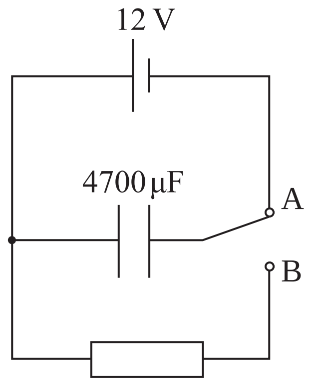
Capacitors QP2

1 Some lights are designed to dim gradually after being switched off. This can be done using a capacitor in a timer circuit.

The circuit diagram shows how a potential difference (p.d.) can be supplied across a resistor for a limited time.



(a) When the switch is at position A, the capacitor charges.

(i) In terms of the movement of electrons, explain what happens to the capacitor as it becomes fully charged.

(2)

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(ii) Calculate the energy stored in the charged capacitor.

(2)

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Energy = ...

(b) The switch is moved to position B and the capacitor discharges through the resistor.

(i) Describe what happens to the current through the resistor.

(2)

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(ii) For the circuit shown, the p.d. across the capacitor falls to 10% of the supply p.d. after 25 s.

Calculate the resistance of the resistor in the circuit.

(3)

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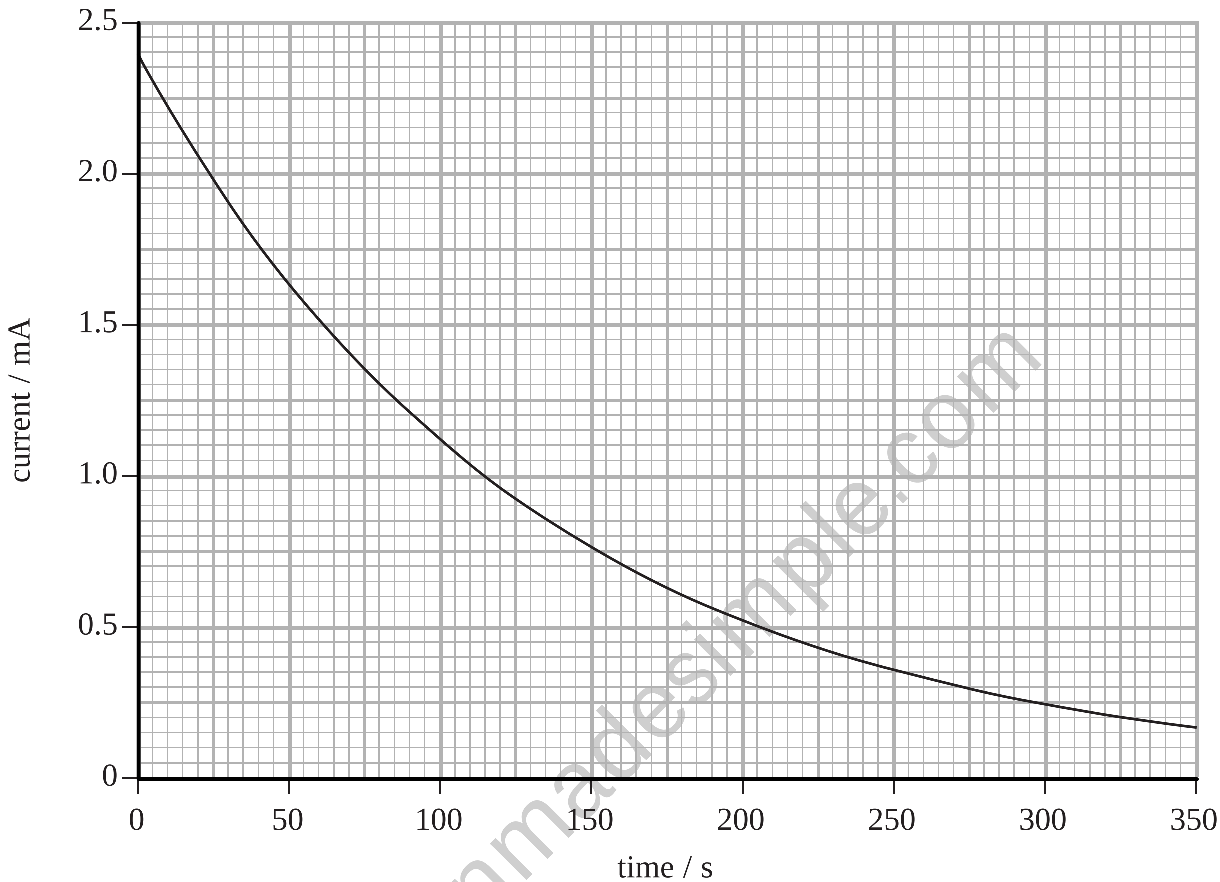
Resistance = ...

(Total for Question = 9 marks)

2 A timer circuit includes a capacitor and a variable resistor in series.

(a) The graph shows how the current in the timer circuit varies with time when the capacitor discharges through the variable resistor. The resistance of the variable resistor is 8.2 kΩ.



(i) Show that the capacitance of the capacitor is about 0.02 F.

(3)

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(ii) Calculate the initial charge on the capacitor.

(3)

Initial charge = ...

(iii) Calculate the energy initially stored in the capacitor.

(2)

Energy = ...

(b) In another timer circuit the capacitance of the capacitor is 470 μF. The circuit switches off when the potential difference falls to 15% of its initial value. The variable resistor is adjusted so that the timer circuit switches off after 3.5 minutes.

Calculate the resistance of the variable resistor.

(3)

Resistance = ...

(Total for Question = 11 marks)

3 A student needs to order a capacitor for a project. He sees this picture on a web site accompanied by this information: capacitance tolerance ±20%.

Taking the tolerance into account, calculate

(a) the maximum charge a capacitor of this type can hold.

(3)

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Maximum charge = ...

(b) the maximum energy it can store.

(2)

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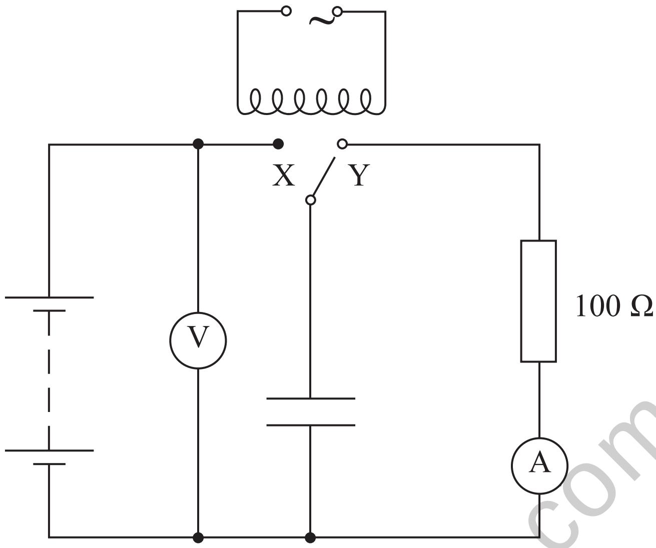
Maximum energy = ...

(Total for Question = 5 marks)

4 A student is investigating capacitors. She uses the circuit below to check the capacitance of a capacitor labelled 2.2 μF which has a tolerance of ±30%.



The switch flicks between contacts, X and Y, so that the capacitor charges and discharges *f* times per second.

(a) The capacitor must discharge fully through the 100 Ω resistor.

(i) Explain why 400 Hz is a suitable value for *f*.

(3)

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(ii) Show that the capacitance C can be given by

$$C = \frac{I}{fV}$$

where I is the reading on the ammeter and V is the reading on the voltmeter.

(3)

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(iii) The student records I as 5.4 mA and V as 5.0 V.

Calculate the capacitance C.

(2)

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C = ...

(iv) Explain whether you think this value is consistent with the tolerance given for this capacitor.

(2)

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(b) Calculate the energy stored on the capacitor when it is charged to a potential difference of 5.0 V.

(2)

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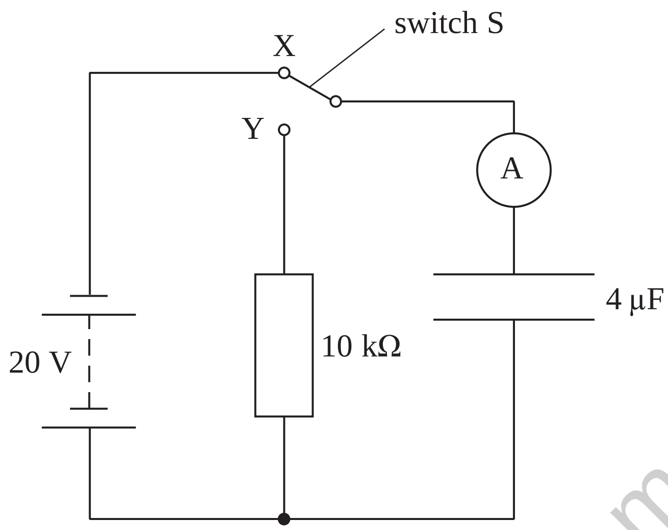
Energy = ...

(Total for Question = 12 marks)

5 A student sets up the circuit as shown in the diagram.



(a) (i) She moves the switch S from X to Y.

Describe what happens to the capacitor.

(2)

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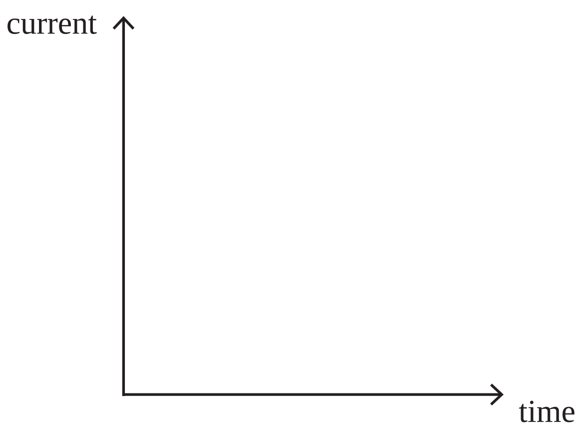
(ii) On the axes below, sketch a graph to show how the current in the ammeter varies with time. Take $t = 0$ as the time when the switch touches Y. Indicate typical values of current and time.

(3)



(iii) Describe and explain what happens when the switch is moved back to X.

(3)

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(b) The student wants to use this circuit to produce a short time delay of 0.20 s after the switch moves from X to Y.

Calculate the value of the potential difference across the capacitor after this time interval.

(3)

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Potential difference = ...

(c) The development of ultracapacitors which have much higher values of capacitance than traditional capacitors allows for capacitors to be used instead of batteries for storing energy.

The picture shows a Formula 1 racing car going around a curved section of a racing track.

Racing cars have to go through large changes in speed in order to go around the corners on the racing tracks. All racing cars have a kinetic energy recovery system which recovers the moving vehicle's kinetic energy when it is braking. The recovered energy can now be stored in ultracapacitors for later use when the car is accelerating.

A particular racing car has a mass of 800 kg and is travelling at 30 m s^{-1}. It uses an ultracapacitor of capacitance 2600 F charging to a potential difference of 2.5 V.

Calculate the ratio of the energy stored on the fully charged ultracapacitor to the kinetic energy of the car.

(3)

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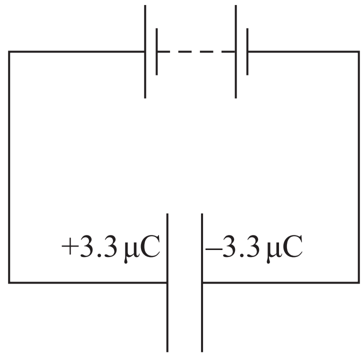
Ratio = ...

(Total for Question = 14 marks)

6 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)

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)

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)

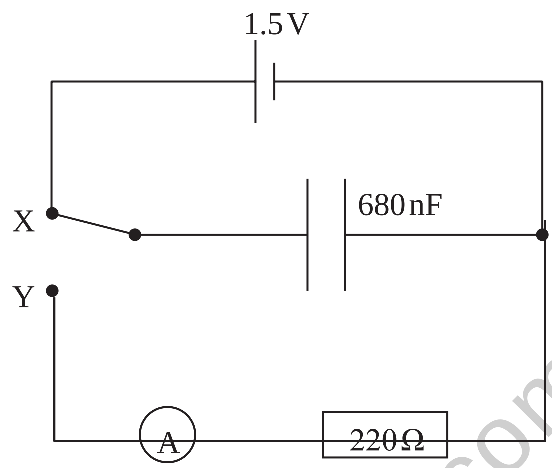
(d) A student carries out an experiment to record data so that she can plot a graph of potential difference against time as the capacitor discharges.

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

(2)

(Total for Question = 12 marks)

7 A capacitor can be charged and discharged using the following circuit. It can be assumed that the ammeter has zero resistance.



(a) Initially the switch makes contact at X.
Calculate the charge stored by the capacitor when it is fully charged.

(2)

Charge =

(b) The switch is moved to make contact at Y so that the fully charged capacitor is discharged through the 220 Ω resistor.

Calculate the charge remaining on the capacitor after it has been discharging for 1.0 ms and comment on your answer.

(4)

Charge =

Comment

(c) The capacitor is charged and discharged 500 times per second.

Calculate the average current through the ammeter.

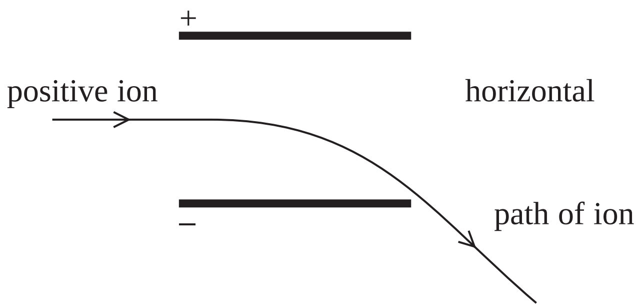
(2)

Average current =

(Total for Question = 8 marks)

8 A beam of identical positive ions travels horizontally in a vacuum. The ions pass between two charged plates and are deflected downwards by the electric field between the plates.

The diagram shows the path of one of the ions.



*(a) Explain the path of the ion both between the plates and when it has left the plates.

(4)

(b) Whilst the electric field is still acting, the path of the ions can be returned to the horizontal by applying a magnetic field over the same region as the electric field acts.

(i) Explain the conditions under which the ions have no overall deflection as they pass between the plates.

(2)

(ii) The ions have a velocity of 260 km s^{-1}. The plate separation is 4.5 cm and the potential difference across the plates is 60 V.

Calculate the magnetic flux density required so that there is no overall deflection of the ions.

(4)

Magnetic flux density =

(c) State and explain how the path of the ions in just the magnetic field would be different from the path in just the electric field.

(3)

(Total for Question = 13 marks)