1)

(a) Define the capacitance of a capacitor.

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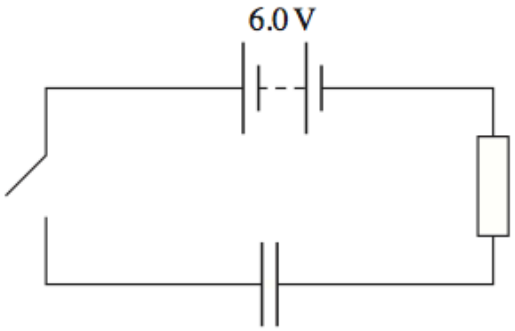
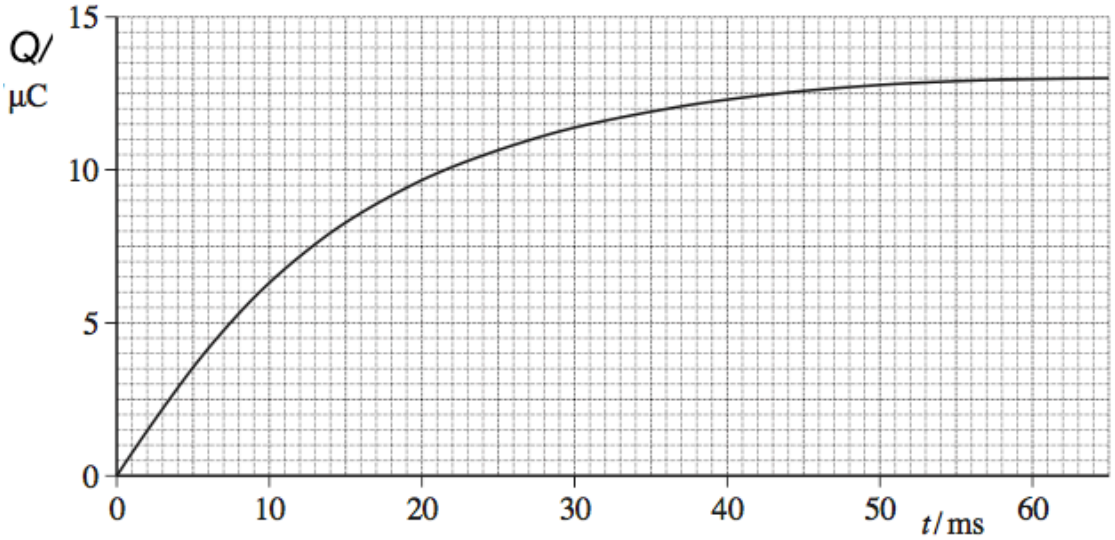
(2 marks)

(b) The circuit shown in **Figure 3** contains a battery, a resistor, a capacitor and a switch.

Figure 3



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 marks)

(b) (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 marks)

(b) (iii) Hence calculate the resistance of the resistor.

answer = ... Ω

(1 mark)

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

.....

.....

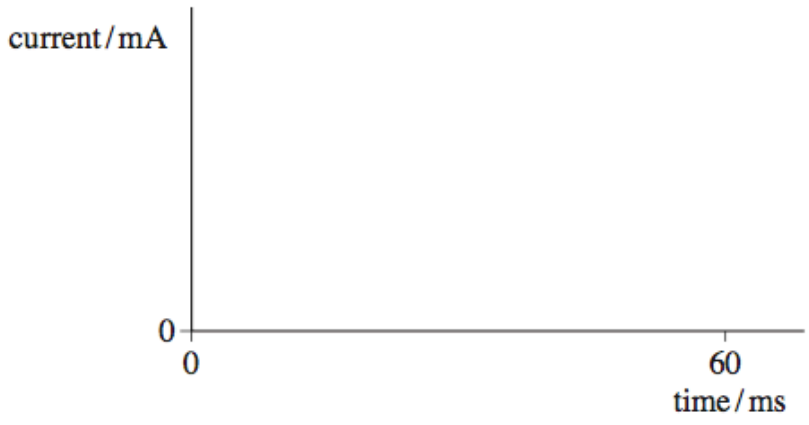
(1 mark)

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

answer = ... mA

(1 mark)

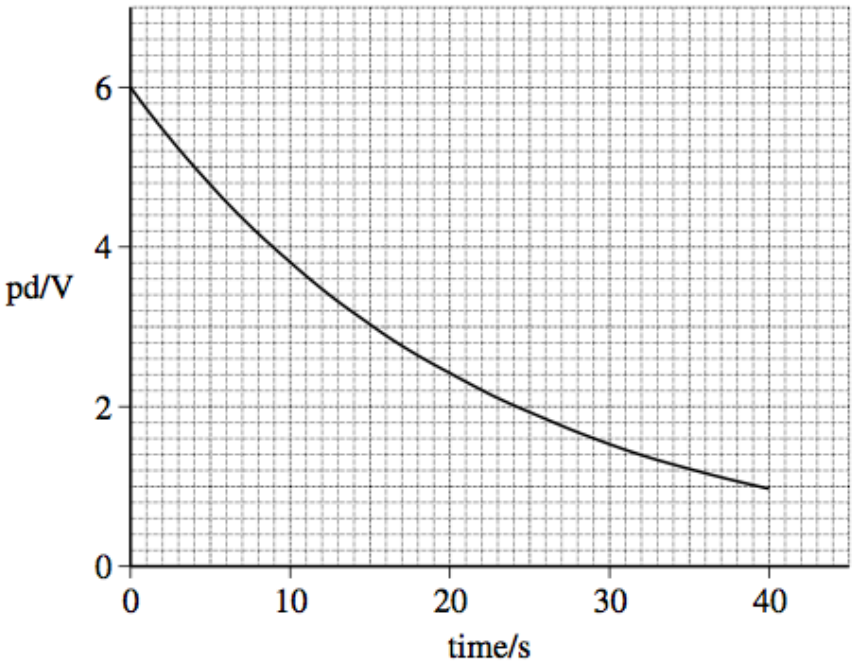
(c) (ii) Sketch a graph on the outline axes to show how the current varies with time as the capacitor is charged. Mark the maximum value of the current on your graph.



(2 marks)

2)

(a) A capacitor, initially charged to a pd of 6.0 V, 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.



(a) (i) Calculate the initial discharge current.

answer = ... A

(1 mark)

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

answer = ...

(4 marks)

(a) (iii) Hence calculate the capacitance of the capacitor.

answer = ... μF
(1 mark)

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

(3 marks)

(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.

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

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(2 marks)

(b) (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.

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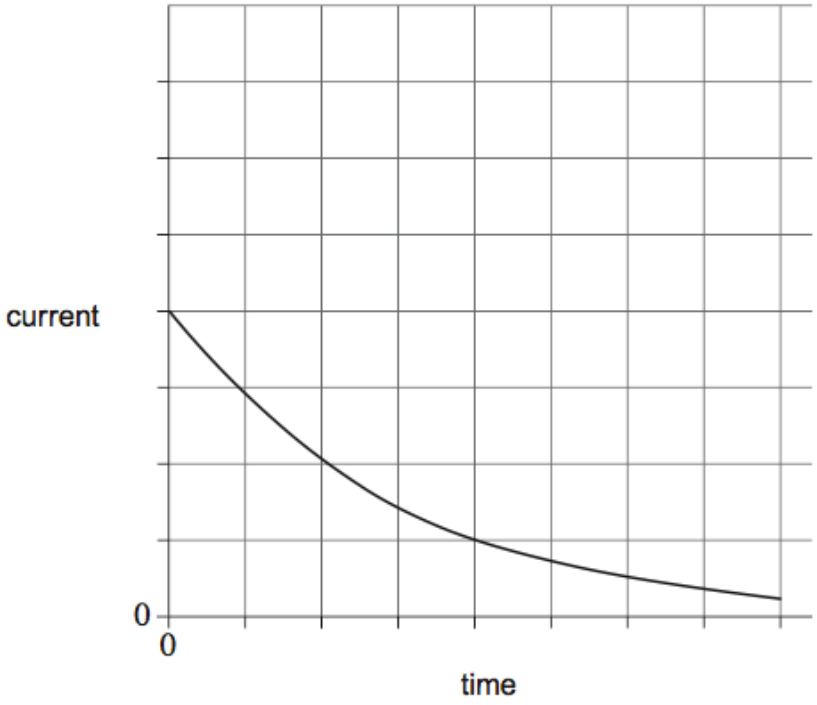
(1 mark)

3)

(a) **Figure 4** shows how the current varies with time as a capacitor is discharged through a 150 Ω resistor.

Figure 4



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

[1 mark]

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

[3 marks]

(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.

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

[4 marks]

maximum height ..... m

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

[2 marks]

1 .....

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2 .....

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4)

(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.

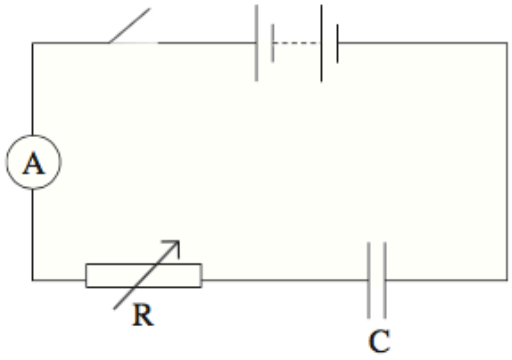
(a) (i) Calculate the capacitance of the capacitor.

[3 marks]

capacitance ..... F

(a) (ii) The capacitor is charged using the circuit shown in **Figure 5**. 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 5



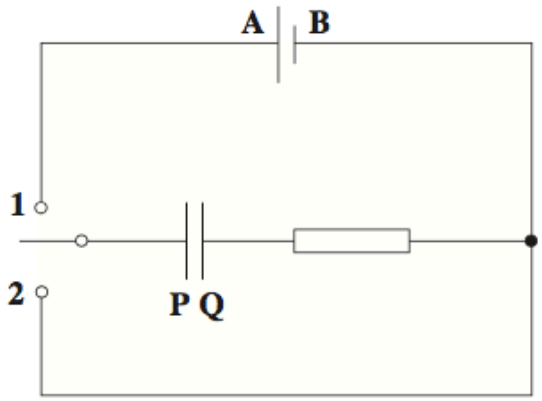
Calculate the resistance of R when the uncharged capacitor has been charging for 30 s.

[3 marks]

resistance ..... Ω

(b) The circuit in **Figure 6** contains a cell, an uncharged capacitor, a fixed resistor and a two-way switch.

Figure 6



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 marks]

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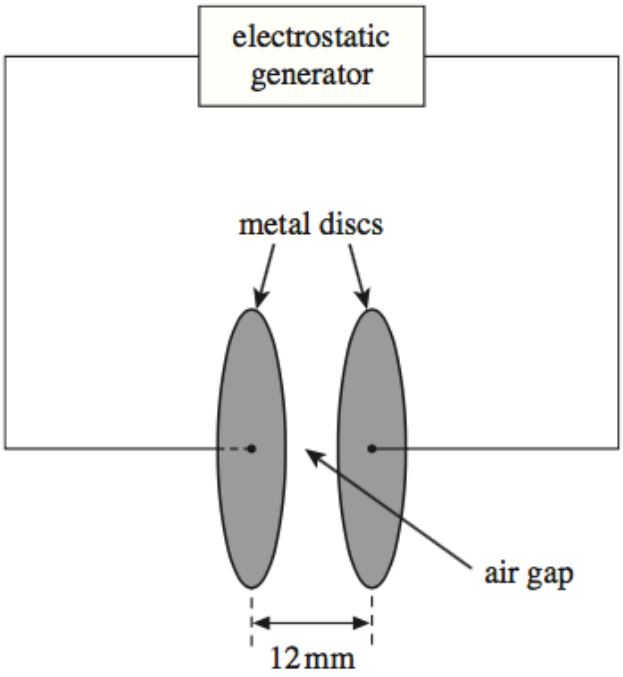
5)

Figure 1 shows an arrangement to demonstrate sparks passing across an air gap between two parallel metal discs. Sparks occur when the electric field in the gap becomes large enough to equal the breakdown field strength of the air. The discs form a capacitor, which is charged at a constant rate by an electrostatic generator until the potential difference (pd) across the discs is large enough for a spark to pass. Sparks are then produced at regular time intervals whilst the generator is switched on.

Figure 1



(a) The electrostatic generator charges the discs at a constant rate of 3.2×10^{-8} A on a day when the minimum breakdown field strength of the air is 2.5×10^{6} V m^{-1}. The discs have a capacitance of 3.7×10^{-12} F.

(a) (i) The air gap is 12 mm wide. Calculate the minimum pd required across the discs for a spark to occur. Assume that the electric field in the air gap is uniform.

pd V

(1 mark)

(a) (ii) Calculate the time taken, from when the electrostatic generator is first switched on, for the pd across the discs to reach the value calculated in part (a)(i).

time ..... s

(2 marks)

(b) The discs are replaced by ones of larger area placed at the same separation, to give a larger capacitance.

State and explain what effect this increased capacitance will have on:

(b) (i) the time between consecutive discharges,

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(2 marks)

(b) (ii) the brightness of each spark.

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(2 marks)

6)

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 marks)

(a) (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 marks)

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

Reason 1.....

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Reason 2.....

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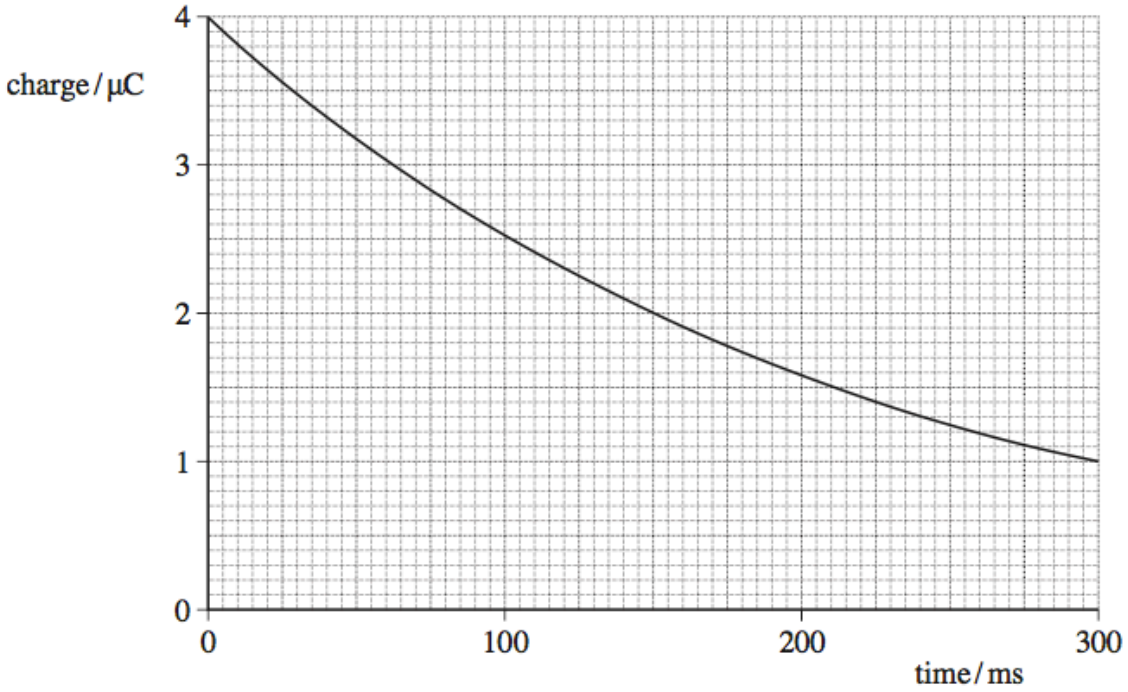
(2 marks)

7)

Figure 2 shows how the charge stored by a capacitor varies with time when it is discharged through a fixed resistor.

Figure 2



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

time constant ..... ms

(3 marks)

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

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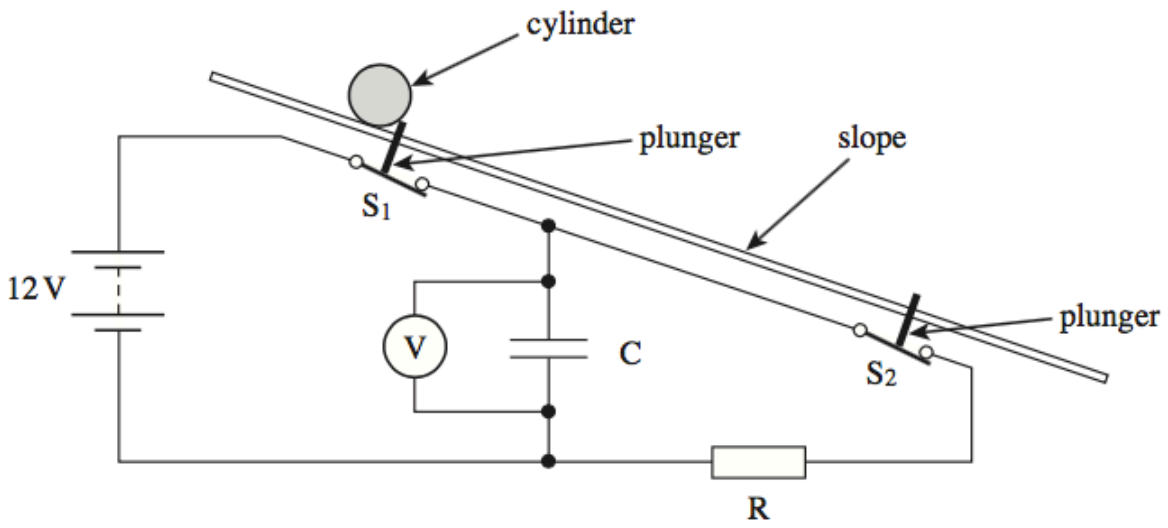
(2 marks)

8)

A student was required to design an experiment to measure the acceleration of a heavy cylinder as it rolled down an inclined slope of constant gradient. He suggested an arrangement that would make use of a capacitor-resistor discharge circuit to measure the time taken for the cylinder to travel between two points on the slope. The principle of this arrangement is shown in **Figure 2**.

Figure 2



S_1 and S_2 are two switches that would be opened in turn by plungers as the cylinder passed over them. Once opened, the switches would remain open. The cylinder would be released from rest as it opened S_1. The pd across the capacitator would be measured by the voltmeter.

(a) Describe the procedure the student should follow, including the measurements he should make, when using this arrangement. Explain how he should use the measurements taken to calculate the acceleration of the cylinder down the slope.

The quality of your written communication will be assessed in this question.

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(6 marks)

(b) When the student set up his experiment using the arrangement shown in **Figure 2**, he used a 22 μF capacitor, C, and a 200 kΩ resistor, R. In one of his results, the initial pd was 12.0 V and the final pd was 5.8 V. The distance between the plungers was 2.5 m.

(b) (i) From the student's result, calculate the time taken for the cylinder to reach the second plunger.

answer = ...s

(3 marks)

(b) (ii) What value does this result give for the acceleration of the cylinder down the slope, assuming the acceleration is constant?

answer = ... $m\,s^{-2}$

(2 marks)