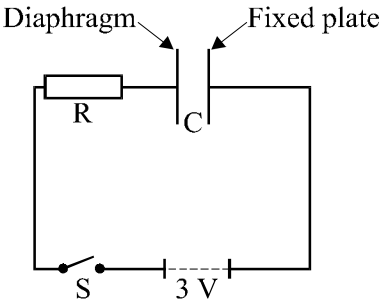
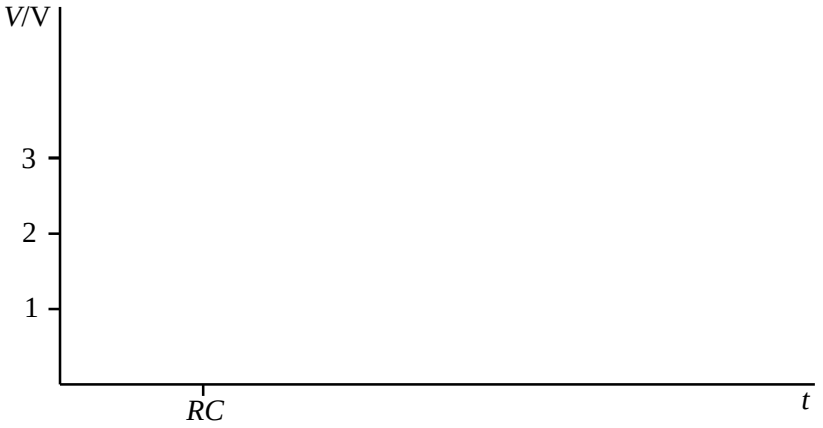
Questions on Capacitors

1. Most types of microphone detect sound because the sound waves cause a diaphragm to vibrate. In one type of microphone this diaphragm forms one plate of a parallel plate capacitor. As the diaphragm plate moves. the capacitance chances. Moving the plates closer together increases the capacitance. Moving the plates further apart reduces the capacitance.

This effect is used to produce the electrical signal. The circuit shown below consists of a 3 V supply, an **uncharged** capacitor microphone C. a resistor R. and a switch S.



The switch S is closed. Sketch a graph of the voltage across the capacitor microphone against time. Assume that the capacitor microphone is not detecting any sound.



(3)

Explain why movement of the diaphragm causes a potential difference (the signal) across R.

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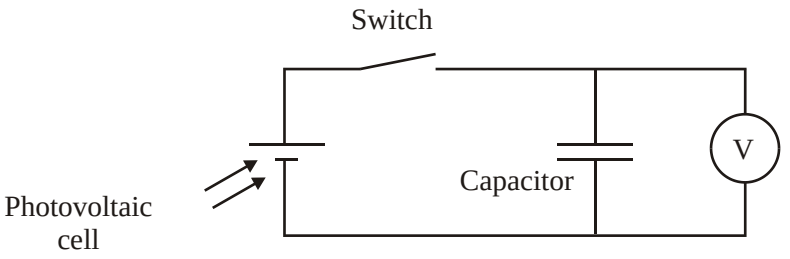
(4)

(Total 7 marks)

2. The circuit below models a single pixel of a CCD device. The photocell generates a voltage which depends on the intensity of light falling on it. When information about light intensity is required, the switch is opened. The voltage across the capacitor at that instant can be read out into an electronic circuit (represented by the voltmeter) at a later time.



The capacitor has a value of 0.22 F. In an experiment the voltmeter reads 95 mV after the switch is opened. Calculate the charge on the capacitor.

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Charge = ...

(2)

This voltmeter reads 95 mV for some considerable time. State what this tells you about this voltmeter.

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(1)

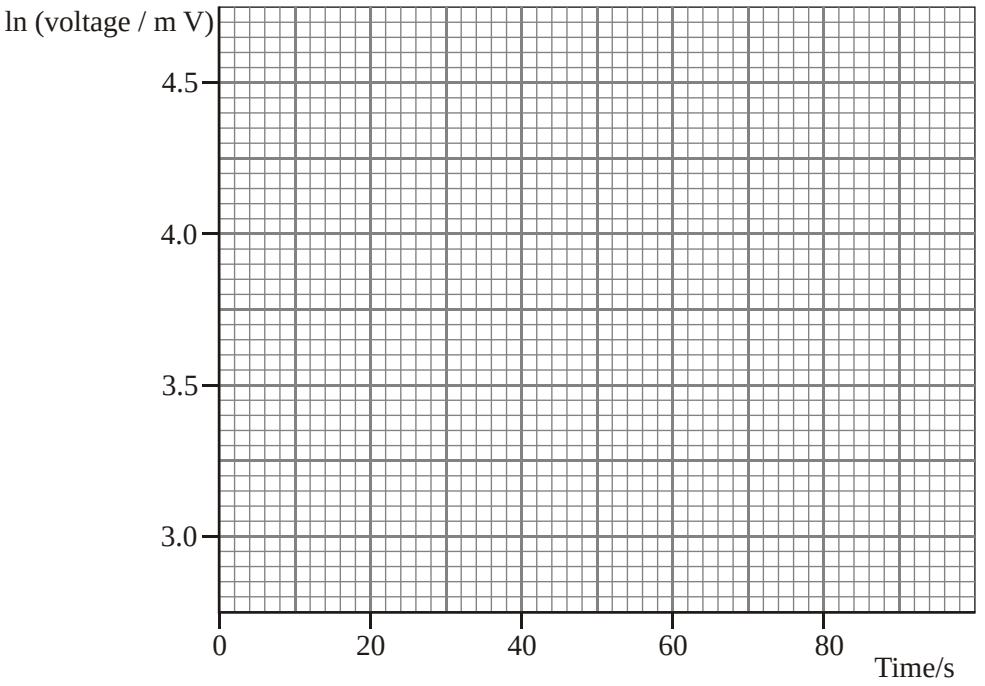
The student doing the experiment changes the voltmeter for another. With the **new** voltmeter the voltage changes with time according to the table below.

Time/s	Voltage/mV	ln(voltage/mV)
0	95	4.55
20	67	4.20
40	46	
60	33	
80	22	

The student thinks the voltage is falling exponentially. To test this he makes a third column in his table to calculate values for ln(voltage/mV). Complete the table.

(1)

Plot the points from the table on the graph below. Join the points with an appropriate line.



(3)

Explain how the graph shows that the voltage decreases exponentially.

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(2)

Find the approximate value for the resistance of the second voltmeter.

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Resistance = ...

(3)

(Total 12 marks)

3. A student is learning about how capacitors work. He uses the circuit shown in Figure 1 to investigate the capacitor C. Letter X labels a connection which he can make to either of the points L or M. Each cell has an e.m.f. of 1.5 V.

Figure 1

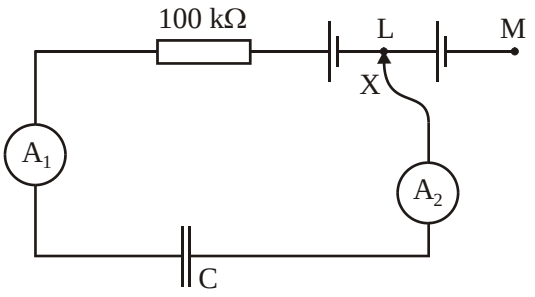
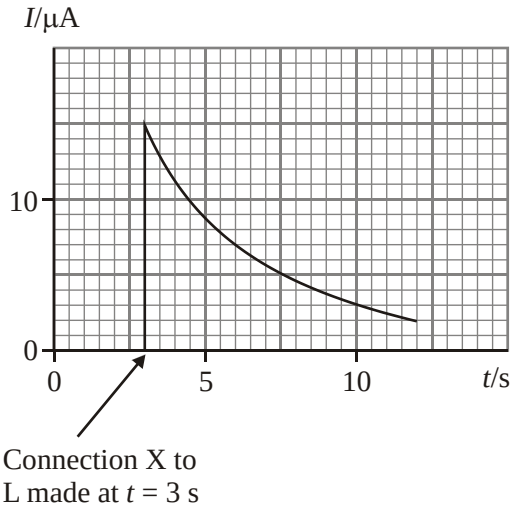


Figure 2



He connects X to L. He sketches how the reading on ammeter 1 varies with time (Figure 2).

Explain in terms of charge what has happened in the circuit.

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(3)

Explain what he would have seen if he had watched ammeter 2.

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(2)

Use his sketch graph (Figure 2) to estimate the charge which has passed through ammeter 1 between the times $t = 3$ s and $t = 10$ s.

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Charge = ...

(2)

Use the graph and your answer above to estimate the capacitance of the capacitor.

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Capacitance = ...

(3)

State and explain what he would observe on each ammeter if he then continued the experiment by moving the connection X from L to M.

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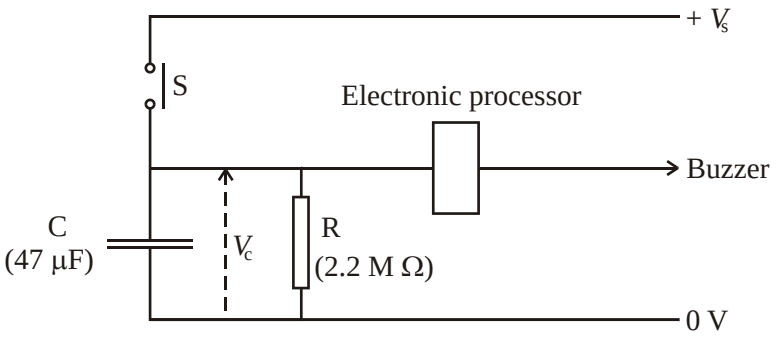
(2)

(Total 12 marks)

4. The diagram shows a simple timing circuit.



The electronic processor operates so that the buzzer sounds when V_c is greater than $\frac{3}{4} V_s$. The switch S is normally open. Explain in detail what happens in the circuit after the switch S is closed for a moment then opened again. Your answer should include an appropriate calculation and a sketch graph.

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(Total 7 marks)

5. Define capacitance.

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(2)

An uncharged capacitor of 200 μF is connected in series with a 470 kΩ resistor, a 1.50 V cell and a switch. Draw a circuit diagram of this arrangement.

(1)

Calculate the maximum current that flows.

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Current .....

(2)

Sketch a graph of voltage against charge for your capacitor as it charges. Indicate on the graph the energy stored when the capacitor is fully charged.

(4)

Calculate the energy stored in the fully-charged capacitor.

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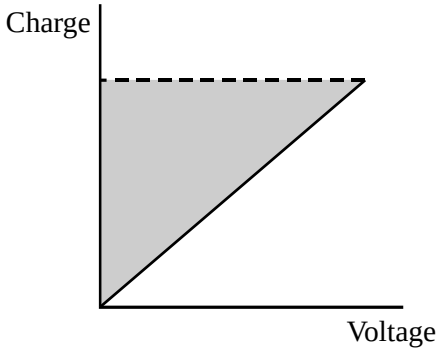
Energy = ...

(2)

(Total 11 marks)

6. The diagram shows a graph of charge against voltage for a capacitor.



What quantity is represented by the slope of the graph?

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What quantity is represented by the shaded area?

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(2)

An electronic camera flash gun contains a capacitor of 100 μF which is charged to a voltage of 250 V. Show that the energy stored is 3.1 J.

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(2)

The capacitor is charged by an electronic circuit that is powered by a 1.5 V cell. The current drawn from the cell is 0.20 A. Calculate the power from the cell and from this the minimum time for the cell to recharge the capacitor.

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Minimum time = ...

(3)

(Total 7 marks)

7. A defibrillator is a machine that is used to correct irregular heartbeats by passing a large current through the heart for a short time. The machine uses a 6000 V supply to charge a capacitor of capacitance 20 μF. The capacitor is then discharged through the metal electrodes (defibrillator paddles) which have been placed on the chest of the patient.

Calculate the charge on the capacitor plates when charged to 6000 V.

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Charge = ...

(2)

Calculate the energy stored in the capacitor.

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Energy = ...

(2)

When the capacitor is discharged, there is an initial current of 40 A through the patient.

Calculate the electrical resistance of the body tissue between the metal electrodes of the paddles.

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Resistance = ...

(1)

Assuming a constant discharge rate of 40 A, calculate how long it would take to discharge the capacitor.

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Time = ...

(2)

In practice the time for discharge is longer than this calculated time. Suggest a reason for this

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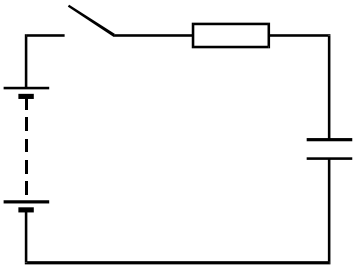
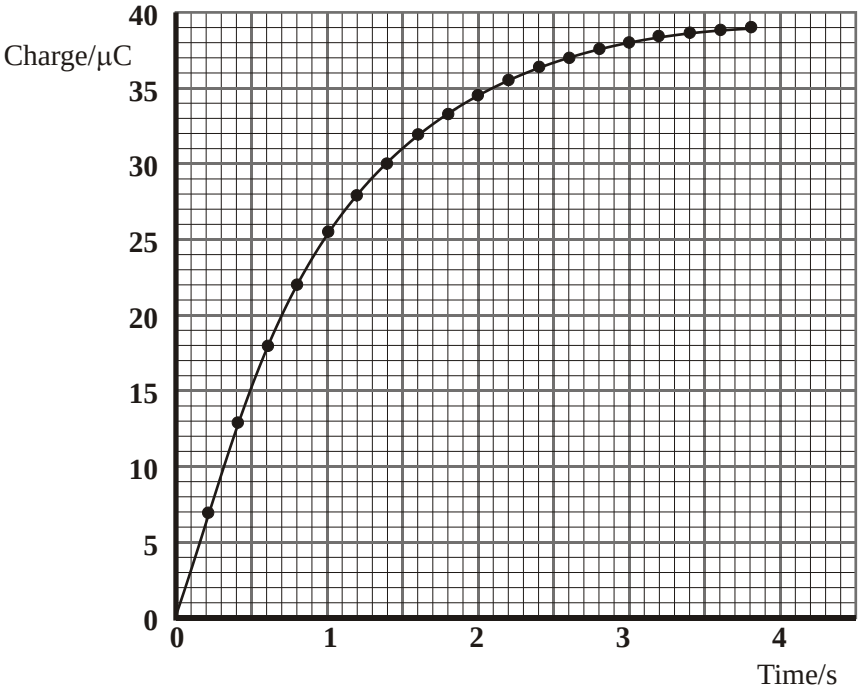
(1)

(Total 8 marks)

8. The circuit shown is used to charge a capacitor.



The graph shows the charge stored on the capacitor whilst it is being charged.



On the same axes, sketch as accurately as you can a graph of current against time.
Label the current axis with an appropriate scale.

(4)

The power supply is 3 V. Calculate the resistance of the charging circuit.

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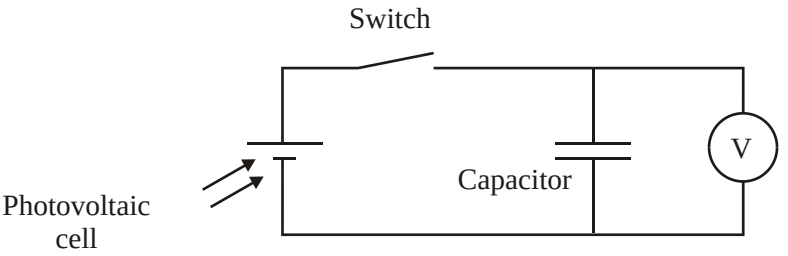
Resistance = ...

(2)
(Total 6 marks)

9. The circuit below models a single pixel of a CCD device. The photocell generates a voltage which depends on the intensity of light falling on it. When information about light intensity is required, the switch is opened. The voltage across the capacitor at that instant can be read out into an electronic circuit (represented by the voltmeter) at a later time.



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.....

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(2)

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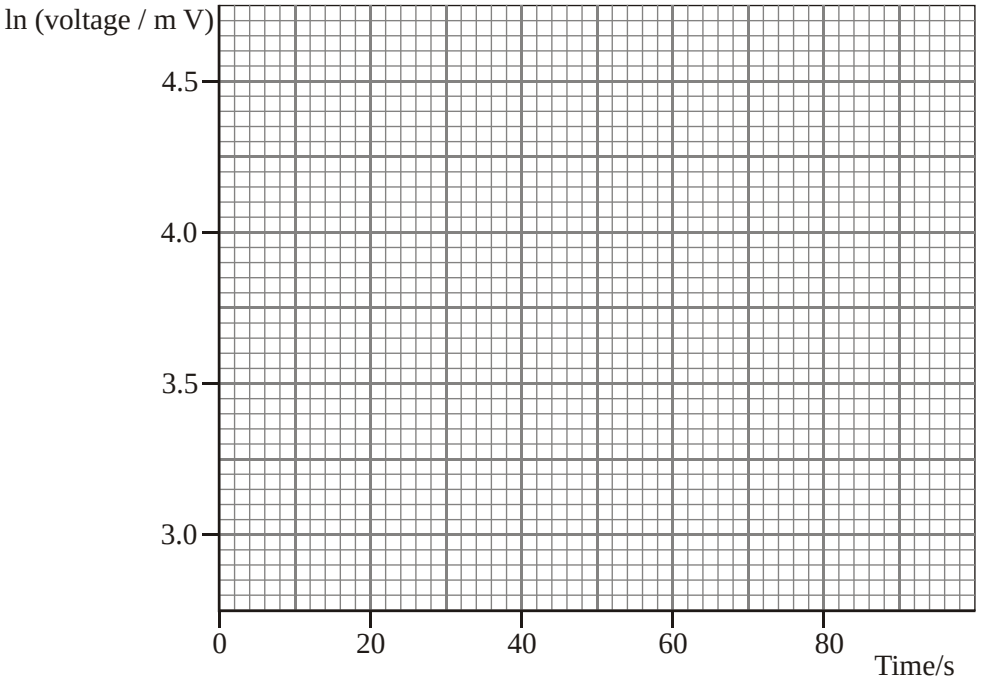
(1)

Plot the points from the table on the graph below. Join the points with an appropriate line.



(3)

Explain how the graph shows that the voltage decreases exponentially.

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(2)

Find the approximate value for the resistance of the second voltmeter.

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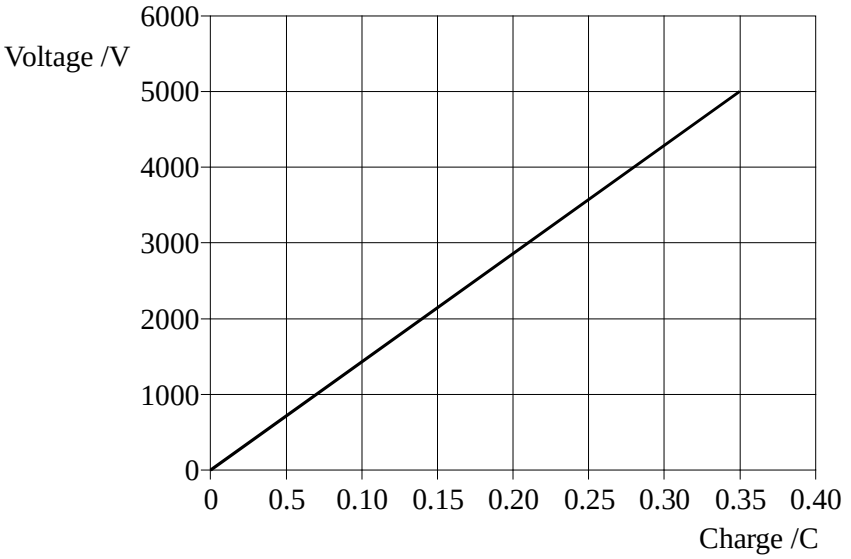
Resistance = ...

(3)

(Total 12 marks)

10. To restore a regular heart rhythm to a patient in an emergency, paramedics can use a machine called a defibrillator. The defibrillator uses a capacitor to store energy at a voltage of several thousand volts. Conducting 'paddles' are placed on either side of the patient's chest, and a short pulse of current flows between them when the capacitor is discharged.

The graph below shows voltage against charge for the capacitor used in a defibrillator.



With reference to the graph, show that the energy stored in a capacitor is given by the formula $W = \frac{1}{2}QV$.

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(2)

Calculate the energy stored by the capacitor when charged to 5000 V.

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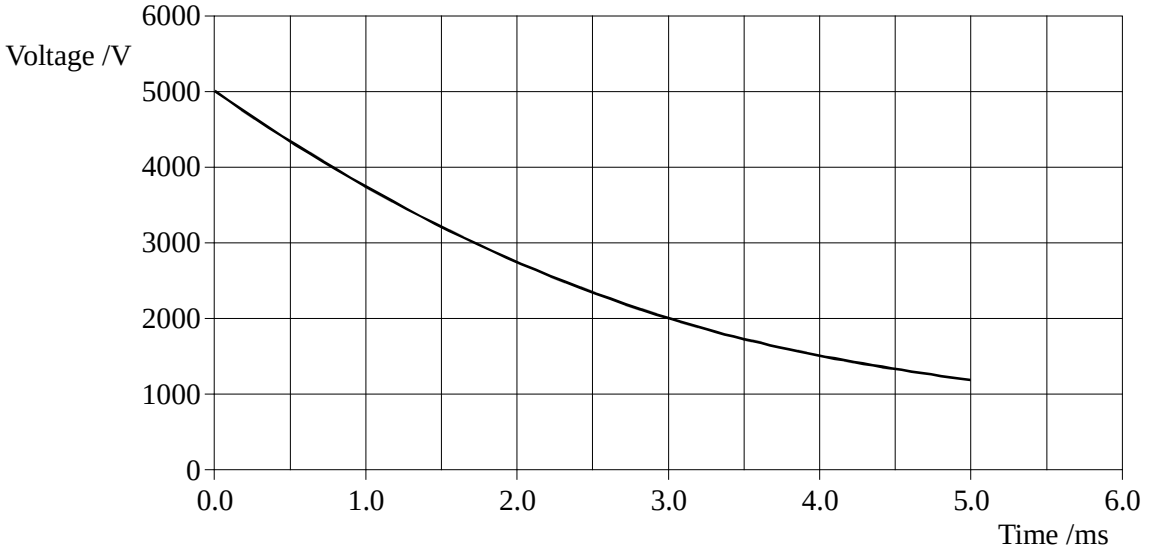
Energy = ...

(1)

The graph below shows how voltage varies with time as the capacitor's discharged across a test circuit that has a resistance equivalent to that of the patient's chest.



Use the graph to find the time constant for the circuit.

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Time constant = ...

(2)

The total resistance of the circuit, including the paddles and chest, is 47 Ω. Calculate the capacitance of the capacitor.

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Capacitance = ...

(2)

The energy delivered to the patient's chest is selected by the operator from these settings: 50 J, 180 J, 380 J. This is achieved inside the machine electronically, by allowing the discharge to proceed for an appropriate length of time.

On one particular setting, the discharge lasts for 2.0 ms. Calculate the energy left in the capacitor at this time.

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(2)

Some energy loss occurs and roughly 60% of the energy leaving the capacitor during the discharge actually goes into the patient. Find which setting the operator has selected.

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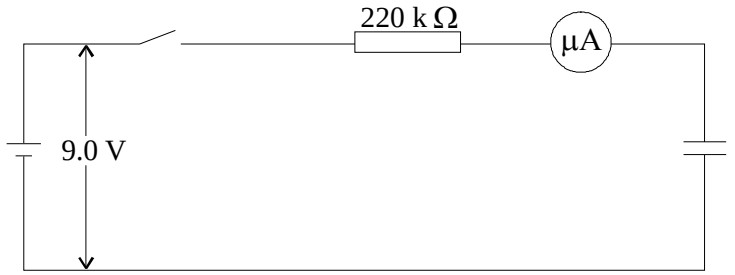
Energy setting = ...

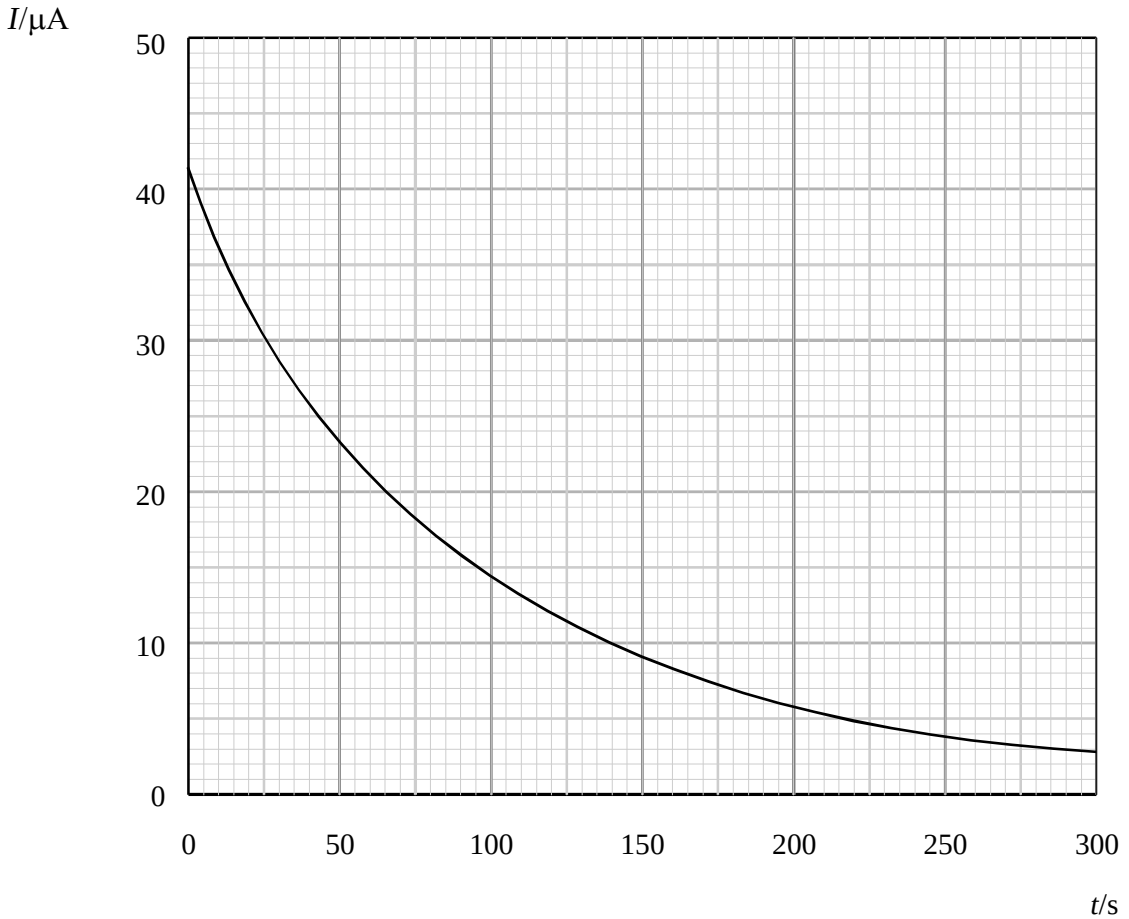
(2)

(Total 11 marks)

11. A student assembles the circuit shown in which the switch is initially open and the capacitor uncharged.



He closes the switch and reads the microammeter at regular intervals of time. The battery maintains a steady p.d. of 9.0 V throughout. The graph shows how the current *I* varies with the time *t* since the switch was closed.



Use the graph to estimate the total charge delivered to the capacitor.

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Charge =.....

(3)

Estimate its capacitance.

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Capacitance =.....

(2)

(Total 5 marks)

12. The potential difference between the plates of a 220 μF capacitor is 5.0 V.

Calculate the **charge** stored on the capacitor.

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Charge = ...

(2)

Calculate the **energy** stored by the capacitor.

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Energy = ...

(2)

Describe how you would show experimentally that the charge stored on a 220 μF capacitor is proportional to the potential difference across the capacitor for a range of potential differences between 0 and 15 V. Your answer should include a circuit diagram.

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(5)
(Total 9 marks)