

1

The figure below shows a capacitor of capacitance 370 pF. It consists of two parallel metal plates of area 250 cm^2 . A sheet of polythene that has a relative permittivity 2.3 completely fills the gap between the plates.



- (a) Calculate the thickness of the polythene sheet.

thickness = _____ m

(2)

- (b) The capacitor is charged so that there is a potential difference of 35 V between the plates. The charge on the capacitor is then 13 nC and the energy stored is $0.23 \mu\text{J}$.

The supply is now disconnected and the polythene sheet is pulled out from between the plates without discharging or altering the separation of the plates.

Show that the potential difference between the plates increases to about 80 V.

(2)

- (c) Calculate the energy that is now stored by the capacitor.

energy stored = _____ μJ

(2)

- (d) Explain why there is an increase in the energy stored by the capacitor when the polythene sheet is pulled out from between the plates.

(2)

(Total 8 marks)

2

Which of the following statements about a parallel plate capacitor is **incorrect**?

A The capacitance of the capacitor is the amount of charge stored by the capacitor when the pd across the plates is 1 V.

☐

B A uniform electric field exists between the plates of the capacitor.

☐

C The charge stored on the capacitor is inversely proportional to the pd across the plates.

☐

D The energy stored when the capacitor is fully charged is proportional to the square of the pd across the plates.

☐

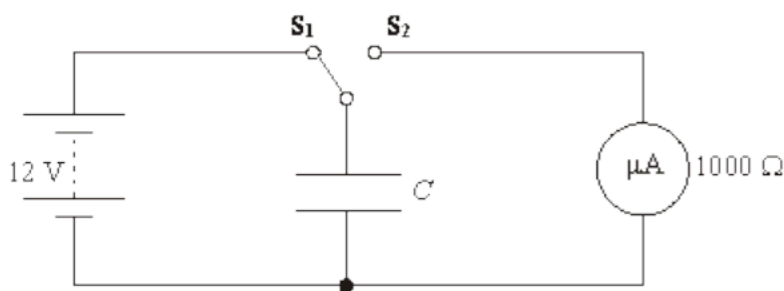
(Total 1 mark)

3

(a) State the **three** factors upon which the capacitance of a parallel plate capacitor depends.

(2)

- (b) The figure below shows a circuit for measuring the capacitance of a capacitor.



The switch is driven by a signal generator and oscillates between **S₁** and **S₂** with frequency f .

When the switch is in position **S₁** the capacitor charges until the potential difference across it is equal to the supply emf. When the switch moves to position **S₂** the capacitor discharges through the microammeter which has a resistance of $1000\ \Omega$.

In one experiment a $0.047\ \mu\text{F}$ capacitor is used with a 12 V supply.

- (i) Calculate the charge stored by the capacitor when the switch is in position **S₁**.
- (ii) Calculate the time for which the switch must remain in contact with **S₂** in order for the charge on the capacitor to fall to 1% of its initial charge.
- (iii) Assuming that the capacitor discharges all the stored charge through the microammeter, calculate the reading on the meter when the switch oscillates at 400 Hz.

(6)

(Total 8 marks)

4

The Earth's surface and the base of a charged cloud can be considered to be two plates of a parallel-plate capacitor.

- (a) Calculate the capacitance of an Earth-cloud system when the base of the cloud has an area of $1.4 \times 10^6\ \text{m}^2$ and is 800 m above the Earth's surface.

$$\epsilon_0 = 8.9 \times 10^{-12}\ \text{F m}^{-1}$$

$$\epsilon_r \text{ for air} = 1.0$$

(2)

- (b) A potential difference of $3.0 \times 10^6 \text{ V}$ across each metre of air will cause the air to break down and allow the cloud to discharge to the Earth.
- (i) Show that the average breakdown p.d. for the 800 m layer of air between the Earth and the base of the cloud is about $2.5 \times 10^9 \text{ V}$.

(1)

- (ii) Calculate the maximum energy that the charged Earth – cloud system can store.

(2)

- (iii) Calculate the maximum charge stored by the system before breakdown commences.

(1)

- (c) By considering the cloud discharge to be modelled by a resistor connected across a capacitor, calculate the resistance that would allow a cloud to discharge 99% of its charge to Earth in a time of 0.25 s.

(3)

(Total 9 marks)

5

- (a) Explain what is meant by a capacitance of 1 farad (F).

(1)

- (b) A parallel plate capacitor was made from two circular metal plates with air between them. The distance between the plates was 1.8 mm. The capacitance of this capacitor was found to be $2.3 \times 10^{-11} \text{ F}$.

The permittivity of free space $\epsilon_0 = 8.9 \times 10^{-12} \text{ F m}^{-1}$

The relative permittivity of air = 1.0

Calculate:

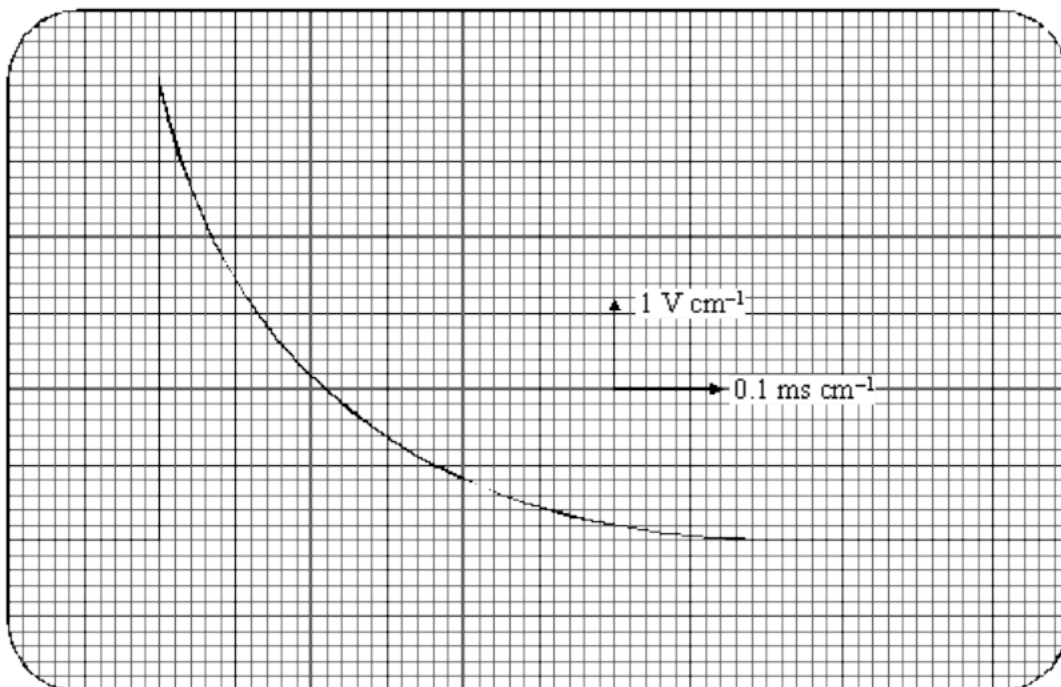
- (i) the radius of the plates used in the capacitor;

(3)

- (ii) the energy stored when the potential difference between the capacitor plates is 6.0 V.

(2)

- (c) A student charged the capacitor and then tried to measure the potential difference between the plates using an oscilloscope. The student observed the trace shown in the diagram below and concluded that the capacitor was discharging through the oscilloscope.



Calculate the resistance of the oscilloscope.

(3)

(Total 9 marks)

1

$$1.4 \times 10^{-3} \text{ m (1.4 (1.38) mm)} \checkmark$$

2

$$\text{New } V = 0.13 \text{ nC} / 161 \text{ pF} = 81 \text{ V}$$

0.53 $\mu\text{J}\checkmark$

In the polar dielectric molecules align in the field with positive charged end toward the negative plate (or WTTE).✓

Work is done on the capacitor separating the positively charged surface of the dielectric from the negatively charged plate (or vice versa).✓

2

[8]

2 C

[1]

3 (a) area of overlap of the plates

B1

separation of/distance between the plates

$$\epsilon_0 = \text{permittivity/dielectric constant of free space/the material/dielectric between the plates (condone of the gap)}$$

B1

2

B1 for 1 factor clearly stated
B1 for other two clearly stated

- (b) (i) $Q = VC$ (any form) or $0.047 \mu\text{F} \times 12$
(ignoring powers of 10)

C1

$$5.6(4) \times 10^{-7} \text{ C (0.56 } \mu\text{C)}$$

A1

- (ii) time constant = $4.7 \times 10^{-5} \text{ s}$ or $0.01 = e^{-t/RC}$

C1

$$0.01 = e^{-t/(0.000047)} \text{ or } 0.01 = e^{-t/47} \text{ or } \frac{t}{RC} = 4.605$$

C1

$$2.2 (2.16) \times 10^{-4} \text{ s or } 0.22 \text{ ms}$$

A1

- (iii) their (i) $\times 400$ (230 (226) μA or $2.3 \times 10^{-4} \text{ A}$ if correct)

B1

6

[8]

4

- (a) $C = \epsilon_0 \epsilon_r A/d$

C1

$$15.6 \text{ nF or } 16 \text{ nF}$$

A1

2

(b) (i) 2.4×10^9 (V)

B1

1

(ii) $\frac{1}{2} CV^2$ (or $\frac{1}{2} QV$ if attempt to calculate Q made)

C1

4.3–5.0 $\times 10^{10}$ J

A1

2

(iii) 36–40 C

B1

1

(c) recognition that 1% of charge or voltage remains

C1

any appropriate form of decay equation (either exponential or logarithmic)

C1

$3.48 \times 10^6 \Omega$ **cao** (but do not allow if physics error)

A1

3

[9]

5

(a) 1 coulomb of charge is stored for a p.d. of 1 V between the plates
(or equivalent statement) Condone 1 coulomb per volt

B1

1

- (b) (i) Correct substitution in $C = \frac{\epsilon_0 \epsilon_r A}{d}$ (ignore powers of 10)

C1

Plate area = $4.65 \times 10^{-3} \text{ m}^2$ or $C = \frac{\epsilon_0 \epsilon_r \pi r^2}{d}$ with correct data

A1

Radius = (their area / 3.14)^{1/2}; 0.038(4 or 5) m if correct

B1

3

- (ii) $E = \frac{1}{2} CV^2$ or correct numerical substitution or
 $E = \frac{1}{2} QV$ & $Q = VC$

C1

$4.1(4) \times 10^{-10} \text{ J}$

A1

2

- (c) Time constant = RC or Time to halve = $0.69 RC$
or $V = V_0 e^{-t/RC}$

C1

Time to fall to 1/e (0.19 ms) or time to halve (0.13 ms)
or $V_0 = 6 \text{ V}$ and correct coordinates of point on line
(0.6 ms max)

C1

8.1 - 8.6 MΩ

A1

3

[9]