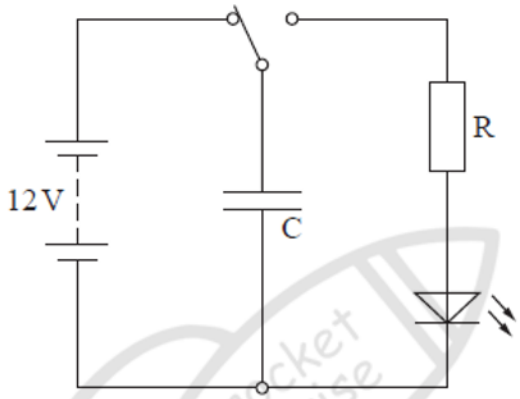
Questions

Q1.

A student is designing a night light for a child. When switched on, the night light should come on brightly and its intensity should then gradually decrease to zero.

The time taken for the light intensity to decrease to zero should be as close to 10 minutes as possible. The time must not be less than 10 minutes.

(a) The diagram shows the student's design.



The student uses a light emitting diode (LED) and a resistor R. The LED stops emitting light when the potential difference across it falls to 1.4 V. The student assumes the LED has a constant resistance of 340 Ω.

Capacitors with the following capacitances are available: 0.50 F, 0.51 F, 0.54 F, 0.58 F, 0.60 F.

Determine which capacitance the student should use.

resistance of R = 860 Ω

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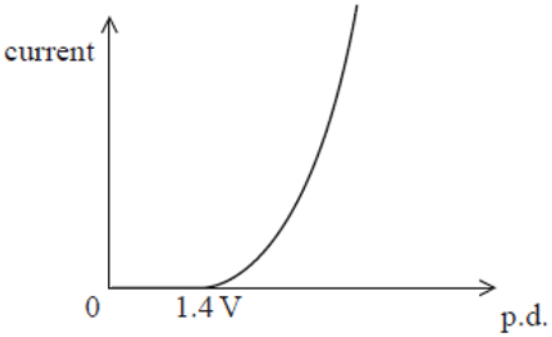
(b) In practice, the resistance of the LED does not stay constant. The graph shows how current varies with potential difference (p.d.) for the LED.



Explain how the behaviour of the LED shown in the graph will affect the time taken for the light intensity to decrease to zero.

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(c) The student states:

"A capacitor is being used in this circuit. The function of the capacitor is to store electric charge."

Explain why this is not a complete description of the function of a capacitor.

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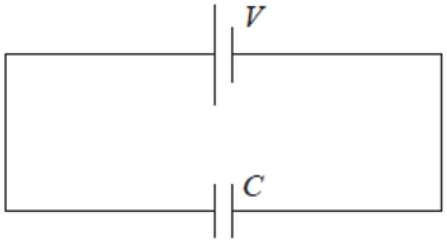
(Total for question = 10 marks)

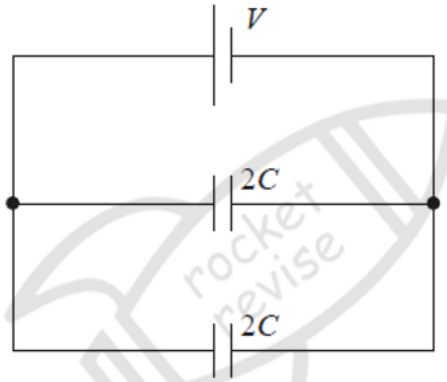
Q2.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

A potential difference (p.d.) V is connected across a capacitor of capacitance C. The charge stored on the capacitor is Q.



The capacitor is replaced with two capacitors, each of capacitance $2C$, in parallel.



What is the total charge stored?

☒ **A** $\frac{Q}{4}$

☒ **B** Q

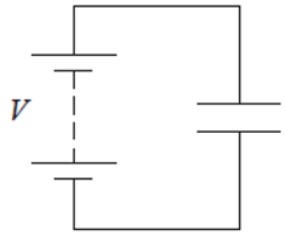
☒ **C** $2Q$

☒ **D** $4Q$

(Total for question = 1 mark)

Q3.

A battery of e.m.f. V is connected to a capacitor as shown. The capacitor is initially uncharged.



Work is done by the battery to transfer a charge Q from one plate of the capacitor to the other plate. The final potential difference across the capacitor is V.

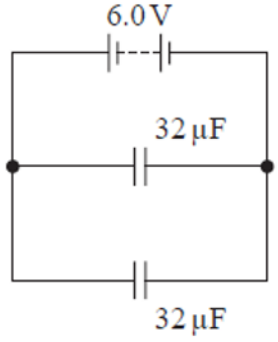
Which row of the table gives the work done by the battery, and the energy stored by the capacitor, at the end of this process?

	Work done by battery	Energy stored by capacitor
☒ A	$\frac{QV}{2}$	$\frac{QV}{2}$
☒ B	$\frac{QV}{2}$	QV
☒ C	QV	$\frac{QV}{2}$
☒ D	QV	QV

(Total for question = 1 mark)

Q4.

The diagram shows two capacitors, each of capacitance 32 μF. The capacitors are connected to a battery of e.m.f. 6.0 V.



(a) Calculate the total charge stored by the capacitors.

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Total charge stored = ...

(b) Calculate the total energy stored by the capacitors.

(2)

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Total energy stored = ...

(Total for question = 4 marks)

Q5.

A student investigated the properties of capacitors.

The student connected a capacitor in series with a resistor. The capacitor was charged through the resistor by applying a potential difference (p.d.) using a battery of e.m.f. 6.0 V and negligible internal resistance. The capacitor was then discharged through the resistor. The p.d. across the capacitor was measured during the charging and discharging processes.

(a) Add to the diagram to show a suitable circuit for charging and discharging the capacitor while measuring the p.d.
across it.

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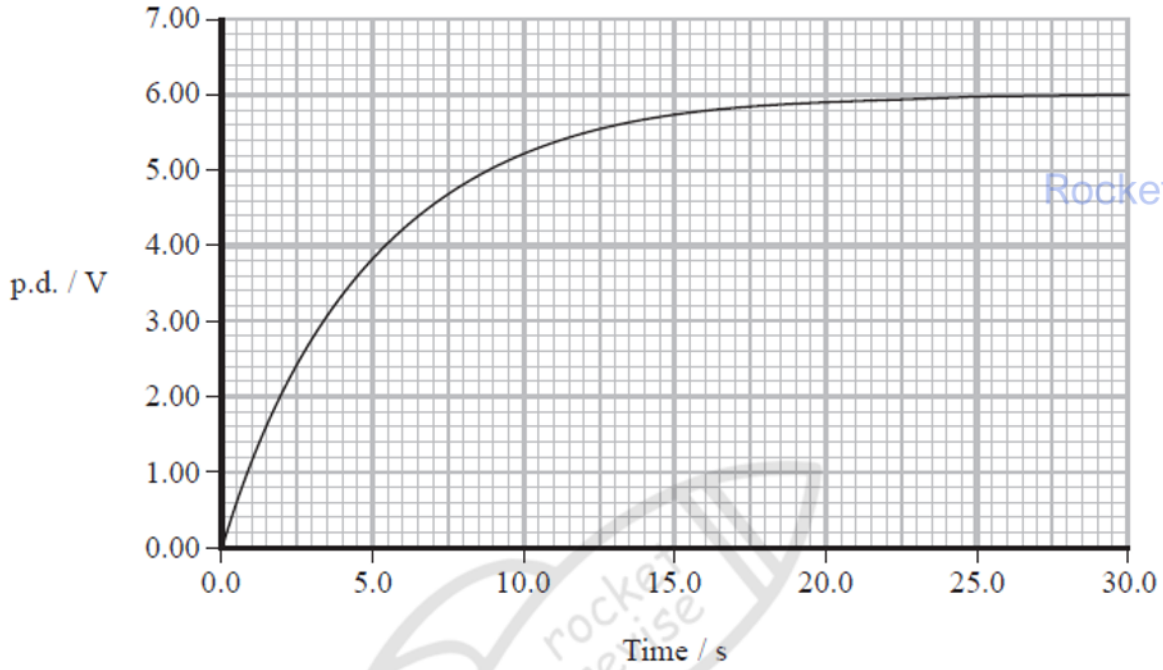
(b) The graph shows how the p.d. across the capacitor varies with time as it is being charged by the 6.0 V battery.



(i) Sketch, on the same axes, a graph to show how the p.d. across the resistor varies with time.

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(ii) Show that the p.d V across the capacitor when it is charging is given by

$$V = V_0 - V_0\, e^{-t/RC}$$

where V_0 is the e.m.f. of the battery
t is the time
R is the resistance of the resistor
and C is the capacitance of the capacitor.

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(iii) During the charging process, the student recorded the p.d. across the capacitor and the resistance of the resistor.

The capacitors available had the following values:

10 μF 15 μF 47 μF 100 μF 150 μF

Deduce the value of capacitance for the capacitor that was used.

R = 330 kΩ

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(iv) Calculate the charge on the fully charged capacitor.

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Charge = ...

(v) Calculate the energy stored by the fully charged capacitor.

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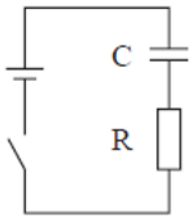
Energy stored = ...

(Total for question = 16 marks)

Q6.

An uncharged capacitor, a resistor, a switch and a cell are connected in series as shown.



Which of the following shows how the charge stored on the capacitor and the potential difference (p.d.) across the resistor vary with time, after the switch is closed?

	capacitor	resistor
☒ **A**	charge / time	p.d. / time
☒ **B**	charge / time	p.d. / time
☒ **C**	charge / time	p.d. / time
☒ **D**	charge / time	p.d. / time

(Total for question = 1 mark)

Q7.

A charged capacitor is connected across a resistor of resistance R and the current in the resistor is measured.

A graph of ln (current) against time is plotted and the gradient of the graph is determined.

Which of the following gives the capacitance of the capacitor?

☒ **A** $-\text{gradient} \times R$

☒ **B** $\dfrac{-1}{(\text{gradient} \times R)}$

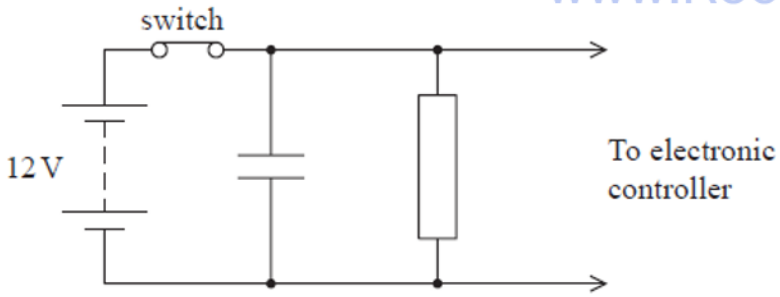
☒ **C** $\dfrac{-R}{\text{gradient}}$

☒ **D** $\dfrac{-\text{gradient}}{R}$

(Total for question = 1 mark)

Q8.

The train on a model railway is powered by contact with the rails. The train sometimes loses contact with the rails. The diagram shows a circuit that can maintain power for an electronic controller on the train even when the power is disconnected for a short time. The switch represents the contact between the train and the rails.



(a) Explain how this circuit can maintain power to the electronic controller if the switch is opened for a short time.

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(b) The switch is opened.

Calculate the time taken for the potential difference across the capacitor to decrease to 4.0 V.

Assume the resistance of the electronic controller is infinite.

capacitance of capacitor = 47 mF
resistance of resistor = 470 Ω

(2)

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Time taken = ...

(c) The switch is closed at time $t = 0$ and then opened at $t = 20$ s.

Sketch a graph on the axes below to show how current I through the resistor varies with t.

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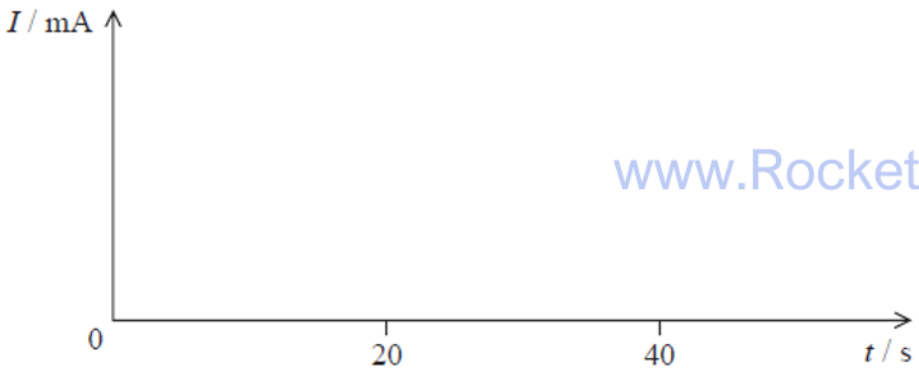

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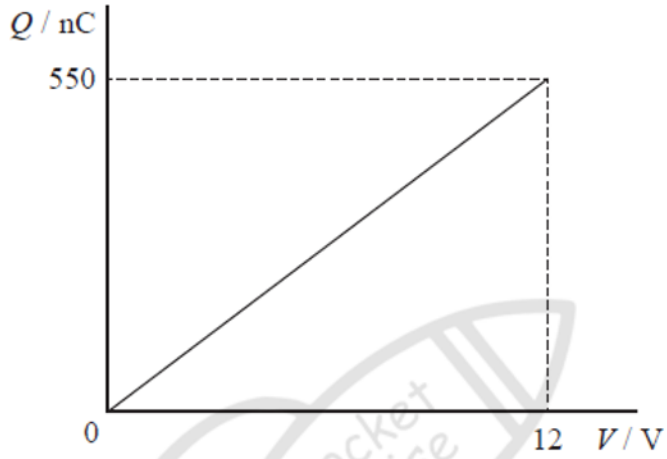
(Total for question = 9 marks)

Q9.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The graph shows how the charge Q stored on the plates of a capacitor varies with the potential difference V across the plates.



Which of the following expressions gives the energy, in J, stored by the capacitor when V is 12 V?

☒ **A** $\frac{550}{12}$

☒ **B** $\frac{12}{550 \times 10^{-9}}$

☒ **C** $\frac{550 \times 12}{2}$

☒ **D** $\frac{550 \times 10^{-9} \times 12}{2}$

(Total for question = 1 mark)

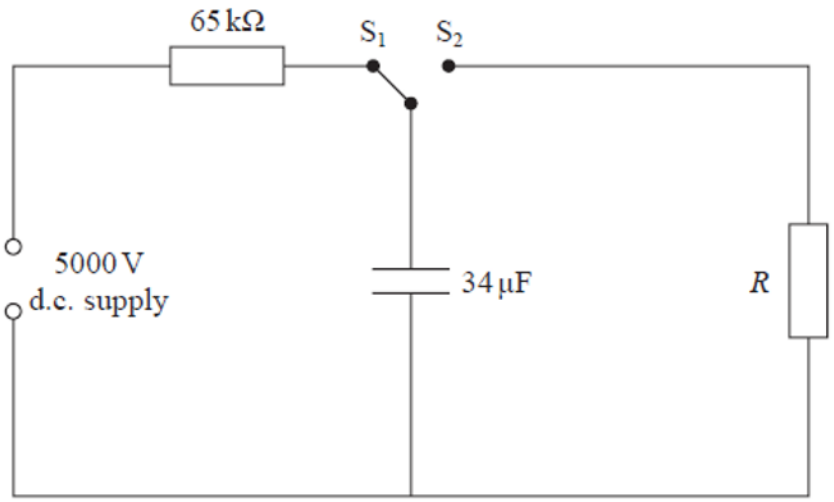
Q10.

A defibrillator is a device that can restart a person's heart. The defibrillator applies an electric

current to a person's heart for a short time.

The defibrillator uses a capacitor circuit. A person's body has an electrical resistance *R*.

A simplified circuit diagram is shown.



(a) When the capacitor is completely discharged, the two-way switch is moved to position S_1 at time $t = 0$ s.

Complete the graph to show how the current varies with time until the capacitor is fully charged.

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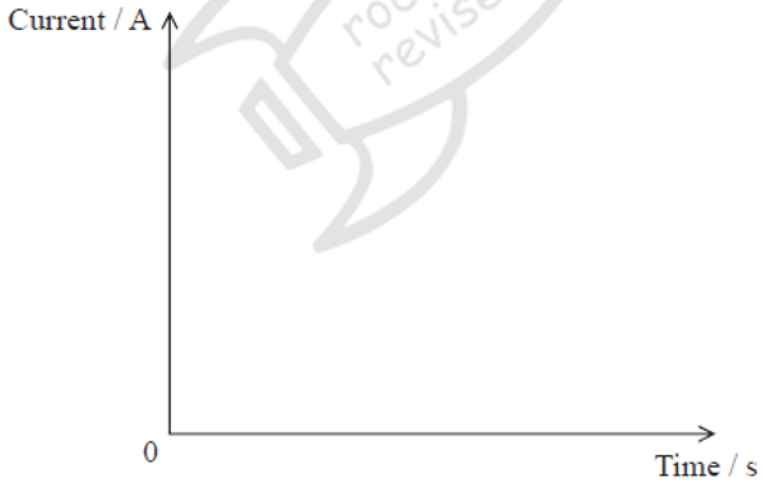

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(b) The capacitor in the defibrillator discharges when the switch is moved to position S_2.

The defibrillator is required to deliver a discharge current of at least 30 A for a time of 2.0 ms.

A typical person's body has an electrical resistance of 150 Ω.

Deduce whether the design of the defibrillator meets this requirement.

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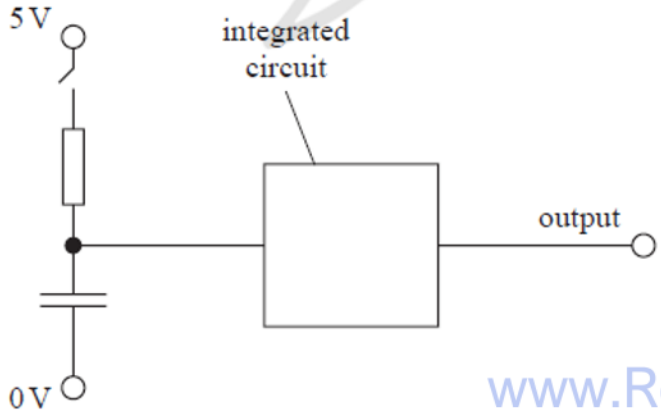
(Total for question = 8 marks)

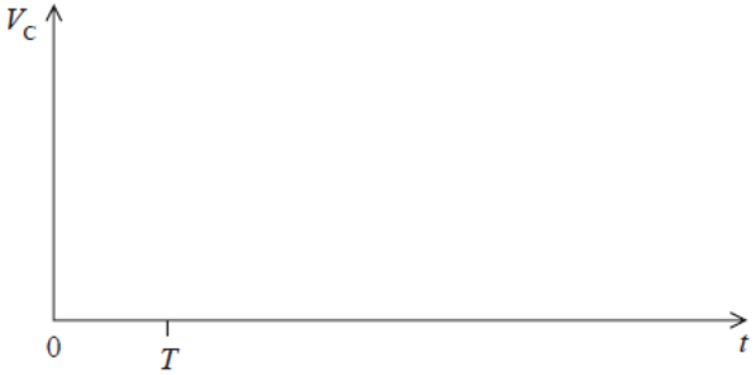
Q11.

A resistor-capacitor circuit provides an input for an integrated circuit as shown.
The integrated circuit can be assumed to have infinite resistance.



(a)(i) Sketch a graph to show how the potential difference V_C across the capacitor varies with time t as the switch is closed. The time constant T for this circuit is marked on the time axis.

(2)



(ii) Explain how the potential difference V_R across the resistor varies with time after the switch is closed.

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(iii) Show that V_C is given by the equation

$$V_C = 5 - 5e^{-\frac{t}{RC}}$$

where R is the resistance of the resistor
and C is the capacitance of the capacitor.

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(b) The input to the integrated circuit should be 3.3 V at a time 3.5 seconds after the switch is closed.

The following capacitors are available:

4.7 μF 10 μF 15 μF 47 μF 150 μF

Deduce which capacitor should be used.

R = 68 kΩ

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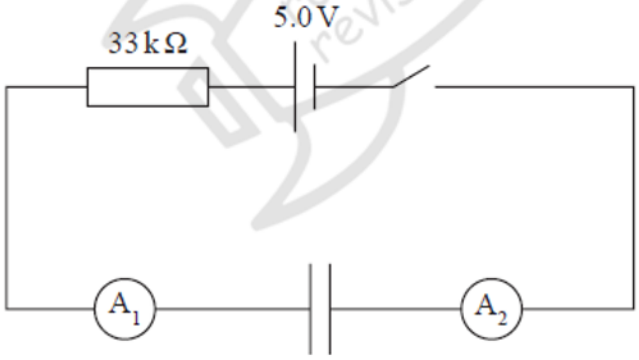
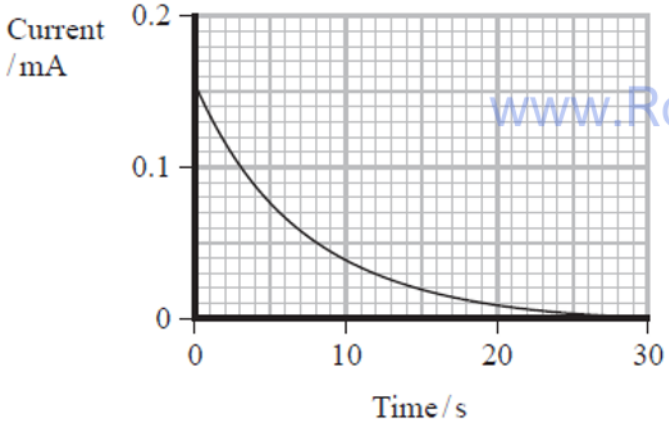
(Total for question = 9 marks)

Q12.

A student built the circuit shown. The capacitor was initially uncharged.



She closed the switch and plotted a graph of current on ammeter A_1 against time.



(a) Determine whether the initial value of current on the graph is consistent with the values stated on the circuit diagram.

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(b) Explain how the current on ammeter A_2 would vary over the same time interval.

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(c) Determine the capacitance of the capacitor.

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Capacitance = ...

(d) Determine the charge stored on the capacitor after 30 s.

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Charge stored on capacitor after 30 s = ...

(e) Determine the maximum energy stored by the capacitor.

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Maximum energy = ...

(Total for question = 11 marks)

Q13.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which of the following units is equivalent to the farad?

☒ **A** $C\ V^{-1}$

☒ **B** $J\ V^{-1}$

☒ **C** Ωs^{-1}

☒ **D** sJ^{-1}

(Total for question = 1 mark)

Q14.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

When the potential difference across a capacitor is V, the energy stored by the capacitor is W.

Which of the following gives the energy stored by the capacitor when the potential difference across the capacitor is $2V$?

☒ **A** W

☒ **B** $2W$

☒ **C** $3W$

☒ **D** $4W$

(Total for question = 1 mark)

Q15.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A capacitor discharges through a resistor. The time constant of the circuit is 5 s.

What is the time taken, in s, for the charge on the plates of the capacitor to halve?

☒ **A** 0.5 ln2

☒ **B** 0.5 ln5

☒ **C** 2 ln5

☒ **D** 5 ln2

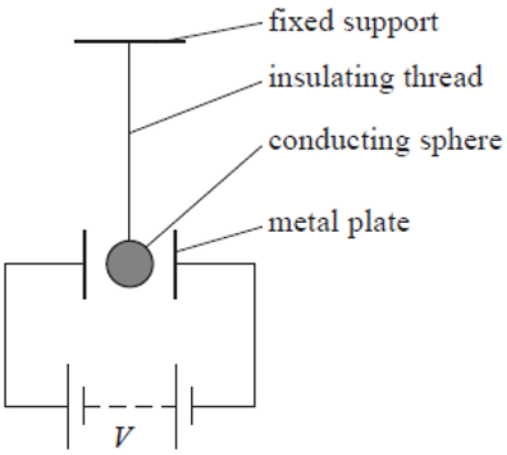
(Total for question = 1 mark)

Q16.

In the 18^{th} century, a scientist called Gordon made the first device that used electrostatic forces to produce continuous motion.

A demonstration of the principle of Gordon's device is shown.

A light, conducting sphere of radius r is suspended from an insulating thread between two parallel metal plates. A large potential difference V is applied between the plates.



(a) There is an electrostatic force on the sphere when the sphere is charged.

The capacitance C of the sphere is given by

$$C = 4\pi\varepsilon_0 r$$

where r is the radius of the conducting sphere.

The sphere is charged by touching it onto one of the plates. The plates are a distance d apart.

Calculate the electrostatic force exerted on the sphere.

V = 4500 V
d = 5.0 cm
r = 3.5 cm

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Electrostatic force on sphere = ...

(b) After the sphere has been charged, the sphere starts to oscillate between the plates. The sphere touches each plate alternately.

Explain why the conducting sphere oscillates between the two plates.

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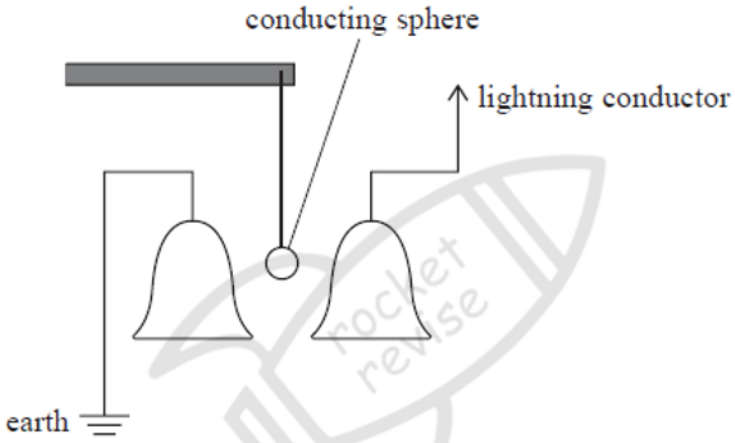
(c) A few years later, another scientist called Franklin adapted Gordon's device. Franklin suspended a conducting sphere between two metal bells.

One metal bell was connected to earth and the other metal bell was connected to a lightning conductor, as shown. During an electrical storm, the sphere oscillates between the bells and the bells ring.



The lightning conductor is a long wire, attached to the top of a building.
The lightning conductor becomes positively charged when in an electric field.

The conducting sphere is initially uncharged.

Explain why the conducting sphere starts to move between the bells during an electrical storm.

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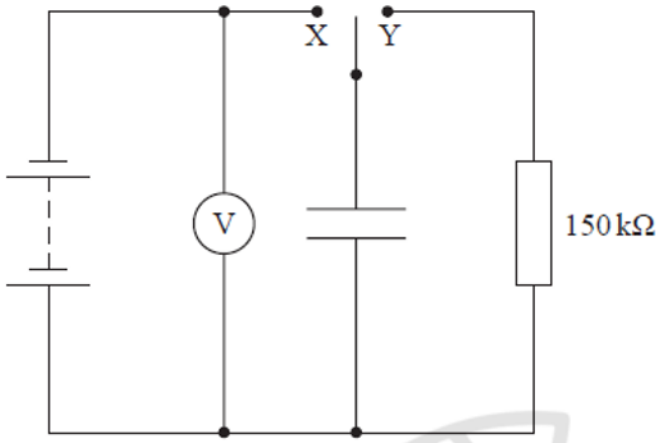
(Total for question = 10 marks)

Q17.

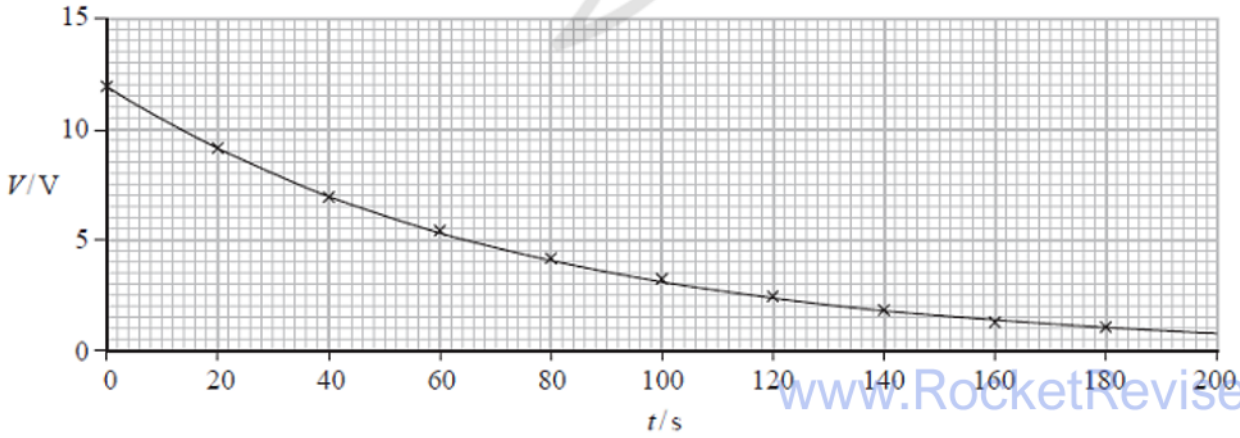
A student used the circuit shown to determine the capacitance of a capacitor.



The student connected the switch to X to charge the capacitor. She then connected the switch to Y so that the capacitor discharged through the 150 kΩ resistor.

The student started a stopwatch when she connected the switch to Y and recorded the voltmeter reading *V* every 20 s as the capacitor discharged.

The graph shows how *V* varied with time *t*.



(a) The capacitor is labelled as 470 μF, with a tolerance of ±10%.

Evaluate whether the capacitance of the capacitor is within the stated tolerance.

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(b) An ultracapacitor is a high-capacity capacitor.

One ultracapacitor has a capacitance of 47 F. The maximum charge this capacitor can store is 56 C.

It is suggested that this capacitor could store 1000 times as much energy as a 470 μF capacitor charged to a potential difference of 12 V.

Assess the validity of this suggestion.

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(Total for question = 7 marks)

Q18.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

There is a potential difference of 6 V across a 220 μF capacitor.

Which of the following expressions gives the charge stored on the capacitor?

☒ **A** $0.5 \times 2.2 \times 10^{-4} \times 6$

☒ **B** $2.2 \times 10^{-4} \times 6$

☒ **C** $\frac{0.5 \times 2.2 \times 10^{-4}}{6}$

☒ **D** $\frac{2.2 \times 10^{-4}}{6}$

(Total for question = 1 mark)

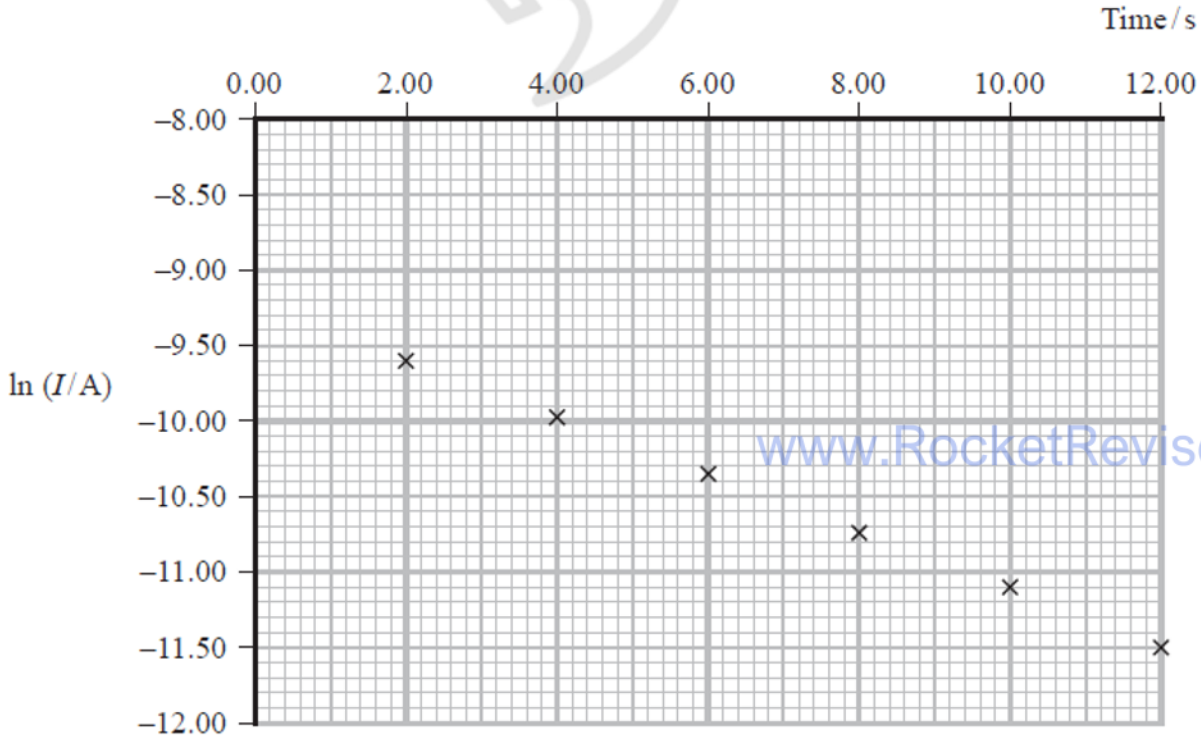
Q19.

A student planned to use a capacitor in a timing circuit.

The capacitor was connected in series with a resistor to determine the capacitance of the capacitor.

The capacitor was charged while measuring the current *I* in the circuit.

The following graph was plotted.



(a) The value marked on the capacitor is 22 μF.

Show that this value is correct.

resistance of resistor = 240 kΩ

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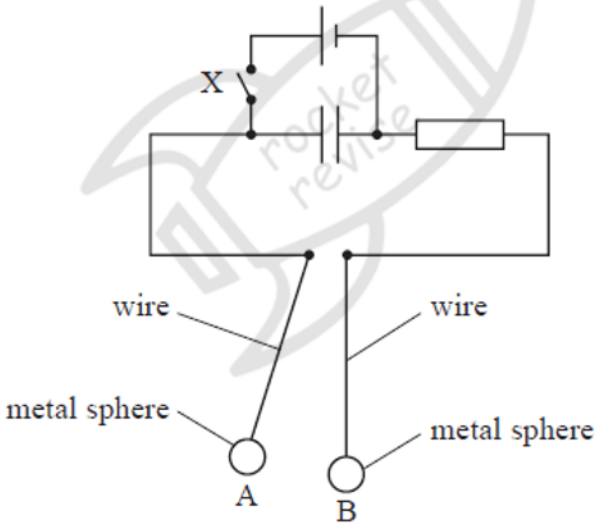
(b) The capacitor was used in a circuit to time a collision between two identical metal spheres.

The spheres were suspended from wires. The wires were connected to the circuit, as shown.



When the wires hang vertically the spheres are in contact and the discharging circuit is complete.

Switch X was closed to charge the capacitor. The switch was then opened and sphere A was released.

Sphere A collided with sphere B.

While the spheres were in contact, the capacitor partially discharged.

Sphere B moved to the right. The maximum height *h* of sphere B above its starting position was measured.

(i) Calculate the maximum speed of sphere B after the collision.

h = 1.1 cm
mass of sphere B = 28 g

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Maximum speed = ...

(ii) Calculate the time for which the spheres were in contact.

resistance in circuit = 49 Ω
potential difference across capacitor before collision = 6.18 V
potential difference across capacitor after collision = 5.43 V
capacitance of capacitor = 22 μF

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Time spheres in contact = ...

(iii) The student stated that the average force acting on sphere B cannot be more than the weight of sphere A.

Deduce whether this statement is correct.

mass of each sphere = 28 g

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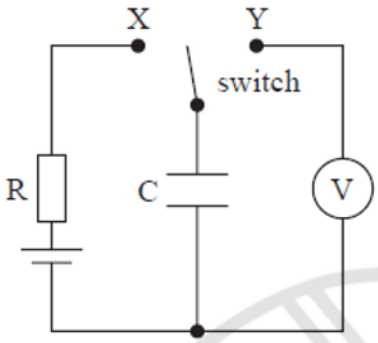
(Total for question = 13 marks)

Q20.

A student was investigating capacitors and set up the circuit shown.



The student planned to use the circuit to measure the potential difference *V* across the capacitor C as it was charged and discharged through the resistor R.

(a) Give two reasons why the circuit did not operate as intended.

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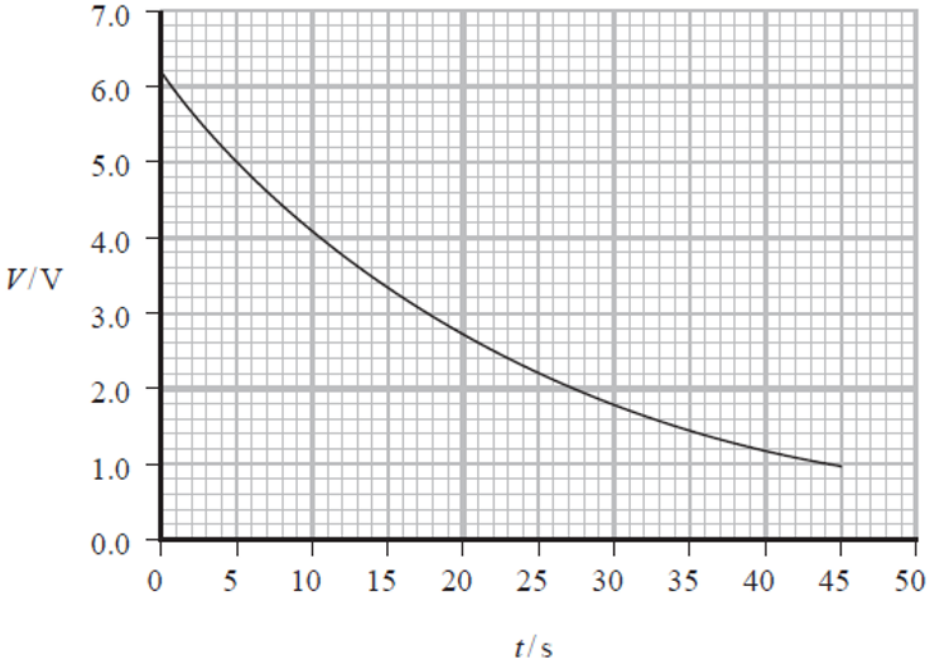
(b) The student moved the switch from position X to position Y at time $t = 0$ s.

The student recorded values of *V* as *t* increased and plotted the graph shown.



The capacitance of capacitor C was 2.2 μF.

(i) Determine the resistance in the circuit when the switch was at position Y.

(3)

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Resistance = ...

(ii) Determine the average current in the circuit between $t = 0$ s and $t = 30$ s.

(4)

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Average current = ...

(iii) Calculate the energy dissipated by the current in the circuit between $t = 0$ s and $t = 30$ s.

(3)

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Energy dissipated = ...

(Total for question = 12 marks)