Name: ____

Capacitors

Questions

Date:

Time:

Total marks available:

Total marks achieved: ______

Questions

Q1.

A capacitor of capacitance *C* is charged to a potential difference *V* by a power supply.
The energy stored on the charged capacitor is *W*.

What would be the energy stored if the potential difference were 2*V*?

(1)

☐ **A** $\frac{W}{4}$

☐ **B** $\frac{W}{2}$

☐ **C** $2W$

☐ **D** $4W$

(Total for question = 1 mark)

Q2.

A capacitor of capacitance *C* has a potential difference *V* across it. The energy stored on the capacitor is Z joules. A second capacitor of capacitance *C*/2 has a potential difference 2*V* across it.
The energy stored on the second capacitor is

☐ **A** Z

☐ **B** 2Z

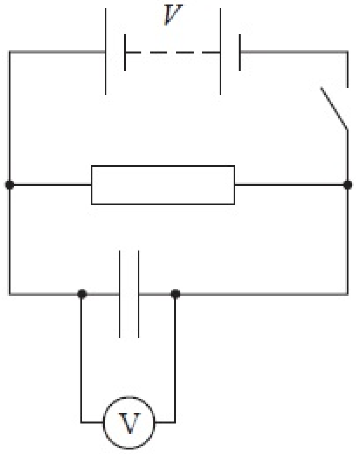
☐ **C** 4Z

☐ **D** 8Z

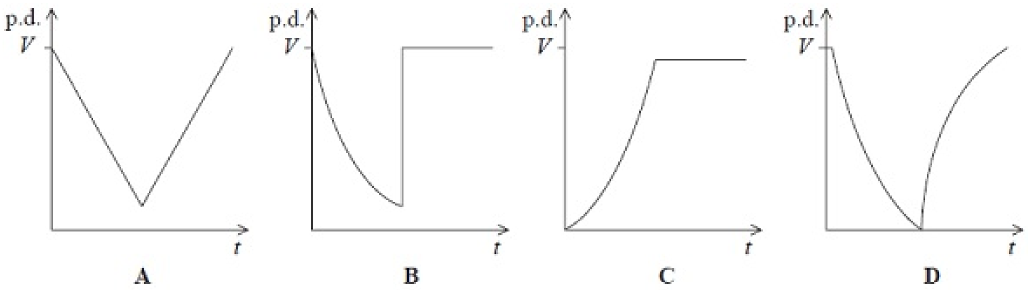
(Total for question = 1 mark)

Q3. The capacitor shown in the circuit below is initially charged to a potential difference (p.d.) *V* by closing the switch.

The power supply has negligible internal resistance.



The switch is opened and the p.d. across the capacitor allowed to fall. A short time later the switch is closed again. Select the graph that shows how the p.d. across the capacitor varies with time, after the switch is opened.

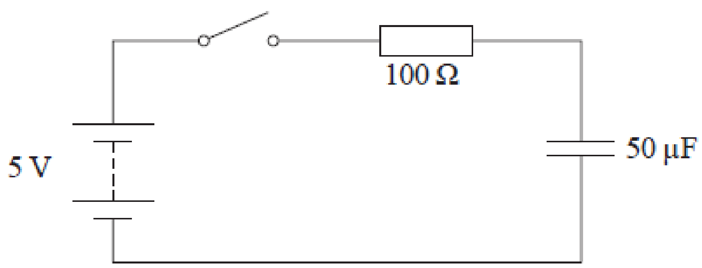


- **A**
- **B**
- **C**
- **D**

(Total for Question = 1 mark)

Q4.

A circuit consists of a battery of e.m.f. 5 V and negligible internal resistance, a switch, a 100 Ω resistor and an uncharged 50 μF capacitor.



Describe what happens to the potential difference across the resistor and the potential difference across the capacitor after the switch is closed.

(4)

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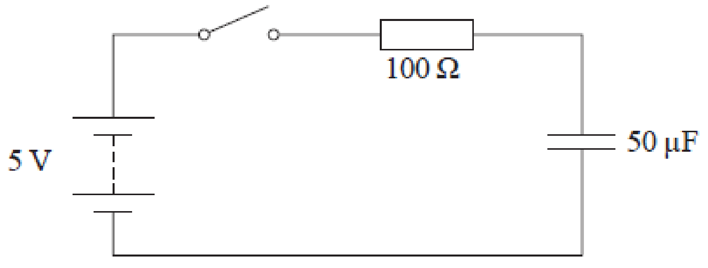
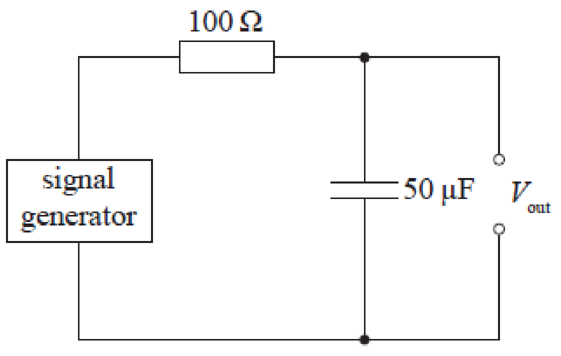
(Total for question = 4 marks)

Q5.

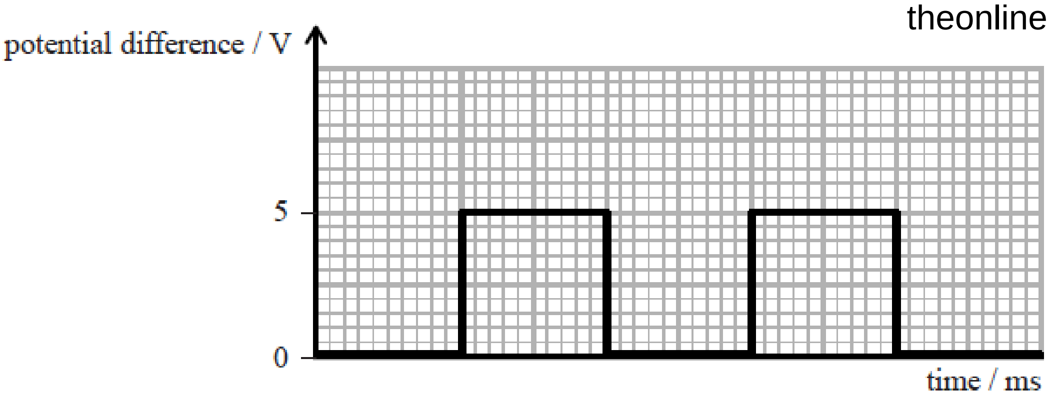
A circuit consists of a battery of e.m.f. 5 V and negligible internal resistance, a switch, a 100 Ω resistor and an uncharged 50 μF capacitor.



The battery and switch are replaced by a signal generator providing a square wave output of peak potential difference 5 V. The signal generator has negligible internal resistance.



The graph shows the square wave output of the signal generator. The frequency of the square wave is 20 Hz.



On the graph add values to the time axis and sketch a graph of the potential difference, V_{out}, across the capacitor for two cycles of the square wave. Assume the capacitor is initially uncharged.

(5)

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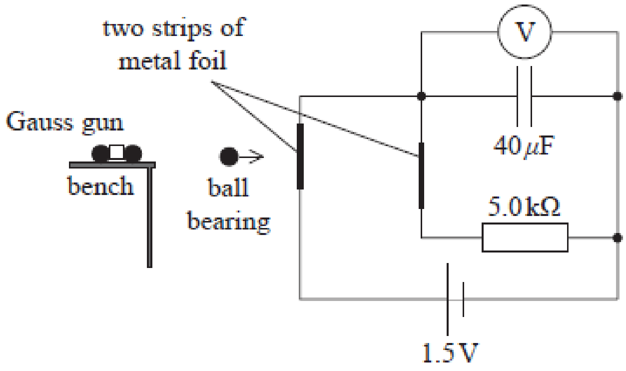
(Total for question = 5 marks)

Q6.

A 'Gauss gun' can be made from five ball bearings of equal mass and two magnets, as shown.

Pairs of ball bearings are placed to the right of two strong magnets. A single ball bearing is released from the left, as shown. The ball bearing is attracted to, and collides with, the first magnet. This and all subsequent collisions can be assumed to be elastic.

A student set up the apparatus shown to measure the speed of the last ball bearing. The 'Gauss gun' was placed at the end of a bench, so that the ball bearing left the gun and broke two strips of metal foil which formed part of an electric circuit.



As the ball bearing left the gun, it broke the first foil strip at its centre so that the capacitor started to discharge. When the ball bearing broke the second foil strip the capacitor discharge stopped.

(i) Calculate the energy stored in the capacitor when it was fully charged.

(2)

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Energy stored = ...

(ii) The voltmeter reading halved in the time taken for the ball bearing to travel between the two foil strips.

Show that the time taken for the ball bearing to travel between the two foil strips was about 0.1 s.

(2)

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(iii) The two foil strips were 0.50 m apart.

Calculate the horizontal velocity of the ball bearing.

(2)

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....

Horizontal velocity = ...

(iv) The student positioned the second foil strip with its centre 8.0 cm lower than the centre of the first foil strip.

Deduce whether the ball bearing broke the second foil strip at its centre.

Assume the ball bearing was travelling horizontally as it broke the first foil strip.

(2)

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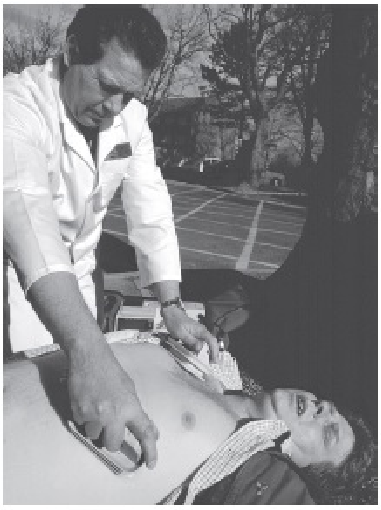
(Total for question = 8 marks)

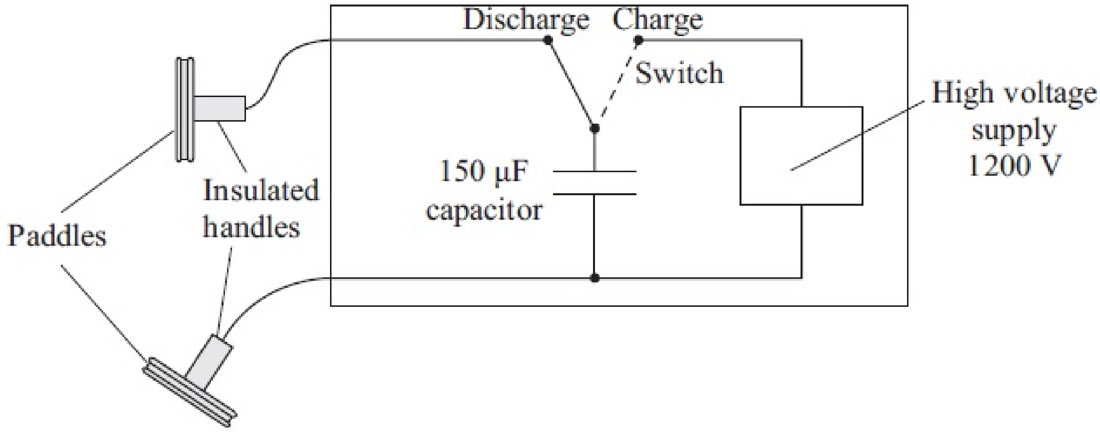
Q7.

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)

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....

....

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)

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

(3)

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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)

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(Total for question = 9 marks)

Q8. A particular experiment requires a very large current to be provided for a short time.

(a) An average current of 2.0×10^3 A is to be supplied to a coil of wire for a time of 1.4×10^{-3} s. The resistance of the coil is 0.50 Ω.

(i) Show that the charge that flows through the coil during this time is about 3 C.

(2)

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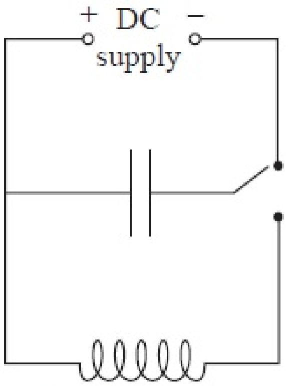
(ii) The circuit shows how a capacitor could be charged and then discharged through the coil to provide the current.



The circuit contains a capacitor of capacitance 600 μF. This capacitor is suitable to provide the current for 1.4×10^{-3} s.

Explain why the capacitor is suitable.

(3)

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(b) It can be assumed that the 600 μF capacitor completely discharges in 1.4×10^{-3} s.

(i) Calculate the potential difference of the power supply.

(2)

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Potential difference = ...

(ii) Calculate the average power delivered to the coil in this time.

(3)

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....

Average power = ...

(Total for Question = 10 marks)

Q9. A student is investigating how the potential difference across a capacitor varies with time as the capacitor is charging.

He uses a 100 μF capacitor, a 5.0 V d.c. supply, a resistor, a voltmeter and a switch.

(a) (i) Draw a diagram of the circuit he should use.

(2)

(ii) Suggest why a voltage sensor connected to a data logger might be a suitable instrument for measuring the potential difference across the capacitor in this investigation.

(1)

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(b) Calculate the maximum charge stored on the capacitor.

(2)

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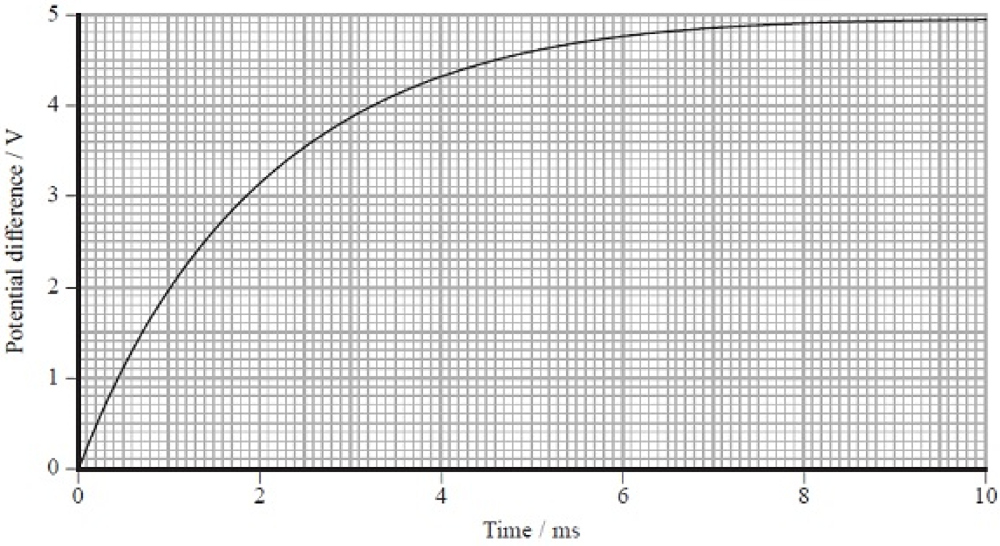
Charge = ...

(c) The graph shows how the potential difference across the capacitor varies with time as the capacitor is charging.



(i) Estimate the average charging current over the first 10 ms.

(2)

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Average charging current = ...

(ii) Use the graph to estimate the initial rate of increase of potential difference across the capacitor and hence find the initial charging current.

(3)

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Initial charging current = ...

(iii) Use the value of the initial charging current to find the resistance of the resistor.

(2)

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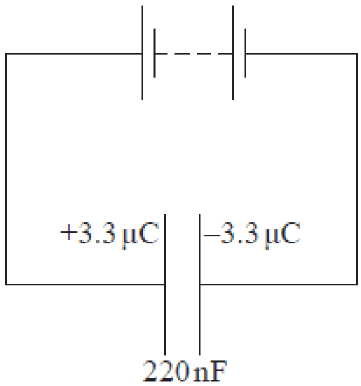
Resistance = ...

(Total for Question = 12 marks)

Q10.

A capacitor is charged by a battery as shown in the circuit diagram.



(a) Calculate the e.m.f. of the battery and the energy stored in the charged capacitor.

(4)

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E.m.f. = ...

Energy = ...

(b) The capacitor is disconnected from the battery and discharged through a 20 MΩ resistor.

Calculate the time taken for 80% of the charge on the capacitor to discharge through the resistor.

(3)

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Time taken = ...

(c) Use an equation to explain whether the time taken for the capacitor to lose half its energy is greater or less than the time taken to lose half its charge.

(3)

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(d) A student carries out an experiment to record data so that she can plot a graph of potential difference against time as the capacitor discharges.

State **two** advantages of using a datalogger rather than a voltmeter and stopwatch to record this data.

(2)

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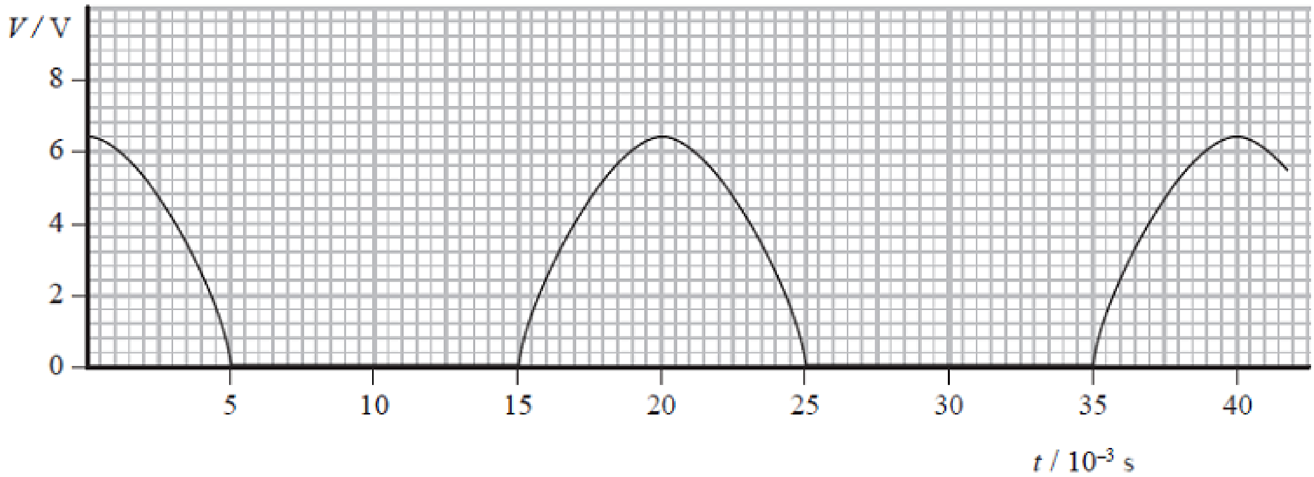
(Total for question = 12 marks)

Q11.
The graph shows how the output V from the terminals of a power supply labelled d.c. (direct current) varies with time t. This type of supply will not allow current to flow backwards through it.



(a) A student connects a capacitor across the terminals of this power supply in order to try to produce a constant voltage.

Suggest how this produces a constant voltage.

(2)

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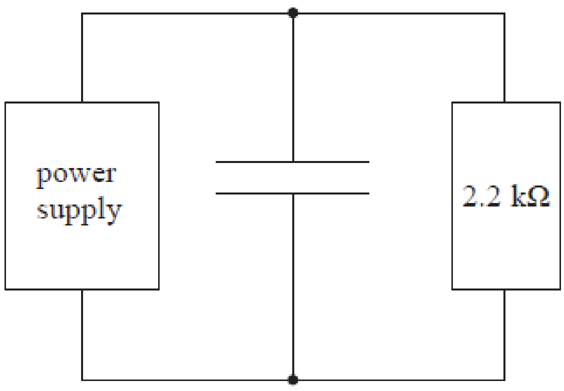
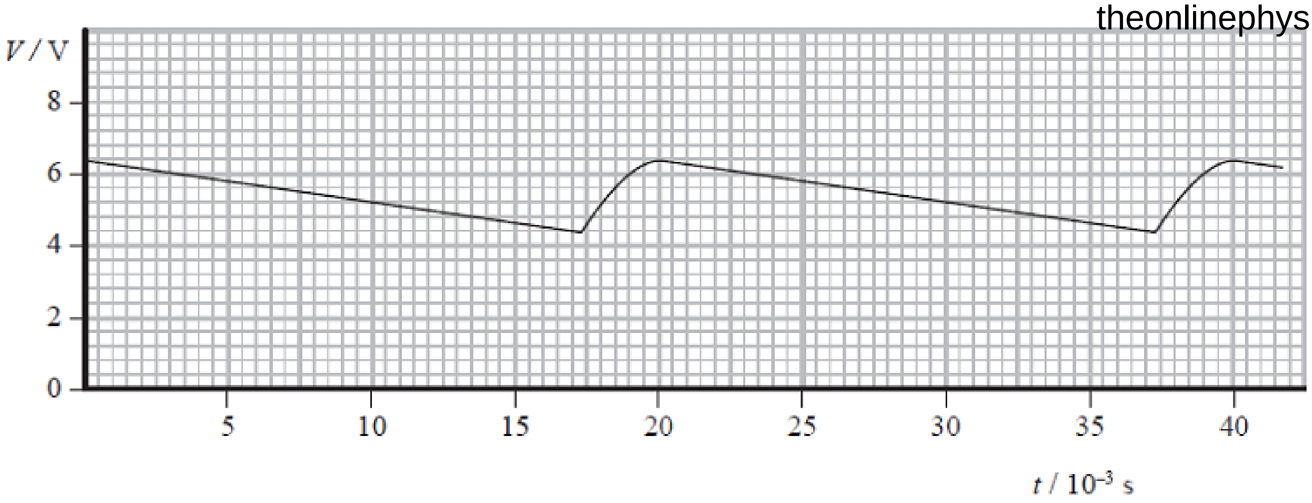
(b) The student then connects a resistor across the capacitor as shown.



The graph shows the variation of the potential difference V across the resistor with time t.



(i) Estimate the average potential difference across the resistor.

(1)

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Average potential difference = ...

(ii) Calculate the average current in the resistor.

(2)

....

....

Average current = ...

(iii) Determine the time in each cycle for which the capacitor discharges through the resistor.

(1)

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....

Discharge time = ...

(iv) Calculate the charge passing through the resistor during one discharge of the capacitor and hence determine the capacitance of the capacitor.

(4)

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Charge = ...

Capacitance = ...

(c) The student wants to produce a potential difference across the same resistor that has less variation in magnitude.
State, with a reason, what the student could do to achieve this.

(2)

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(Total for question = 12 marks)

Q12.

In recent years there has been a development of ultracapacitors which have much higher capacitance than traditional capacitors. Capacitors store energy due to charge in an electric field whereas batteries store energy due to a chemical reaction. There are several applications where ultracapacitors have an advantage over batteries; for example storing energy from rapidly fluctuating supplies or delivering charge very quickly.

(a) A typical ultracapacitor has a capacitance of 1500 F and a maximum operating potential difference of 2.6 V.

(i) Show that the charge on this capacitor when fully charged is about 4000 C.

(2)

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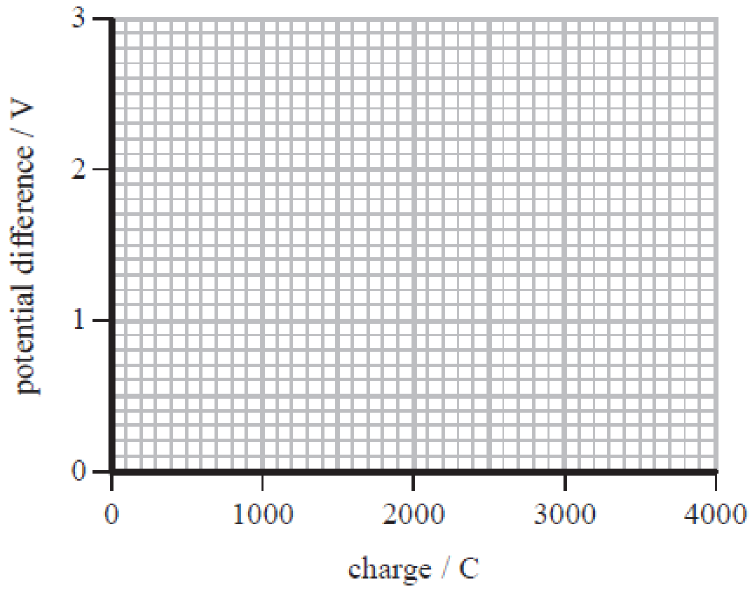
(ii) Complete the graph on the axes below to show how the potential difference varies with charge for this capacitor.

(2)



(iii) Calculate the energy stored in this capacitor when fully charged.

(2)

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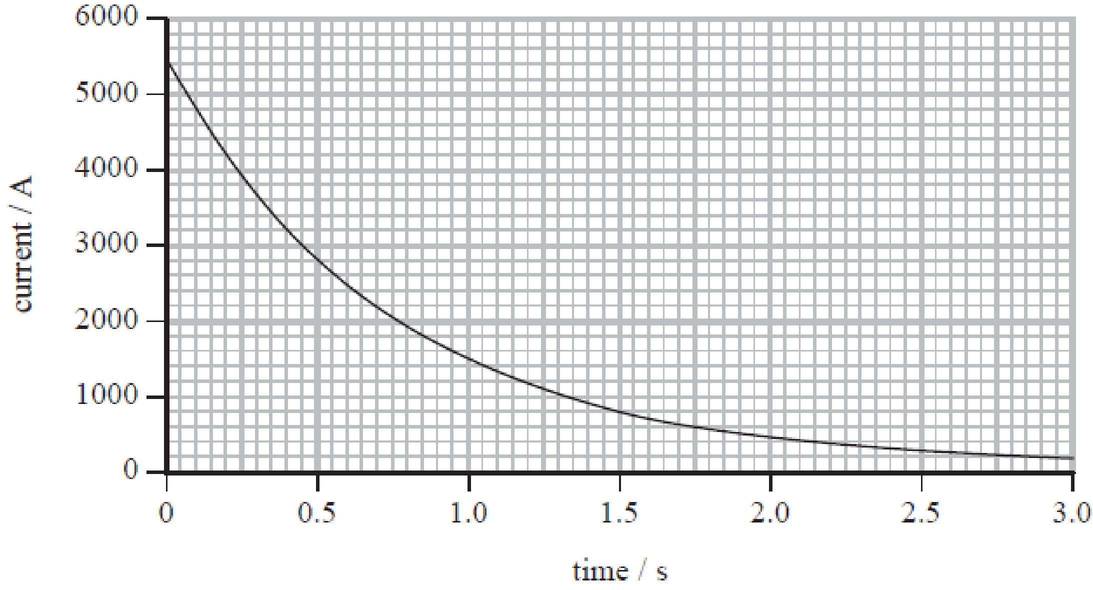
Energy = ...

(b) The graph below shows how the current varies with time as the capacitor is discharged through a circuit.



(i) Describe and explain the shape of the graph.

(2)

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(ii) Calculate the resistance of the circuit.

(4)

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Resistance = ...

(c) There is a limit to the amount of charge an ultracapacitor can hold but it can deliver the charge very quickly. A battery can deliver much more charge but only at a slower rate. For electric powered vehicles it is suggested that using a combination of batteries and ultracapacitors would give the best performance.

Suggest, with reasons, which stages of a journey would be more suited to ultracapacitors and which would be more suited to batteries.

(3)

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(Total for question = 15 marks)