Electro-Statics
May 02

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

....

....[2]

(b) An isolated metal sphere of radius *r* carries a charge $+Q$. The charge may be assumed to be concentrated at the centre of the sphere.

(i) State, in terms of *r* and *Q*, the electric potential *V* at the surface of the sphere. Identify any other symbols you use.

....

....

(ii) Write down the relationship between capacitance *C*, charge *Q* and potential *V*.

....

(iii) Hence show that the capacitance *C* of the sphere is given by

$$C = 4\pi\varepsilon_0 r.$$

[3]

(c) The sphere in **(b)** has a radius of 15 cm and carries a charge of 2.0×10^{-6} C.

Calculate

(i) the capacitance of the sphere,

capacitance = ... μF

(ii) the energy stored on the sphere.

energy = ... J

[4]

Nov 02

5 Some capacitors are marked '48 μF, safe working voltage 25 V'.

Show how a number of these capacitors may be connected to provide a capacitor of capacitance

(a) 48 μF, safe working voltage 50 V,

[2]

(b) 72 μF, safe working voltage 25 V.

[2]

May 03

4 In a particular experiment, a high voltage is created by charging an isolated metal sphere, as illustrated in Fig. 4.1.

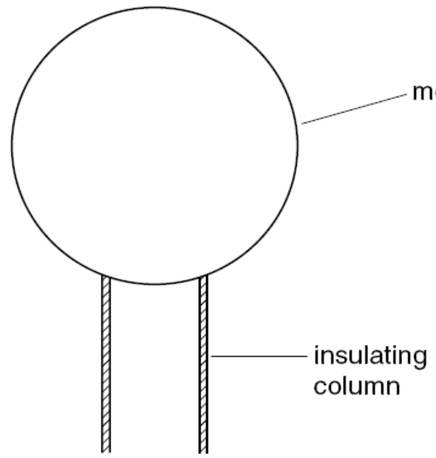


Fig. 4.1

The sphere has diameter 42 cm and any charge on its surface may be considered as if it were concentrated at its centre.

The air surrounding the sphere loses its insulating properties, causing a spark, when the electric field exceeds 20 kV cm^{-1}.

(a) By reference to an atom in the air, suggest the mechanism by which the electric field causes the air to become conducting.

....

....

....

.... [3]

(b) Calculate, for the charged sphere when a spark is about to occur,

(i) the charge on the sphere,

charge = ... C [3]

(ii) its potential.

potential = ... V [2]

(c) Under certain conditions, a spark sometimes occurs before the potential reaches that calculated in **(b)(ii)**. Suggest a reason for this.

....

.... [1]

Nov 04

2 An α-particle (^4_2He) is moving directly towards a stationary gold nucleus ($^{197}_{79}Au$).

The α-particle and the gold nucleus may be considered to be solid spheres with the charge and mass concentrated at the centre of each sphere.

When the two spheres are just touching, the separation of their centres is 9.6×10^{-15} m.

(a) The α-particle and the gold nucleus may be assumed to be an isolated system. Calculate, for the α-particle just in contact with the gold nucleus,

(i) its gravitational potential energy,

gravitational potential energy = ... J [3]

(ii) its electric potential energy.

electric potential energy = ... J [3]

(b) Using your answers in **(a)**, suggest why, when making calculations based on an α-particle scattering experiment, gravitational effects are not considered.

....

....[1]

(c) In the α-particle scattering experiment conducted in 1913, the maximum kinetic energy of the available α-particles was about 6 MeV. Suggest why, in this experiment, the radius of the target nucleus could not be determined.

....

....

....[2]

May 05

5 An isolated conducting sphere of radius r is given a charge $+Q$. This charge may be assumed to act as a point charge situated at the centre of the sphere, as shown in Fig. 5.1.

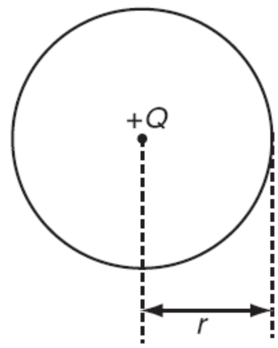


Fig. 5.1

Fig. 5.2. shows the variation with distance x from the centre of the sphere of the potential V due to the charge $+Q$.

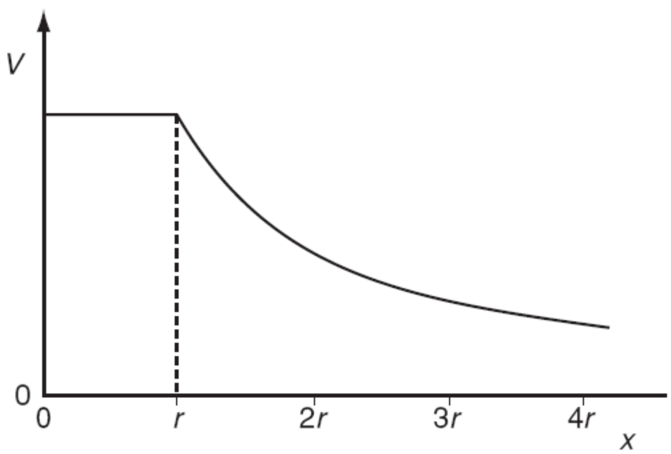
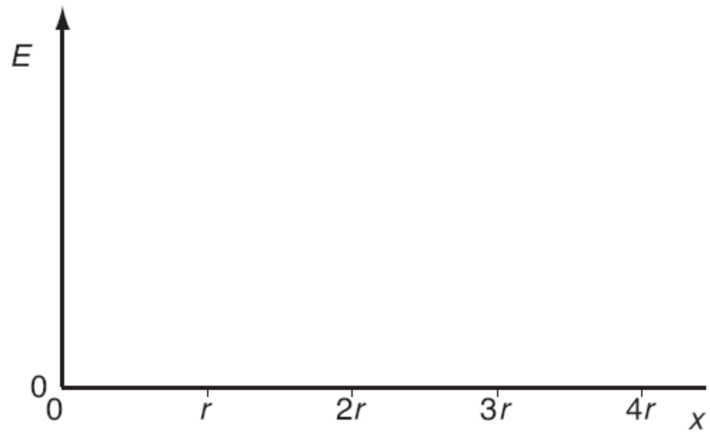


Fig. 5.2

(a) State the relation between electric field and potential.

....[1]

(b) Using the relation in **(a)**, on Fig. 5.3 sketch a graph to show the variation with distance x of the electric field E due to the charge $+Q$.



[3]

Fig. 5.3

May 05

8 **(a)** Define *capacitance*.

....

....[1]

(b) **(i)** One use of a capacitor is for the storage of electrical energy.
Briefly explain how a capacitor stores energy.

....

....

....[2]

(ii) Calculate the change in the energy stored in a capacitor of capacitance 1200 μF when the potential difference across the capacitor changes from 50 V to 15 V.

energy change = ... J [3]

May 06

5 An isolated conducting sphere of radius *r* is placed in air. It is given a charge $+Q$. This charge may be assumed to act as a point charge situated at the centre of the sphere.

(a) **(i)** Define *electric field strength*.

....

.... [1]

(ii) State a formula for the electric field strength E at the surface of the sphere. Also, state the meaning of any other symbols used.

....

....

.... [2]

(b) The maximum field strength at the surface of the sphere before electrical breakdown (sparking) occurs is 2.0×10^6 V m^{-1}. The sphere has a radius r of 0.35 m.

Calculate the maximum values of

(i) the charge that can be stored on the sphere,

charge = ………..………………… C [2]

(ii) the potential at the surface of the sphere.

potential = ………..………………… V [2]

(c) Suggest the effect of the electric field on a single atom near the sphere's surface as electrical breakdown of the air occurs.

....

....

.... [2]

Nov 06

1 The definitions of electric potential and of gravitational potential at a point have some similarity.

(a) State one similarity between these two definitions.

....

.... [1]

(b) Explain why values of gravitational potential are always negative whereas values of electric potential may be positive or negative.

....

....

....

....

.... [4]

May 07

3 Two charged points A and B are separated by a distance of 6.0 cm, as shown in Fig. 3.1.

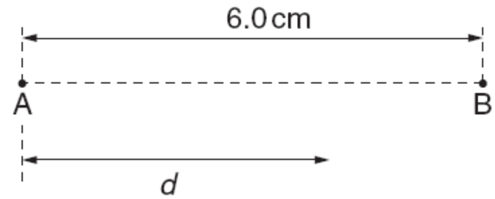


Fig. 3.1

The variation with distance *d* from A of the electric field strength *E* along the line AB is shown in Fig. 3.2.

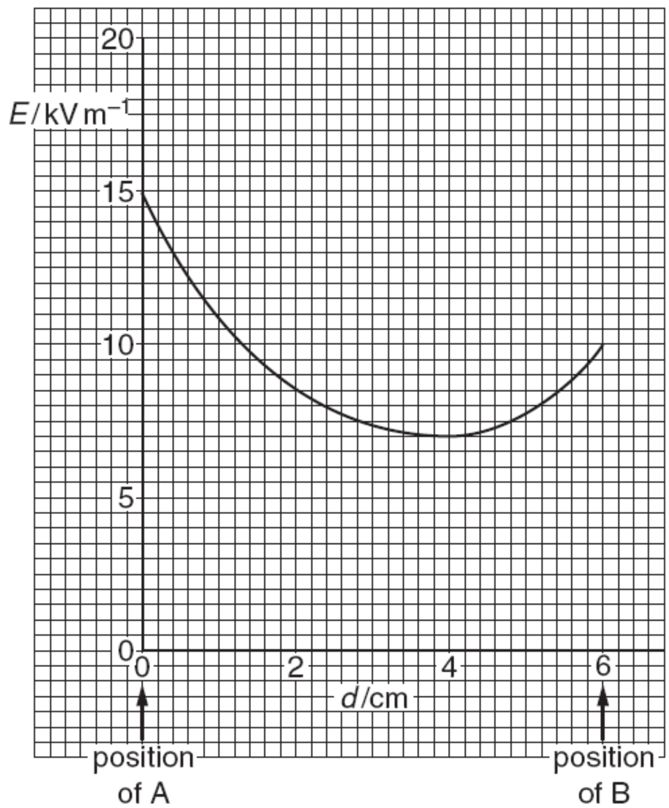


Fig. 3.2

An electron is emitted with negligible speed from A and travels along AB.

(a) State the relation between electric field strength *E* and potential *V*.

....

.... [2]

(b) The area below the line of the graph of Fig. 3.2 represents the potential difference between A and B.

Use Fig. 3.2 to determine the potential difference between A and B.

potential difference = ... V [4]

(c) Use your answer to **(b)** to calculate the speed of the electron as it reaches point B.

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

(d) **(i)** Use Fig. 3.2 to determine the value of d at which the electron has maximum acceleration.

d = ... cm [1]

(ii) Without any further calculation, describe the variation with distance d of the acceleration of the electron.

....

....

.... [2]

Nov 07

4 A small charged metal sphere is situated in an earthed metal box. Fig. 4.1 illustrates the electric field between the sphere and the metal box.

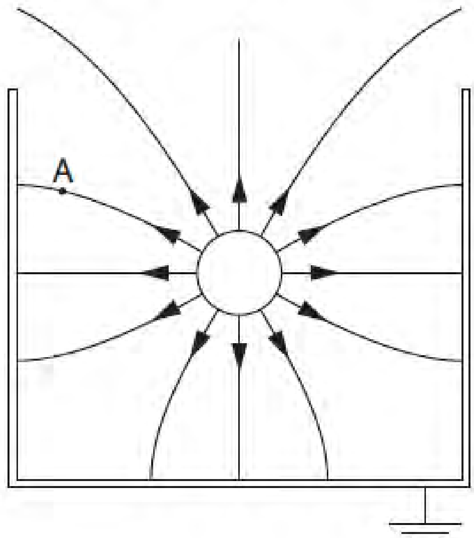


Fig. 4.1

(a) By reference to Fig. 4.1, state and explain

(i) whether the sphere is positively or negatively charged,

....

....

....[2]

(ii) why it appears as if the charge on the sphere is concentrated at the centre of the sphere.

....

....[1]

(b) On Fig. 4.1, draw an arrow to show the direction of the force on a stationary electron situated at point A. [2]

(c) The radius *r* of the sphere is 2.4 cm. The magnitude of the charge *q* on the sphere is 0.76 nC.

(i) Use the expression

$$V = \frac{Q}{4\pi\varepsilon_0 r}$$

to calculate a value for the magnitude of the potential *V* at the surface of the sphere.

V = ...V [2]

(ii) State the sign of the charge induced on the inside of the metal box. Hence explain whether the actual magnitude of the potential will be greater or smaller than the value calculated in **(i)**.

....

....

....

....[3]

(d) A lead sphere is placed in a lead box in free space, in a similar arrangement to that shown in Fig. 4.1. Explain why it is **not** possible for the gravitational field to have a similar shape to that of the electric field.

....

....

....[1]

Nov 07

5 (a) State one function of capacitors in simple circuits.

....

....[1]

(b) A capacitor is charged to a potential difference of 15 V and then connected in series with a switch, a resistor of resistance 12 kΩ and a sensitive ammeter, as shown in Fig. 5.1.

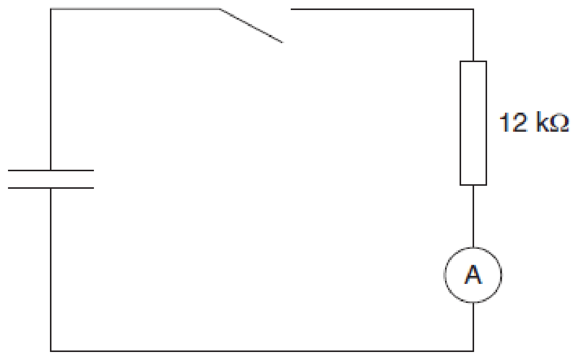


Fig. 5.1

The switch is closed and the variation with time *t* of the current *I* in the circuit is shown in Fig. 5.2.

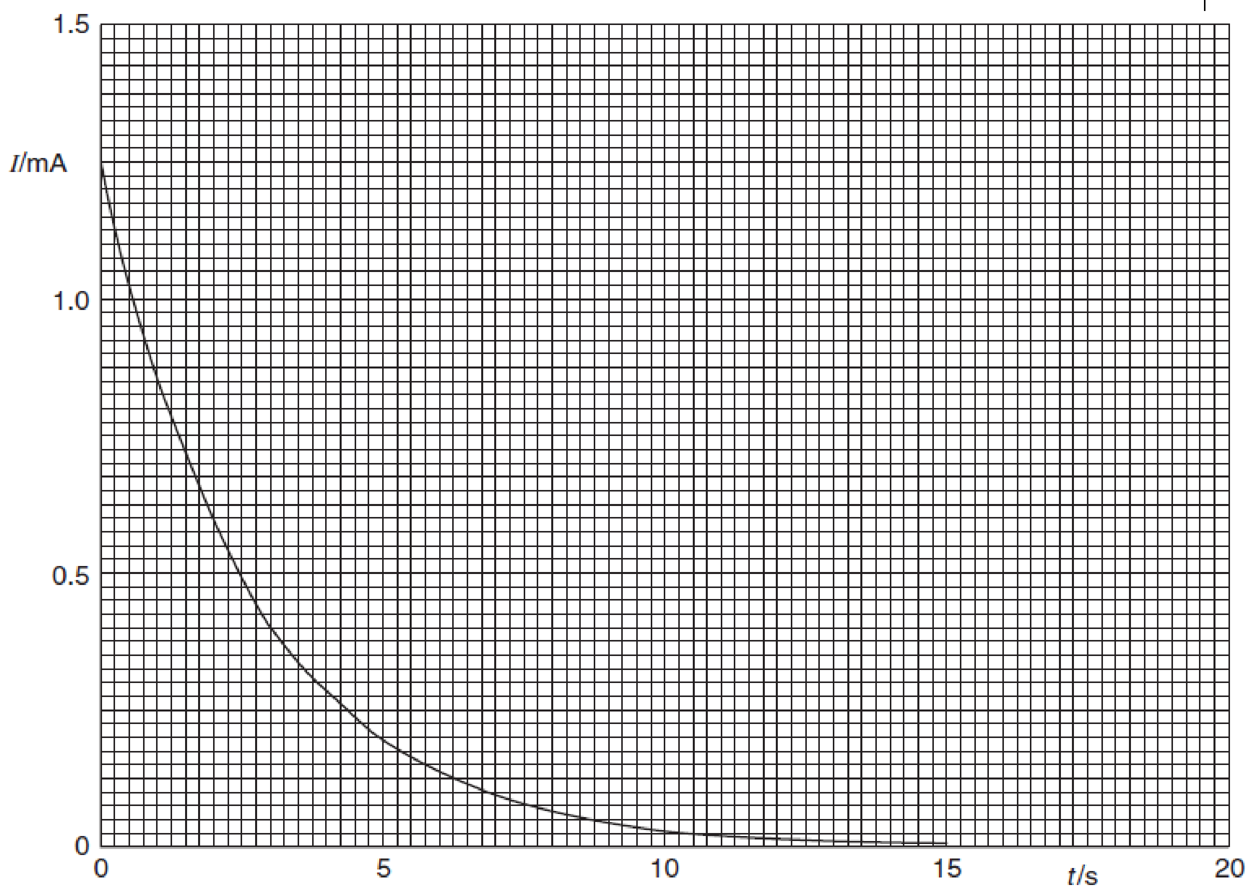


Fig. 5.2

(i) State the relation between the current in a circuit and the charge that passes a point in the circuit.

....

....[1]

(ii) The area below the graph line of Fig. 5.2 represents charge.
Use Fig. 5.2 to determine the initial charge stored in the capacitor.

charge = ... μC [4]

(iii) Initially, the potential difference across the capacitor was 15 V.
Calculate the capacitance of the capacitor.

capacitance = ... μF [2]

(c) The capacitor in **(b)** discharges one half of its initial energy. Calculate the new potential difference across the capacitor.

potential difference = ...V [3]

May 08

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

....

....

....[2]

(b) Two isolated point charges A and B are separated by a distance of 30.0 cm, as shown in Fig. 4.1.

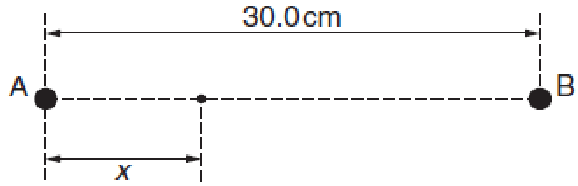


Fig. 4.1

The charge at A is + 3.6×10^{-9} C.
The variation with distance x from A along AB of the potential V is shown in Fig. 4.2.

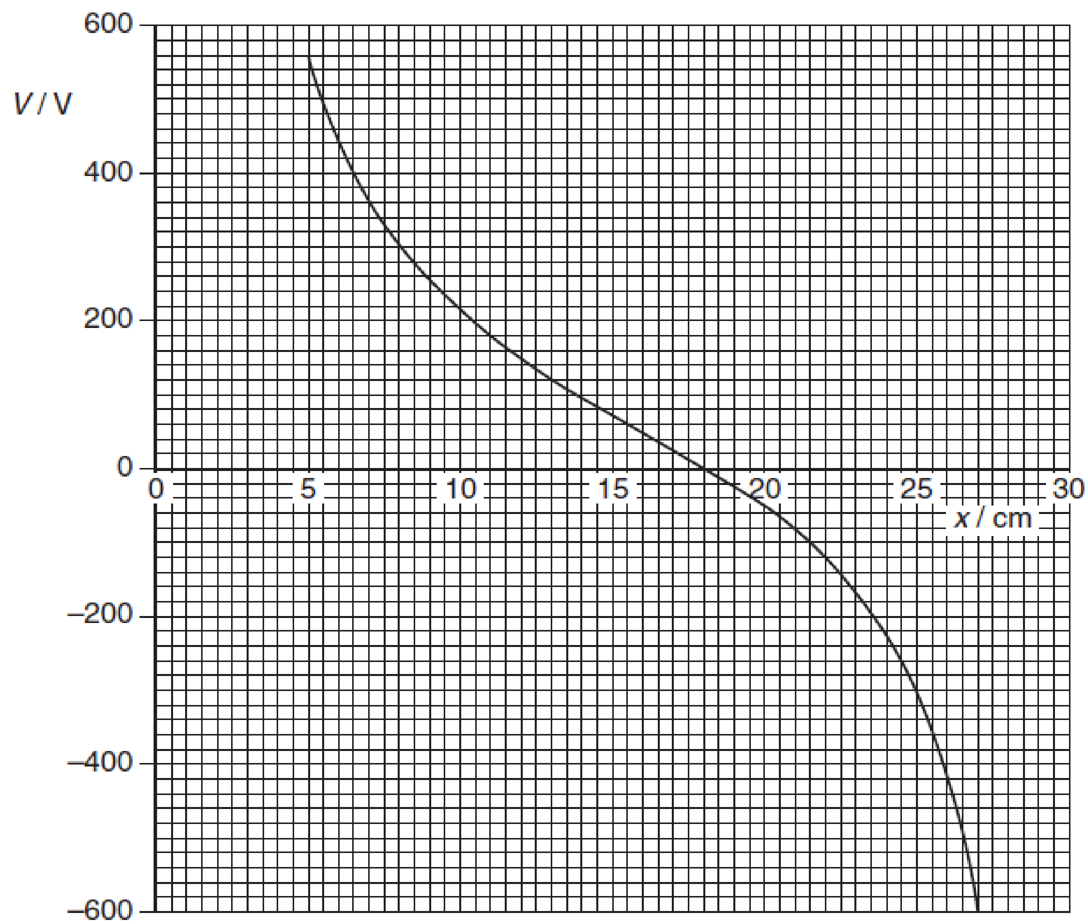


Fig. 4.2

(i) State the value of x at which the potential is zero.

x = ... cm [1]

(ii) Use your answer in **(i)** to determine the charge at B.

charge = ... C [3]

(c) A small test charge is now moved along the line AB in **(b)** from $x = 5.0\,\text{cm}$ to $x = 27\,\text{cm}$. State and explain the value of x at which the force on the test charge will be maximum.

....

....

....

....[3]

May 08

5 A capacitor C is charged using a supply of e.m.f. 8.0V. It is then discharged through a resistor R.
The circuit is shown in Fig. 5.1.

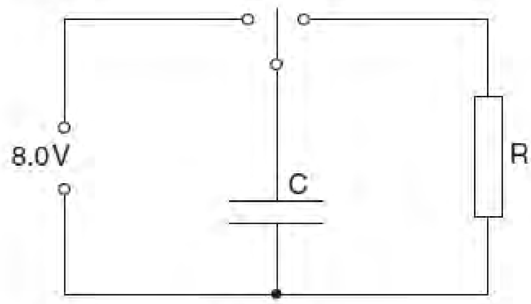


Fig. 5.1

The variation with time *t* of the potential difference *V* across the resistor R during the discharge of the capacitor is shown in Fig. 5.2.

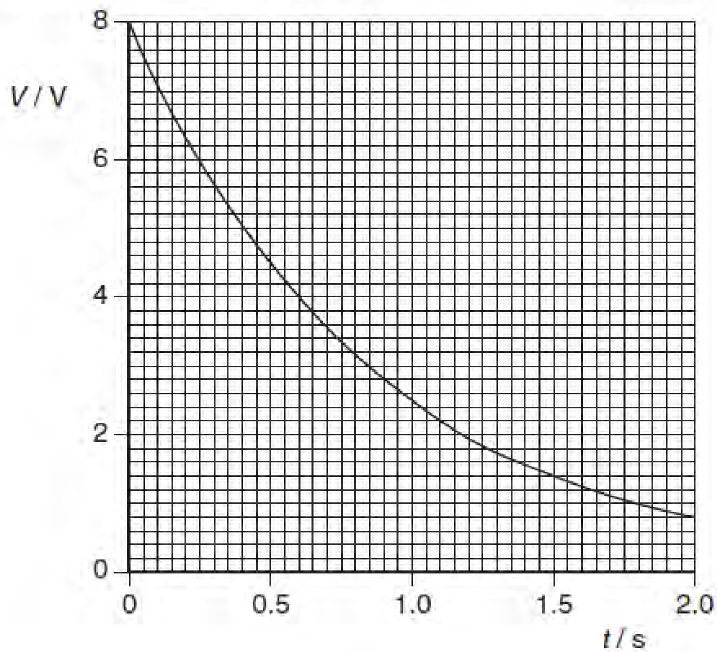


Fig. 5.2

(a) During the first 1.0s of the discharge of the capacitor, 0.13J of energy is transferred to the resistor R.
Show that the capacitance of the capacitor C is 4500 μF.

[3]

(b) Some capacitors, each of capacitance 4500 μF with a maximum working voltage of 6V, are available.

Draw an arrangement of these capacitors that could provide a total capacitance of 4500 μF for use in the circuit of Fig. 5.1.

[2]

Nov 08

5 Two deuterium (^2_1H) nuclei are travelling directly towards one another. When their separation is large compared with their diameters, they each have speed *v* as illustrated in Fig. 5.1.

Fig. 5.1

The diameter of a deuterium nucleus is 1.1×10^{-14} m.

(a) Use energy considerations to show that the initial speed *v* of the deuterium nuclei must be approximately $2.5 \times 10^6\,\text{m s}^{-1}$ in order that they may come into contact. Explain your working.

[3]

(b) For a fusion reaction to occur, the deuterium nuclei must come into contact. Assuming that deuterium behaves as an ideal gas, deduce a value for the temperature of the deuterium such that the nuclei have an r.m.s. speed equal to the speed calculated in **(a)**.

temperature = ... K [4]

(c) Comment on your answer to **(b)**.

....

....[1]

May 09

5 A solid metal sphere, of radius *r*, is insulated from its surroundings. The sphere has charge $+Q$.
This charge is on the surface of the sphere but it may be considered to be a point charge at its centre, as illustrated in Fig. 5.1.

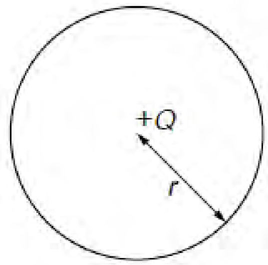


Fig. 5.1

(a) **(i)** Define *capacitance*.

....

.... [1]

(ii) Show that the capacitance *C* of the sphere is given by the expression

$$C = 4\pi\varepsilon_0 r.$$

[1]

(b) The sphere has radius 36 cm.
Determine, for this sphere,

(i) the capacitance,

capacitance = ... F [1]

(ii) the charge required to raise the potential of the sphere from zero to 7.0×10^5 V.

charge = ... C [1]

(c) Suggest why your calculations in **(b)** for the metal sphere would not apply to a plastic sphere.

....

....

....

.... [3]

(d) A spark suddenly connects the metal sphere in **(b)** to the Earth, causing the potential of the sphere to be reduced from 7.0×10^5V to 2.5×10^5V.

Calculate the energy dissipated in the spark.

energy = ... J [3]