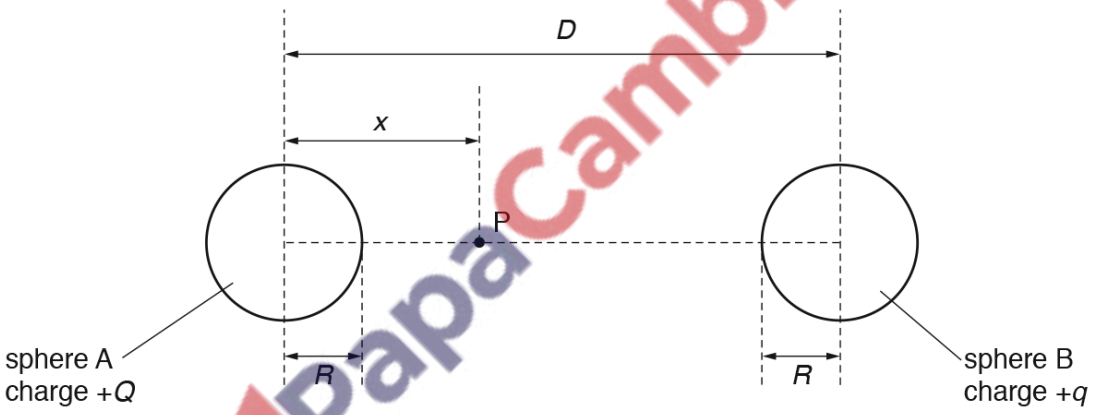


Fig. 6.1

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.

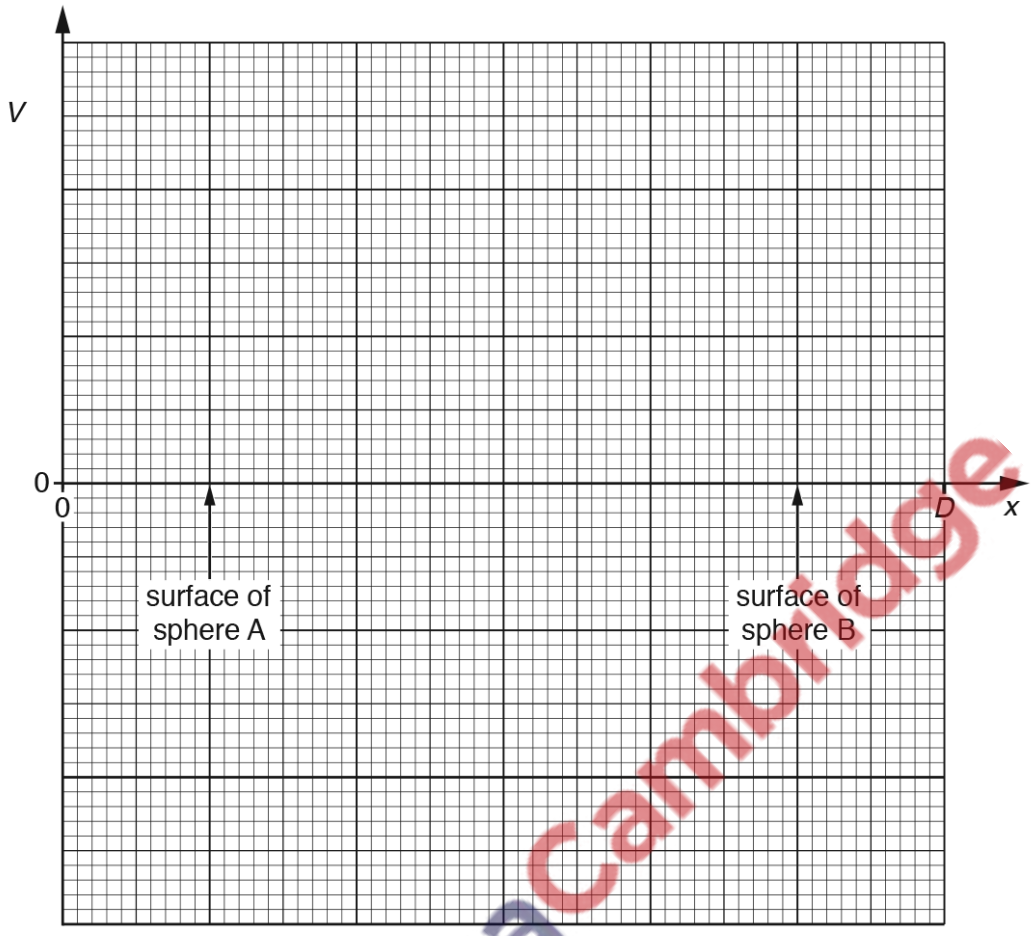


Fig. 6.2

[4]

[Total: 8]

189. 9702_w18_qp_43 Q: 6

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

.....

.....

.....[2]

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

.....

.....

.....[2]

(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.

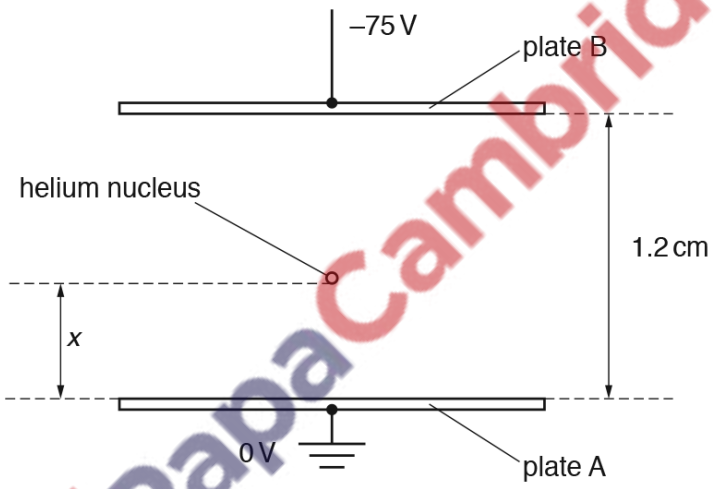


Fig. 6.1

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.

.....

.....

.....

.....[2]

(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 $x = 0.40\,\text{cm}$ from plate A.

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

[Total: 9]

190. 9702_s17_qp_42 Q: 6

(a) State Coulomb's law.

.....

.....

.....[2]

(b) Two charged metal spheres A and B are situated in a vacuum, as illustrated in Fig. 6.1.

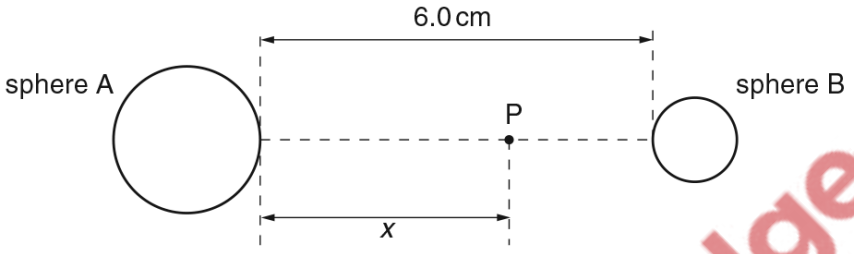


Fig. 6.1

The shortest distance between the surfaces of the spheres is 6.0 cm.

A movable point P lies along the line joining the centres of the two spheres, a distance x from the surface of sphere A.

The variation with distance x of the electric field strength E at point P is shown in Fig. 6.2.

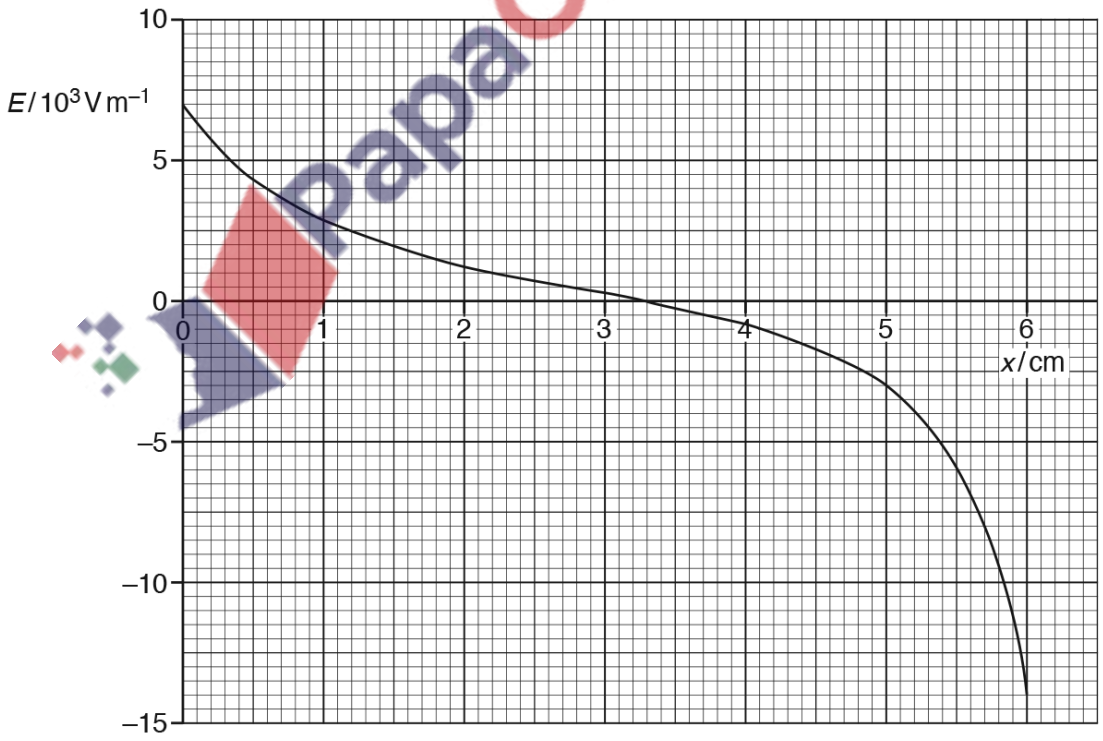


Fig. 6.2

(i) Use Fig. 6.2 to explain whether the two spheres have charges of the same, or opposite, sign.

.....

.....

.....

.....[2]

(ii) A proton is at point P where $x = 5.0\,\text{cm}$.
Use data from Fig. 6.2 to determine the acceleration of the proton.

acceleration = ... m s^{-2} [3]

(c) Use data from Fig. 6.2 to state the value of x at which the rate of change of electric potential is maximum. Give the reason for the value you have chosen.

.....

.....

.....[2]

[Total: 9]

191. 9702_s17_qp_43 Q: 5

An α-particle is travelling in a vacuum towards the centre of a gold nucleus, as illustrated in Fig. 5.1.

Fig. 5.1

The gold nucleus has charge $79e$.
The gold nucleus and the α-particle may be assumed to behave as point charges.
At a large distance from the gold nucleus, the α-particle has energy 7.7×10^{-13} J.

(a) The α-particle does not collide with the gold nucleus. Show that the radius of the gold nucleus must be less than 4.7×10^{-14} m.

[3]

(b) Determine the acceleration of the α-particle for a separation of 4.7×10^{-14} m between the centres of the gold nucleus and of the α-particle.

acceleration = ... $m\,s^{-2}$ [3]

(c) In an α-particle scattering experiment, the beam of α-particles is incident on a very thin gold foil.
Suggest why the gold foil must be very thin.

.....

.....[1]

[Total: 7]

192. 9702_w17_qp_42 Q: 6

(a) For any point outside a spherical conductor, the charge on the sphere may be considered to act as a point charge at its centre. By reference to electric field lines, explain this.

.....

.....

.....

.....[2]

(b) An isolated spherical conductor has charge q, as shown in Fig. 6.1.

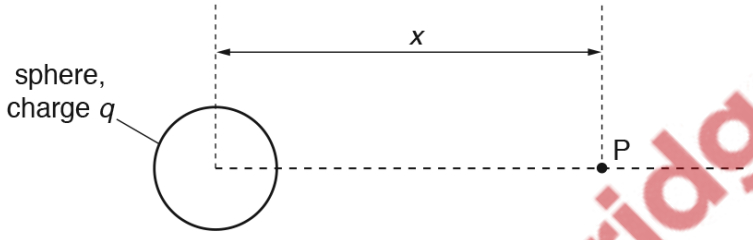


Fig. 6.1

Point P is a movable point that, at any one time, is a distance x from the centre of the sphere.

The variation with distance x of the electric potential V at point P due to the charge on the sphere is shown in Fig. 6.2.

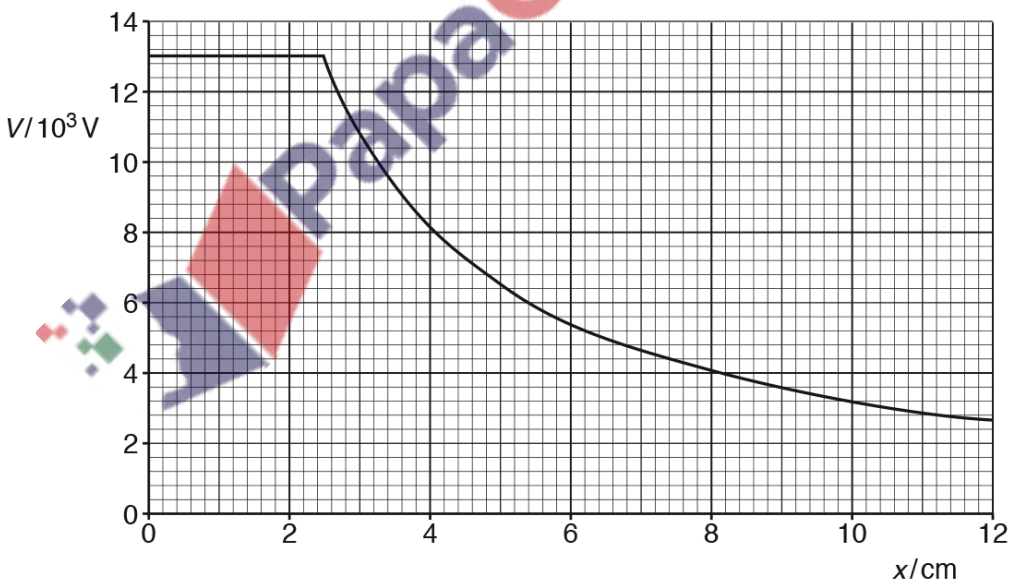


Fig. 6.2

Use Fig. 6.2 to determine

(i) the electric field strength E at point P where $x = 6.0\,\text{cm}$,

$E =$ ..... N C^{-1} [3]

(ii) the radius R of the sphere. Explain your answer.

$R =$ ..... cm [2]

[Total: 7]

193. 9702_w16_qp_41 Q: 5

Two small solid metal spheres A and B have equal radii and are in a vacuum. Their centres are 15 cm apart.
Sphere A has charge +3.0 pC and sphere B has charge +12 pC. The arrangement is illustrated in Fig. 5.1.

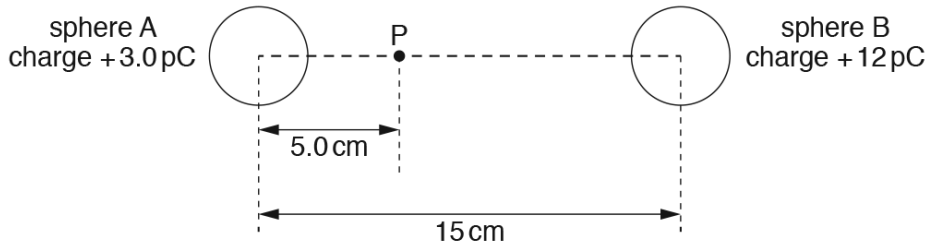


Fig. 5.1

Point P lies on the line joining the centres of the spheres and is a distance of 5.0 cm from the centre of sphere A.

(a) Suggest why the electric field strength in both spheres is zero.

.....

.....

..... [2]

(b) Show that the electric field strength is zero at point P. Explain your working.

[3]

(c) Calculate the electric potential at point P.

electric potential = ... V [2]

(d) A silver-107 nucleus ($^{107}_{47}$Ag) has speed v when it is a long distance from point P.

Use your answer in **(c)** to calculate the minimum value of speed v such that the nucleus can reach point P.

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

[Total: 10]

194. 9702_w16_qp_42 Q: 6

Two solid metal spheres A and B, each of radius 1.5 cm, are situated in a vacuum. Their centres are separated by a distance of 20.0 cm, as shown in Fig. 6.1.

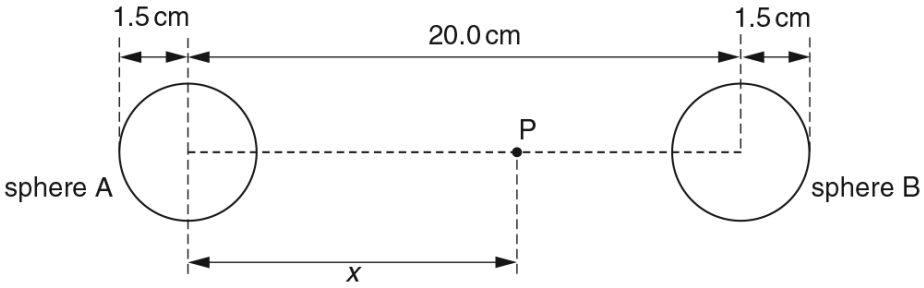


Fig. 6.1 (not to scale)

Both spheres are positively charged.

Point P lies on the line joining the centres of the two spheres, at a distance x from the centre of sphere A.

The variation with distance x of the electric field strength E at point P is shown in Fig. 6.2.

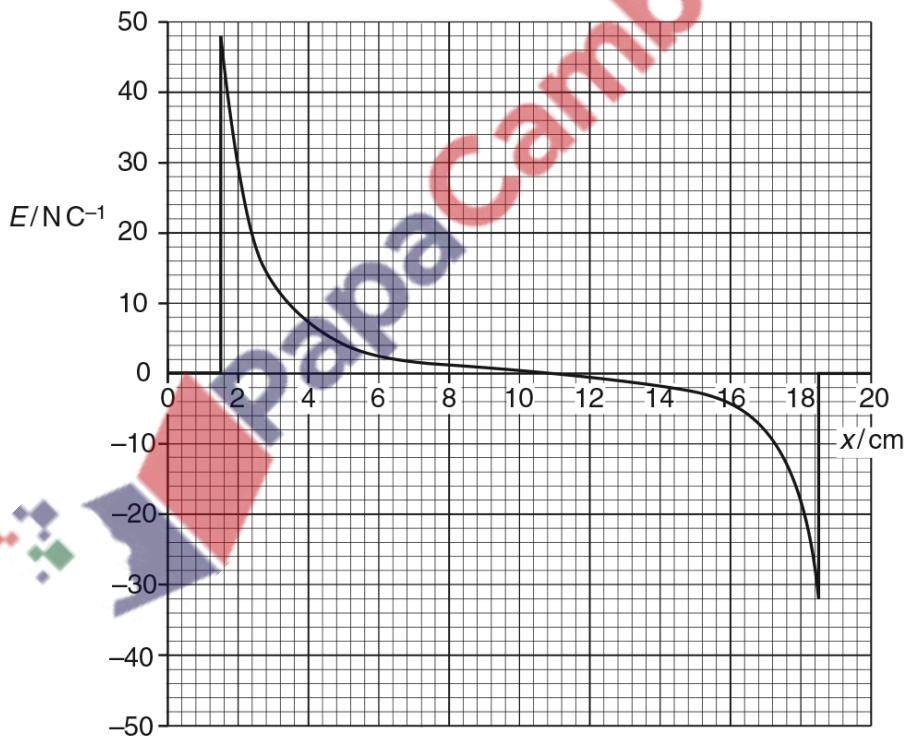


Fig. 6.2

(a) Use Fig. 6.2 to determine the ratio

$$\frac{\text{magnitude of charge on sphere A}}{\text{magnitude of charge on sphere B}}.$$

Explain your working.

ratio = ...[3]

(b) The variation with distance x of the electric potential V at point P is shown in Fig. 6.3.

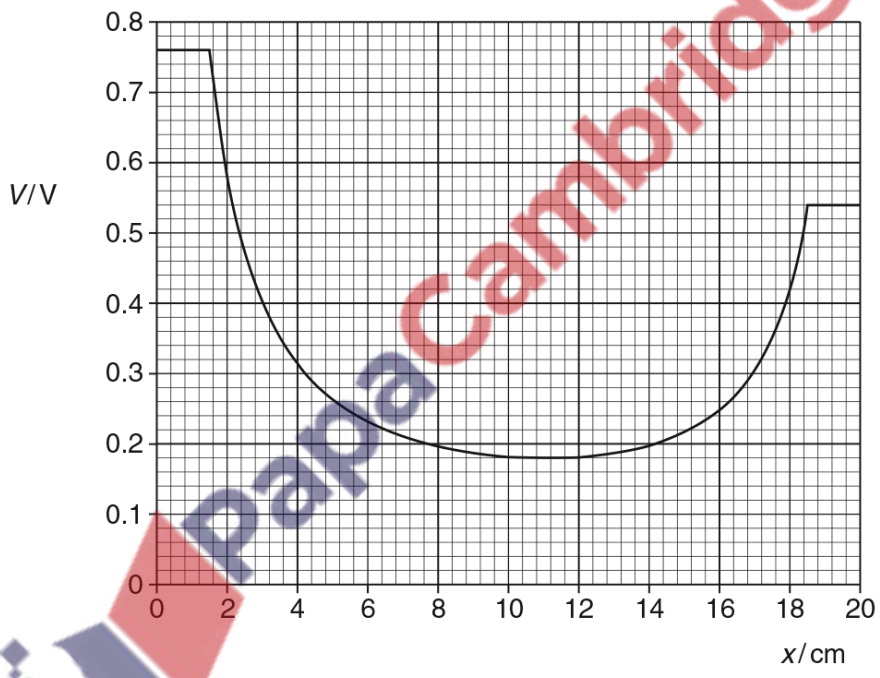


Fig. 6.3

An α-particle is initially at rest on the surface of sphere A.
The α-particle moves along the line joining the centres of the two spheres.

Determine, for the α-particle as it moves between the two spheres,

(i) its maximum speed,

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

(ii) its speed on reaching the surface of sphere B.

speed = ... $m s^{-1}$ [2]

[Total: 8]

195. 9702_w16_qp_43 Q: 5

Two small solid metal spheres A and B have equal radii and are in a vacuum. Their centres are 15 cm apart.
Sphere A has charge +3.0 pC and sphere B has charge +12 pC. The arrangement is illustrated in Fig. 5.1.

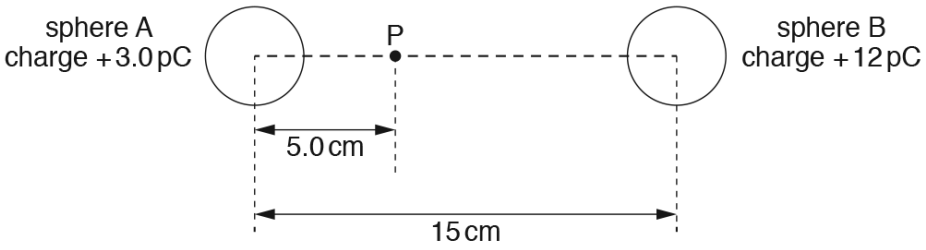


Fig. 5.1

Point P lies on the line joining the centres of the spheres and is a distance of 5.0 cm from the centre of sphere A.

(a) Suggest why the electric field strength in both spheres is zero.

.....

.....

..... [2]

(b) Show that the electric field strength is zero at point P. Explain your working.

[3]

(c) Calculate the electric potential at point P.

electric potential = ... V [2]

(d) A silver-107 nucleus ($^{107}_{47}Ag$) has speed v when it is a long distance from point P.

Use your answer in **(c)** to calculate the minimum value of speed v such that the nucleus can reach point P.

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

[Total: 10]