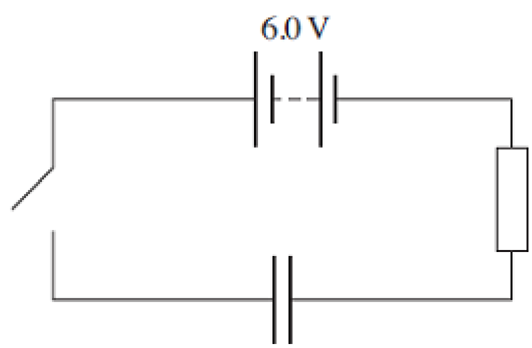
1 (a) Define the capacitance of a capacitor.

charge stored per volt

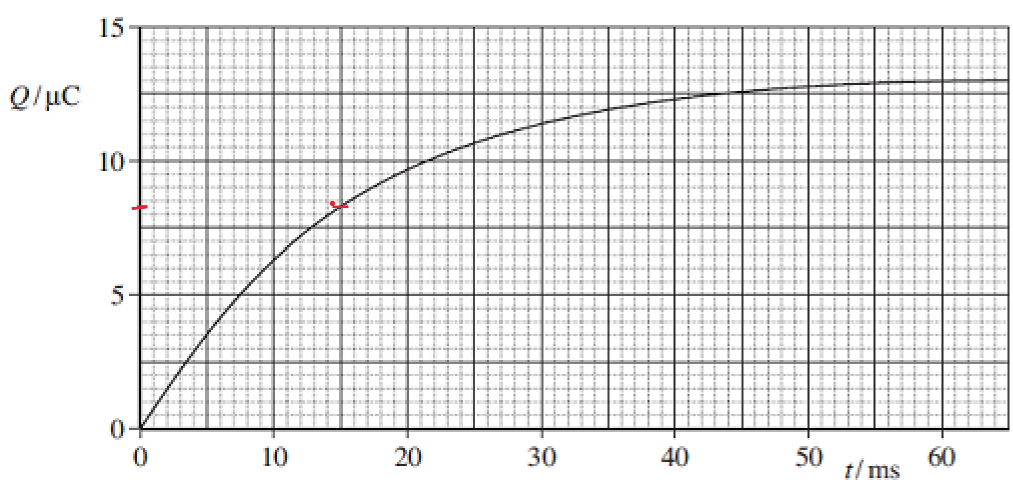
$C = Q/V$

(2)

(b) The circuit shown in the figure below contains a battery, a resistor, a capacitor and a switch.



The switch in the circuit is closed at time *t* = 0. The graph shows how the charge *Q* stored by the capacitor varies with *t*.



(b) (i) When the capacitor is fully charged, the charge stored is 13.2 μC. The electromotive force (emf) of the battery is 6.0 V. Determine the capacitance of the capacitor.

$C = \frac{Q}{V} = \frac{13.2 \times 10^{-6}}{6}$

answer = 2.2×10^{-6} F

(2)

(ii) The time constant for this circuit is the time taken for the charge stored to increase from 0 to 63% of its final value. Use the graph to find the time constant in milliseconds.

13.2 × 0.63 = 8.3

answer = 15 ms

(2)

(iii) Hence calculate the resistance of the resistor.

Time Const = RC

2.2 × 10⁻⁶

answer = 6.8×10^3 Ω

(1)

(iv) What physical quantity is represented by the gradient of the graph?

Current (change in Q / t)

(1)

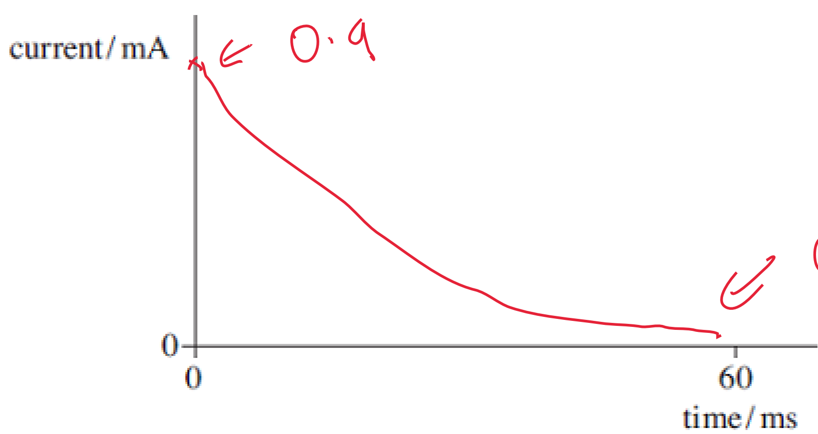
(c) (i) Calculate the maximum value of the current, in mA, in this circuit during the charging process.

$\frac{V}{R} = I \Rightarrow I = \frac{6}{6.8k} =$

answer = 0.9 (0.88) mA

(1)

(ii) Sketch a graph on the outline axes to show how the current varies with time as the capacitor is charged. Mark the maximum value of the current on your graph.



approaching 0 ∴ 4 time consts

(2)

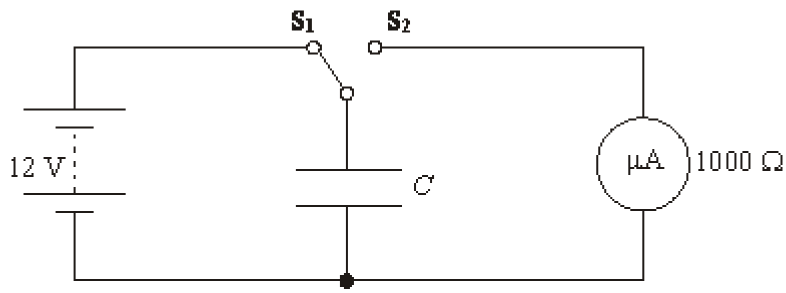
(Total 11 marks)

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

A of plate that are parallel
d between plate
material of dielectric

(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 $\mathbf{S_1}$ and $\mathbf{S_2}$ with frequency f.

When the switch is in position $\mathbf{S_1}$ the capacitor charges until the potential difference across it is equal to the supply emf. When the switch moves to position $\mathbf{S_2}$ the capacitor discharges through the microammeter which has a resistance of 1000 Ω.

In one experiment a 0.047 μF capacitor is used with a 12 V supply.

(i) Calculate the charge stored by the capacitor when the switch is in position $\mathbf{S_1}$.

$Q = CV = 0.047 \times 10^{-6} \times 12$

$= 5.6(4) \times 10^{-7}$ C

(2)

(ii) Calculate the time for which the switch must remain in contact with $\mathbf{S_2}$ in order for the charge on the capacitor to fall to 1% of its initial charge.

$Q = Q_0 e^{-t/RC} \Rightarrow \frac{Q}{Q_0} = e^{-t/RC} \Rightarrow \ln\left(\frac{Q}{Q_0}\right) = -\frac{t}{RC}$

$RC \ln\left(\frac{1}{100}\right) = -t$

2.2×10^{-4} s

$1000 \times 0.047 \times 10^{-6} \times \ln(0.01) = -t$

(3)

(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.

$400 \times 5.6\times10^{-7} = 0.2\,mA$

(1)

(Total 8 marks)

3 A capacitor of capacitance C has a charge of Q stored on the plates. The potential difference between the plates is doubled.

What is the change in the energy stored by the capacitor?

$E = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}QV = \frac{1}{2}CV^2$

double V the Q doubles

So $E' = \frac{1}{2}\frac{(2Q)^2}{C} = \frac{1}{2}\frac{4Q^2}{C} = \frac{2Q^2}{C}$

$\Delta E = E' - E = \frac{2Q^2}{C} - \frac{1}{2}\frac{Q^2}{C} = \frac{Q^2}{C}(2 - \frac{1}{2}) = \frac{3Q^2}{C}$

A	$\frac{Q^2}{2C}$	○
B	$\frac{Q^2}{C}$	○
C	$\frac{3Q^2}{2C}$	○
D	$\frac{2Q^2}{C}$	○

(Total 1 mark)

4 A parallel-plate capacitor has square plates of length l separated by distance d and is filled with a dielectric.

A second capacitor has square plates of length $2l$ separated by distance $2d$ and has air as its dielectric.

Both capacitors have the same capacitance.

What is the relative permittivity of the dielectric in the first capacitor?

$C = \frac{A\varepsilon_0\varepsilon_r}{d}$

$C_1 = C_2$

$C_1 = \frac{l^2\varepsilon_0\varepsilon_r}{d}$

$C_2 = \frac{(2l)^2\varepsilon_0\varepsilon_r'}{2d} = \frac{4l^2\varepsilon_0}{2d}$

$C_2 = \frac{2l^2\varepsilon_0}{d}$

$\frac{l^2\varepsilon_0\varepsilon_r}{d} = \frac{2l^2\varepsilon_0}{d}$

A	$\frac{1}{2}$	○
B	1	○
C	2	○
D	8	○

(Total 1 mark)

5 A parallel-plate capacitor is fully charged and then disconnected from the power supply.
A dielectric is then inserted between the plates.

Which row correctly identifies the charge on the plates and the electric field strength between the plates?

	Charge	Electric field strength	
A	Stays the same	Increases	⬭
B	Increases	Decreases	⬭
C	Increases	Increases	⬭
D	Stays the same	Decreases	⬭

(Total 1 mark)

- Theres no more charge to go on plate so stays the same
- the dipoles in dielectric effectively cancel out some of the potential, so decrease

Mark schemes

1 (a) charge (stored) ✓ per unit potential difference ✓

[**or** $C = Q/V$ where Q = charge (stored by one plate) ✓ V = pd (across plates) ✓]

2

(b) (i) $C\left(=\frac{Q}{V}\right) = \frac{13.2 \times 10^{-6}}{6.0}$ ✓ $= 2.2 \times 10^{-6}$ (F) ✓ (or 2.2 μF)

2

(ii) when t = time constant $Q = 0.63 \times 13.2 = 8.3$ (μC) ✓

[**or** = 0.63 × 13(.0) (from graph) = 8.2 (μC)]

reading from graph gives time constant = 15 (± 1) (ms) ✓

2

(iii) resistance of resistor $= \left(= \frac{\text{time constant}}{C}\right) = \frac{15 \times 10^{-3}}{2.2 \times 10^{-6}} = 6820$ (Ω) ✓

1

(iv) gradient = current ✓

1

(c) (i) maximum current $= \left(= \frac{V}{R}\right) = \frac{6.0}{6820} = 0.88$ (mA) ✓

[**or** value from initial gradient of graph: allow 0.70 – 1.00 mA for this approach]

1

(ii) curve starts at marked I_{max} on I axis and has decreasing negative gradient ✓

line is asymptotic to t axis and approaches ≈ 0 by t = 60 ms ✓

2

[11]

2 (a) area of overlap of the plates

B1

separation of/distance between the plates

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 μF × 12
(ignoring powers of 10)

C1

5.6(4) × 10^{-7} C (0.56 μC)

A1

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

C1

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

C1

2.2 (2.16) × 10^{-4} s or 0.22 ms

A1

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

B1

6

[8]

3 **C**

[1]

4 **C**

[1]

5 **D**

[1]