1. A capacitor of capacitance 63 pF is made from two parallel metal plates separated by an air gap. The capacitor is charged so that it stores a charge of 7.6×10^{-10} 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.

(a) Explain what is meant by a dielectric constant of 6.0

(1)

(b) 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)

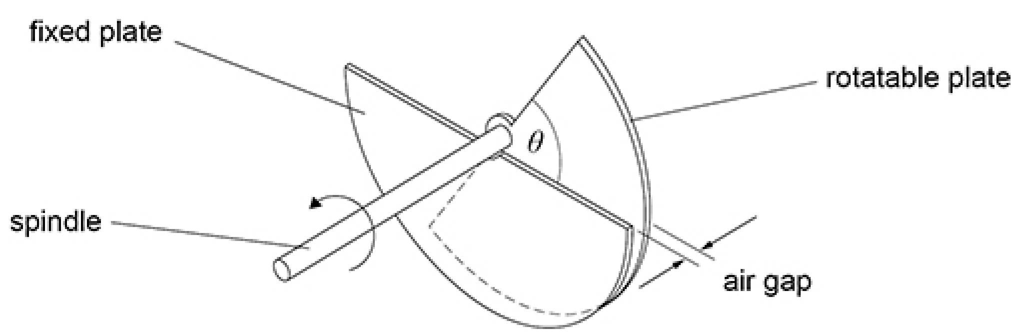
(c) Calculate the difference between the initial energy stored by the capacitor and the energy stored when the mica has been fully inserted.

energy difference = _______________ J

(3)

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

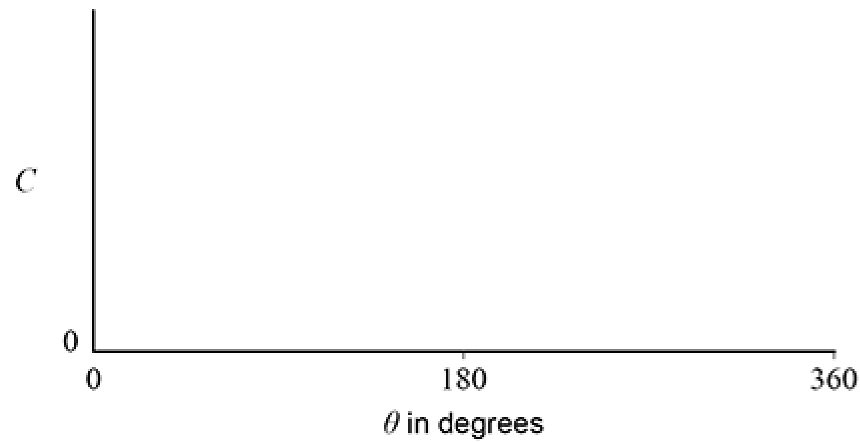


To vary the capacitance, one of the plates is rotated through an angle θ using the spindle. The other plate remains fixed.

(d) 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.

Figure 2



(2)

(e) 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.

1 ___

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2 ___

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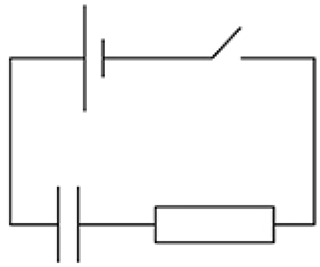
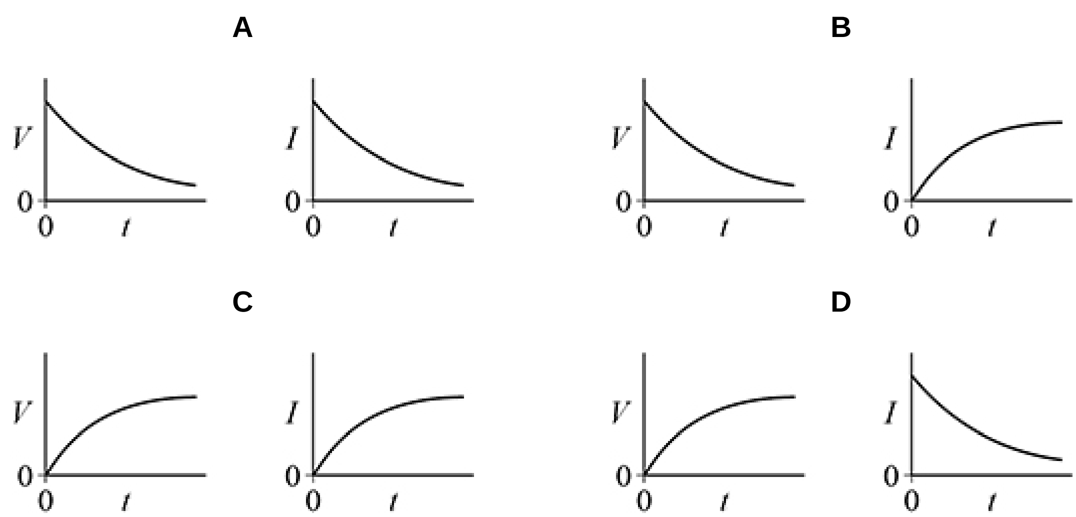
(3)

(Total 12 marks)

2. 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?



A ⬭

B ⬭

C ⬭

D ⬭

(Total 1 mark)

3. 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?

A $0.5W$ ○

B W ○

C $2W$ ○

D $4W$ ○

(Total 1 mark)

4. An uncharged capacitor is connected to a power supply which supplies a constant current of 10 μA.

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

What is the capacitance of the capacitor?

A 2.0×10^{-10} F ○

B 4.0×10^{-10} F ○

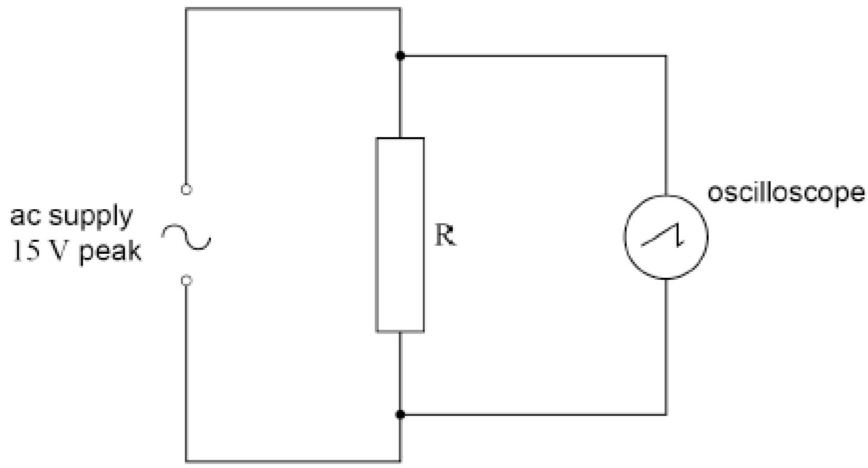
C 2.5×10^{9} F ○

D 5.0×10^{9} F ○

(Total 1 mark)

5. **Figure 1** 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 1



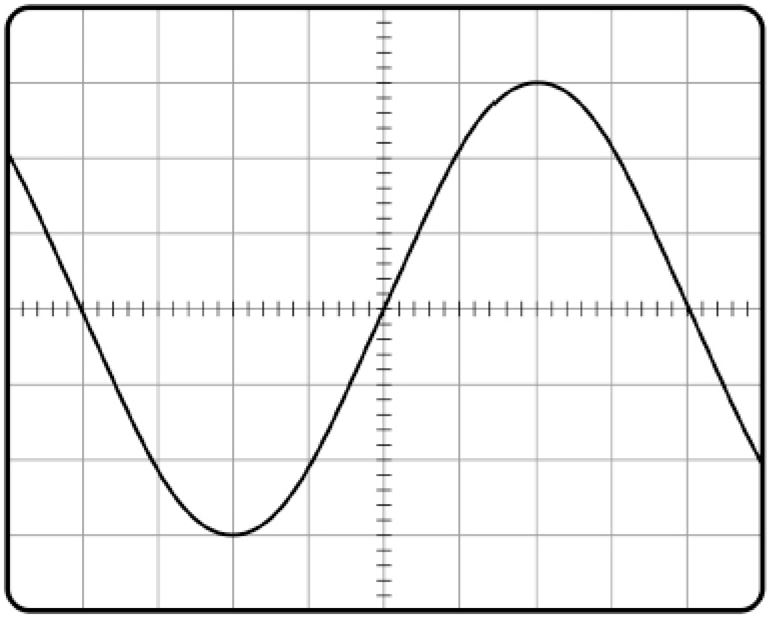
(a) Calculate the rms voltage of the supply.

rms voltage = ____________________ V

(1)

Figure 2 shows the trace of the waveform displayed on the oscilloscope.

Figure 2



(b) Determine the y-voltage gain of the oscilloscope used for **Figure 2**.

y-voltage gain = _______________ V div^{-1}

(1)

(c) A dc supply gives the same rate of energy dissipation in R as the ac supply in **Figure 1**.

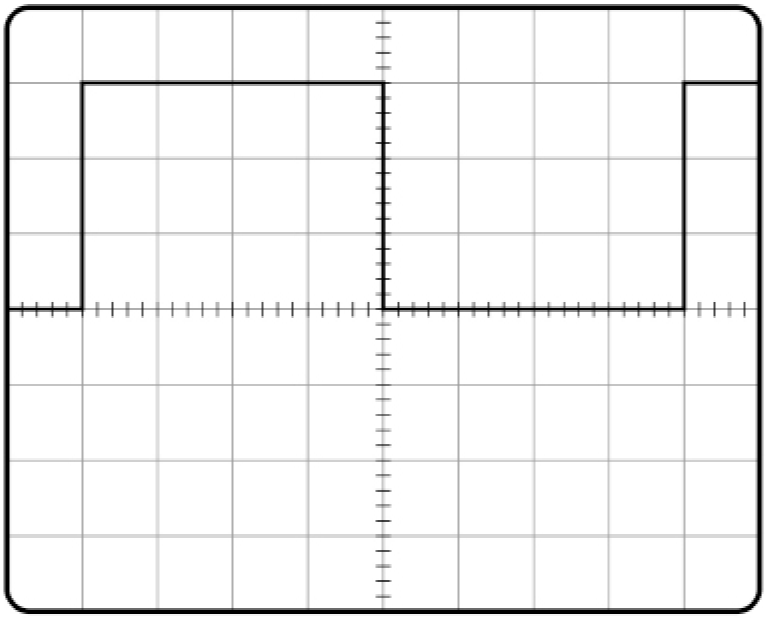
Draw the trace of the output of the dc supply on **Figure 2**.
The oscilloscope settings remain the same.

(1)

(d) The ac supply shown in **Figure 1** is replaced with a square-wave generator operating between 0 and +15 V.

Figure 3 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 3



Calculate the frequency of the square waves.

frequency = ________________ Hz

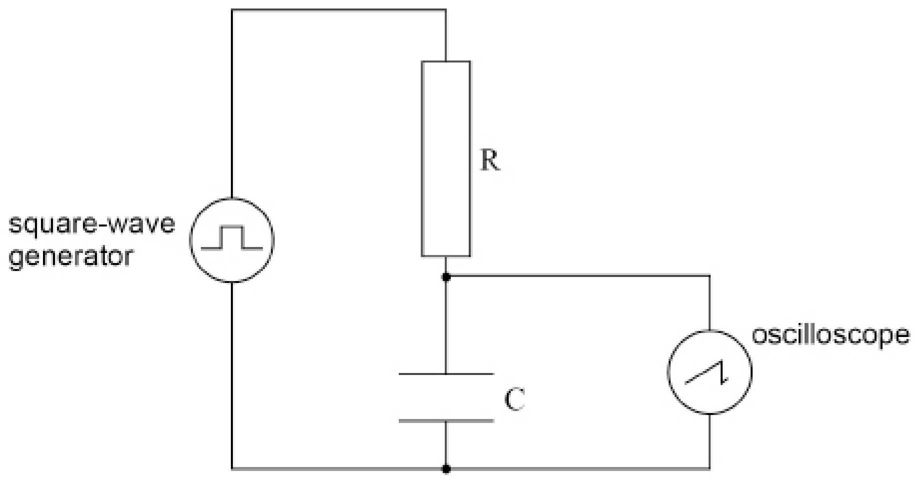
(1)

(e) **Figure 4** 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.

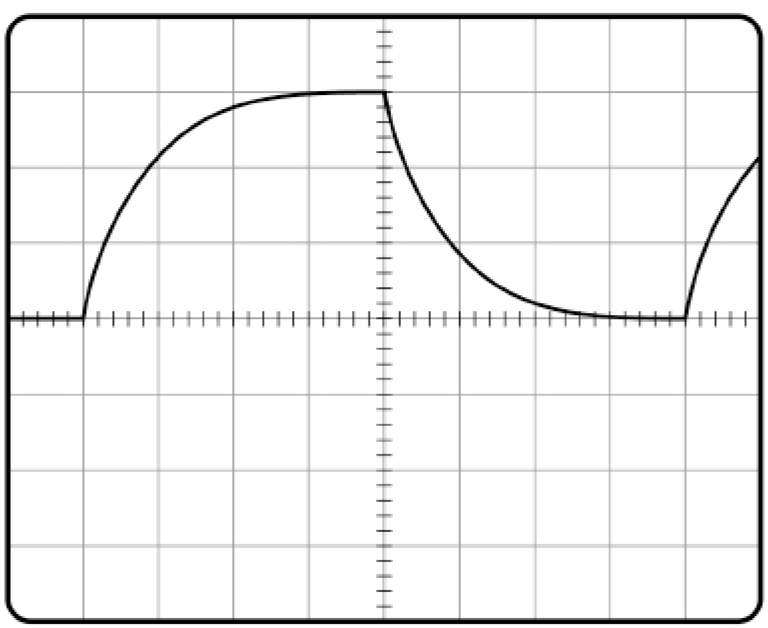
Figure 4



The capacitor charges and discharges.

Figure 5 shows the trace of the waveform displayed on the oscilloscope. The settings of the oscilloscope remain the same as in part (d).

Figure 5



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

time constant = ______________ s

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(3)

(f) State and explain a change to **one** control setting on the oscilloscope that would reduce the uncertainty in the value of the time constant.

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(2)

(Total 9 marks)

6. 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?

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

(Total 1 mark)

7. 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?

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

(Total 1 mark)

8. 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?

A 1.2 A ⬭

B 18 A ⬭

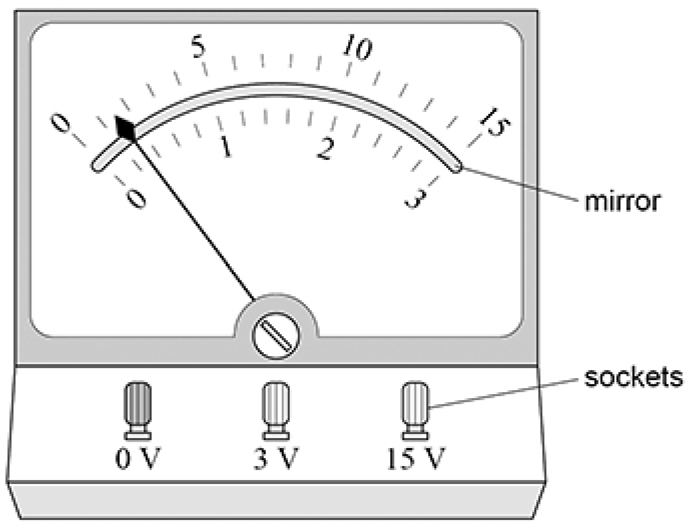
C 30 A ⬭

D 36 A ⬭

(Total 1 mark)

9. An analogue voltmeter has a resistance that is much less than that of a modern digital voltmeter.
Analogue meters can be damaged if the full-scale reading is exceeded.
Figure 1 shows a dual-range analogue voltmeter with a zero error.

Figure 1



(a) The voltmeter is set to the **more sensitive** range and then used in a circuit.

What is the potential difference (pd) between the terminals of the voltmeter when a full-scale reading is indicated?

Tick (✓) **one** box.

2.7 V ☐

3.3 V ☐

13.5 V ☐

16.5 V ☐

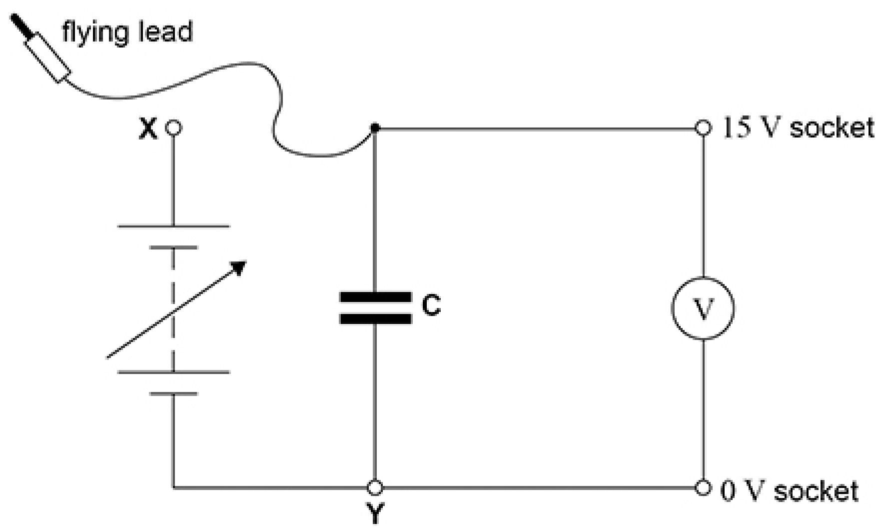
(1)

(b) Explain the use of the mirror when reading the meter.

(2)

A student corrects the zero error on the meter and then assembles the circuit shown in **Figure 2**.
The capacitance of the capacitor **C** is not known.

Figure 2



The output pd of the power supply is set to zero.
The student connects the flying lead to socket **X** and adjusts the output pd until the voltmeter reading is full scale (15 V).
She disconnects the flying lead from socket **X** so that **C** discharges through the voltmeter.

She measures the time $T_{½}$ for the voltmeter reading V to fall from 10 V to 5 V.

She repeats this process several times.

Table 1 shows the student's results, **none** of which is anomalous.

Table 1

$T_{½}$ / s	12.00	11.94	12.06	12.04	12.16

(c) Determine the percentage uncertainty in $T_{½}$.

percentage uncertainty = ________________ %

(2)

(d) Show that the time constant for the discharge circuit is about 17 s.

(1)

(e) The student thinks that the time constant of the circuit in **Figure 2** is directly proportional to the range of the meter.
To test her theory, she repeats the experiment with the voltmeter set to the 3 V range.
She expects $T_{½}$ to be about 2.5 s.

Explain:

- what the student should do, before connecting capacitor **C** to the 0 V and 3 V sockets, to avoid exceeding the full-scale reading on the voltmeter
- how she should develop her procedure to get an accurate result for the time constant
- how she should use her result to check whether her theory is correct.

(4)

The student wants to find the resistance of the voltmeter when it is set to the 15 V range.
She replaces **C** with an 820 μF capacitor and charges it to 15 V.
She discharges the capacitor through the voltmeter, starting a stopwatch when V is 14 V.
She records the stopwatch reading T at other values of V as the capacitor discharges.

Table 2 shows her results.

Table 2

***V* / V**	14	11	8	6	4	3	2
***t* / s**	0.0	3.1	7.2	11.0	16.2	19.9	25.2

(f) Suggest **two** reasons why the student selected the values of V shown in **Table 2**.
Explain each of your answers.

1 ____

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2 ____

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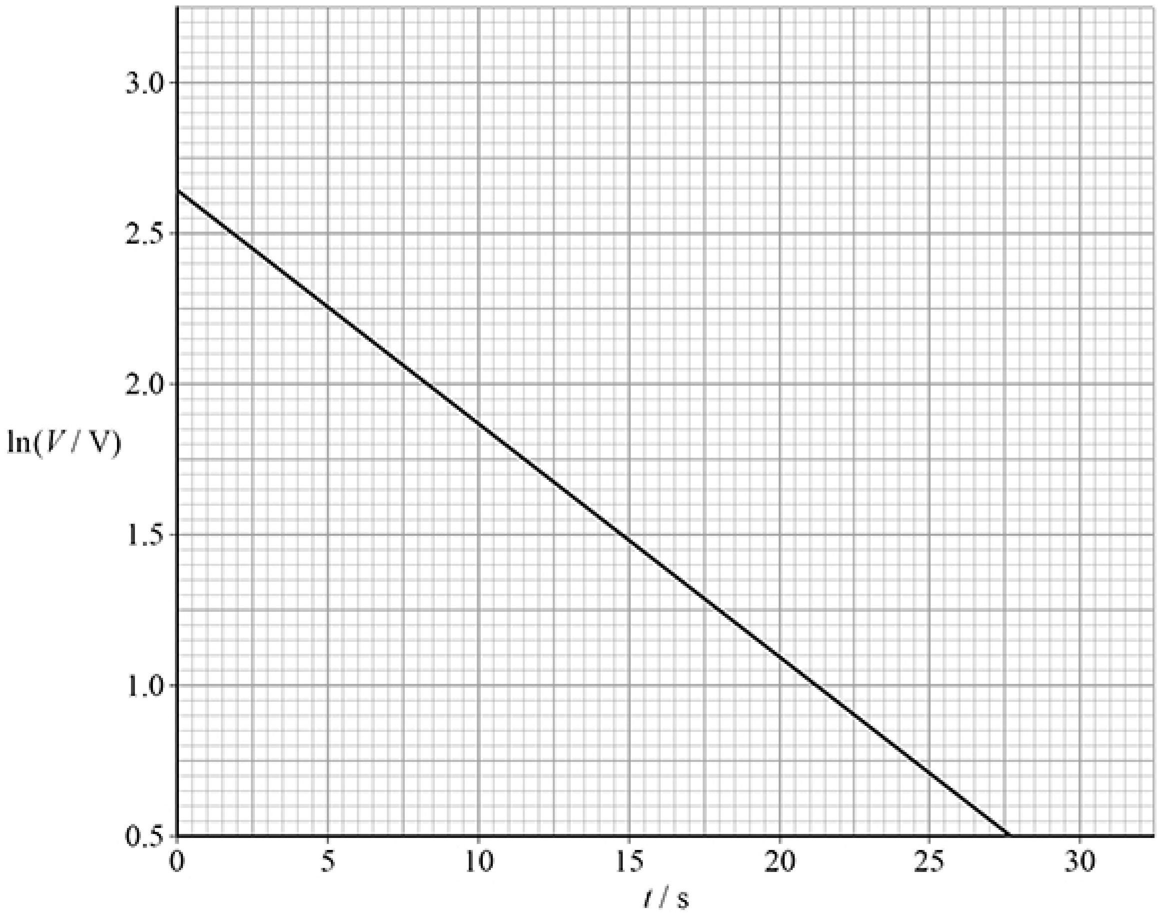
(4)

Figure 3 shows a graph of the experimental data.

Figure 3



(g) Show, using **Figure 3**, that the resistance of the voltmeter is about 16 kΩ.

(3)

(h) Determine the current in the voltmeter at t = 10 s.

current = ________________ A

(2)

(Total 19 marks)

10. A 1.0 μF capacitor is charged for 20 s using a constant current of 10 μA.

What is the charge collected by the sphere each second?

A 5.0×10^{-3} J ○

B 1.0×10^{-2} J ○

C 2.0×10^{-2} J ○

D 4.0×10^{-2} J ○

(Total 1 mark)

11. A 1.0 μF capacitor initially stores 15 μC of charge. It then discharges through a 25 Ω resistor.

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

A 0.60 mA ○

B 1.2 mA ○

C 0.60 A ○

D 1.2 A ○

(Total 1 mark)

12. 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?

A $\frac{V_0}{e}$ ☐

B $\frac{V_0}{e}$ ☐

C V_0e ☐

D V_0ln2 ☐

(Total 1 mark)

13. (a) State what is meant by a capacitance of 370 μF

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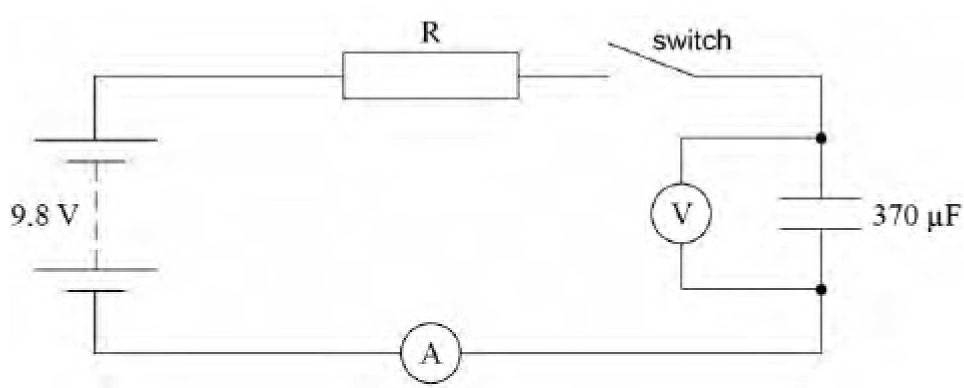
(2)

(b) The charging of a 370 μF capacitor is investigated using the circuit shown in **Figure 1**. Both meters in the circuit are ideal.

Figure 1



The power supply of emf 9.8V has a negligible internal resistance. The capacitor is initially uncharged. When the switch is closed at time t = 0 charge begins to flow through resistor R. The time constant of the charging circuit is 1.0 s

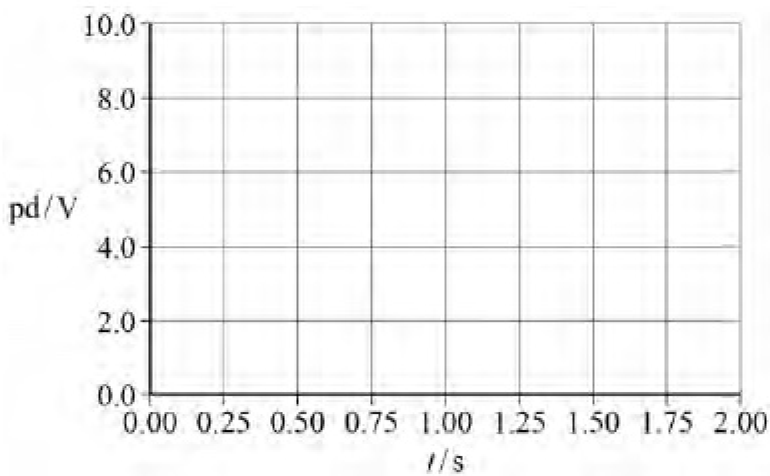
Calculate the resistance of R.

resistance of R = ____________________ Ω

(1)

(c) Identify, with the symbol X on **Figure 2**, the potential difference (pd) across the capacitor when the switch has been closed for 2.0 s
Sketch the graph that shows how the pd varies from t = 0 to t = 2.0 s

Figure 2



(2)

(d) Calculate the time taken for the charging current to fall to half its initial value.

time = ____________________ s

(1)

(e) Calculate the time taken for the charge on the capacitor to reach 3.0 mC

time = ____________________ s

(3)

(Total 9 marks)

14. An air-filled parallel-plate capacitor is charged from a source of emf. The electric field has a strength E between the plates. The capacitor is disconnected from the source of emf and the separation between the isolated plates is doubled.

What is the final electric field between the plates?

A $2E$ ⬭

B E ⬭

C $\frac{E}{2}$ ⬭

D $\frac{E}{4}$ ⬭

(Total 1 mark)

15. 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?

A $\frac{1}{2}$ ⬭

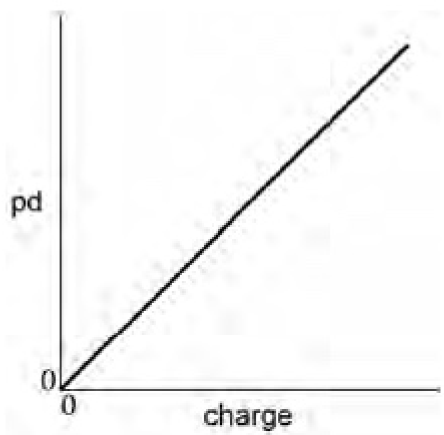
B 1 ⬭

C 2 ⬭

D 8 ⬭

(Total 1 mark)

16. The graph shows the variation of potential difference (pd) with charge for a capacitor while it is charging.



Which statement can be deduced from the graph?

A The charging current is constant. ⬭

B The energy stored in the capacitor increases uniformly with time. ⬭

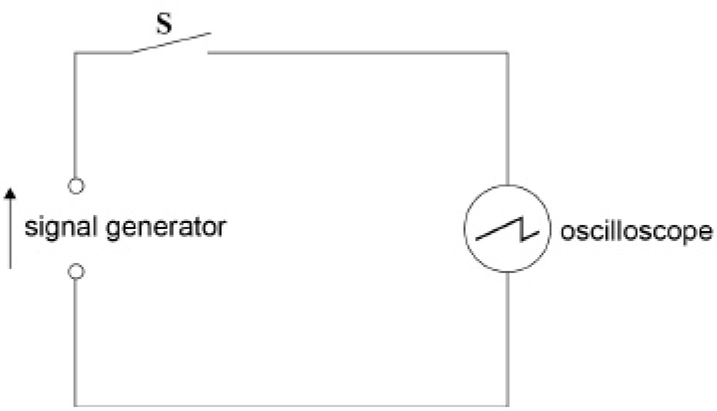
C The capacitance of the capacitor is constant. ⬭

D The power supply used to charge the capacitor had a constant terminal pd. ⬭

(Total 1 mark)

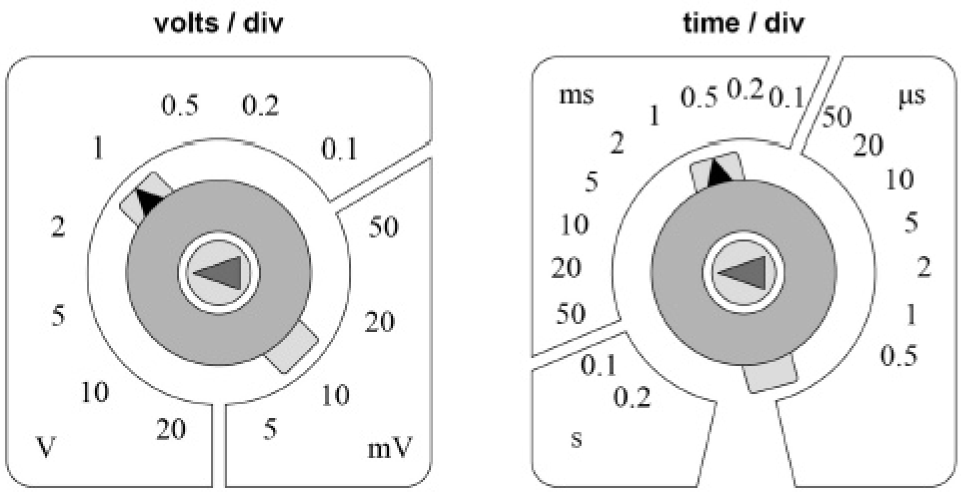
17. A signal generator is connected to an oscilloscope, as shown in **Figure 1**.

Figure 1



The Y-voltage gain and time-base settings of the oscilloscope are shown in **Figure 2**.

Figure 2



When switch **S** is open (off) the oscilloscope displays the waveform shown in **Figure 3**.

When **S** is closed (on) the oscilloscope displays the waveform shown in **Figure 4**.

(a) Determine the peak-to-peak voltage V of the waveform shown in **Figure 4**.

V = ____________________ V

(1)

(b) Determine the frequency *f* of the waveform shown in **Figure 4**.

f = ____________________ Hz

(2)

Figure 3

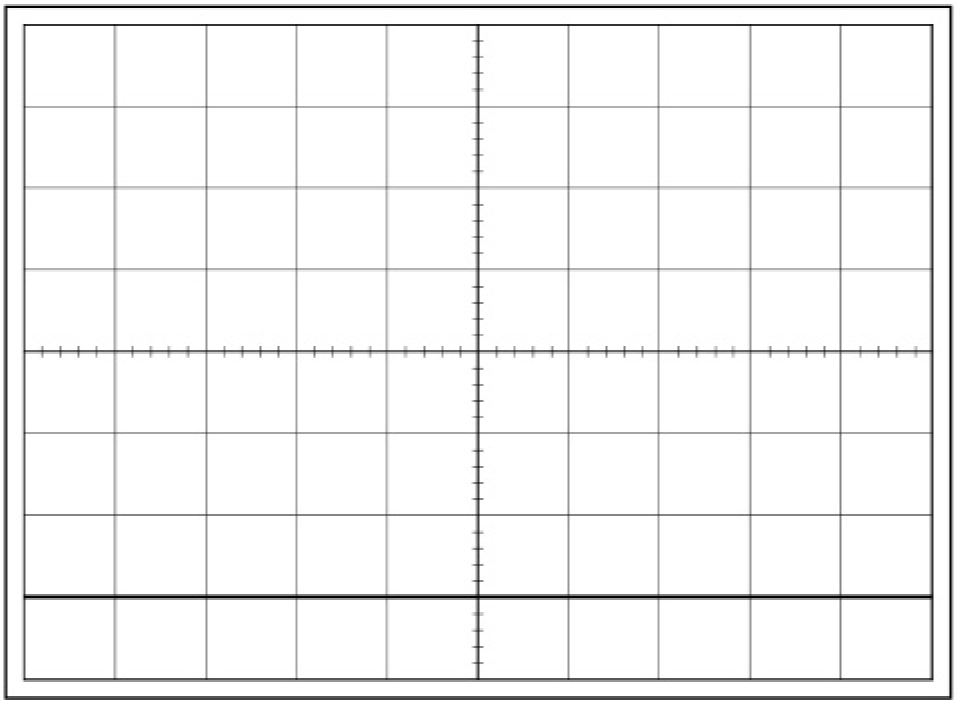
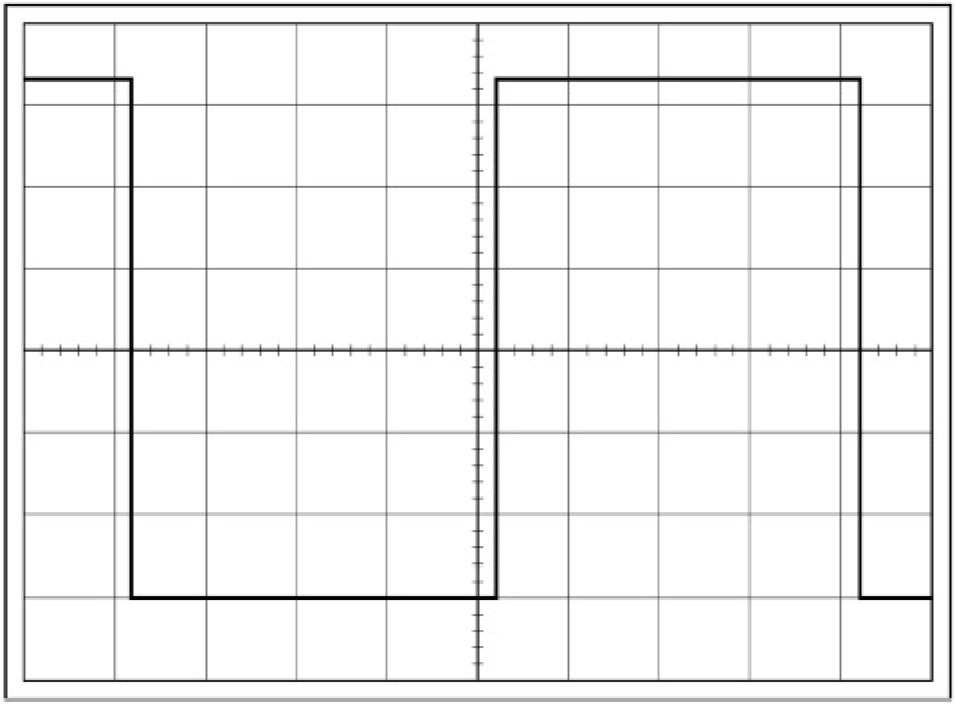
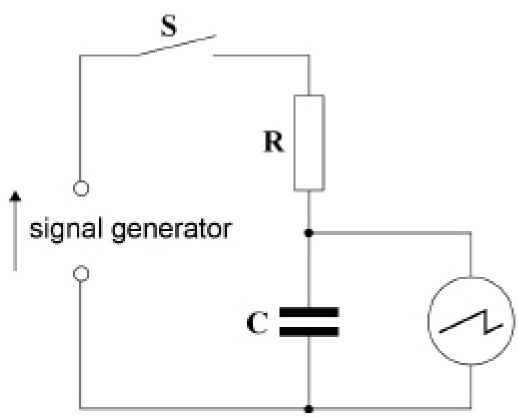


Figure 4



(c) **Figure 5** shows the signal generator connected in series with a resistor **R** and a capacitor **C**.

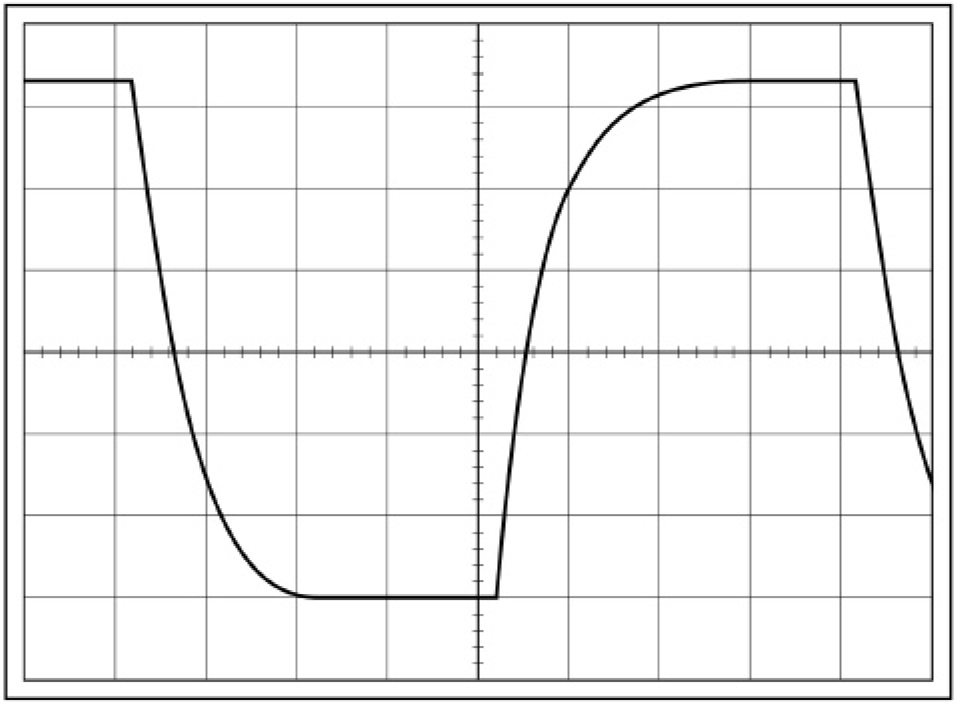
Figure 5



The oscilloscope is connected across the capacitor.
The Y-voltage gain and time-base settings are still the same as shown in **Figure 2**.

When **S** is closed (on) the oscilloscope displays the waveform shown in **Figure 6**.

Figure 6



Determine the time constant of the circuit in **Figure 5**.

time constant = ____________________ s

(2)

(d) A student suggests that setting the time-base to 0.2 ms division^{-1} might reduce uncertainty in the determination of the time constant.

State and explain any possible advantage or disadvantage in making this suggested adjustment.

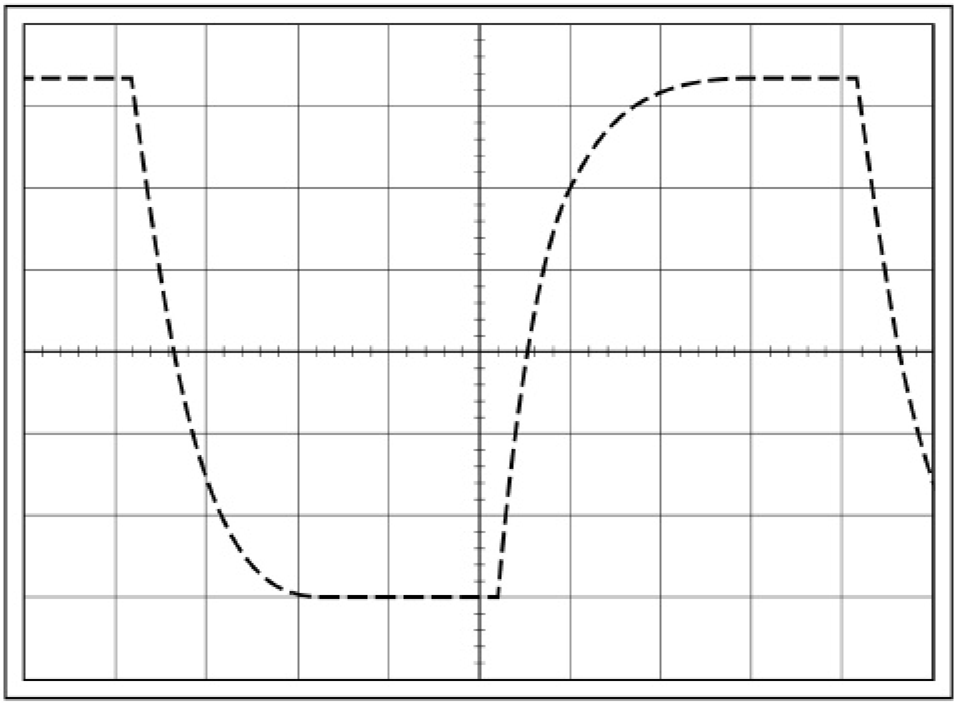
(3)

(e) The student connects an identical resistor in parallel with **R** and uses the oscilloscope to display the waveform across **C**.

Draw on **Figure 7** the waveform you expect the student to see.

The waveform of **Figure 6** is shown as a dashed line to help you show how the waveform changes.

Figure 7



Explain the change in the waveform.

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(2)

(f) **Figure 8a** is a graph of voltage against time showing the output of the signal generator. **Figure 8b** shows the voltage across **C** during the same time interval.

The student interchanges the positions of **R** and **C** and connects the oscilloscope across **R**.

Complete **Figure 8c** to draw the voltage across R during the time interval.

Figure 8a

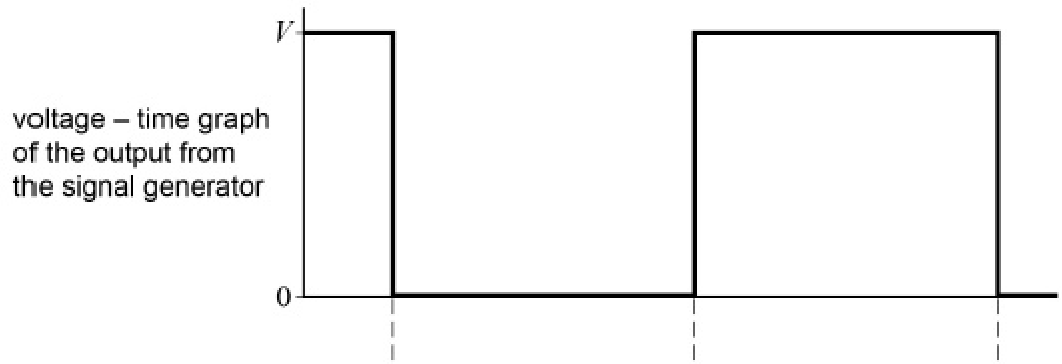


Figure 8b

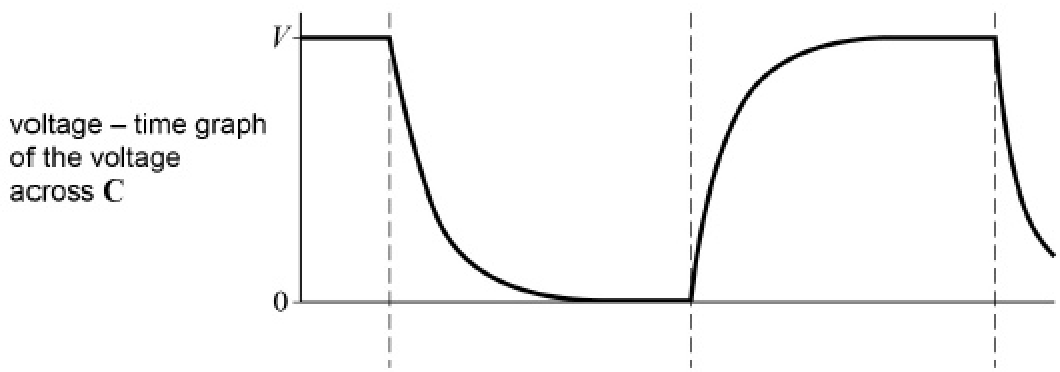
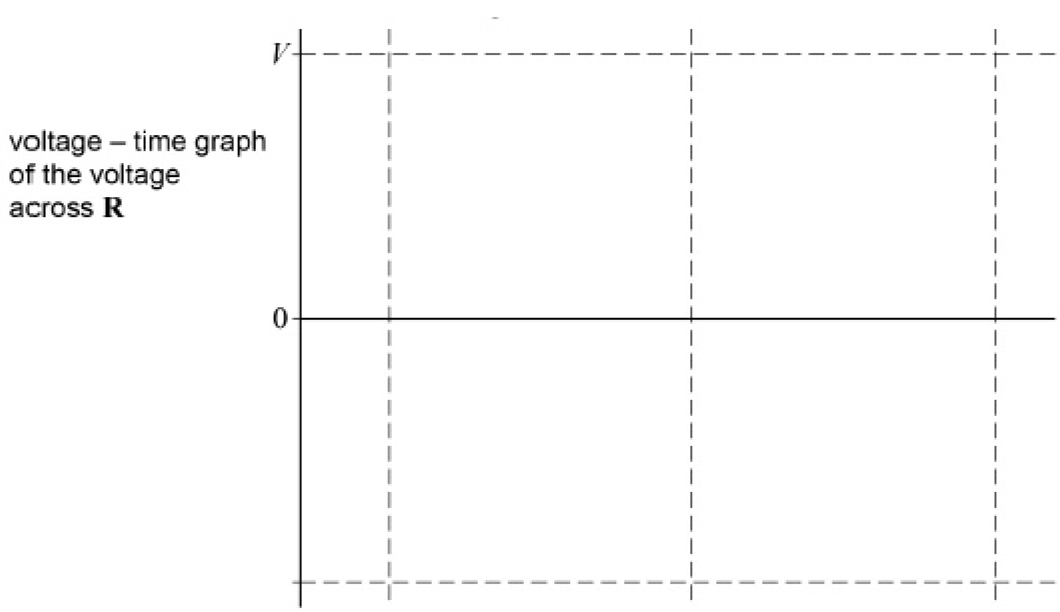


Figure 8c



(2)

(g) State and explain what changes, if any, the student needs to make to the settings of the oscilloscope so the waveform across **R** is fully displayed.

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(2)

(Total 14 marks)

18. A capacitor of capacitance 120 μF is charged and then discharged through a 20 kΩ resistor.

What fraction of the original charge remains on the capacitor 4.8 s after the discharge begins?

A 0.14 ○

B 0.37 ○

C 0.63 ○

D 0.86 ○

(Total 1 mark)

19. A capacitor consists of two parallel square plates of side l separated by distance d.
The capacitance of the arrangement is C.

What is the capacitance of a capacitor with square plates of side $2l$ separated by a distance $\frac{d}{2}$?

A C ○

B $2C$ ○

C $4C$ ○

D $8C$ ○

(Total 1 mark)

20. 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?

A $\frac{Q^2}{2C}$ ☐

B $\frac{Q^2}{C}$ ☐

C $\frac{3Q^2}{2C}$ ☐

D $\frac{2Q^2}{C}$ ☐

(Total 1 mark)