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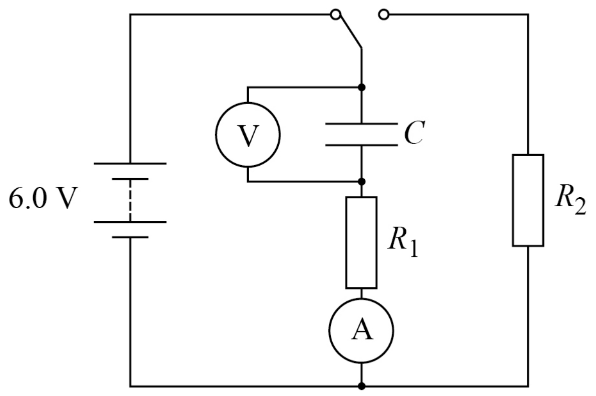
0 5 **Figure 8** shows a circuit used to investigate the charge and discharge of a capacitor of capacitance C using resistors of resistances R_1 and R_2.

Figure 8



The battery has an emf of 6.0 V and negligible internal resistance.

0 5 . 1 Show that the time taken for the capacitor to charge from 2.0 V to 4.0 V is approximately $0.7R_1C$.

[3 marks]

$\frac{V}{V_0} = 1 - e^{-t/RC} \Rightarrow \frac{V}{V_0} + e^{-t/RC} = 1 \Rightarrow 1 - \frac{V}{V_0} = e^{-t/RC}$

$\ln\left(1 - V/V_0\right) = -t/RC$

t2 = time to 4V, t1=time to 2v and so we want t2-t1

$t_2: \ln\left(1 - \frac{4}{6}\right) = -\frac{t_2}{R_1 C} \Rightarrow t_2 = -R_1 C\left(\ln \frac{2}{6}\right)$

$\Delta t_1 = -R_1 C\left(1 - \frac{2}{6}\right) -$ ← double neg

so $t_2 - t_1: -R_1 C \ln(2/6) + R_1 C(\ln 2/3)$

$R_1 C(\ln \frac{2}{3} - \ln \frac{1}{3}) = 0.69 R_1 C$

Question 5 continues on the next page

Turn over ▶

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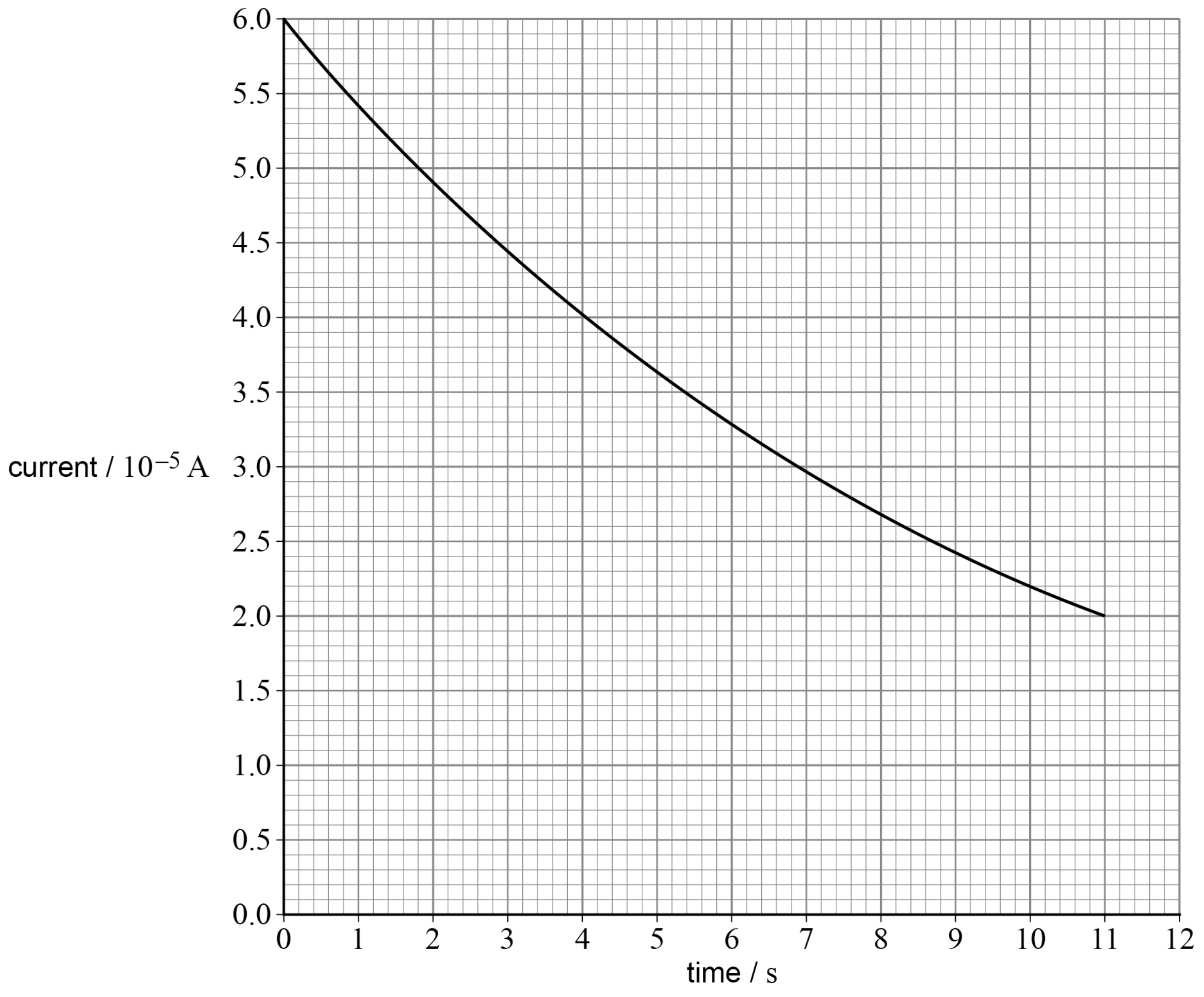
The capacitor is fully discharged.
The capacitor is then charged until the potential difference (pd) across it is 4.0 V.
Figure 9 shows the variation with time of the ammeter reading as the capacitor is charged.

Figure 9



$\frac{V}{V_0} = e^{-t/RC} \Rightarrow \ln\left(\frac{V}{V_0}\right) = -\frac{t}{RC}$

Find RC using $\ln\left(\frac{2}{6}\right) = -\frac{11}{RC}$

$\Rightarrow RC = \frac{-11}{\ln(1/3)} = 8.91$ sec

PTO

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0 5 . 2 Show that the capacitance of the capacitor is about 1×10^{-4} F.

[4 marks]

Get R from $I_0 = 6 \times 10^{-5}$ A

& $V = 60$ $\frac{V}{I} = R \Rightarrow$

$R = 1 \times 10^5 \Omega$

$RC = 8.91 = 1 \times 10^5 \times C$

$\therefore C = 8.9 \times 10^{-5}$

$\approx 1 \times 10^{-4}$ F

Question 5 continues on the next page

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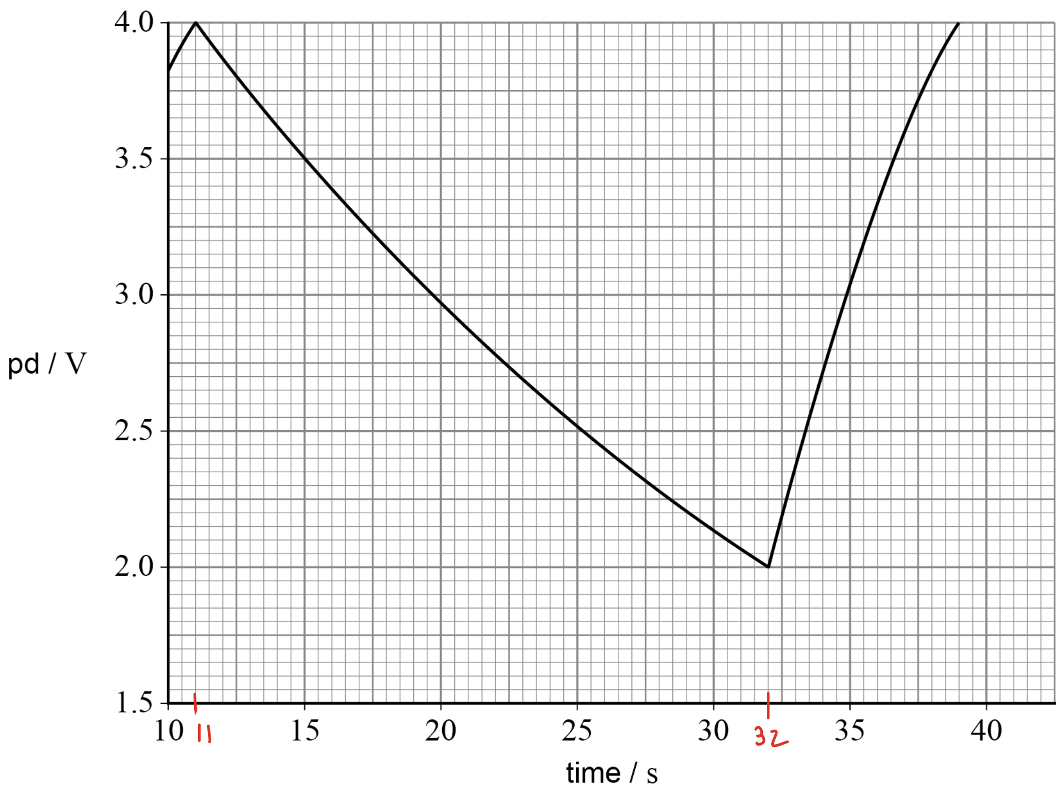
0 5 . 3 When the pd reaches 4.0 V the switch is immediately set to discharge the capacitor. When the pd reaches 2.0 V the switch is immediately set to charge the capacitor.

Figure 10 shows how the pd across the capacitor varies with time.

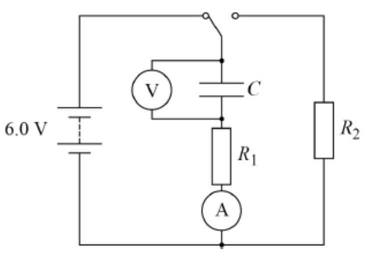
Figure 10



Determine the value of R_2.

[3 marks]

Figure 8



capacitor discharges through R1+

need RC. T = 32 − 11 = 21 sec

for V from 4 → 2

$\frac{V}{V_0} = \frac{1}{2} = e^{-21/RC} \Rightarrow \ln\left(\frac{1}{2}\right) = \frac{-21}{RC} \Rightarrow RC = 30.3\ s$

$RC = 8.9\times10^{-5} \times R = 30.3 \Rightarrow R = 3.4\times10^{5}\ \Omega$

Got

$\therefore R_2 = 3.4\times10^{+5} - 1\times10^{5}$

$R_2 =$ 2.4×10^{5} Ω

10

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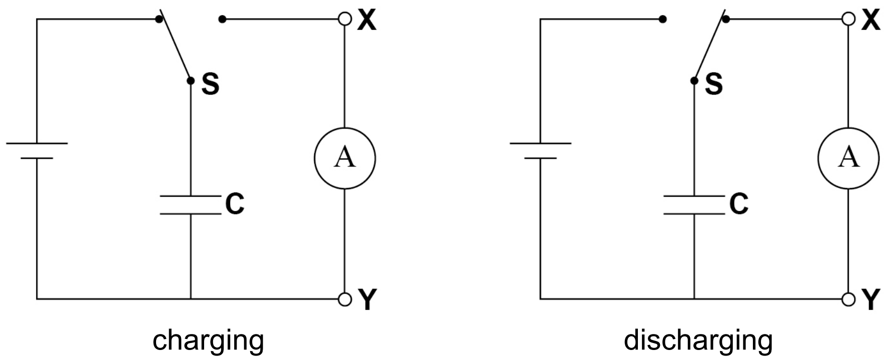
1 7 A switch **S** allows capacitor **C** to be completely charged by a cell and then completely discharged through an ammeter.
The emf of the cell is 4.0 V and it has negligible internal resistance.
The capacitance of **C** is 0.40 μF and there are 8000 charge−discharge cycles every second.



What are the magnitude and direction of the average conventional current in the ammeter?
[1 mark]

	Magnitude of current / A	Direction of current	
A	1.3×10^{-2}	**X** to **Y**	⬭
B	1.3×10^{-2}	**Y** to **X**	⬭
C	2.0×10^{-10}	**X** to **Y**	⬭
D	2.0×10^{-10}	**Y** to **X**	⬭

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1 8 A $30\ \mu F$ capacitor is charged by connecting it to a battery of emf $4.0\ V$.
The initial charge on the capacitor is Q_0.

The capacitor is then discharged through a $500\ k\Omega$ resistor.
The time constant for the circuit is T.

Which is correct?

[1 mark]

A T is $15\ ms$.

B Q_0 is $12\ \mu C$.

C After a time T the pd across the capacitor is $1.5\ V$.

D After a time $2T$ the charge on the capacitor is Q_0e^2.

1 9 Capacitor **X** of capacitance C has square plates of side length l and separation d and is made with a dielectric of relative permittivity ε.

Capacitor **Y** has square plates of side length $3l$ and separation $\frac{d}{3}$ and is made with a dielectric of relative permittivity $\frac{\varepsilon}{3}$.

What is the capacitance of **Y**?

[1 mark]

A $\frac{C}{27}$

B $\frac{C}{9}$

C $9C$

D $27C$

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2 0 A parallel plate capacitor is connected across a battery and the energy stored in the capacitor is E.
Without disconnecting the battery, the separation of the plates is halved.

What is the energy now stored in the capacitor?

[1 mark]

A $0.5E$ ○

B E ○

C $2E$ ○

D $4E$ ○

2 1 A fully charged capacitor of capacitance $2.0\ \text{mF}$ discharges through a $15\ \text{k}\Omega$ resistor.

What fraction of the stored energy remains after 1.0 minute?

[1 mark]

A $\frac{1}{4}$ ○

B $\frac{1}{e^2}$ ○

C $\frac{1}{16}$ ○

D $\frac{1}{e^4}$ ○

2 2 A horizontal wire of length $0.25\ \text{m}$ carrying a current of $3.0\ \text{A}$ is perpendicular to a magnetic field. The mass of the wire is $3.0 \times 10^{-3}\ \text{kg}$ and the weight of the wire is supported in equilibrium by the magnetic field.

What is the flux density of the magnetic field?

[1 mark]

A $2.6\ \text{T}$ ○

B $3.9 \times 10^{-2}\ \text{T}$ ○

C $2.2 \times 10^{-2}\ \text{T}$ ○

D $4.0 \times 10^{-3}\ \text{T}$ ○