For Examiner's Use

1 **(a)** Define *capacitance*. [May/June 2005]

....

....[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]

2 **(a)** Define potential at a point in an electric field. [May/June 2002]

....

....[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]

For Examiner's Use

[May/June 2003]

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

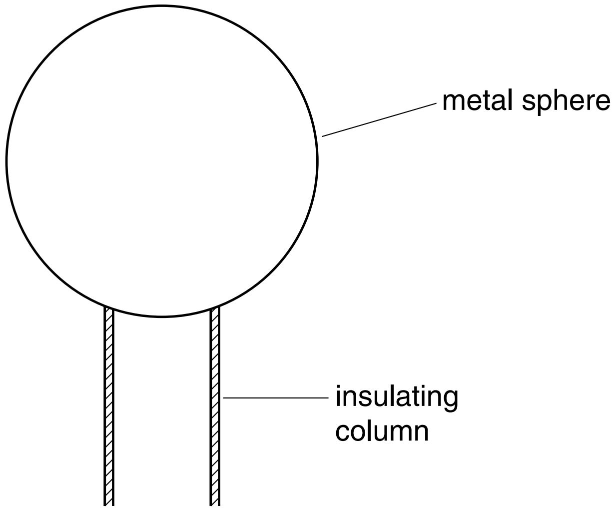

Fig. 4.1

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]

[May/June 2006]

4 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 $2.0 \times 10^6\ \mathrm{V\,m^{-1}}$. 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]

[November/December 2006]

5 An alternating supply of frequency 50 Hz and having an output of 6.0 V r.m.s. is to be rectified so as to provide direct current for a resistor R. The circuit of Fig. 6.1 is used.

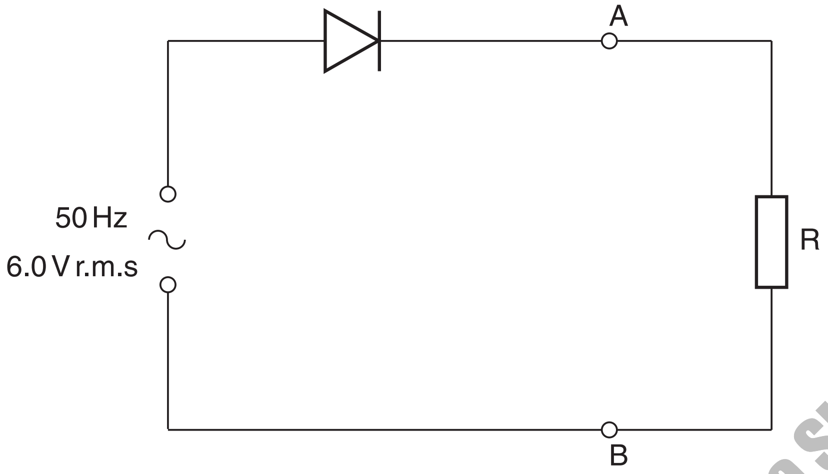

Fig. 6.1

The diode is ideal. The Y-plates of a cathode-ray oscilloscope (c.r.o.) are connected between points A and B.

(a) **(i)** Calculate the maximum potential difference across the diode during one cycle.

potential difference = ... V [2]

(ii) State the potential difference across R when the diode has maximum potential difference across it. Give a reason for your answer.

....

.... [1]

(b) The Y-plate sensitivity of the c.r.o. is set at 2.0 V cm^{-1} and the time-base at 5.0 ms cm^{-1}.

On Fig. 6.2, draw the waveform that is seen on the screen of the c.r.o. [3]

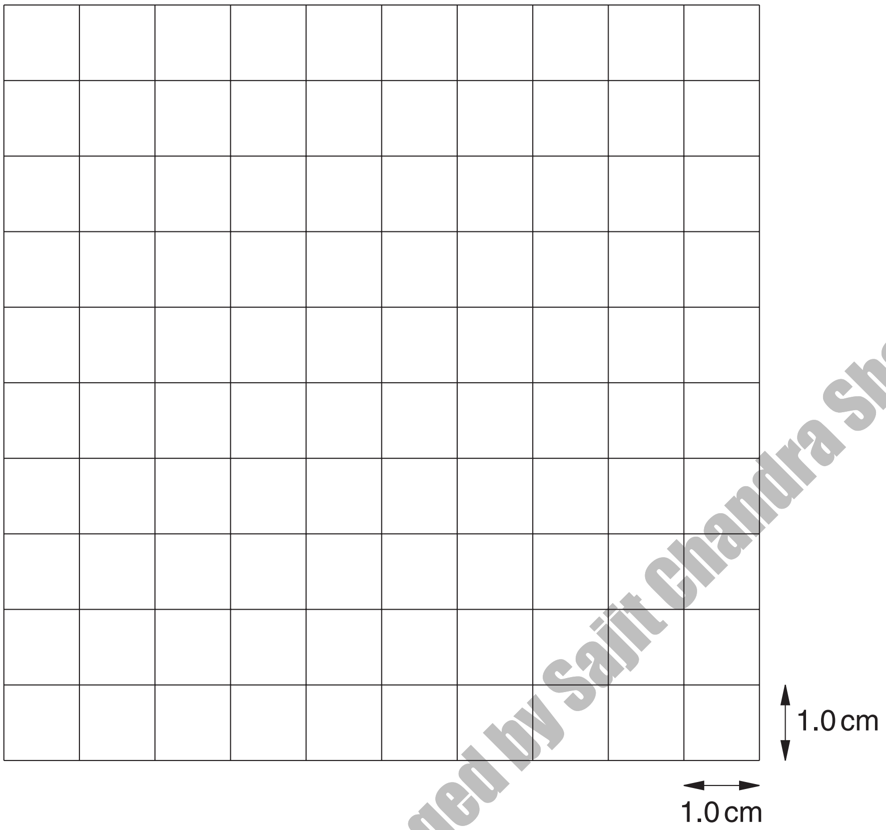

Fig. 6.2

(c) A capacitor of capacitance 180 μF is connected into the circuit to provide smoothing of the potential difference across the resistor R.

(i) On Fig. 6.1, show the position of the capacitor in the circuit. [1]

(ii) Calculate the energy stored in the fully-charged capacitor.

energy = ... J [3]

(iii) During discharge, the potential difference across the capacitor falls to $0.43\,V_0$, where V_0 is the maximum potential difference across the capacitor.

Calculate the fraction of the total energy that remains in the capacitor after the discharge.

fraction = ... [2]

[November/December 2007]

6 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.

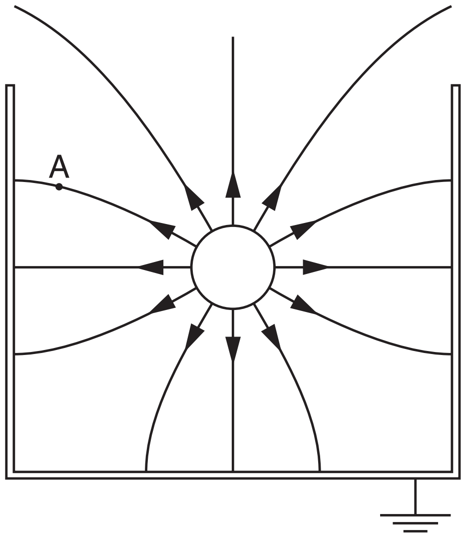

Fig. 4.1

(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]

[May/June 2008]

7 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.

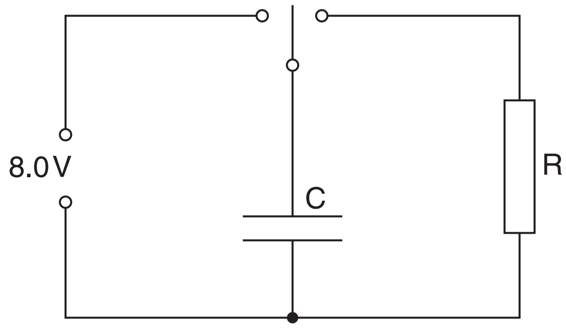

Fig. 5.1

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.

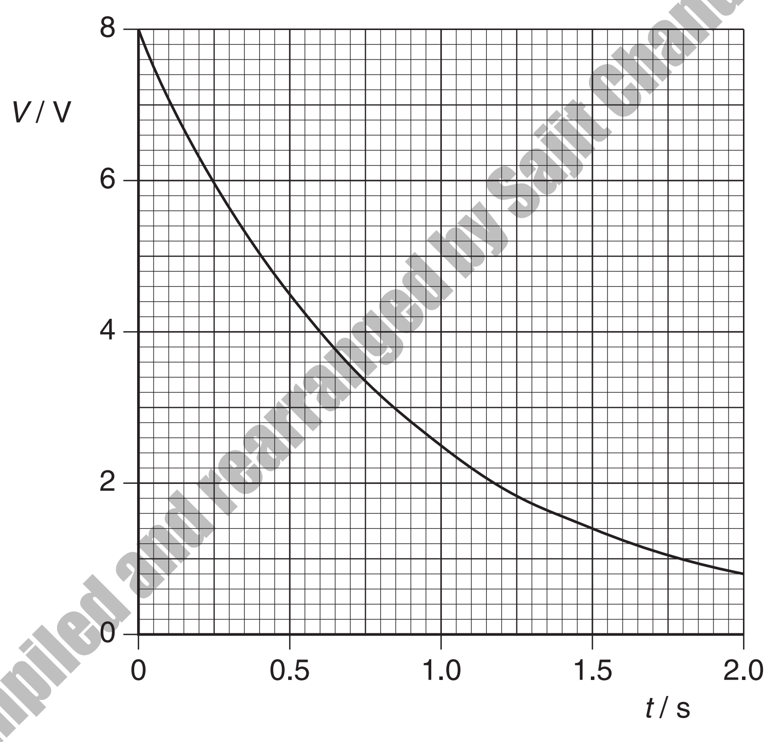

Fig. 5.2

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

For Examiner's Use

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

[November/December 2007]

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

....

....[1]

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

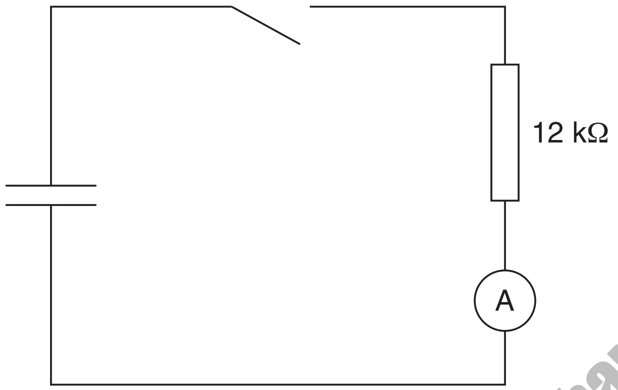

Fig. 5.1

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

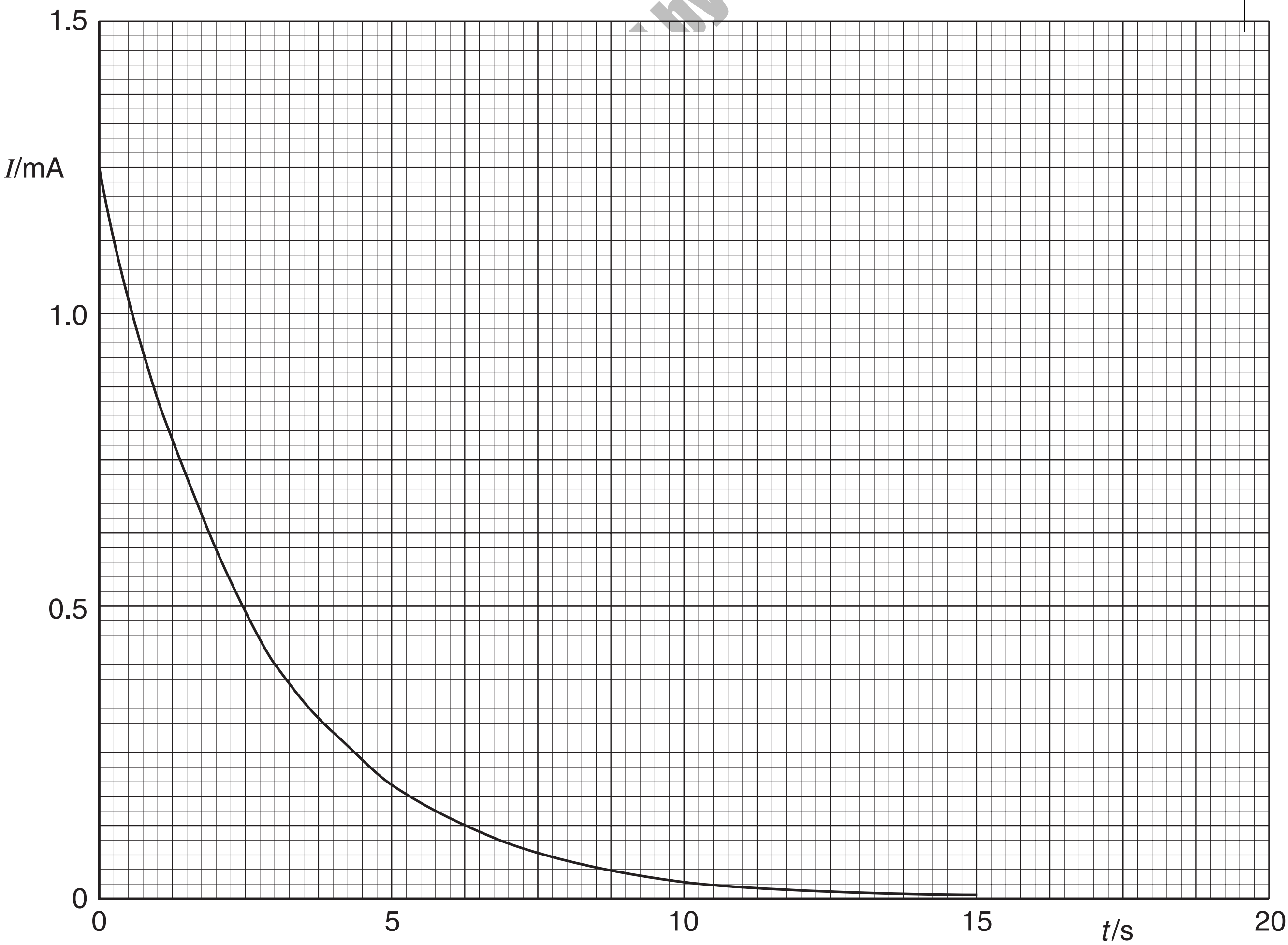

Fig. 5.2

(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 June 2008]

10 **(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.

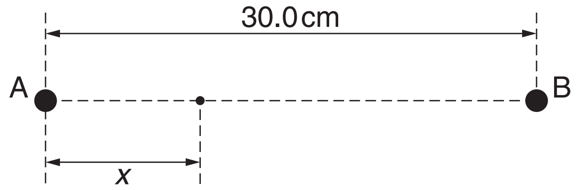

Fig. 4.1

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.

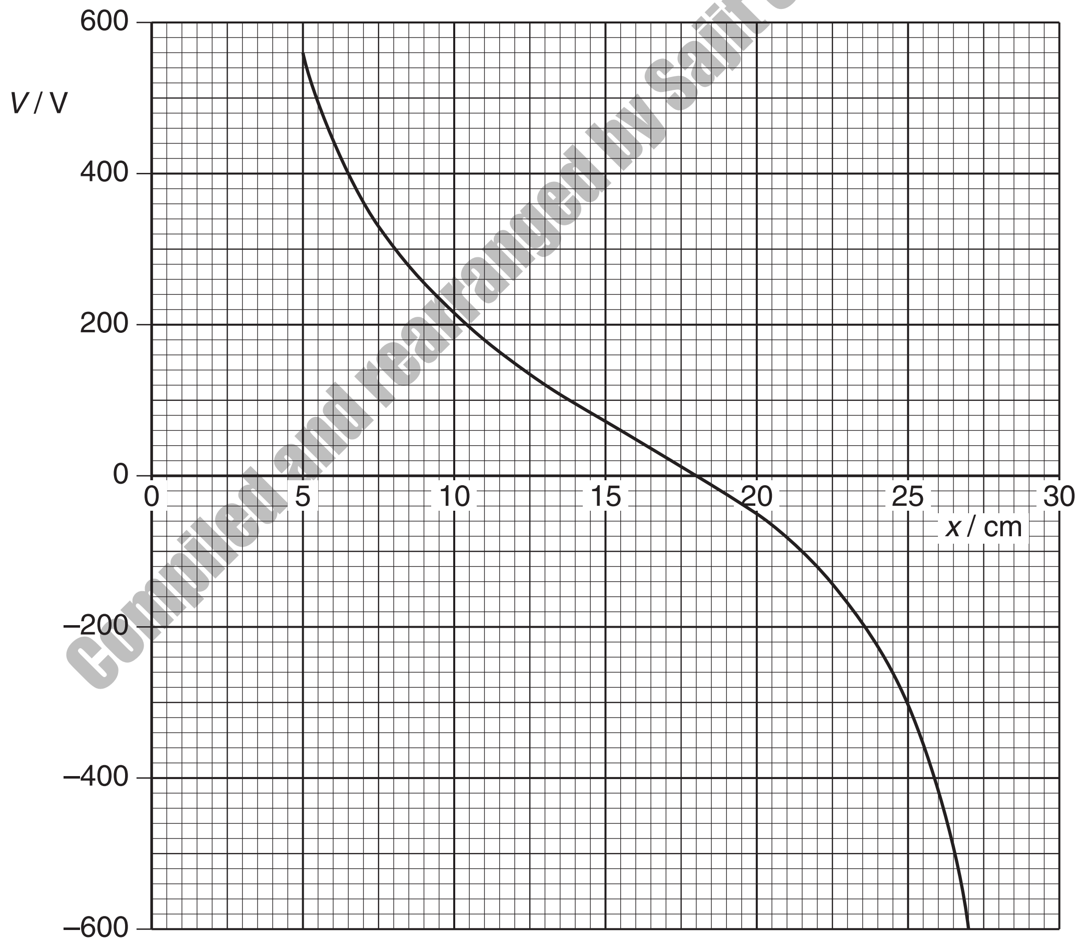

Fig. 4.2

For Examiner's Use

For Examiner's Use

(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 June 2008]

For Examiner's Use

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

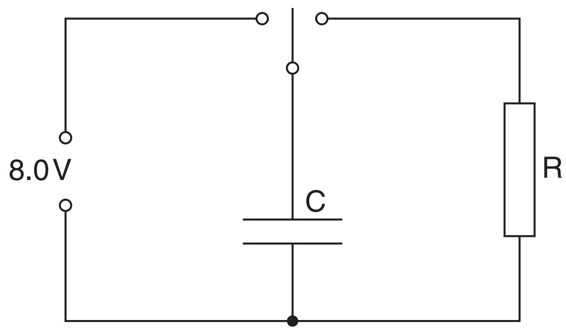

Fig. 5.1

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.

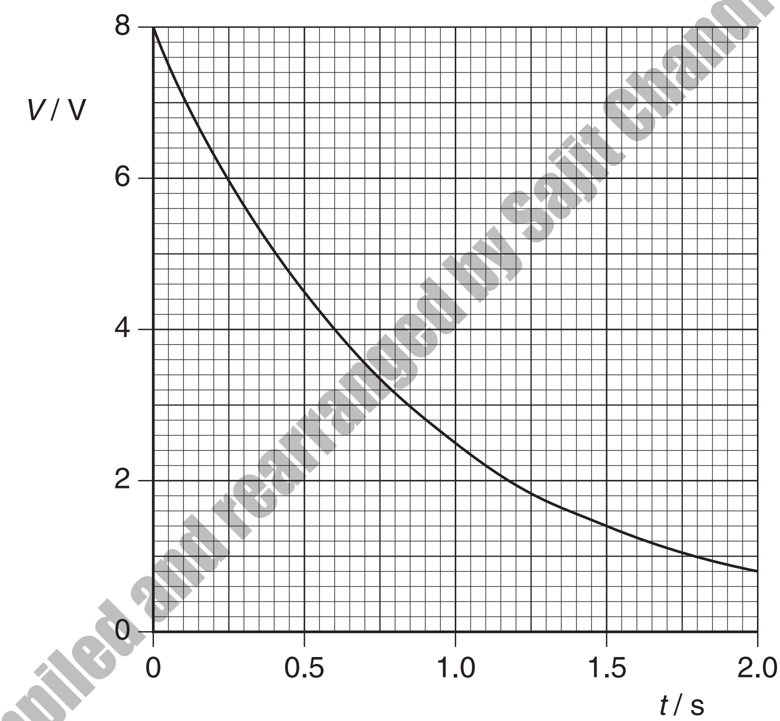

Fig. 5.2

(a) During the first 1.0 s of the discharge of the capacitor, 0.13 J 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 6 V, 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]

[May June 2009]

12 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.

For Examiner's Use

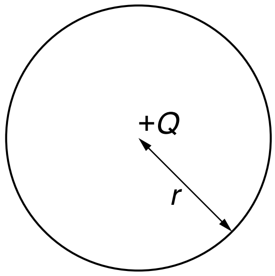

Fig. 5.1

(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 7.0×10^5 V to 2.5×10^5 V.

Calculate the energy dissipated in the spark.

energy = ... J [3]

[October November 2009]

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

....

....

.... [2]

(b) An α-particle is emitted from a radioactive source with kinetic energy of 4.8 MeV.

The α-particle travels in a vacuum directly towards a gold ($^{197}_{79}Au$) nucleus, as illustrated in Fig. 5.1.

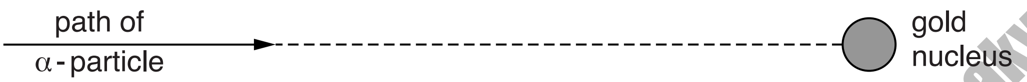

Fig. 5.1

The α-particle and the gold nucleus may be considered to be point charges in an isolated system.

(i) Explain why, as the α-particle approaches the gold nucleus, it comes to rest.

....

....

.... [2]

(ii) For the closest approach of the α-particle to the gold nucleus determine

1. their separation,

separation = ... m [3]

14 **(a)** Define *capacitance*. [October November 2009]

....

.... [1]

(b) An isolated metal sphere of radius R has a charge $+Q$ on it.

The charge may be considered to act as a point charge at the centre of the sphere.

Show that the capacitance C of the sphere is given by the expression

$$C = 4\pi\varepsilon_0 R$$

where ε_0 is the permittivity of free space.

[1]

(c) In order to investigate electrical discharges (lightning) in a laboratory, an isolated metal sphere of radius 63 cm is charged to a potential of 1.2×10^6 V.

At this potential, there is an electrical discharge in which the sphere loses 75% of its energy.

Calculate

(i) the capacitance of the sphere, stating the unit in which it is measured,

capacitance = ... [3]

(ii) the potential of the sphere after the discharge has taken place.

potential = ... V [3]

15 **(a)** State two functions of capacitors in electrical circuits.

1. ....

2. ....
[2]

(b) Three capacitors, each marked '30 μF, 6 V max', are arranged as shown in Fig. 5.1.

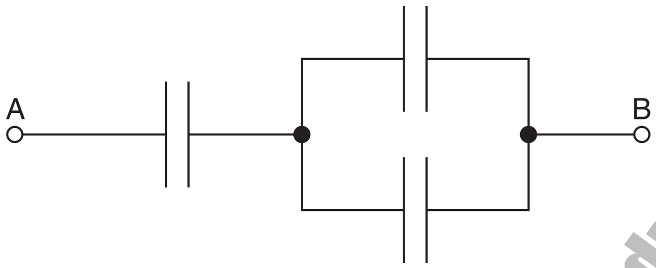

Fig. 5.1

Determine, for the arrangement shown in Fig. 5.1,

(i) the total capacitance,

capacitance = ... μF [2]

(ii) the maximum potential difference that can safely be applied between points A and B.

potential difference = ... V [2]

(c) A capacitor of capacitance 4700 μF is charged to a potential difference of 18 V. It is then partially discharged through a resistor. The potential difference is reduced to 12 V. Calculate the energy dissipated in the resistor during the discharge.

For Examiner's Use

energy = ... J [3]

For Examiner's Use

16 **(a)** Define *capacitance*.

....

.... [1]

(b) An isolated metal sphere has a radius r. When charged to a potential V, the charge on the sphere is q.
The charge may be considered to act as a point charge at the centre of the sphere.

(i) State an expression, in terms of r and q, for the potential V of the sphere.

.... [1]

(ii) This isolated sphere has capacitance. Use your answers in **(a)** and **(b)(i)** to show that the capacitance of the sphere is proportional to its radius.

[1]

(c) The sphere in **(b)** has a capacitance of 6.8 pF and is charged to a potential of 220 V.

Calculate

(i) the radius of the sphere,

radius = ... m [3]

(ii) the charge, in coulomb, on the sphere.

charge = ... C [1]

(d) A second uncharged metal sphere is brought up to the sphere in **(c)** so that they touch. The combined capacitance of the two spheres is 18 pF.

Calculate

(i) the potential of the two spheres,

potential = ... V [1]

(ii) the change in the total energy stored on the spheres when they touch.

change = ... J [3]

For Examiner's Use

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

....

....

.... [2]

(ii) Define *capacitance*.

....

.... [1]

(b) The variation of the potential V of an isolated metal sphere with charge Q on its surface is shown in Fig. 4.1.

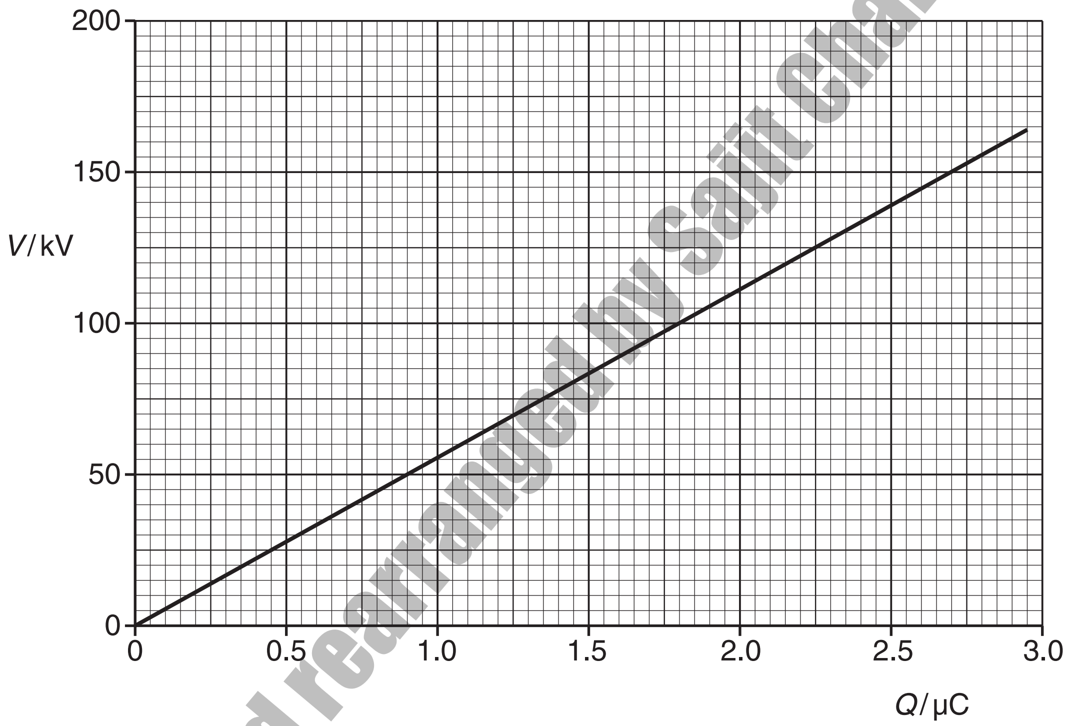

Fig. 4.1

An isolated metal sphere has capacitance.

Use Fig. 4.1 to determine

(i) the capacitance of the sphere,

capacitance = ... F [2]

(ii) the electric potential energy stored on the sphere when charged to a potential of 150 kV.

energy = ... J [2]

(c) A spark reduces the potential of the sphere from 150 kV to 75 kV.
Calculate the energy lost from the sphere.

energy = ... J [2]

3 A capacitor consists of two metal plates separated by an insulator, as shown in Fig. 3.1.

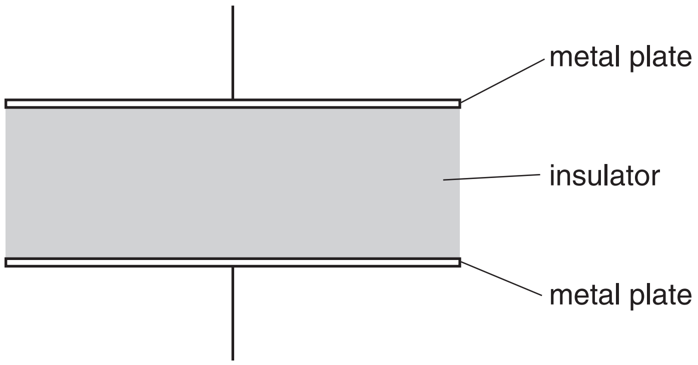

Fig. 3.1

The potential difference between the plates is V. The variation with V of the magnitude of the charge Q on one plate is shown in Fig. 3.2.

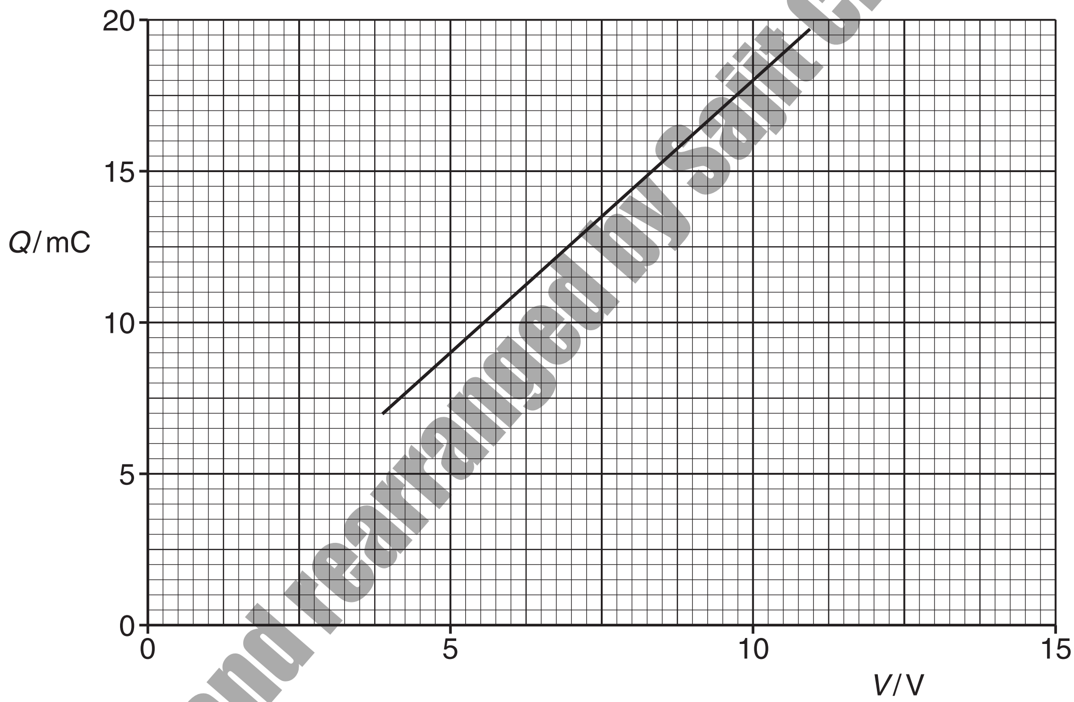

Fig. 3.2

(a) Explain why the capacitor stores energy but not charge.

....

....

....

.... [3]

(b) Use Fig. 3.2 to determine

For
Examiner's
Use

(i) the capacitance of the capacitor,

capacitance = ... μF [2]

(ii) the loss in energy stored in the capacitor when the potential difference *V* is reduced from 10.0V to 7.5V.

energy = ... mJ [2]

(c) Three capacitors X, Y and Z, each of capacitance 10 μF, are connected as shown in Fig. 3.3.

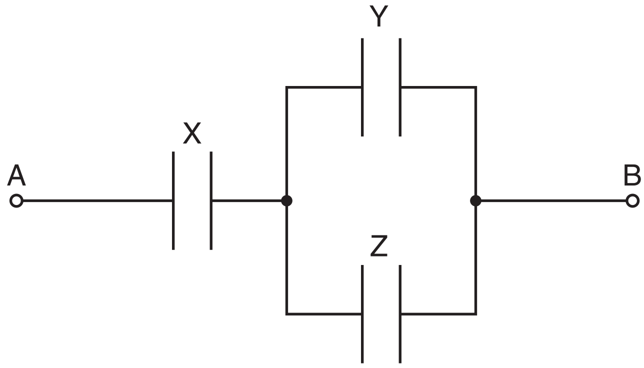

Fig. 3.3

Initially, the capacitors are uncharged.
A potential difference of 12 V is applied between points A and B.
Determine the magnitude of the charge on one plate of capacitor X.

charge = ... μC [3]

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

....

....

.... [2]

(b) Two small spherical charged particles P and Q may be assumed to be point charges located at their centres. The particles are in a vacuum.

Particle P is fixed in position. Particle Q is moved along the line joining the two charges, as illustrated in Fig. 4.1.

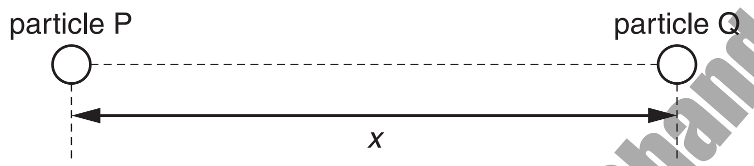

Fig. 4.1

The variation with separation x of the electric potential energy E_P of particle Q is shown in Fig. 4.2.

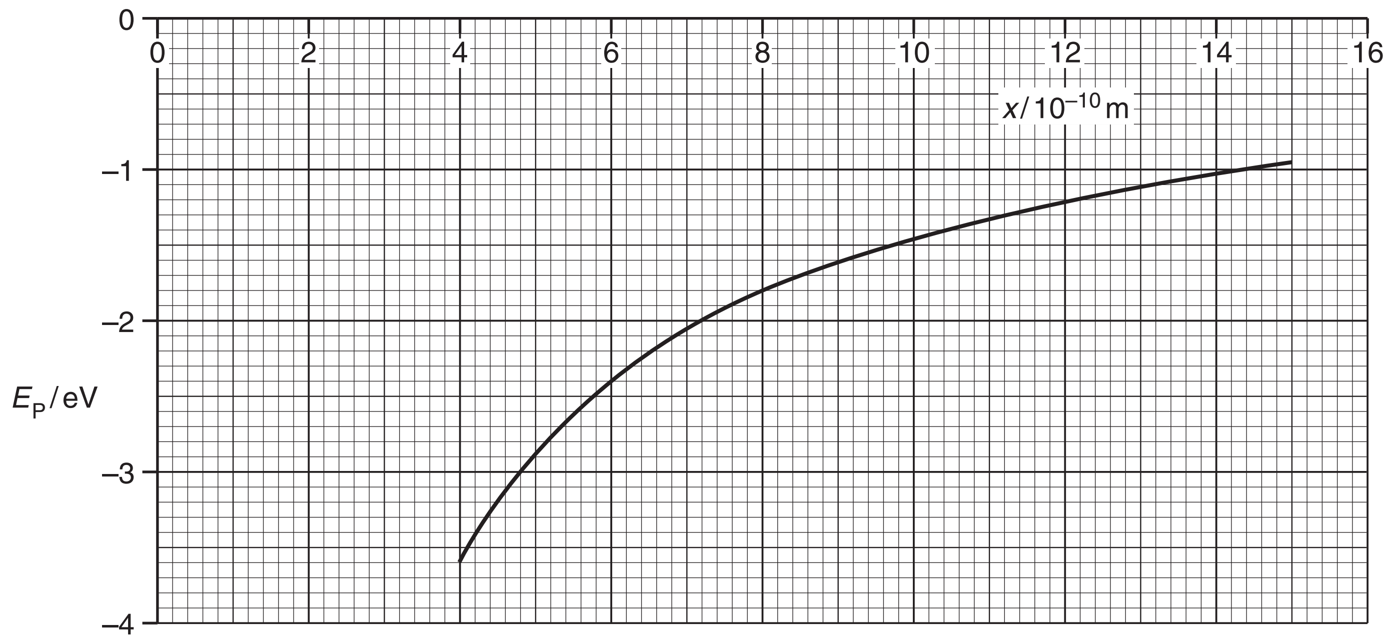

Fig. 4.2

(i) State how the magnitude of the electric field strength is related to potential gradient.

....

.... [1]

For Examiner's Use

(ii) Use your answer in **(i)** to show that the force on particle Q is proportional to the gradient of the curve of Fig. 4.2.

....

....

.... [2]

(c) The magnitude of the charge on each of the particles P and Q is 1.6×10^{-19} C.
Calculate the separation of the particles at the point where particle Q has electric potential energy equal to –5.1 eV.

separation = ... m [4]

(d) By reference to Fig. 4.2, state and explain

(i) whether the two charges have the same, or opposite, sign,

....

....

.... [2]

(ii) the effect, if any, on the shape of the graph of doubling the charge on particle P.

....

....

.... [2]