For Examiner's Use

1 **(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]

For Examiner's Use

2 **(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]

For Examiner's Use

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

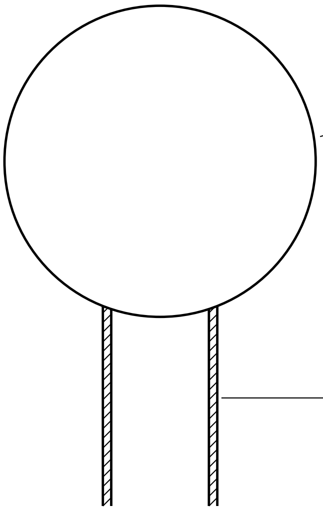

Fig. 4.1

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]

For Examiner's Use

(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]

For Examiner's Use

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 $2.0 \times 10^6\ \text{V m}^{-1}$. 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]

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.

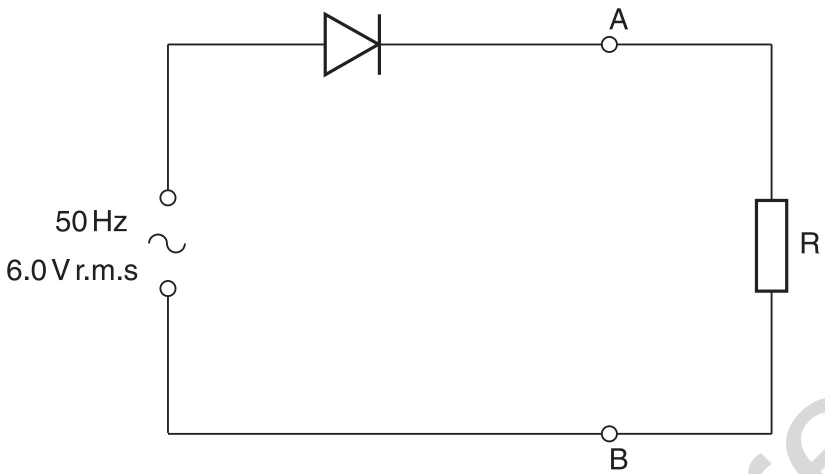

Fig. 6.1

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]

For Examiner's Use

(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]

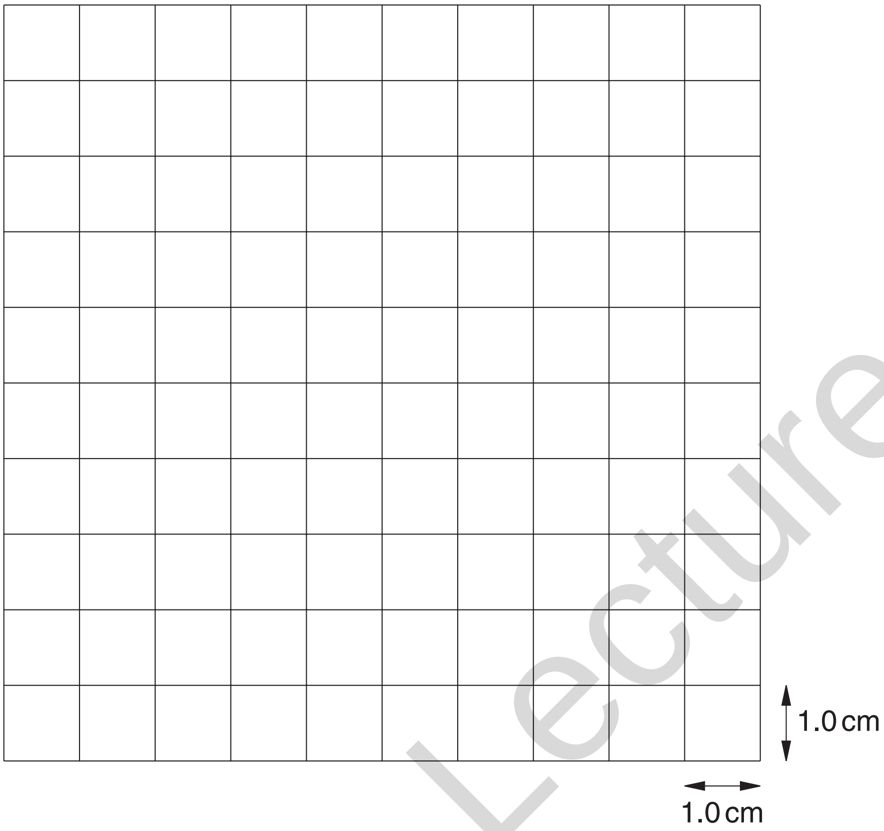

Fig. 6.2

(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]

For Examiner's Use

(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]

For Examiner's Use

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.

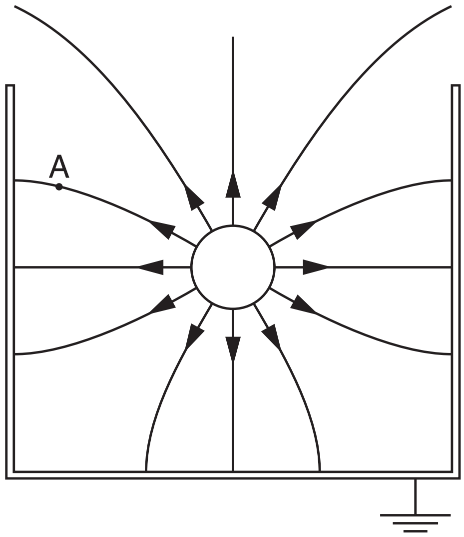

Fig. 4.1

(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]

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.

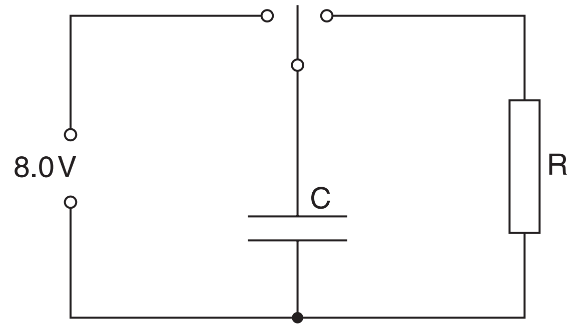

Fig. 5.1

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.

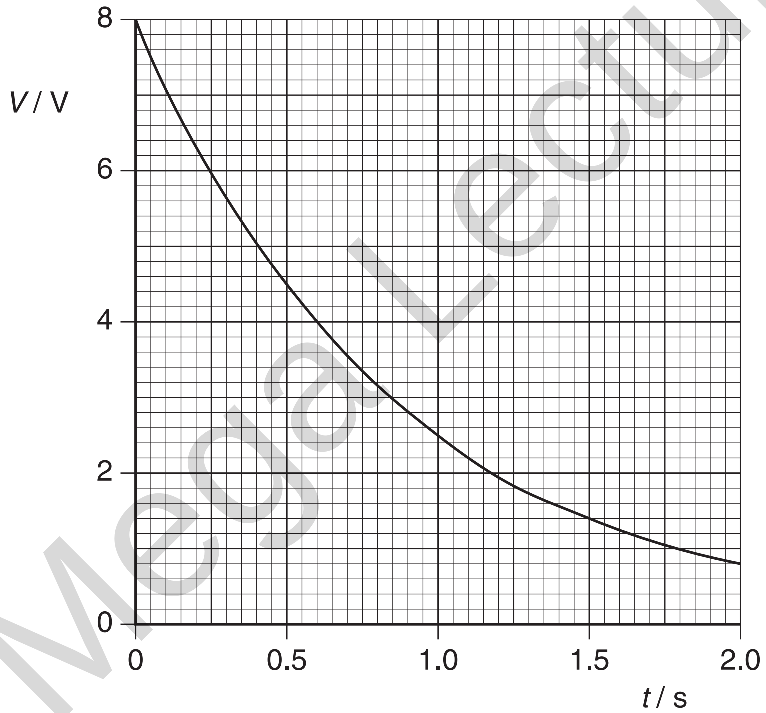

Fig. 5.2

(a) During the first 1.0s 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.

For Examiner's Use

(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]

For Examiner's Use

8 (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.

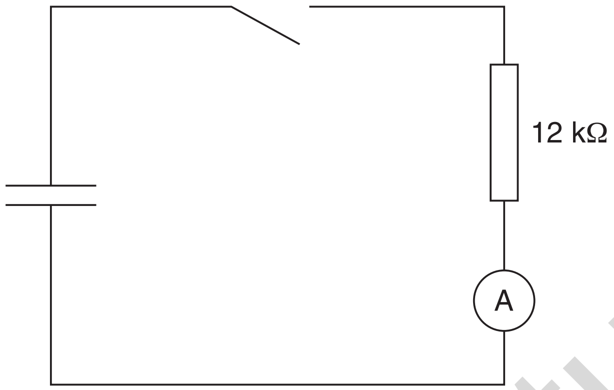

Fig. 5.1

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

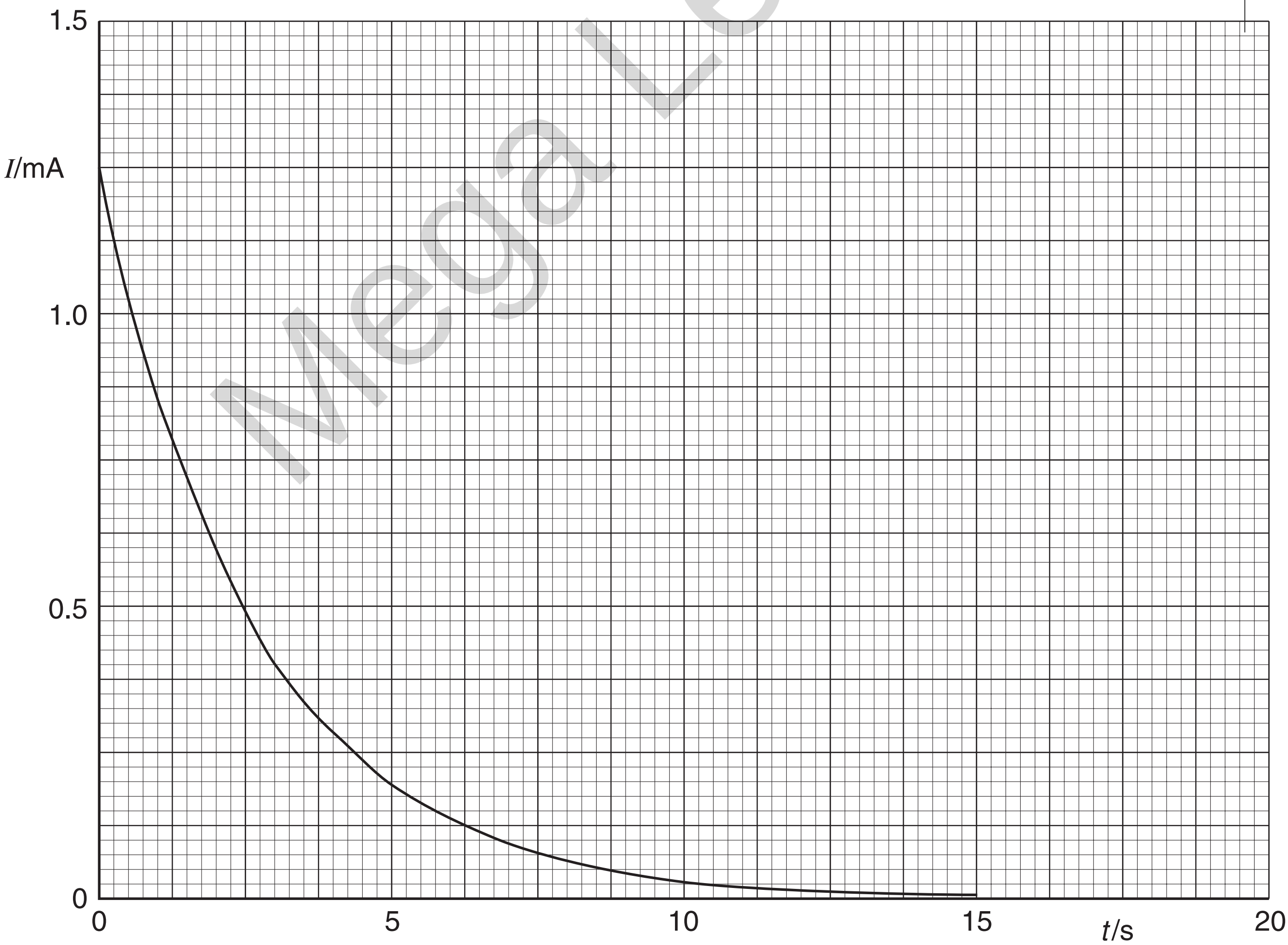

Fig. 5.2

(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]