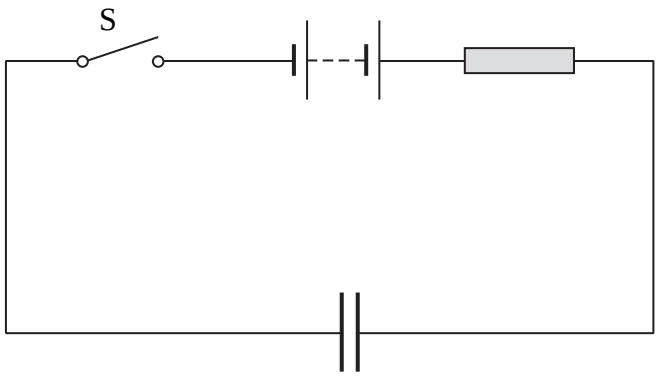
Capacitors QP1

1 An uncharged capacitor is connected into a circuit as shown.



(a) Describe what happens to the capacitor when the switch S is closed.

(2)

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(b) A student models the behaviour of the circuit using a spreadsheet. The student uses a 100 μF capacitor, a 3.00 kΩ resistor and 5.00 V power supply. The switch is closed at time t = 0 s.

	A	B	C	D	E
1	t / s	I / mA	ΔQ / μC	Q / μC	p.d. across capacitor/V
2	0	1.67	167	167	1.67
3	0.1	1.11	111	278	2.78
4	0.2	0.74	74	352	3.52
5	0.3	0.49	49	401	4.01
6	0.4	0.33	33	434	4.34
7	0.5	0.22	22	456	4.56
8	0.6	0.15	15	471	4.71
9	0.7	0.10	10	480	4.80
10	0.8	0.07	7	487	4.87

(i) Explain how the value in cell C4 is calculated.

(2)

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(ii) Explain how the value in cell E3 is calculated.

(2)

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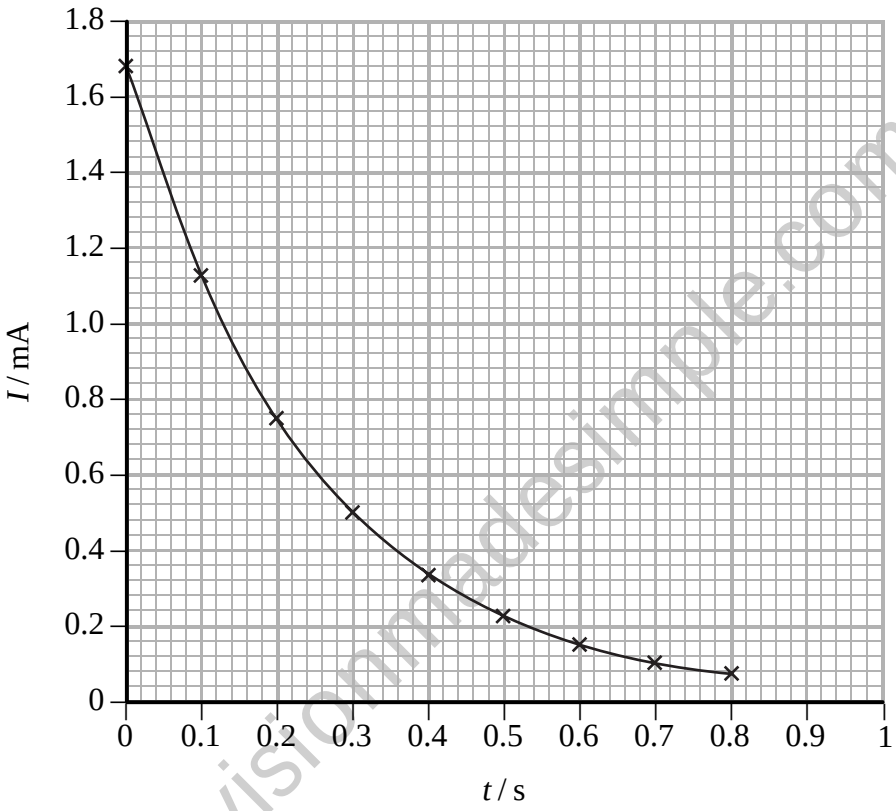
(c) The graph shows how the spreadsheet current varies with time.



(i) Use the graph to show that the time constant is approximately consistent with the component values.

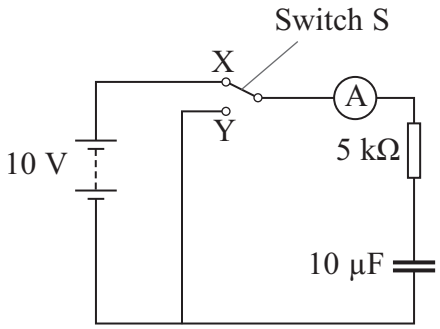
(4)

(ii) The student thinks that the graph is an exponential curve. How would you use another graph to confirm this?

(3)

(Total for Question = 13 marks)

2 A student sets up the circuit shown in the diagram.



(a) (i) She moves switch S from X to Y. Explain what happens to the capacitor.

(2)

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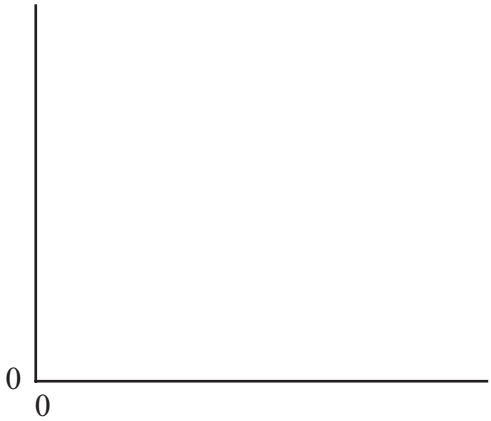
(ii) On the axis below, sketch a graph to show how the current in the ammeter varies with time from the moment the switch touches Y. Indicate typical values of current and time on the axes of your graph.

(3)



(iii) Describe how the graph would appear when the switch is moved back to X.

(2)

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(b) Calculate the maximum energy stored on the capacitor in this circuit.

(2)

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Maximum energy = ...

(c) The student wants to use this circuit to produce a short time delay, equal to the time it takes for the potential difference across the capacitor to fall to 0.07 of its maximum value.

Calculate this time delay.

(2)

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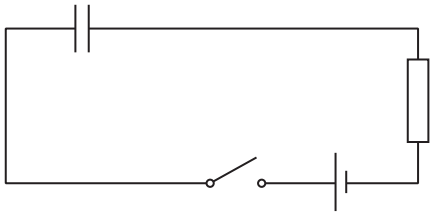
Time delay = ...

(Total for Question = 11 marks)

3 The diagram shows a circuit that includes a capacitor.



(a) (i) Explain what happens to the capacitor when the switch is closed.

(2)

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(ii) The potential difference (p.d.) across the resistor rises to a maximum as the switch is closed.

Explain why this p.d. subsequently decreases to zero.

(2)

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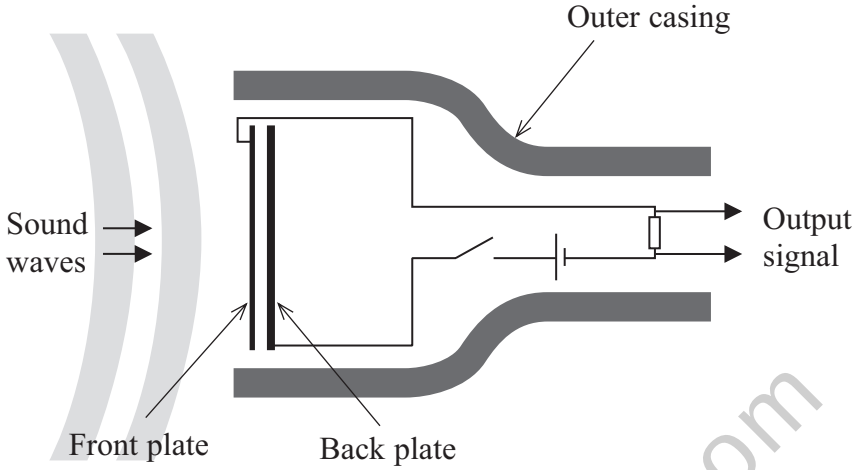
*(b) One type of microphone uses a capacitor. The capacitor consists of a flexible front plate (diaphragm) and a fixed back plate. The output signal is the potential difference across the resistor.



The sound waves cause the flexible front plate to vibrate and change the capacitance. Moving the plates closer together increases the capacitance. Moving the plates further apart decreases the capacitance.

Explain how the sound wave produces an alternating output signal.

(4)

(c) A microphone has a capacitor of capacitance 500 pF and resistor of resistance 10 MΩ.

Explain why these values are suitable even for sounds of the lowest audible frequency of about 20 Hz.

(4)

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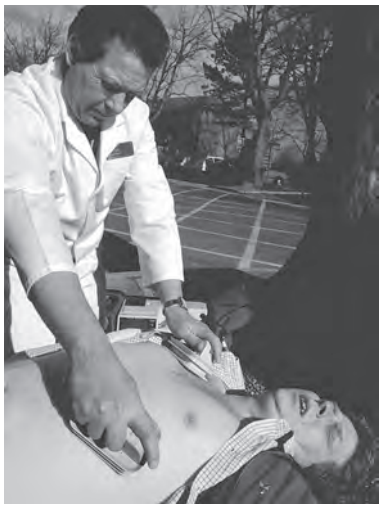
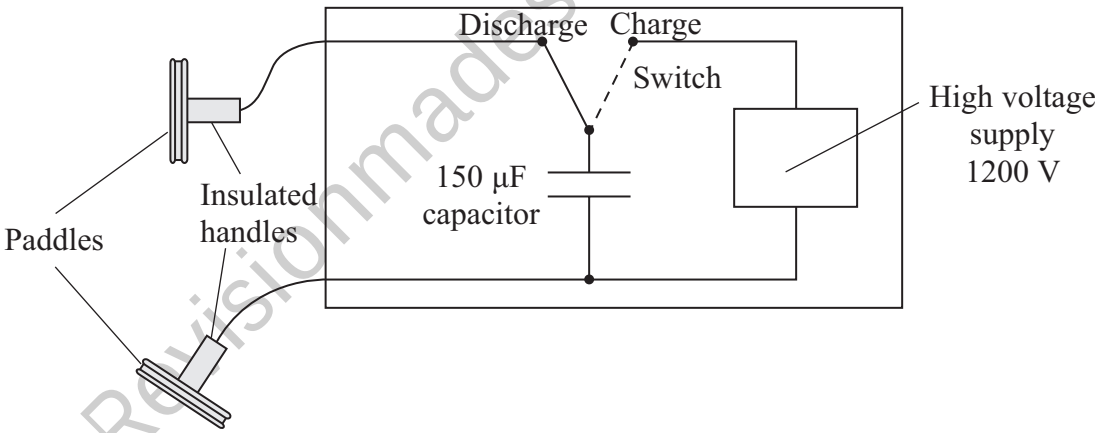
(Total for Question = 12 marks)

4 A defibrillator is a machine that is used to correct an irregular heartbeat or to start the heart of someone who is in cardiac arrest.



The defibrillator passes a large current through the heart for a short time.

The machine includes a high voltage supply which is used to charge a capacitor. Two defibrillation 'paddles' are placed on the chest of the patient and the capacitor is discharged through the patient.



(a) The 150 μF capacitor is first connected across the 1200 V supply.

Calculate the charge on the capacitor.

(2)

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Charge = ...

(b) Calculate the energy stored in the capacitor.

(2)

Energy stored = ...

(c) When the capacitor discharges there is an initial current of 14 A in the chest of the patient.

(i) Show that the electrical resistance of the body tissue between the paddles is about 90 Ω.

(1)

(ii) Calculate the time it will take for three quarters of the charge on the capacitor to discharge through the patient.

(3)

Time = ...

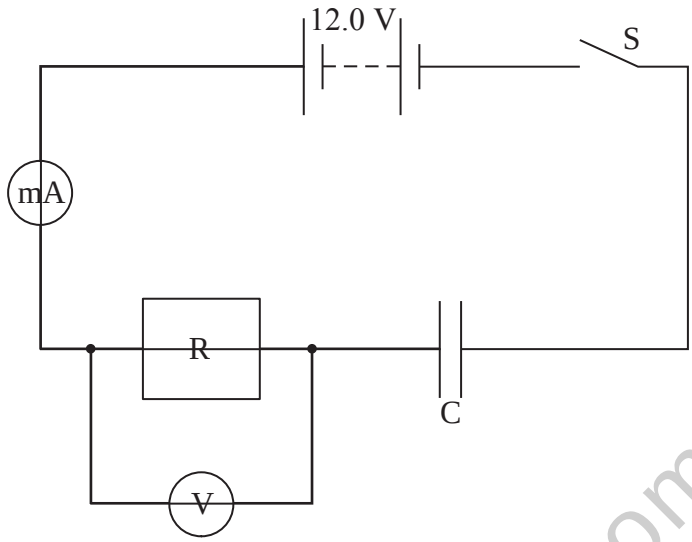
(iii) Body resistance varies from person to person. If the body resistance was lower, the initial current would be greater.

State how this lower body resistance affects the charge passed through the body from the defibrillator.

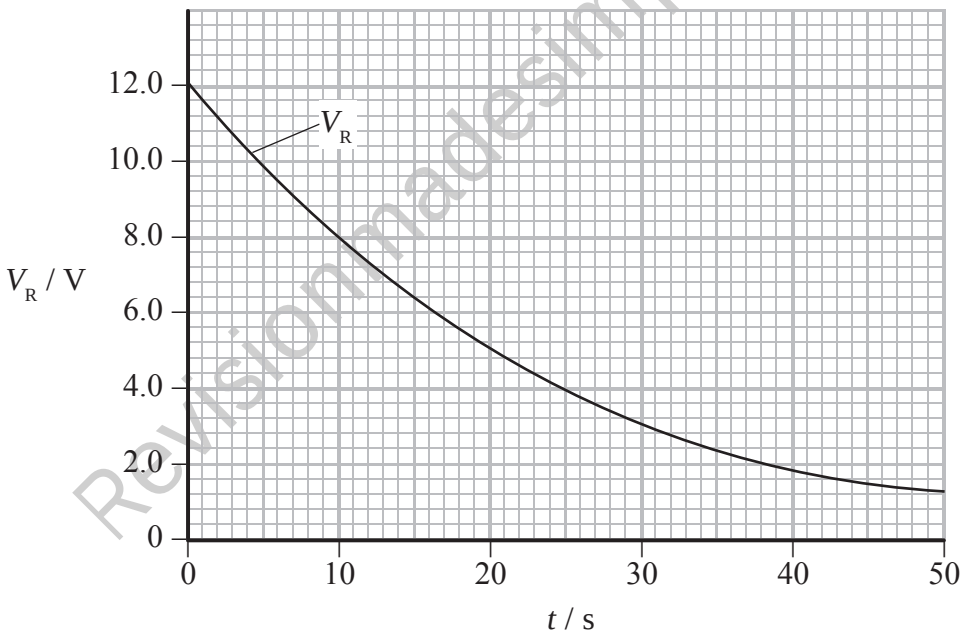
(1)

(Total for Question = 9 marks)

5 A capacitor circuit is set up as shown in the diagram.



The capacitor is initially uncharged and the switch is closed at time $t = 0$. The graph shows how the potential difference V_R across the resistor varies with time t.



(a) (i) Explain the shape of the graph.

(2)

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(ii) On the same axes draw a graph to show how the potential difference V_C across the capacitor varies with time.

(2)

(b) The time constant for this circuit is 25 s.

(i) Describe how you could have determined the value of the time constant from the graph.

(2)

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(ii) The initial current is 0.25 mA.
Calculate the resistance R of the resistor and the capacitance C of the capacitor.

(4)

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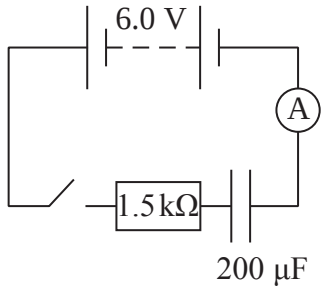
R = ...

C = ...

(Total for Question = 10 marks)

6 A student was investigating the charge and discharge of a capacitor.

He set up the following circuit.



(a) Calculate the time constant for the circuit.

(2)

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Time constant = ...

(b) The student wanted to plot a current-time graph as the capacitor charged, but found that the current changed too rapidly for him to take readings.

Instead, he modelled the experiment using a spreadsheet. The switch was closed at time $t = 0$ s. V is the potential difference across the capacitor.

	A	B	C	D	E
1	t/s	I/mA	ΔQ/μC	Q/μC	V/V
3	0.0	4.00	400	400	2.00
4	0.1	2.67	267	667	3.33
5	0.2	1.78	178	844	4.22
6	0.3	1.19	119	963	4.81
7	0.4	0.79	79	1042	5.21
8	0.5	0.53	53	1095	5.47
9	0.6	0.35	35	1130	5.65
10	0.7	0.23	23	1153	5.77
11	0.8	0.16	16	1169	5.84
12	0.9	0.10	10	1179	5.90
13	1.0	0.07	7	1186	5.93

Explain how the value in cell B5 is calculated.

(2)

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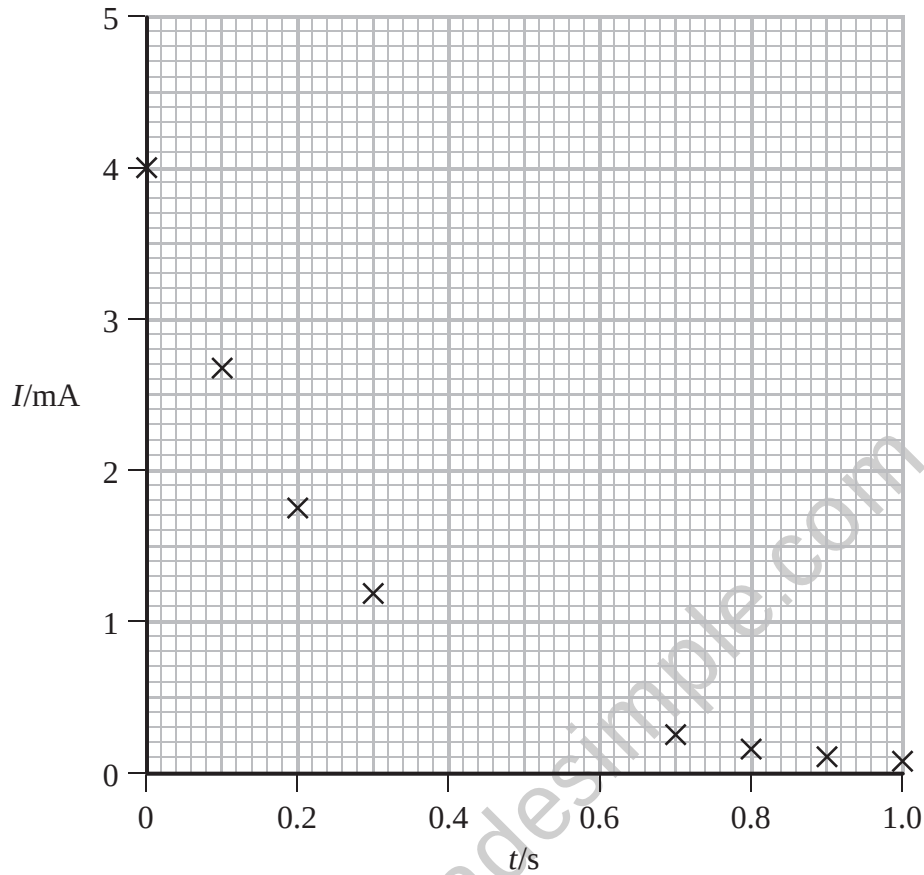
(c) Some of the data from the spreadsheet has been plotted on a graph of current I against time t.



(i) Plot the missing points and draw a line of best fit.

(2)

(ii) Use the graph to determine a second value for the time constant.

(2)

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Time constant = ...

(iii) Suggest how the student might change his spreadsheet to give a more accurate model of the charging of the capacitor.

(1)

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*(d) An alternative method of determining the time constant is to use a straight line graph.

State and explain the variables that the student should plot and how he should determine the time constant from this graph.

(3)

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(Total for Question = 12 marks)