18. Electric Fields

18.4 Electric field of a point charge

Paper 4

Question Paper

1 **(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.

(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 $2x$.

(ii) State an expression, in terms of Q, x and the permittivity of free space ε_0, for the electric field strength E_X at P due to sphere X.

E_X = ... [1]

(iii) Determine an expression, in terms of Q, x and ε_0, for the resultant electric field strength E at point P due to the two spheres.

E = ... [2]

2 **(c)** Fig. 6.2 shows the variation of the electric field strength E with distance x from the centre of the sphere in **(b)**.

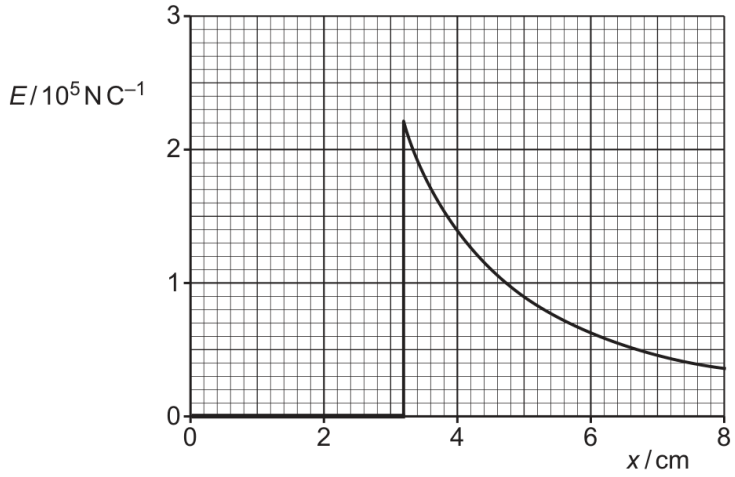


Fig. 6.2

(i) Determine the radius, in cm, of the sphere.

radius = ... cm [1]

(ii) Calculate the charge on the sphere.

charge = ... C [3]

3 **(b)** An isolated uniform conducting sphere has mass M and charge Q.
The gravitational field strength at the surface of the sphere is g.
The electric field strength at the surface of the sphere is E.

(ii) Show that the numerical value of α is $1.35 \times 10^{20}\,\text{kg}^2\,\text{C}^{-2}$.

[1]

(c) Assume that the Earth is a uniform conducting sphere of mass 5.98×10^{24} kg.
The surface of the Earth carries a charge of -4.80×10^{5} C that is evenly distributed.

(i) Use the information in **(b)** to determine the electric field strength at the surface of the Earth. Give a unit with your answer.

electric field strength = ... unit ..... [2]

4 **(a)** An isolated metal sphere of radius r is charged so that the electric field strength at its surface is E_0.

On Fig. 6.1, sketch the variation of the electric field strength E with distance x from the centre of the sphere. Your sketch should extend from $x = 0$ to $x = 3r$.

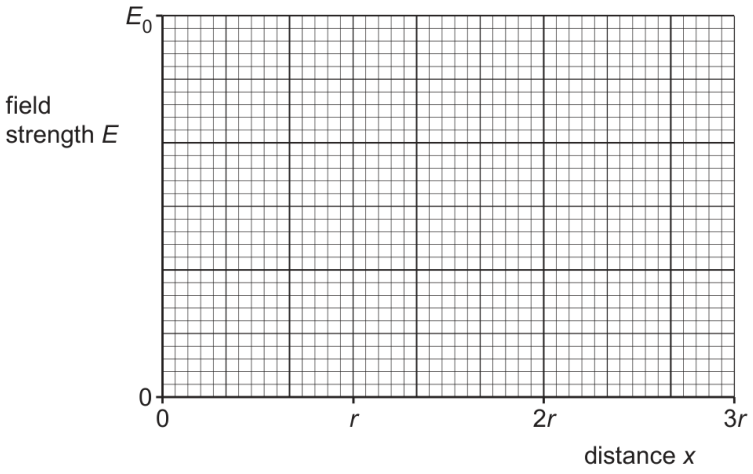


Fig. 6.1

[3]

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.

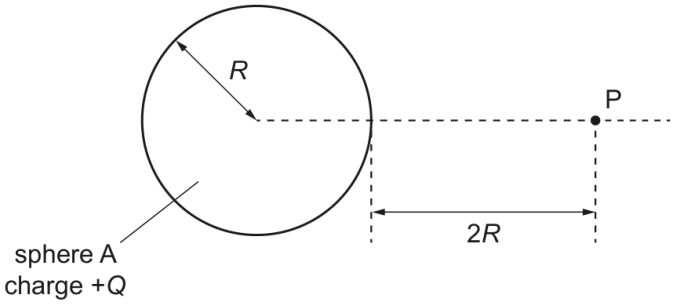


Fig. 5.1

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]

6 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.

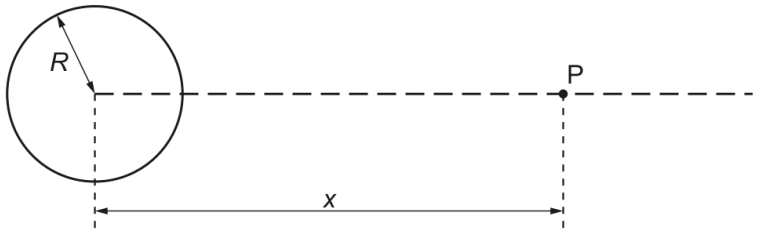


Fig. 7.1

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

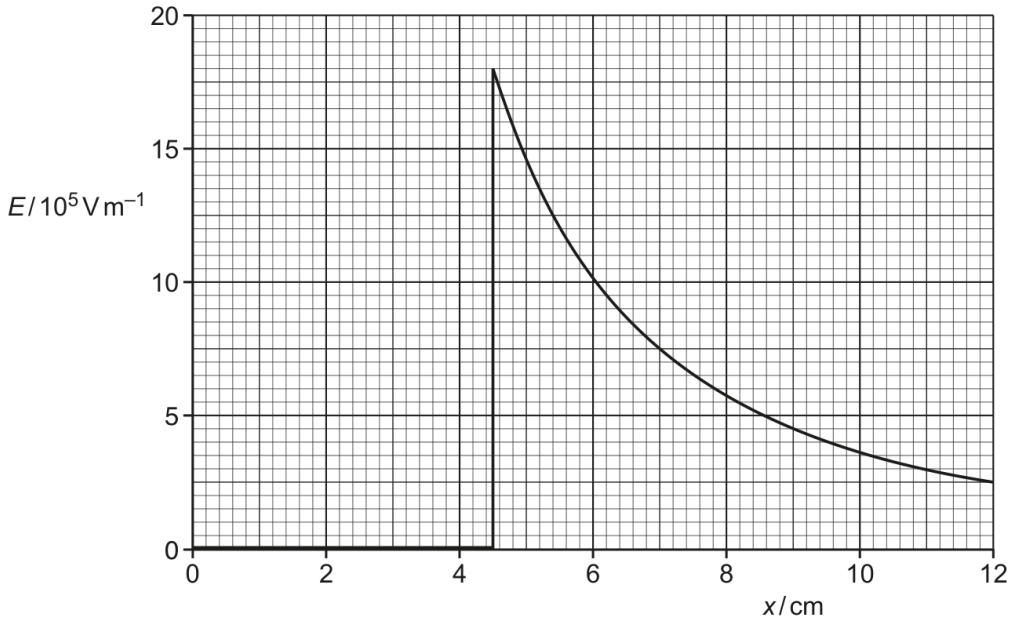


Fig. 7.2

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

Q = ... C [3]

7 **(a)** **(ii)** State **one** similarity and **one** difference between the electric field due to a point charge and the gravitational field due to a point mass.

similarity: .....

.....

.....

difference: .....

.....

.....

[2]

(b) An isolated solid metal sphere of radius 0.15 m is situated in a vacuum, as illustrated in Fig. 5.1.

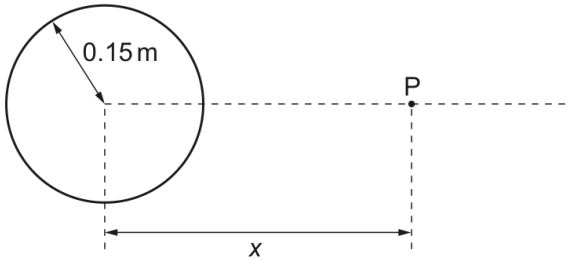


Fig. 5.1

The electric field strength at the surface of the sphere is $84\,V\,m^{-1}$.

Determine:

(i) the charge Q on the sphere

Q = ... C [2]

(ii) the electric field strength at point P, a distance $x = 0.45\,\text{m}$ from the centre of the sphere.

electric field strength = ... V m^{-1} [2]

(c) Use information from **(b)** to show, on the axes of Fig. 5.2, the variation of the electric field strength E with distance x from the centre of the sphere for values of x from $x = 0$ to $x = 0.45\,\text{m}$.

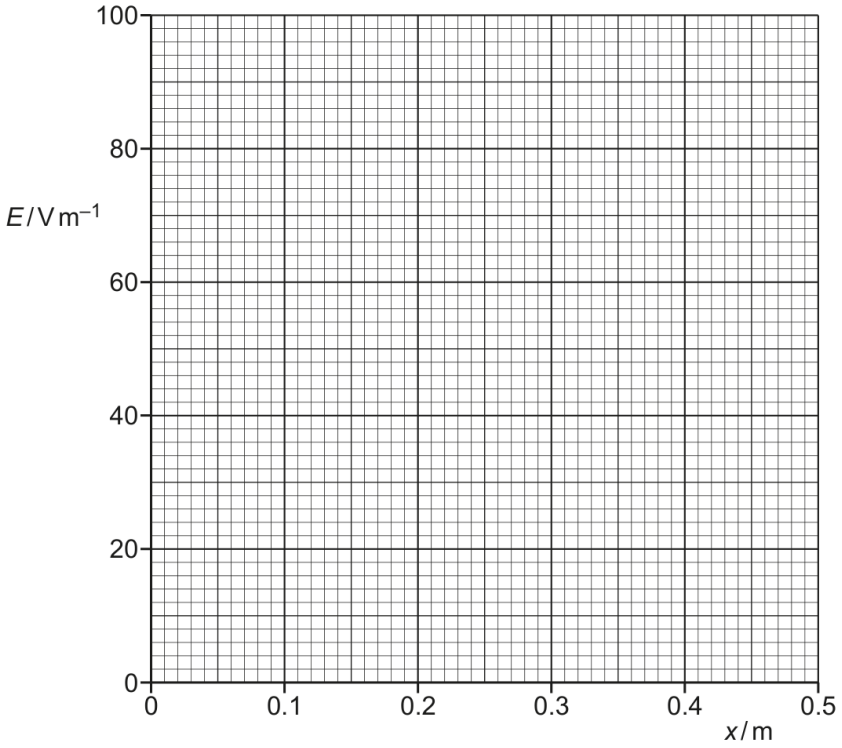


Fig. 5.2

[3]

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

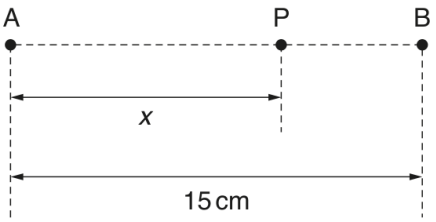


Fig. 5.1

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.

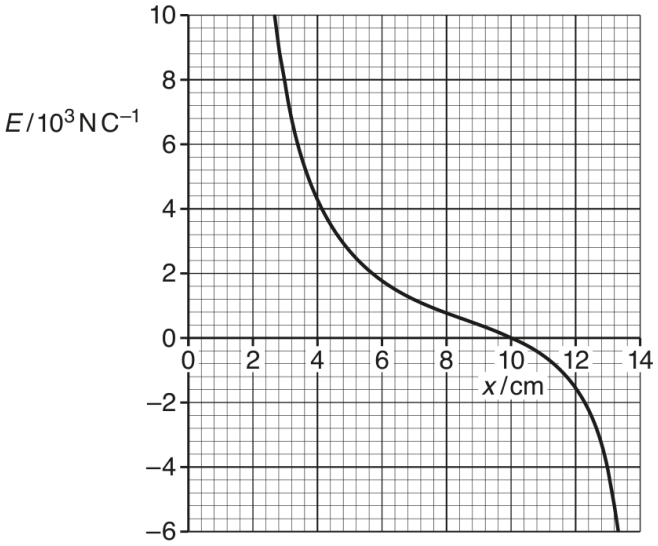


Fig. 5.2

(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 $x = 3$ cm and $x = 7$ 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]

9 **(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.

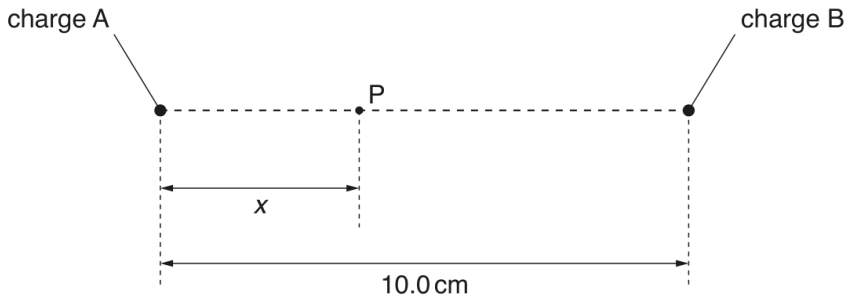


Fig. 6.1

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.

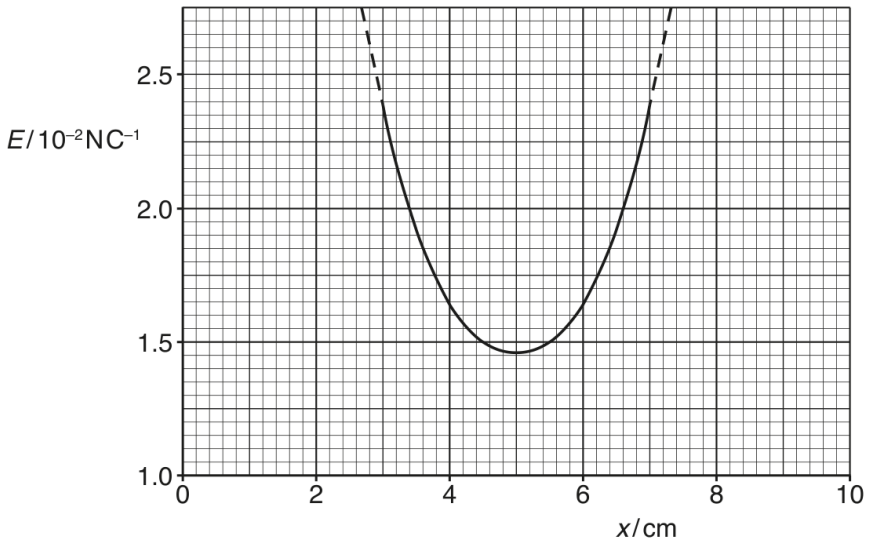


Fig. 6.2

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]

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

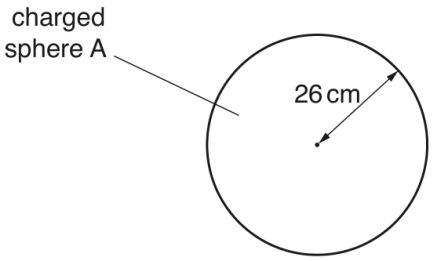


Fig. 6.1

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]