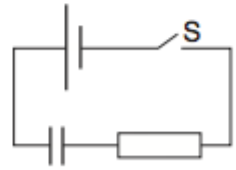
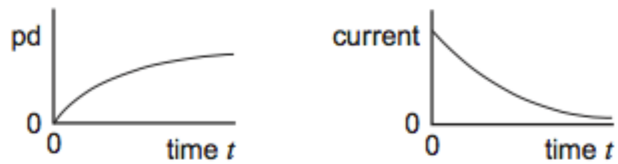
1 The capacitor in the circuit is initially uncharged. The switch S is closed at time t = 0.

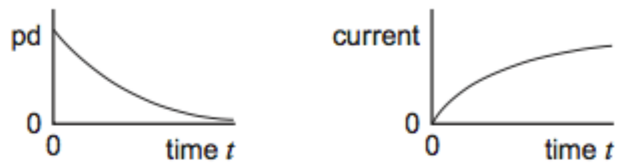
Which pair of graphs, **A** to **D**, correctly shows how the pd across the capacitor and the current in the circuit change with time?



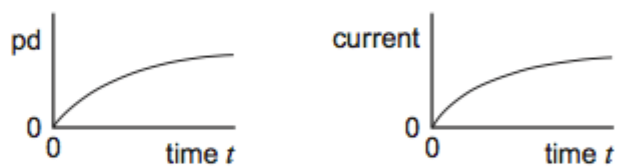
A



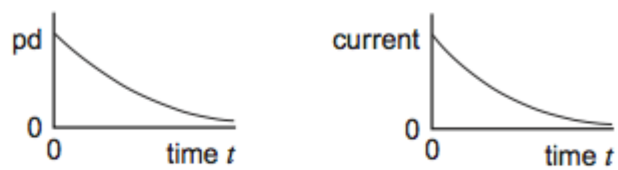
B



C

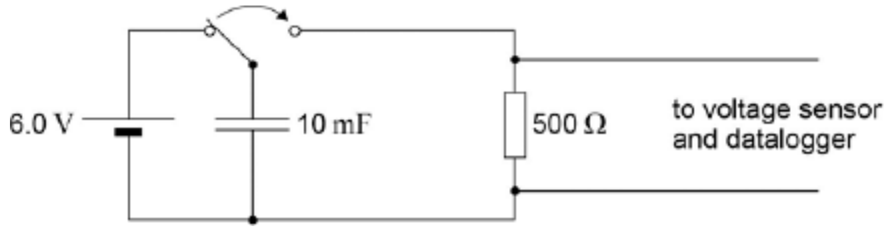


D



(Total 1 mark)

2 A voltage sensor and a datalogger are used to record the discharge of a 10 mF capacitor in series with a 500 Ω resistor from an initial pd of 6.0 V. The datalogger is capable of recording 1000 readings in 10 s.

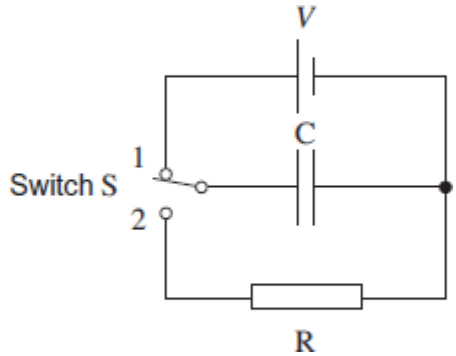


After a time equal to the time constant of the discharge circuit, which one of the rows gives the pd and the number of readings made?

	Potential difference / V	Number of readings	
A	2.2	50	○
B	3.8	50	○
C	3.8	500	○
D	2.2	500	○

(Total 1 mark)

3 Switch S in the circuit is held in position 1, so that the capacitor C becomes fully charged to a pd V and stores energy E.



The switch is then moved quickly to position 2, allowing C to discharge through the fixed resistor R. It takes 36 ms for the pd across C to fall to $\frac{V}{2}$. What period of time must elapse, after the switch has moved to position 2, before the energy stored by C has fallen to $\frac{E}{16}$?

A 51 ms

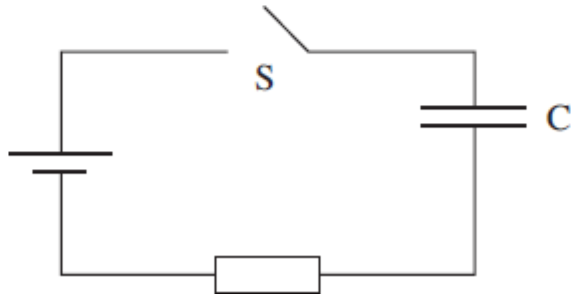
B 72 ms

C 432 ms

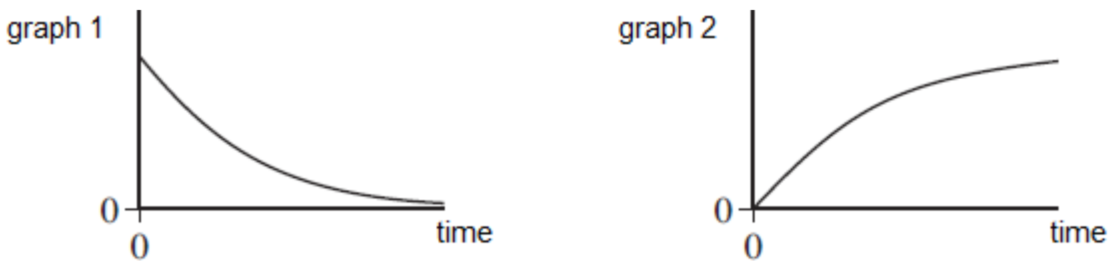
D 576 ms

(Total 1 mark)

4 In the circuit shown the capacitor C charges when switch S is closed.



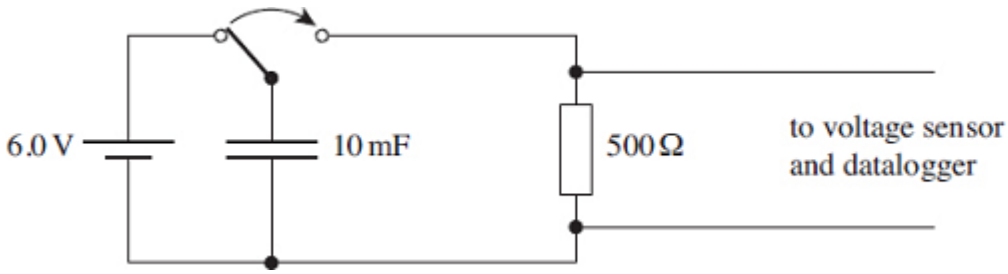
Which line, **A** to **D**, in the table gives a correct pair of graphs showing how the charge on the capacitor and the current in the circuit change with time after S is closed?



	charge	current
A	graph 1	graph 1
B	graph 1	graph 2
C	graph 2	graph 2
D	graph 2	graph 1

(Total 1 mark)

5 A voltage sensor and a datalogger are used to record the discharge of a 10 mF capacitor in series with a 500 Ω resistor from an initial pd of 6.0 V. The datalogger is capable of recording 1000 readings in 10 s. Which line, **A** to **D**, in the table gives the pd and the number of readings made after a time equal to the time constant of the discharge circuit?



	potential difference/V	number of readings
A	2.2	50
B	3.8	50
C	3.8	500
D	2.2	500

(Total 1 mark)

6 When a 220 μF capacitor is discharged through a resistor R, the capacitor pd decreases from 6.0 V to 1.5 V in 92 s.

What is the resistance of R?

A 210 kΩ

B 300 kΩ

C 420 kΩ

D 440 kΩ

(Total 1 mark)

7 A 1000 μF capacitor, initially uncharged, is charged by a steady current of 50 μA. How long will it take for the potential difference across the capacitor to reach 2.5 V?

A 20 s

B 50 s

C 100 s

D 400 s

(Total 1 mark)

8 A capacitor of capacitance *C* discharges through a resistor of resistance *R*.
Which one of the following statements is **not** true?

A The time constant will increase if *R* is increased.

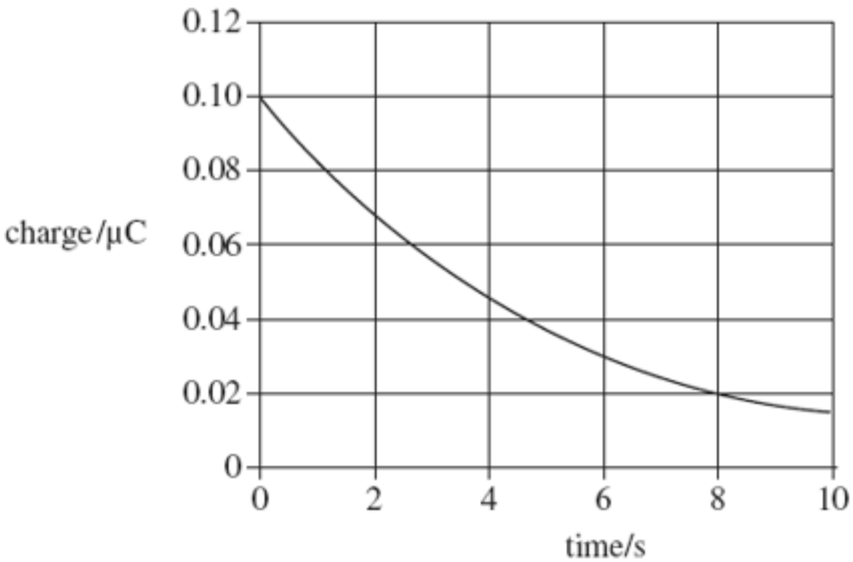
B The time constant will decrease if *C* increased.

C After charging to the same voltage, the initial discharge current will increase if *R* is decreased.

D After charging to the same voltage, the initial discharge current will be unaffected if *C* is increased.

(Total 1 mark)

9 The graph shows how the charge on a capacitor varies with time as it is discharged through a resistor.



What is the time constant for the circuit?

A 3.0 s

B 4.0 s

C 5.0 s

D 8.0 s

(Total 1 mark)

10 A 2.0 mF capacitor, used as the backup for a memory unit, has a potential difference of 5.0 V across it when fully charged. The capacitor is required to supply a constant current of 1.0 μA and can be used until the potential difference across it falls by 10%. How long can the capacitor be used for before it must be recharged?

A 10 s

B 100 s

C 200 s

D 1000 s

(Total 1 mark)

11 When a capacitor discharges through a resistor it loses 50% of its charge in 10 s. What is the time constant of the capacitor-resistor circuit?

A 0.5 s

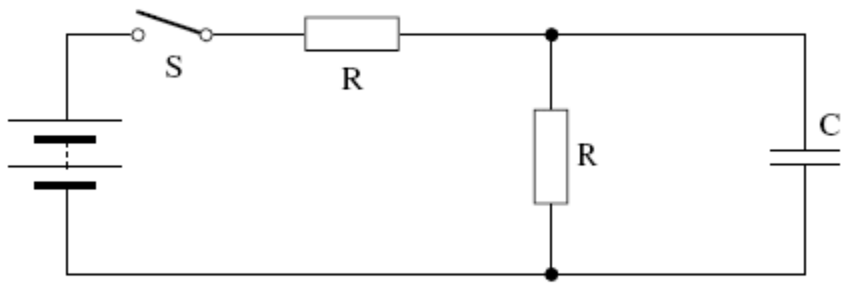
B 5 s

C 14 s

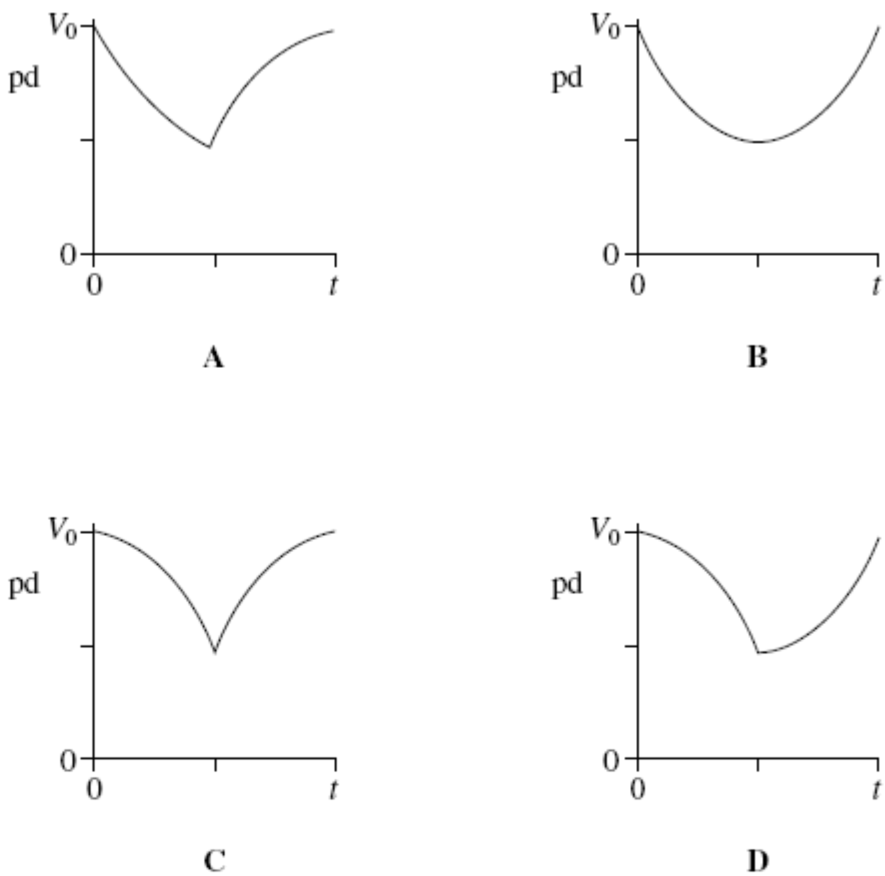
D 17 s

(Total 1 mark)

12 When switch S in the circuit is closed, the capacitor C is charged by the battery to a pd V_0. The switch is then opened until the capacitor pd decreases to 0.5 V_0, at which time S is closed again. The capacitor then charges back to V_0.

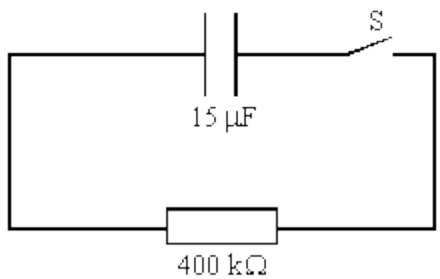


Which graph best shows how the pd across the capacitor varies with time, *t*, after S is opened?



(Total 1 mark)

13 A capacitor of capacitance 15 μF is fully charged and the potential difference across its plates is 8.0 V. It is then connected into the circuit as shown.



The switch S is closed at time $t = 0$. Which one of the following statements is correct?

A The time constant of the circuit is 6.0 ms.

B The initial charge on the capacitor is 12 μC.

C After a time equal to twice the time constant, the charge remaining on the capacitor is Q_0e^2, where Q_0 is the charge at time $t = 0$.

D After a time equal to the time constant, the potential difference across the capacitor is 2.9 V.

(Total 1 mark)

14 A capacitor is first charged through a resistor and then discharged through the same resistor.

The magnitude of which one of the following quantities varies with time in the same way during both charging and discharging?

A Energy stored

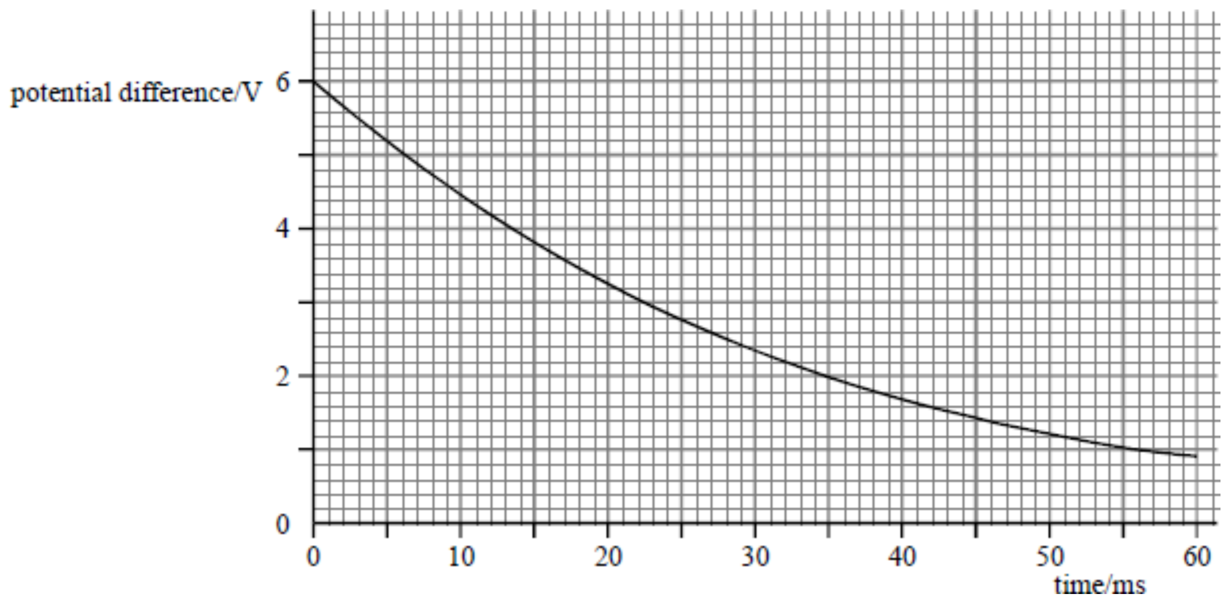
B Current

C Potential difference

D Charge

(Total 1 mark)

15 A student used a voltage sensor connected to a datalogger to plot the discharge curve for a 4.7 μF capacitor. She obtained the following graph.



Use data from the graph to calculate

(a) the initial charge stored,

....

(2)

(b) the energy stored when the capacitor had been discharging for 35 ms,

....

....

(3)

(c) the time constant for the circuit,

....

....

....

....

(3)

(d) the resistance of the circuit through which the capacitor was discharging.

....

....

....

(2)
(Total 10 marks)

16 (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 2.3×10^{-11} F.

The permittivity of free space $\varepsilon_0 = 8.9 \times 10^{-12}$ F m^{-1}

The relative permittivity of air = 1.0

Calculate:

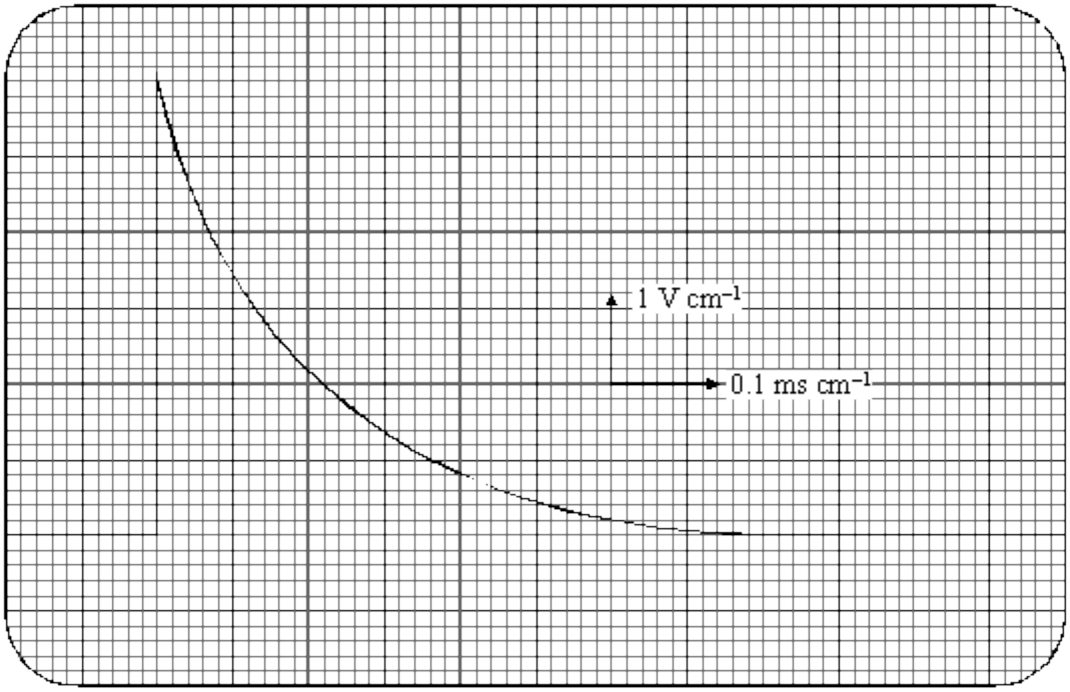
(i) the radius of the plates used in the capacitor;

(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)

17 (a) A capacitor is marked '2200 μF 15 V'.

(i) Explain what is meant by a capacitance of 2200 μF.

....

....

(2)

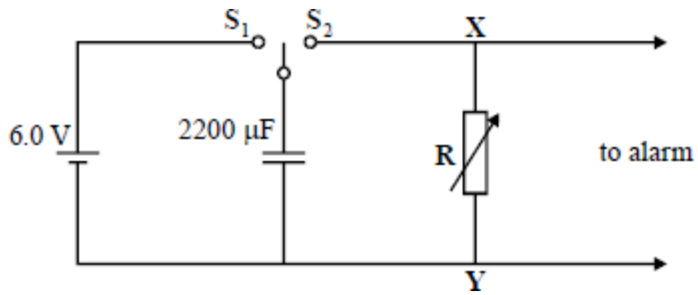
(ii) What is the significance of the 15 V marking?

....

....

(1)

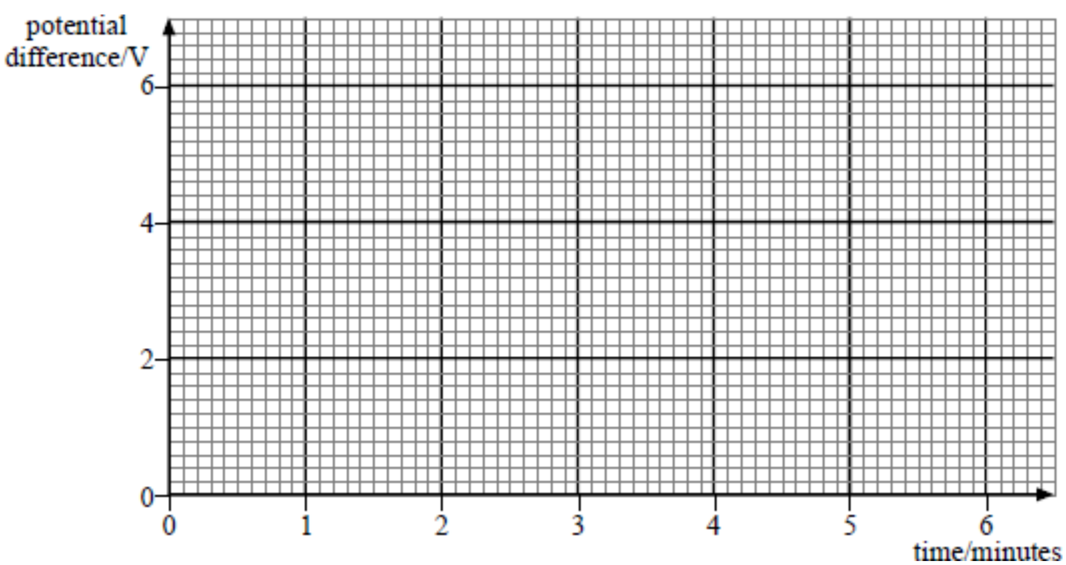
(b) An egg-timer is designed to produce a sound when an egg has been boiled for a sufficient time. The time which elapses before the alarm sounds is controlled by the circuit shown below. The circuit is operated from a 6.0 V cell of negligible internal resistance.



The time is set by means of the variable resistor **R**.

The capacitor is charged by moving the two-way switch to position $\mathbf{S_1}$ for a short time. The timing is then started automatically when the two-way switch is moved to position $\mathbf{S_2}$. An alarm rings when the potential difference between terminals **XY** reaches 2.0 V.

(i) In one setting the time constant of the circuit when the capacitor is discharging is 3.0 minutes. Sketch a graph to show how the potential difference between the terminals **X** and **Y** varies with time for the first 6.0 minutes after the switch moves to the position $\mathbf{S_2}$.



(2)

(ii) How long after timing commences will the alarm sound for the setting in part (i)?

....

(1)

(iii) Calculate the resistance of the variable resistor when the time constant is 3.0 minutes.

(2)

(iv) The system is designed to measure cooking times up to 5.0 minutes. Determine the maximum value of the resistance **R** that is needed.

(2)

(v) State how a suitable capacitor would be connected to increase the measurable cooking time.

....

....

(1)
(Total 11 marks)

18 (a) (i) A label on a capacitor shows it to have a capacitance of 0.020 F. Explain what this tells you about the capacitor.

....

....

(1)

(ii) Sketch on **Figure 1** the graph that shows how the charge on the 0.020 F capacitor varies with the potential difference across it over the voltage range given. Insert an appropriate scale on the charge axis.

(2)

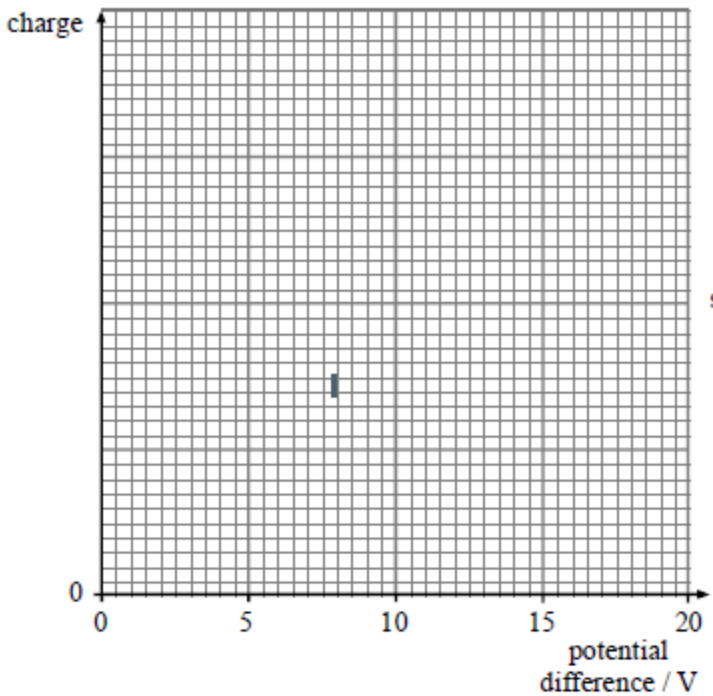
(iii) Explain how your graph could be used to obtain the energy stored for a given potential difference.

....

....

....

(2)



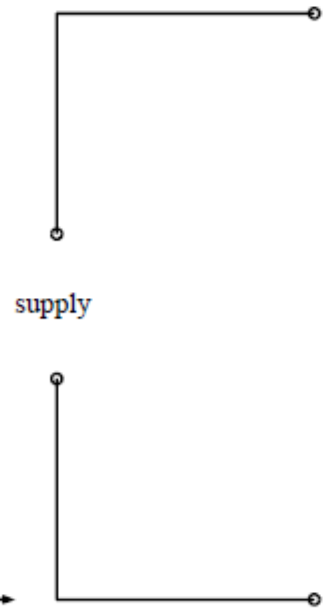


Figure 1 **Figure 2**

(iv) Show on **Figure 2** how **two** similar capacitors could be connected to a supply to store more energy for the same potential difference.

(1)

(b) **Figure 3** shows one 0.020 F capacitor connected to a 20 V supply. By means of the changeover switch **S**, the capacitor is disconnected from the supply and connected to a small motor. The motor lifts an object of mass 0.15 kg through a height of 0.80 m, after which the energy left in the capacitor is negligible.

acceleration of free fall, $g = 9.8\ \text{m s}^{-2}$

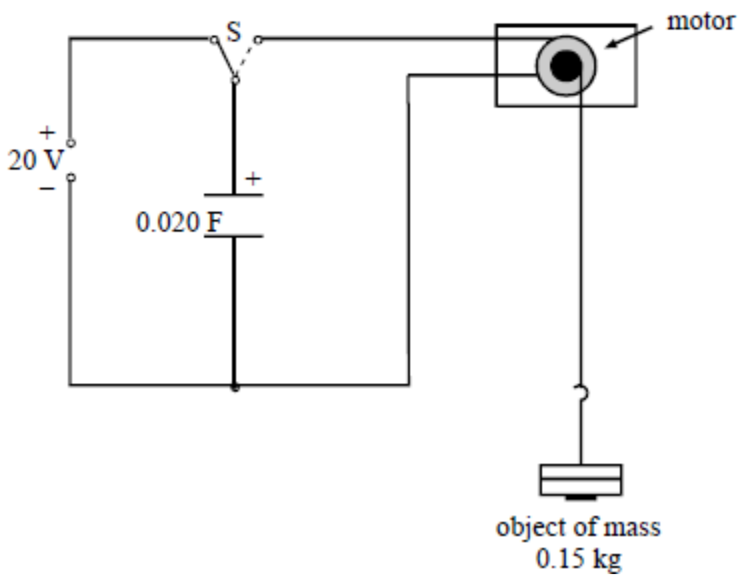


Figure 3

Calculate:

(i) the initial energy stored by the capacitor;

(2)

(ii) the efficiency of the energy conversion.

(3)
(Total 11 marks)

19 (a) As a capacitor was charged from a 12 V supply, a student used a coulomb meter and a voltmeter to record the charge stored by the capacitor at a series of values of potential difference across the capacitor. The student then plotted a graph of pd (on the *y*-axis) against charge (on the *x*-axis).

(i) Sketch the graph obtained.

(ii) State what is represented by the gradient of the line.

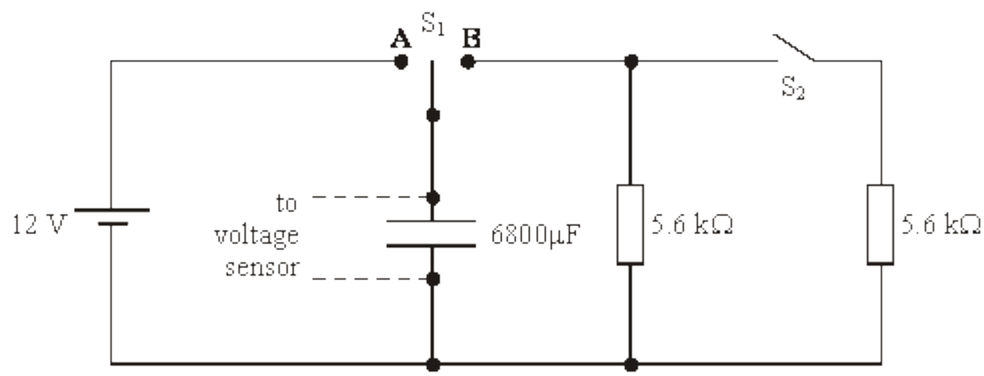
....

(iii) State what is represented by the area enclosed by the line and the *x*-axis of the graph.

....

(3)

(b) The student then connected the capacitor as shown in the diagram below to carry out an investigation into the discharge of the capacitor.



The student used a voltage sensor, datalogger and computer to obtain values for the pd across the capacitor at various times during the discharge.

(i) At time $t = 0$, with switch S_2 open, switch S_1 was moved from position **A** to position **B**. Calculate the pd across the capacitor when $t = 26$ s.

....

....

....

....

(ii) At time $t = 26$ s, as the discharge continued, the student closed switch S_2. Calculate the pd across the capacitor 40 s after switch S_1 was moved from position **A** to position **B**.

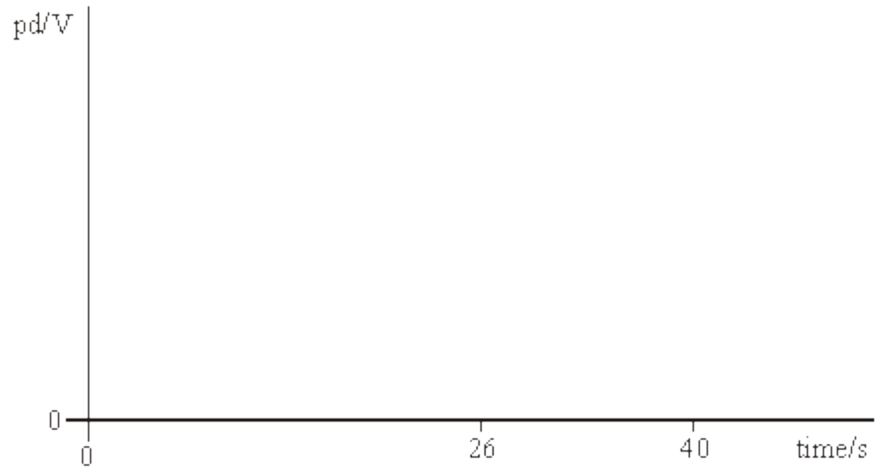
....

....

....

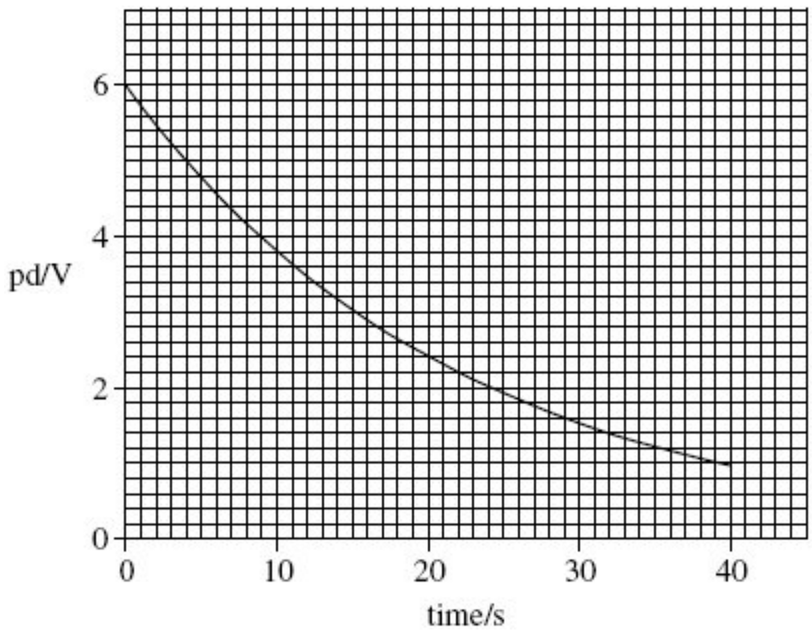
....

(iii) Sketch a graph of pd against time for the student's experiment described in parts (b)(i) and (b)(ii).



(7)
(Total 10 marks)

20 (a) A capacitor, initially charged to a pd of 6.0V, was discharged through a 100 kΩ resistor. A datalogger was used to record the pd across the capacitor at frequent intervals. The graph shows how the pd varied with time during the first 40 s of discharge.



(i) Calculate the initial discharge current.

answer = ... A

(1)

(ii) Use the graph to determine the time constant of the circuit, giving an appropriate unit.

answer = ...

(4)

(iii) Hence calculate the capacitance of the capacitor.

answer = ... μF

(1)

(iv) Show that the capacitor lost 90% of the energy it stored originally after about 25 s.

(3)

(b) In order to produce a time delay, an intruder alarm contains a capacitor identical to the capacitor used in the experiment in part (a). This capacitor is charged from a 12 V supply and then discharges through a 100 kΩ resistor, similar to the one used in the experiment.

(i) State and explain the effect of this higher initial pd on the energy stored by this capacitor initially.

....

....

....

(2)

(ii) State and explain the effect of this higher initial pd on the time taken for this capacitor to lose 90% of its original energy.

....

....

....

(1)
(Total 12 marks)

21 **Figure 1** shows a circuit that is used in a defibrillator in which a short pulse of charge is used to revive a patient who suffers a cardiac arrest in which their heart stops beating.

Figure 2 shows how the charge on the capacitor varies with time when the capacitor is charging.

Figure 1

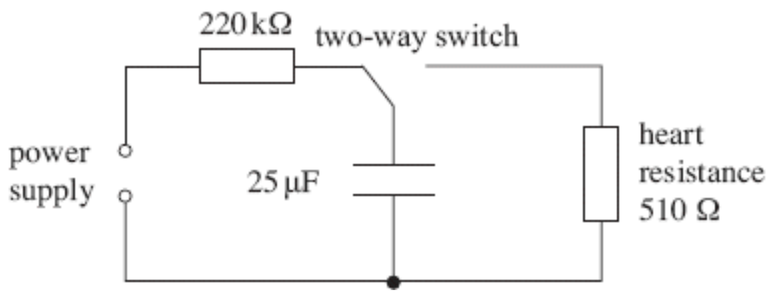
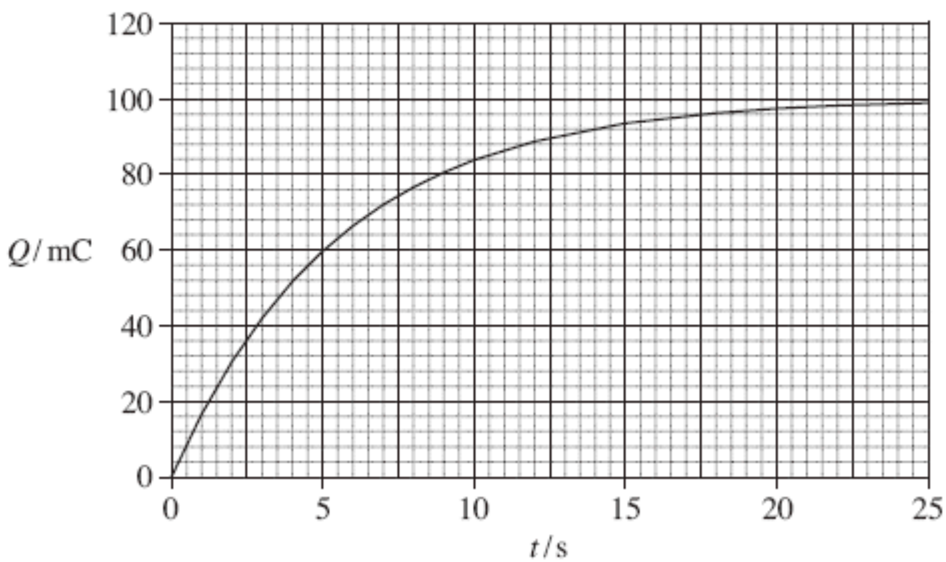


Figure 2



(a) (i) Use **Figure 2** to determine the initial charging current.

....

....

....

....

....

....

....

initial charging current .... A

(2)

(ii) Calculate the emf of the supply used to charge the capacitor.
Assume that the supply has negligible internal resistance.

....

....

....

....

emf of the supply V

(2)

(iii) Explain why the current that charges the capacitor falls as the capacitor charges.

....

....

....

....

....

....

(3)

(b) For the system to work successfully, the capacitor has to deliver 140 J of energy to the heart in a pulse that lasts for 10 ms.

(i) Show that the charge on the capacitor when it is storing this much energy is about 85 mC.

....

....

....

....

....

(2)

(ii) Calculate the average power supplied during the pulse.

....

....

....

average power .... W

(1)

(c) The circuit designer suggests that the capacitor can be used successfully after a charging time equal to 1.5 time constants of the charging circuit shown in **Figure 1**.

Explain with a calculation whether or not the designer's suggestion is valid.

....

....

....

....

....

....

....

....

....

....

(3)
(Total 13 marks)

22 Capacitors and rechargeable batteries are examples of electrical devices that can be used repeatedly to store energy.

(a) (i) A capacitor of capacitance 70 F is used to provide the emergency back-up in a low voltage power supply.

Calculate the energy stored by this capacitor when fully charged to its maximum operating voltage of 1.2 V. Express your answer to an appropriate number of significant figures.

answer = ...J

(3)

(ii) A rechargeable 1.2 V cell used in a cordless telephone can supply a steady current of 55 mA for 10 hours. Show that this cell, when fully charged, stores almost 50 times more energy than the capacitor in part (a)(i).

(2)

(b) Give **two** reasons why a capacitor is **not** a suitable source for powering a cordless telephone.

Reason 1..

....

Reason 2..

....

(2)
(Total 7 marks)

23 (a) A particular heart pacemaker uses a capacitor which has a capacitance of 4.2 μF. Explain what is meant by *a capacitance of 4.2 μF*.

....

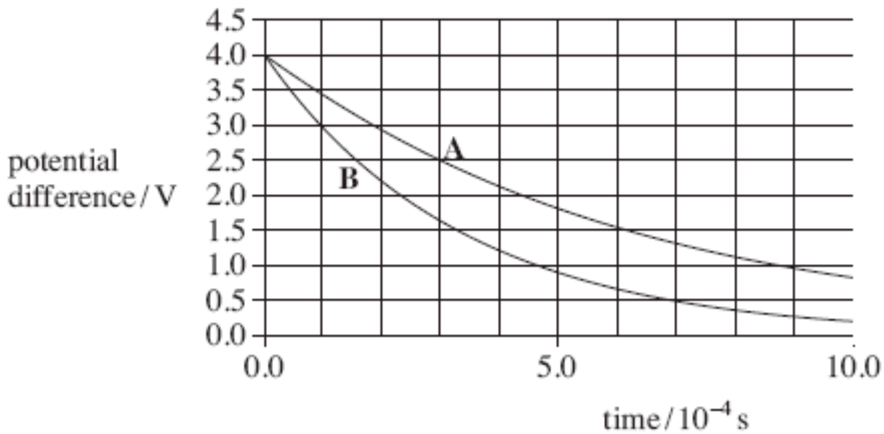
....

....

....

(2)

(b) Capacitor **A**, of capacitance 4.2 μF, is charged to 4.0 V and then discharged through a sample of heart tissue. This capacitor is replaced by capacitor **B** and the charge and discharge process repeated through the same sample of tissue.
The discharge curves are shown in the figure below.



(i) By considering the discharge curve for capacitor **A**, show that the resistance of the sample of heart tissue through which the discharge occurs is approximately 150 Ω.

....

....

....

....

....

(4)

(ii) State and explain whether capacitor **B** has a larger or smaller capacitance than that of capacitor **A**.

....

....

....

....

(2)

(c) Capacitor **A** was charged to a potential difference of 4.0V before discharging through the sample of heart tissue.
Determine how much energy it passed to the sample of heart tissue in the first 0.90 m s of the discharge.

....

....

....

....

....

....

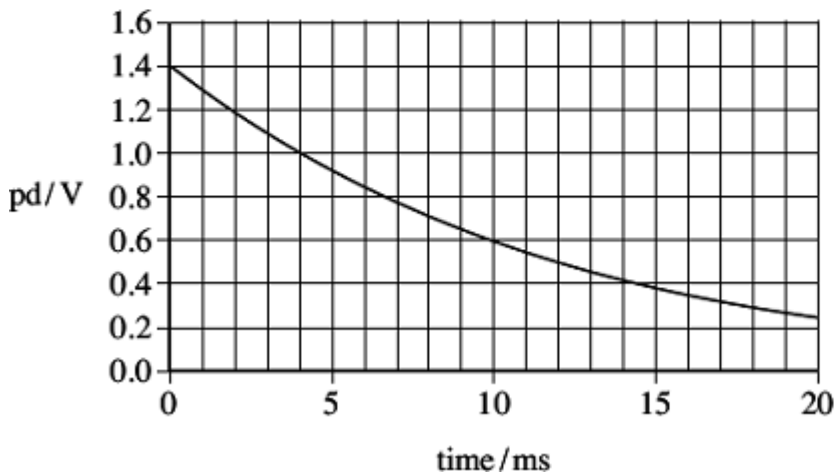
....

....

energy .... J

(3)
(Total 11 marks)

24 The figure below shows part of the discharge curve for a capacitor that a manufacturer tested for use in a heart pacemaker.



The capacitor was initially charged to a potential difference (pd) of 1.4 V and then discharged through a 150 Ω resistor.

(a) Show that the capacitance of the capacitor used is about 80 μF.

....

....

....

....

....

(3)

(b) Explain why the rate of change of the potential difference decreases as the capacitor discharges.

....

....

....

....

....

....

(3)

(c) Calculate the percentage of the initial energy stored by the capacitor that is lost by the capacitor in the first 0.015 s of the discharge.

energy lost ....%

(3)

(d) The charge leaving the capacitor in 0.015 s is the charge used by the pacemaker to provide a single pulse to stimulate the heart.

(i) Calculate the charge delivered to the heart in a single pulse.

charge C

(1)

(ii) The manufacturer of the pacemaker wants it to operate for a minimum of 5 years working at a constant pulse rate of 60 per minute.
Calculate the minimum charge capacity of the power supply that the manufacturer should specify so that it will operate for this time.
Give your answer in amp-hours (Ah).

minimum capacity ....Ah

(2)
(Total 12 marks)

25 (a) Define the capacitance of a capacitor.

....

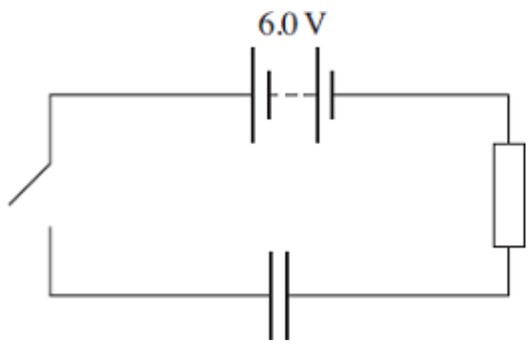
....

....

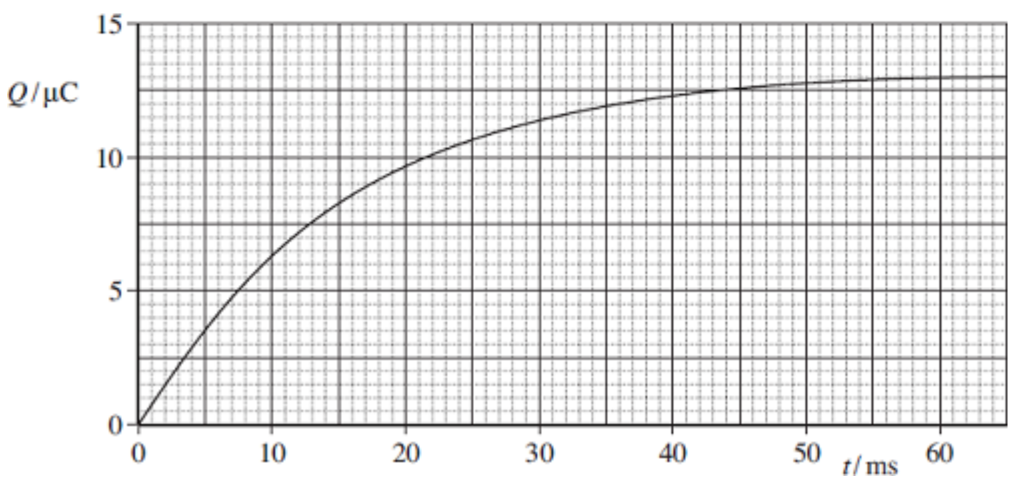
....

(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.

answer = ... 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.

answer = ... ms

(2)

(iii) Hence calculate the resistance of the resistor.

answer = ... Ω

(1)

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

....

....

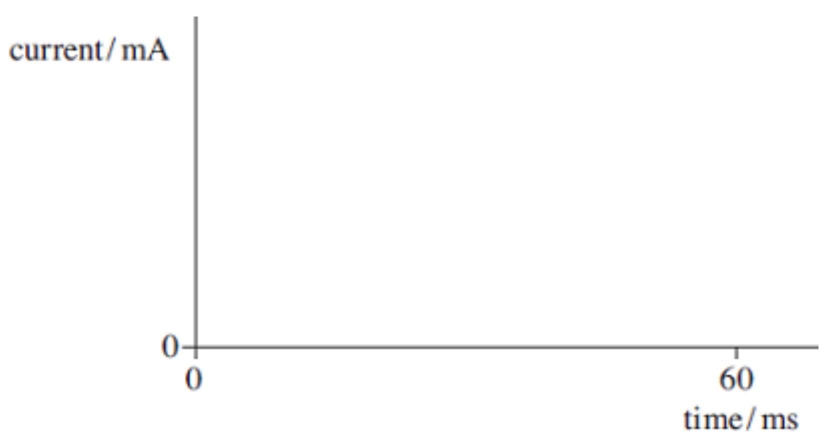
(1)

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

answer = ... mA

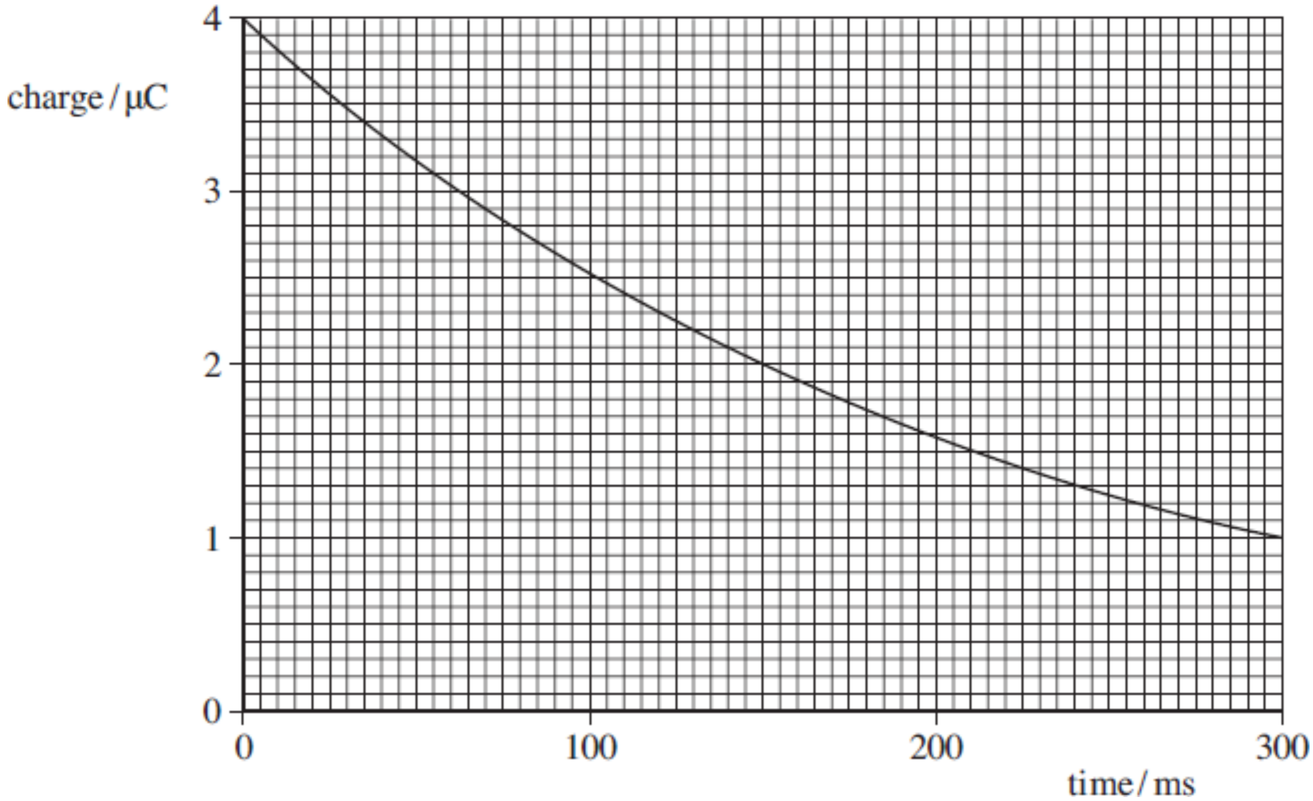
(1)

(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.



(2)
(Total 11 marks)

26 The graph below shows how the charge stored by a capacitor varies with time when it is discharged through a fixed resistor.



(a) Determine the time constant, in ms, of the discharge circuit.

time constant .... ms

(3)

(b) Explain why the rate of discharge will be greater if the fixed resistor has a smaller resistance.

....

....

....

....

....

(2)
(Total 5 marks)

27 (a) When an uncharged capacitor is charged by a **constant** current of 4.5 μA for 60 s the pd across it becomes 4.4 V.

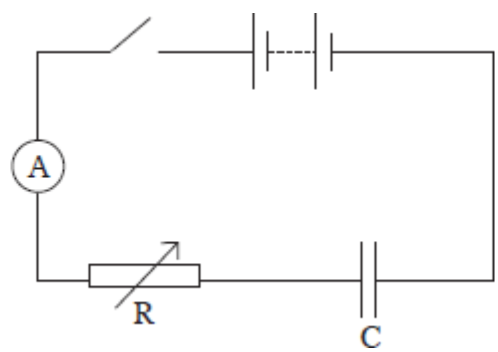
(i) Calculate the capacitance of the capacitor.

capacitance .... F

(3)

(ii) The capacitor is charged using the circuit shown in **Figure 1**. The battery emf is 6.0 V and its internal resistance is negligible. In order to keep the current constant at 4.5 μA, the resistance of the variable resistor R is decreased steadily as the charge on the capacitor increases.

Figure 1



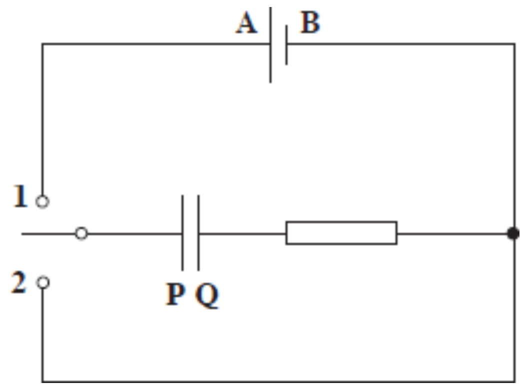
Calculate the resistance of R when the uncharged capacitor has been charging for 30 s.

resistance .... Ω

(3)

(b) The circuit in **Figure 2** contains a cell, an uncharged capacitor, a fixed resistor and a two-way switch.

Figure 2



The switch is moved to position **1** until the capacitor is fully charged. The switch is then moved to position **2**.

Describe what happens in this circuit after the switch is moved to position **1**, and after it has been moved to position **2**. In your answer you should refer to:

- the direction in which electrons flow in the circuit, and how the flow of electrons changes with time,
- how the potential differences across the resistor and the capacitor change with time,
- the energy changes which take place in the circuit.

The terminals of the cell are labelled **A** and **B** and the capacitor plates are labelled **P** and **Q** so that you can refer to them in your answer.

The quality of your written communication will be assessed in your answer.

....

....

....

....

....

....

....

....

....

....

(6)
(Total 12 marks)

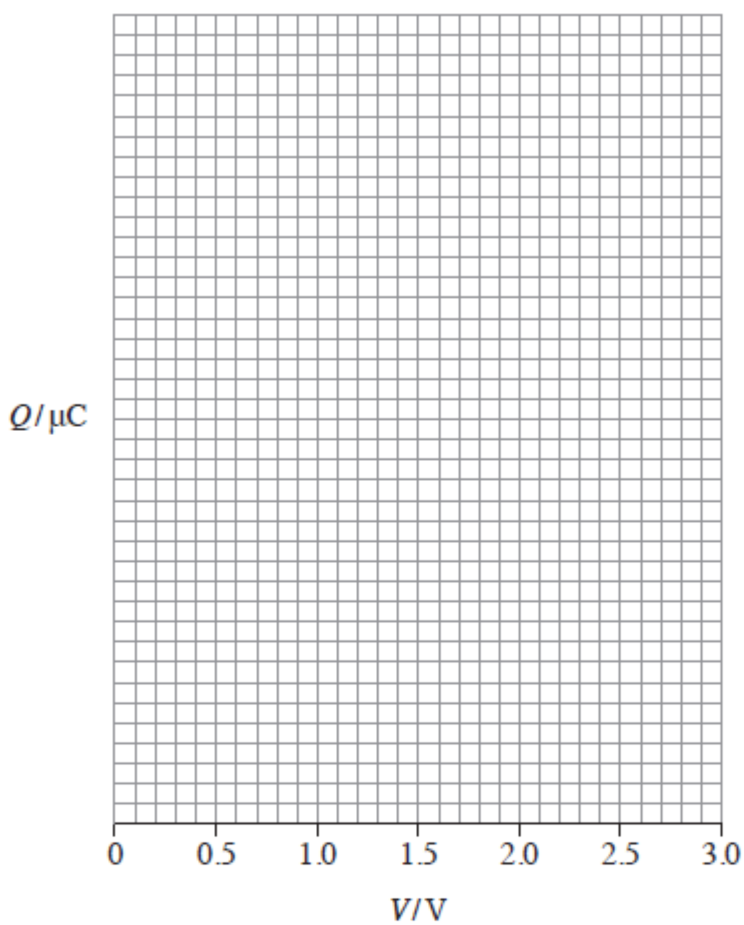
28 The specification for a pacemaker requires a suitable charge to be delivered in 1.4 ms. A designer uses a circuit with a capacitor of capacitance 3.0 μF and a 2.5 V power supply to deliver the charge. The designer calculates that a suitable charge will be delivered to the heart as the capacitor discharges from a potential difference (pd) of 2.5 V to a pd of 1.2 V in 1.4 ms.

(a) (i) Calculate the charge on the capacitor when it is charged to a pd of 2.5 V.

charge C

(1)

(ii) Draw a graph showing how the charge, Q, on the capacitor varies with the pd, V, as it discharges through the heart.
Include an appropriate scale on the charge axis.



(3)

(b) Calculate the energy delivered to the heart in a single pulse from the pacemaker when the capacitor discharges to 1.2 V from 2.5 V.

energy .... J

(3)

(c) (i) Calculate the resistance of the heart that has been assumed in the design.

resistance .... Ω

(3)

(ii) Explain why the rate of change of pd between the capacitor plates decreases as the capacitor discharges.

....

....

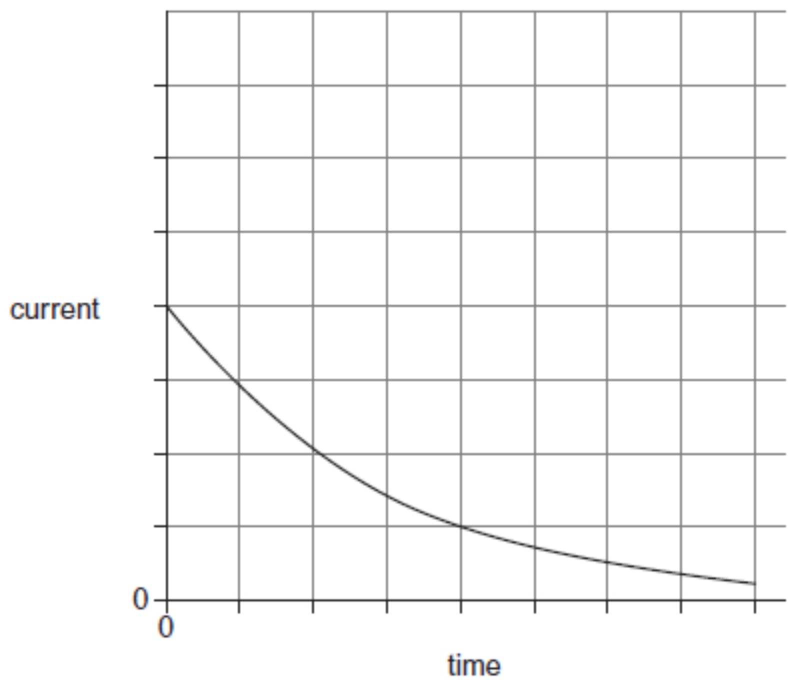
....

....

....

(2)
(Total 12 marks)

29 (a) The graph shows how the current varies with time as a capacitor is discharged through a 150 Ω resistor.



(i) Explain how the initial charge on the capacitor could be determined from a graph of current against time.

....

....

....

....

(1)

(ii) The same capacitor is charged to the same initial potential difference (pd) and then discharged through a 300 kΩ resistor. Sketch a second graph on the same axes above to show how the current varies with time in this case.

(3)

(b) In an experiment to show that a capacitor stores energy, a student charges a capacitor from a battery and then discharges it through a small electric motor. The motor is used to lift a mass vertically.

(i) The capacitance of the capacitor is 0.12 F and it is charged to a pd of 9.0 V.
The weight of the mass raised is 3.5 N.
Calculate the maximum height to which the mass could be raised.
Give your answer to an appropriate number of significant figures.

maximum height .... m

(4)

(ii) Give **two** reasons why the value you have calculated in part (i) would not be achieved in practice.

1 ....

....

....

....

2 ....

....

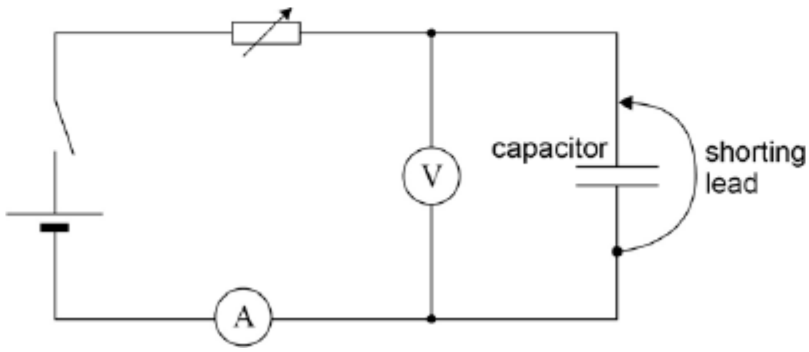
....

....

(2)
(Total 10 marks)

30 This question is about capacitor charging and discharging.

A student designs an experiment to charge a capacitor using a constant current. The figure below shows the circuit the student designed to allow charge to flow onto a capacitor that has been initially discharged.



The student begins the experiment with the shorting lead connected across the capacitor as in the figure above. The variable resistor is then adjusted to give a suitable ammeter reading. The shorting lead is removed so that the capacitor begins to charge. At the same instant, the stop clock is started.

The student intends to measure the potential difference (pd) across the capacitor at 10 s intervals while adjusting the variable resistor to keep the charging current constant.

The power supply has an emf of 6.0 V and negligible internal resistance. The capacitor has a capacitance of 680 μF. The variable resistor has a maximum resistance of 100 kΩ.

(a) The student chooses a digital voltmeter for the experiment. A digital voltmeter has a very high resistance.

Explain why it is important to use a voltmeter with very high resistance.

....

....

....

(1)

(b) Suggest **one** advantage of using an analogue ammeter rather than a digital ammeter for this experiment.

....

....

....

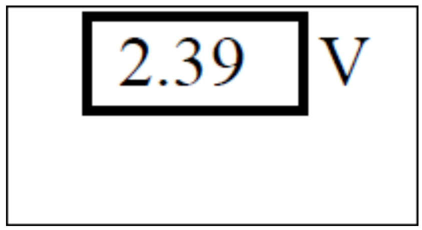
(1)

(c) Suggest a suitable full scale deflection for an analogue ammeter to be used in the experiment.

full scale deflection = ...

(2)

(d) The diagram shows the reading on the voltmeter at one instant during the experiment. The manufacturer gives the uncertainty in the meter reading as 2%.



Calculate the absolute uncertainty in this reading.

uncertainty = ...V

(1)

(e) Determine the number of different readings the student will be able to take before the capacitor becomes fully charged.

number = ...

(3)

(f) The experiment is performed with a capacitor of nominal value 680 μF and a manufacturing tolerance of ± 5 %. In this experiment the charging current is maintained at 65 μA. The data from the experiment produces a straight-line graph for the variation of pd with time. This shows that the pd across the capacitor increases at a rate of 98 mV s^{-1}.

Calculate the capacitance of the capacitor.

capacitance = ...μF

(2)

(g) Deduce whether the capacitor is within the manufacturer's tolerance.

....

....

....

(1)

(h) The student decides to confirm the value of the capacitance by first determining the time constant of the circuit when the capacitor **discharges** through a **fixed** resistor.

Describe an experiment to do this. Include in your answer:

- a circuit diagram
- an outline of a procedure
- an explanation of how you would use the data to determine the time constant.

....

....

....

....

....

....

....

....

....

....

(4)
(Total 15 marks)