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Section A

Answer **all** questions in this section.

0 1 A capacitor of capacitance $63\ \text{pF}$ is made from two parallel metal plates separated by an air gap.
The capacitor is charged so that it stores a charge of $7.6 \times 10^{-10}\ \text{C}$; it is then isolated.

A sheet of mica of dielectric constant 6.0 is inserted between the plates so that it completely fills the space between them. The mica does not discharge the capacitor and does not change the separation of the plates.

0 1 . 1 Explain what is meant by a dielectric constant of 6.0

[1 mark]

0 1 . 2 Mica is made up of polar molecules. As the mica is inserted, the capacitance of the capacitor changes.

Explain how the polar molecules cause this change in capacitance.

[3 marks]

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0 1 . 3 Calculate the difference between the initial energy stored by the capacitor and the energy stored when the mica has been fully inserted.

[3 marks]

energy difference = _____ J

Question 1 continues on the next page

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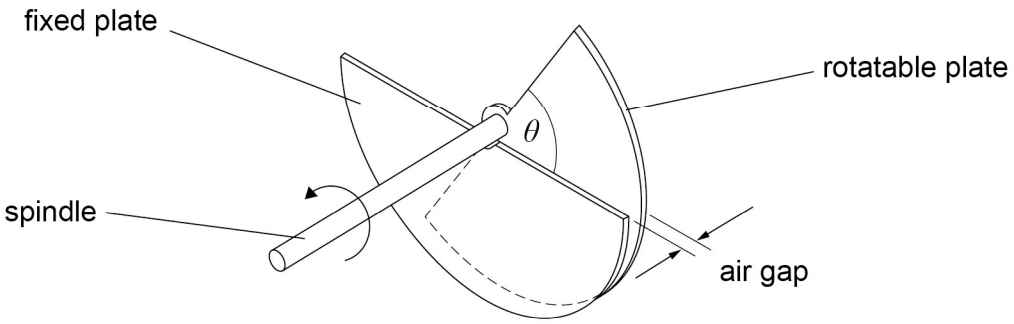
Figure 1 shows the structure of a variable capacitor used for measuring angular movement. The capacitor consists of two semicircular metal plates. These plates are parallel and are separated by an air gap.

Figure 1

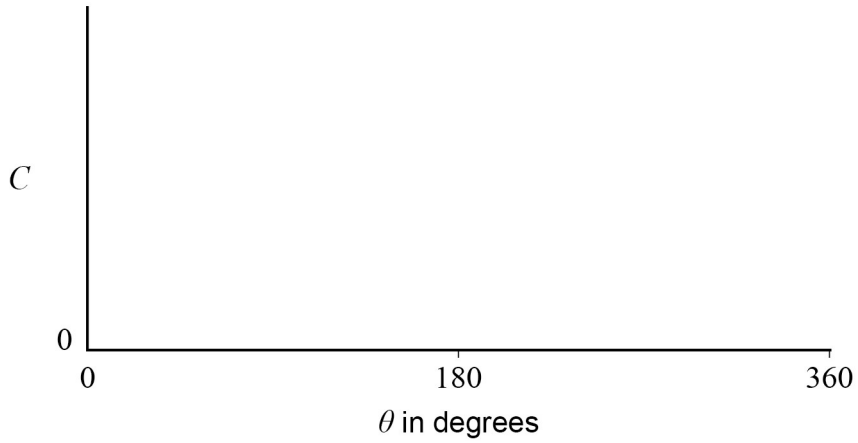


To vary the capacitance, one of the plates is rotated through an angle θ using the spindle. The other plate remains fixed.

0 1 . 4 Sketch a graph on **Figure 2** to show how the capacitance C varies with θ as the spindle is turned through $360°$.
When θ is $0°$, the plates completely overlap.

[2 marks]

Figure 2



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0 1 . 5 In one situation, the variable capacitor is too large for the available space.

The same maximum capacitance is required using plates that have half the diameter of the original capacitor.

Explain, with numerical detail, **two** ways in which this can be achieved.

[3 marks]

1 _____

_____

_____

_____

2 _____

_____

_____

_____

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Turn over for the next question

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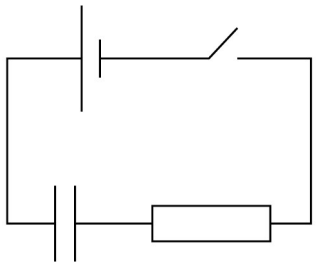
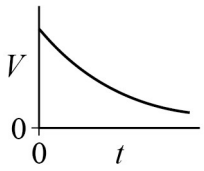
2 0 The capacitor in the circuit is initially uncharged.
The switch is closed at time $t = 0$

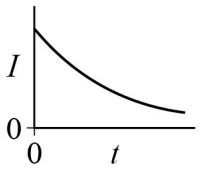


Which pair of graphs shows how the potential difference V across the capacitor and the current I in the circuit change with time t?

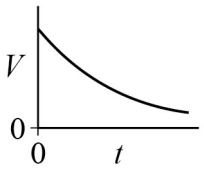
[1 mark]

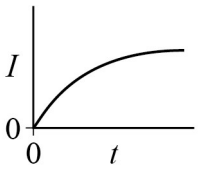
A



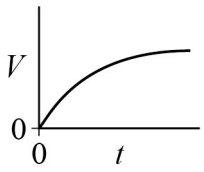


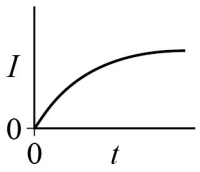
B



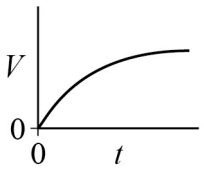


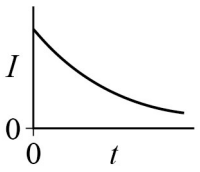
C





D





A ⬭

B ⬭

C ⬭

D ⬭

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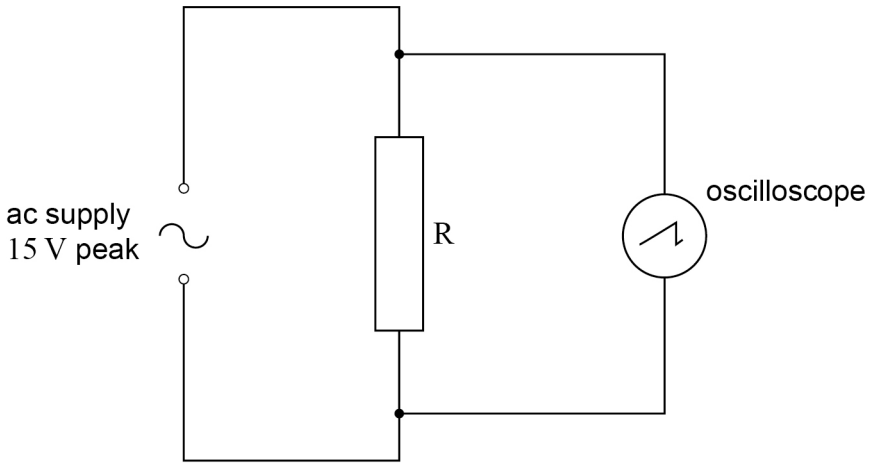
0 4 **Figure 6** shows an oscilloscope connected across resistor R which is in series with an ac supply. The supply provides a sinusoidal output of peak voltage 15 V.

Figure 6



0 4 . 1 Calculate the rms voltage of the supply.

[1 mark]

rms voltage = _____ V

Question 4 continues on the next page

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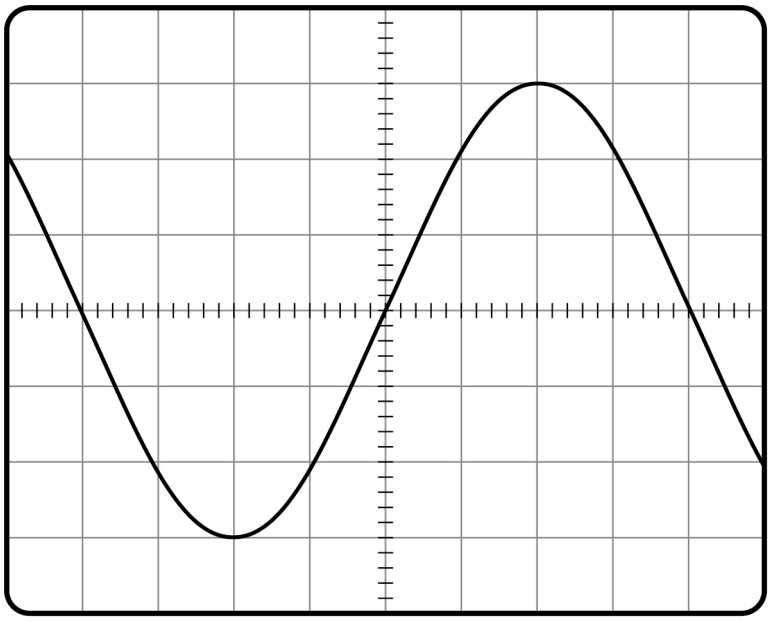
Figure 7 shows the trace of the waveform displayed on the oscilloscope.

Figure 7



0 4 . 2 Determine the y-voltage gain of the oscilloscope used for **Figure 7**.

[1 mark]

y-voltage gain = _____ $\mathrm{V\ div^{-1}}$

0 4 . 3 A dc supply gives the same rate of energy dissipation in R as the ac supply in **Figure 6**.

Draw the trace of the output of the dc supply on **Figure 7**.
The oscilloscope settings remain the same.

[1 mark]

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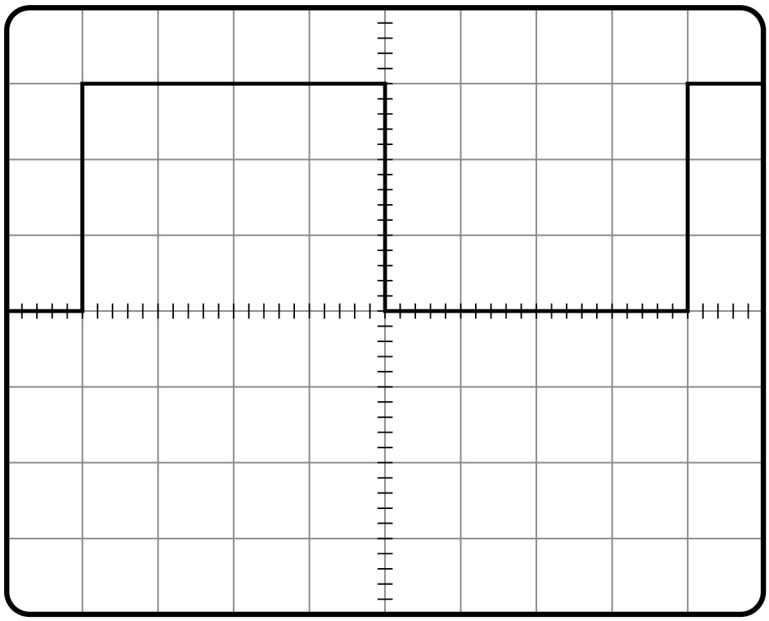
0 4 . 4 The ac supply shown in **Figure 6** is replaced with a square-wave generator operating between 0 and +15 V.

Figure 8 shows the trace of the new waveform displayed on the oscilloscope.
The time-base is set to 5.0×10^{-4} s div^{-1}.

Figure 8



Calculate the frequency of the square waves.

[1 mark]

frequency = _____ Hz

Question 4 continues on the next page

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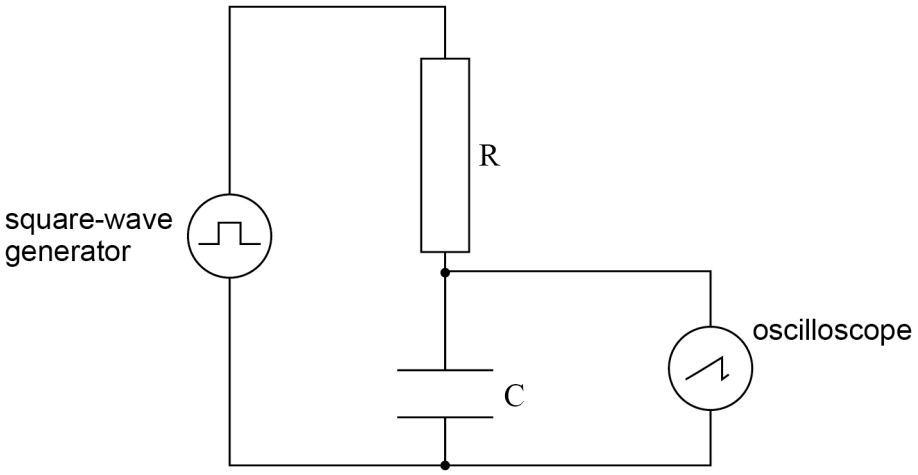
0 4 . 5 **Figure 9** shows the arrangement with the square-wave generator connected to an RC circuit.
A capacitor C is placed in series with the resistor R.
The oscilloscope is connected across the capacitor C.

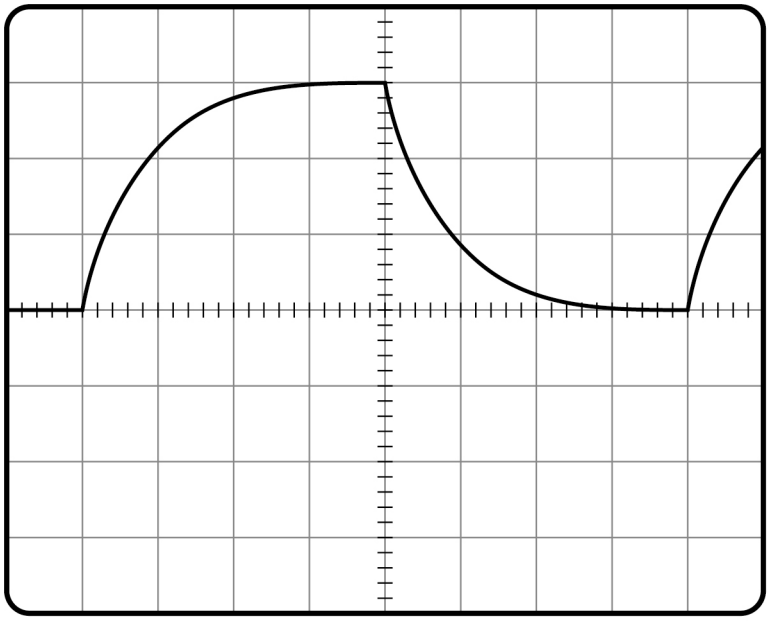
Figure 9



The capacitor charges and discharges.

Figure 10 shows the trace of the waveform displayed on the oscilloscope.
The settings of the oscilloscope remain the same as in Question **04.4**.

Figure 10



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Deduce the time constant for the RC circuit, explaining each step of your method.

[3 marks]

time constant = _____ s

0 4 . 6 State and explain a change to **one** control setting on the oscilloscope that would reduce the uncertainty in the value of the time constant.

[2 marks]

9

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1 9 An uncharged capacitor is connected to a power supply which supplies a constant current of $10\ \mu A$.

After $100\ ms$, the potential difference across the capacitor is $5.0\ kV$.

What is the capacitance of the capacitor?

[1 mark]

A $2.0 \times 10^{-10}\ F$ ⬭

B $4.0 \times 10^{-10}\ F$ ⬭

C $2.5 \times 10^{9}\ F$ ⬭

D $5.0 \times 10^{9}\ F$ ⬭

2 0 When a parallel-plate capacitor is connected across a battery, the energy stored in the capacitor is W.

The battery remains connected as the distance between the capacitor plates is halved.

What is the energy now stored in the capacitor?

[1 mark]

A $0.5W$ ⬭

B W ⬭

C $2W$ ⬭

D $4W$ ⬭

Turn over for the next question

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2 1 A parallel-plate capacitor is made using a sheet of dielectric material between, and in contact with, two plates.
The properties of four sheets of dielectric material are shown.

Which sheet will produce the maximum capacitance?

[1 mark]

Sheet	Relative permittivity	Thickness / mm	
A	2	0.40	⬭
B	3	0.90	⬭
C	4	1.0	⬭
D	6	1.6	⬭

2 2 A 10 μF capacitor stores 4.5 mJ of energy.
It then discharges through a 25 Ω resistor.

What is the maximum current during the discharge of the capacitor?

[1 mark]

A 1.2 A ⬭

B 18 A ⬭

C 30 A ⬭

D 36 A ⬭

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1 8 When a small radioactive source is placed in a cloud chamber, straight tracks about $4\ \text{cm}$ long are observed. The same source is placed $10\ \text{cm}$ from a Geiger tube and a count rate is detected. When a sheet of aluminium $5\ \text{mm}$ thick is placed between the source and the Geiger tube the count rate falls to the background count rate.

Which types of radiation are emitted by the source?

[1 mark]

A α, β and γ ⬭

B β and γ ⬭

C α and γ ⬭

D α and β ⬭

1 9 A parallel-plate capacitor is made by inserting a sheet of dielectric material between two plates. Both plates are in contact with the sheet.

Which relative permittivity and sheet thickness give the greatest capacitance?

[1 mark]

	Relative permittivity	**Thickness / mm**	
A	2	0.40	⬭
B	3	0.90	⬭
C	4	1.0	⬭
D	6	1.6	⬭

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2 0 A $1.0\ \mu\text{F}$ capacitor is charged for $20\ \text{s}$ using a constant current of $10\ \mu\text{A}$.

What is the energy transferred to the capacitor?

[1 mark]

A $5.0 \times 10^{-3}\ \text{J}$ ⬭

B $1.0 \times 10^{-2}\ \text{J}$ ⬭

C $2.0 \times 10^{-2}\ \text{J}$ ⬭

D $4.0 \times 10^{-2}\ \text{J}$ ⬭

2 1 A $1.0\ \mu\text{F}$ capacitor initially stores $15\ \mu\text{C}$ of charge. It then discharges through a $25\ \Omega$ resistor.

What is the maximum current during the discharge of the capacitor?

[1 mark]

A $0.60\ \text{mA}$ ⬭

B $1.2\ \text{mA}$ ⬭

C $0.60\ \text{A}$ ⬭

D $1.2\ \text{A}$ ⬭

2 2 The initial potential difference across a capacitor is V_0. The capacitor discharges through a circuit of time constant T. The base of natural logarithms is e.

What is the potential difference across the capacitor after time T?

[1 mark]

A $\frac{V_0}{2}$ ⬭

B $\frac{V_0}{\text{e}}$ ⬭

C $V_0\,\text{e}$ ⬭

D $V_0 \ln 2$ ⬭