Electrical Circuits and Internal Resistances

Q1.

Small electrical devices are often powered by electric cells; different devices use different types of cell.

The cells normally used in a television remote control have an e.m.f. of 1.5 V.

(i) Describe a procedure to determine the internal resistance and e.m.f. of an electrical cell. You should include a circuit diagram.

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(ii) Describe how you would use your results to find a value for the e.m.f. and internal resistance of the cell.

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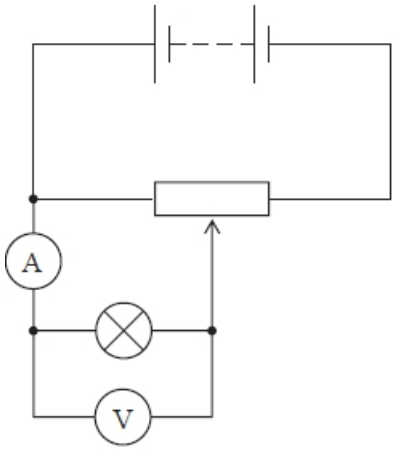
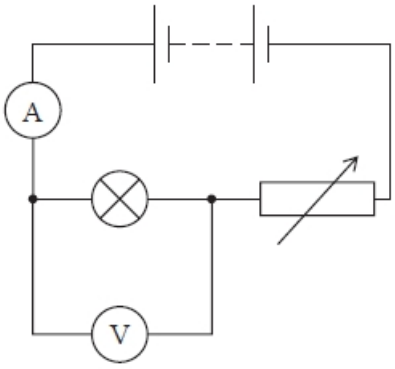
(Total for question = 6 marks)

Q2.

A student is planning to collect data to produce a current-potential difference graph for a filament lamp. Her teacher suggests two circuits that she could use.



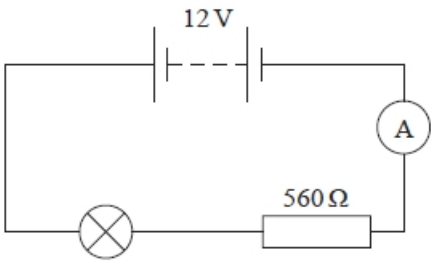
Circuit 1



Circuit 2

Circuit 1 uses a potential divider and circuit 2 uses a variable resistor to vary the potential difference across the filament lamp.

The student sets up the following circuit with the filament lamp. The battery has negligible internal resistance.



(i) The reading on the ammeter is 17.5 mA.

Calculate the value of the potential difference (p.d.) across the filament lamp.

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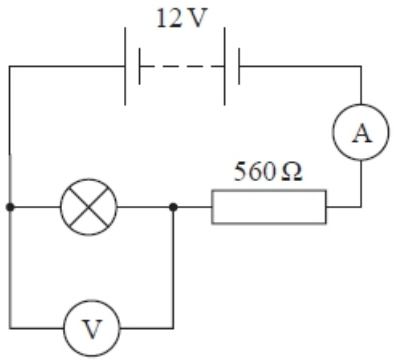
pd across filament lamp = ...

(ii) When a voltmeter with a resistance of 1.5 kΩ is connected as shown, the p.d. across the filament lamp decreases.



Explain why the p.d. across the filament lamp decreases.

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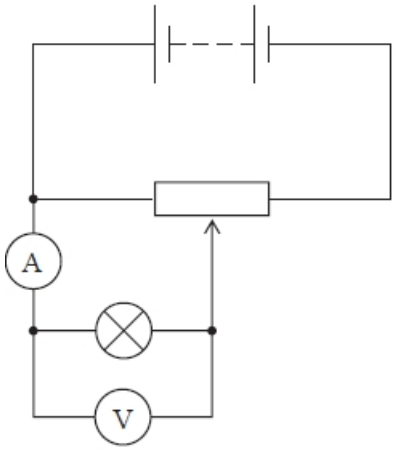
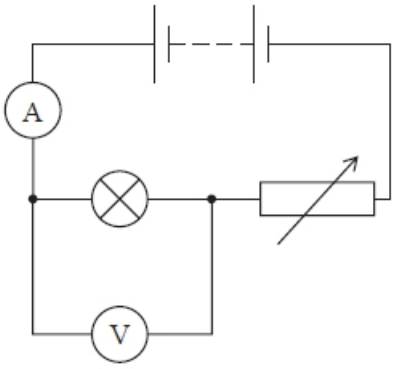
(Total for question = 5 marks)

Q3.

A student is planning to collect data to produce a current-potential difference graph for a filament lamp. Her teacher suggests two circuits that she could use.



Circuit 1



Circuit 2

Circuit 1 uses a potential divider and circuit 2 uses a variable resistor to vary the potential difference across the filament lamp.

*Discuss the suitability of each circuit to collect the data.

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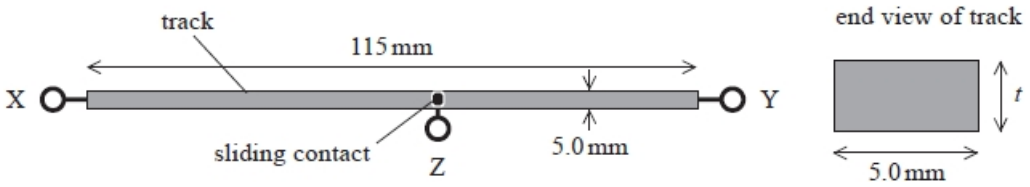
(Total for question = 6 marks)

Q4.

A potential divider circuit may contain a component known as a potentiometer. One type of potentiometer consists of a track with terminals X and Y at either end. There is a sliding contact that can move along the track connected to a terminal Z as shown.

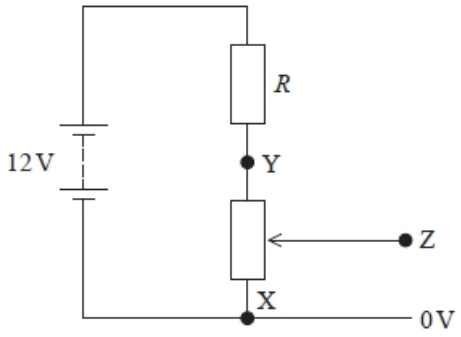


The length of the track is 115 mm and the width is 5.0 mm.

The resistance of the track between terminal X and terminal Y is 12.0 kΩ.

Resistivity of track material = 0.49 Ω m

The potentiometer is used to monitor the displacement of a moving tool on a machine in a production line. The tool is attached to the sliding contact. The potentiometer is connected to a resistor of resistance *R* and a potential difference is applied as shown. The tool moves through a maximum displacement of 60 mm from end X, producing a maximum potential difference of 5.0 V between Z and X.



(i) Show that the potential difference between X and Y is about 10 V.

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(ii) Calculate the value of *R*.

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R = ...

(iii) When the circuit is assembled, using the correctly calculated resistance value and a battery of e.m.f. 12 V, it is found that the maximum output from the potentiometer is slightly less than 5.0 V.

Explain why the maximum output is slightly less than predicted.

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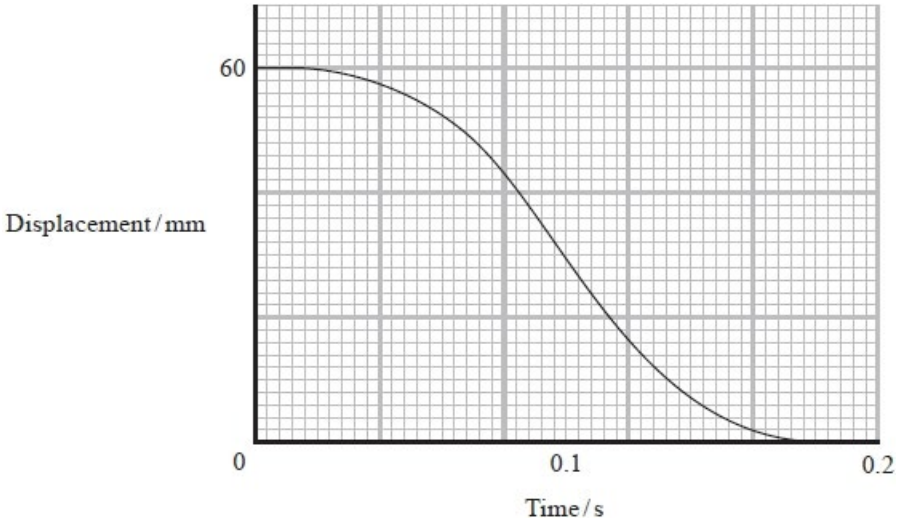
(iv) The tool on the machine should not travel with a speed any larger than 0.8 m s^{-1} .

The graph shows how the displacement varies with time for the downward stroke of the moving tool.



Deduce whether this speed is exceeded by the moving tool.

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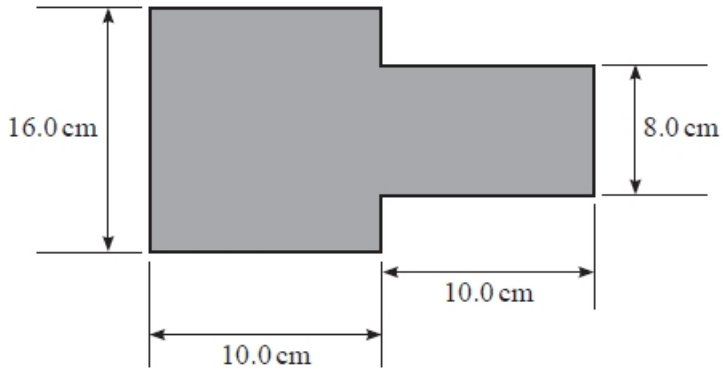
(Total for question = 12 marks)

Q5.

Carbon paper is an electrically conducting paper. A student cut a sheet of this paper into the shape shown, to carry out an investigation.

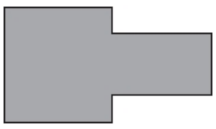


The student followed the procedure below to set up a potential divider circuit:

- connect the 16 cm and 8 cm wide ends to a 1.5 V cell
- connect the 16 cm wide end to the negative (0 V) terminal of the cell
- connect a voltmeter so that it measures the potential at a point 15 cm from the 16 cm wide end.

Add a circuit diagram to the diagram below to show how the carbon paper is connected.

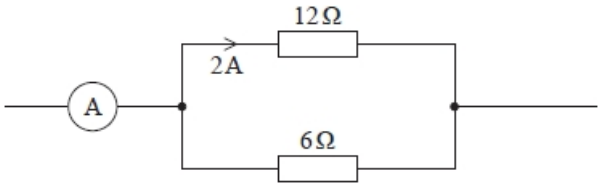
(2)



(Total for question = 2 marks)

Q6.

Part of an electric circuit is shown.



What is the current shown by the ammeter?

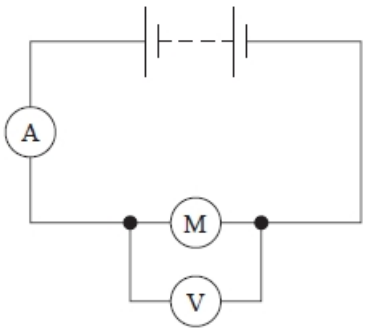
- **A** 3 A
- **B** 4 A
- **C** 5 A
- **D** 6 A

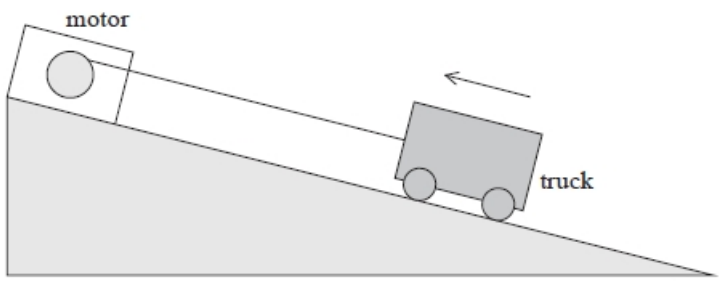
(Total for question = 1 mark)

Q7.

An electric motor is used to pull a truck up a slope at a constant speed.

The electric motor circuit includes a battery with no internal resistance, an ammeter and a very high resistance digital voltmeter as shown.





The truck moves through a vertical height of 0.20 m in 15 s. The current in the motor is 8.1 mA and the potential difference across the motor is 12 V.

mass of truck = 550 g

Calculate the efficiency of the motor.

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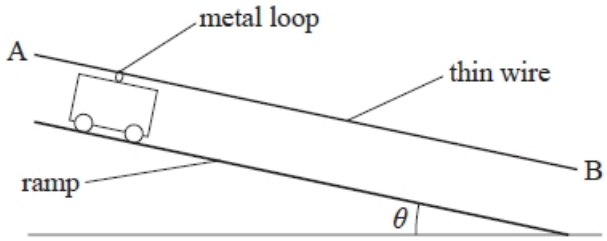
Efficiency = ...

(Total for question = 4 marks)

Q8.

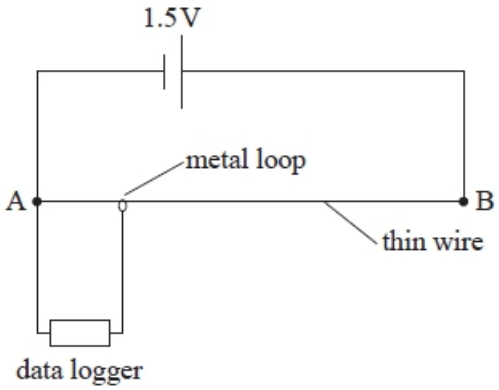
A student investigates the motion of a friction-free trolley down a ramp. On the top of the trolley there is a metal loop which makes contact with a length of thin resistance wire, AB, fixed above the ramp. The resistance wire has a uniform diameter.

The trolley accelerates down the ramp and the metal loop stays in contact with the wire along the full length of the ramp.



The student uses a protractor to measure the angle θ between the ramp and the horizontal and records a value of 4° with an uncertainty of ±1°.

(a) The two ends of the wire are connected to a 1.5 V cell. A data logger, set to measure potential difference, is connected to the metal loop and to the negative terminal of the cell.



Explain how the potential difference recorded by the data logger will vary as the loop moves along the length of the
wire AB.

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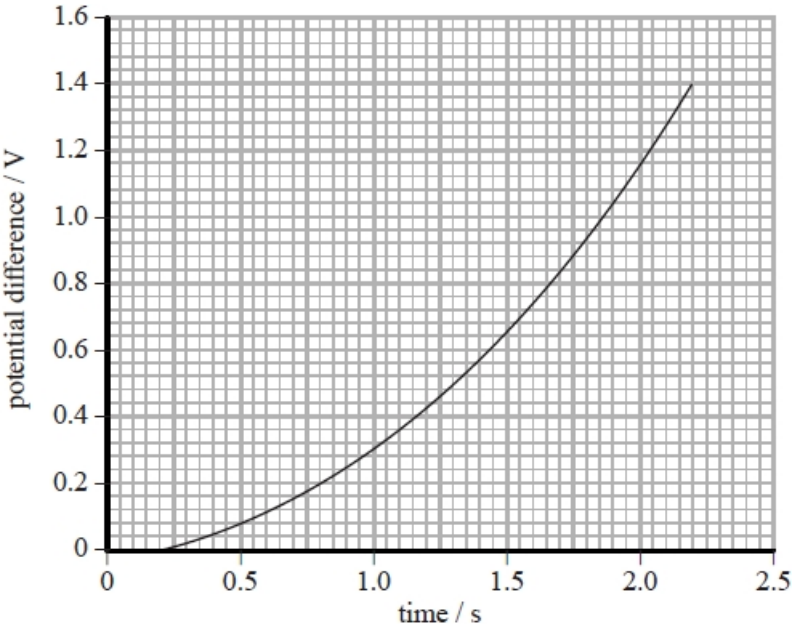
(b) The graph shows the data obtained from the data logger.



Determine the velocity of the trolley at 1.5 s.

1.5 V represents a distance of 2.00 m.

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Velocity = ...

(c) The student calculated the velocity of the trolley at 2.0 s to be 1.5 m s^{-1}.

By considering the acceleration of the trolley, determine whether the student's measurement of θ was within the uncertainty quoted.

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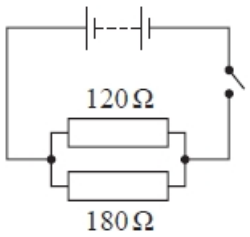
(Total for question = 11 marks)

Q9.

This resistor combination is connected to a battery of e.m.f. ε and internal resistance *r*.



The switch is closed for 5 minutes.

Calculate the energy dissipated in the resistor combination.

ε = 9.0 V
r = 2.5 Ω

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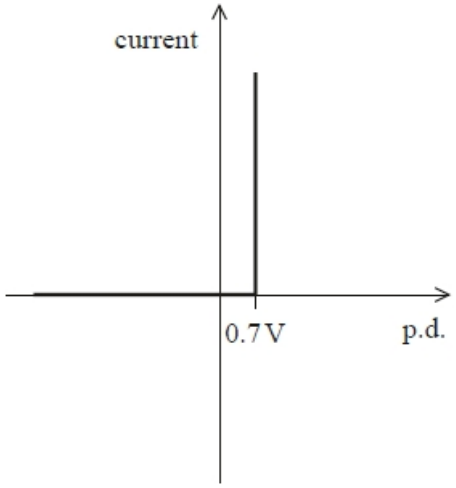
Energy dissipated in resistor combination = ...

(Total for question = 4 marks)

Q10.

The graph shows how current varies with potential difference (p.d.) for an ideal diode.



An alternating p.d. V_{IN} has a peak value of 3.4 V.

(i) Calculate the r.m.s. value.

(2)

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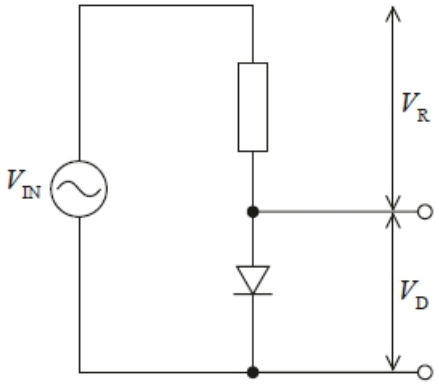
r.m.s. value = ...

(ii) V_{IN} is applied to a diode and resistor as shown.



The p.d. across the resistor is V_R and the p.d. across the diode is V_D. V_D is the output. Explain why $V_{IN} = V_R + V_D$ at any given time.

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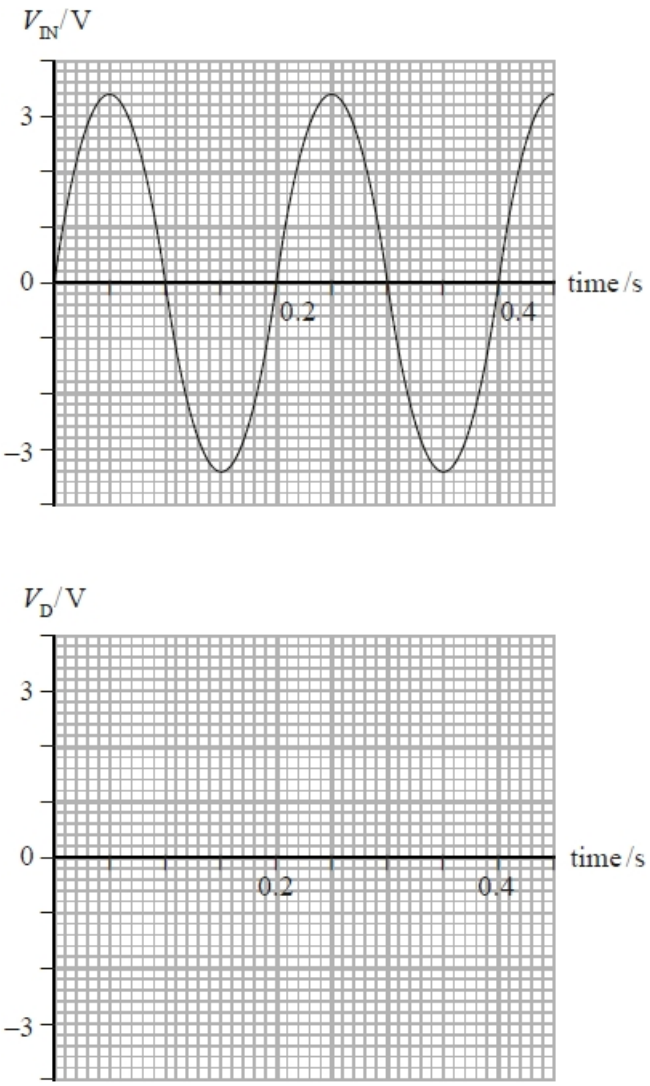
(iii) The graph shows how V_{IN} varies with time.

Sketch a graph of V_D against time using the axes provided below.

(3)

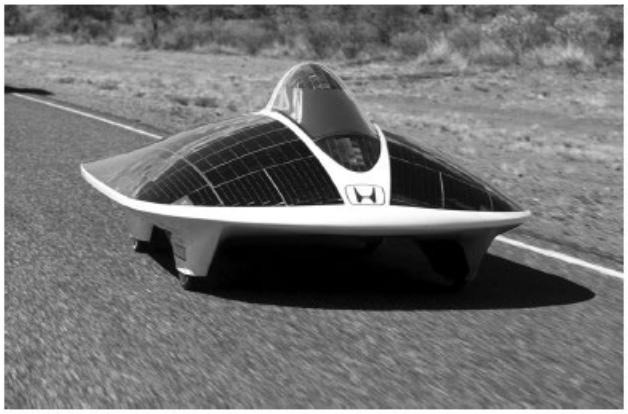


(Total for question = 7 marks)

Q11.

The world solar challenge is set every two years, in Australia. The challenge is to complete a three thousand kilometre route with a vehicle powered only by the Sun.

Vehicles have their surfaces fitted with solar panels, as shown in the photograph.



(Source: © LAURENT DOUEK/LOOK AT SCIENCES/SCIENCE PHOTO LIBRARY)

One of the solar panels has an e.m.f. of 8.2 V when in sunlight. The terminal potential difference is 5.5 V when a current of 0.45 A is drawn from the solar panel.

Calculate the internal resistance of the solar panel in these conditions.

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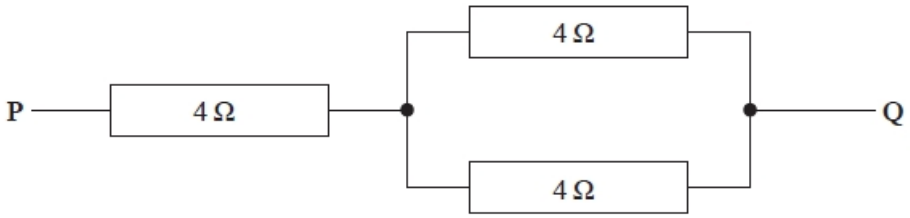
Internal resistance = ...

(Total for question = 3 marks)

Q12.

The diagram shows a combination of three identical resistors.



What is the combined resistance between P and Q?

☒ **A** 4 Ω

☒ **B** 6 Ω

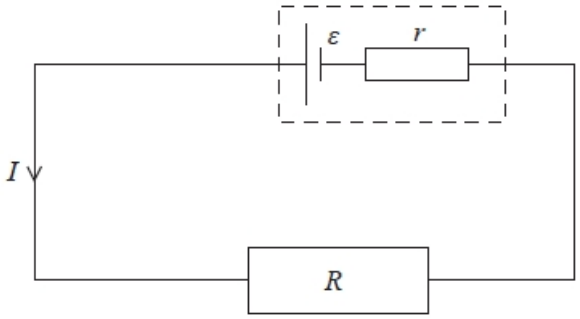
☒ **C** 8 Ω

☒ **D** 12 Ω

(Total for question = 1 mark)

Q13.

The diagram represents a resistor of resistance *R* in a series circuit with a cell of e.m.f. *ε* and internal resistance *r*.



Which of the following correctly gives the potential difference *V* across the internal resistance?

☒ **A** $V = \frac{\varepsilon(R + r)}{r}$

☒ **B** $V = \frac{\varepsilon R}{R + r}$

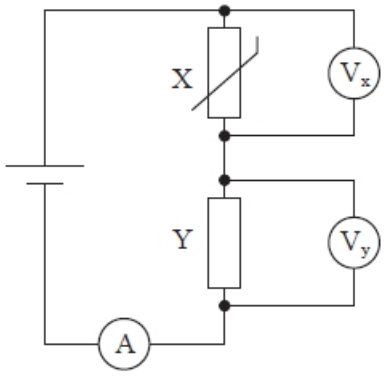
☒ **C** $V = \frac{\varepsilon(R + r)}{R}$

☒ **D** $V = \frac{\varepsilon r}{(R + r)}$

(Total for question = 1 mark)

Q14.

The diagram shows a potential divider circuit that contains a negative temperature coefficient thermistor.



The temperature of the room containing the circuit increases.

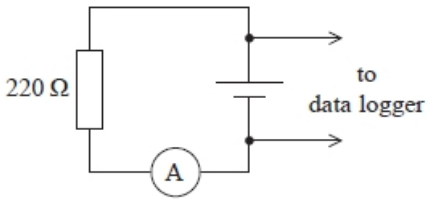
Select the row of the table that correctly shows the changes in readings on the meters.

	V_x	V_y	A
☐ **A**	decrease	increase	decrease
☐ **B**	decrease	increase	increase
☐ **C**	increase	decrease	decrease
☐ **D**	increase	decrease	increase

(Total for question = 1 mark)

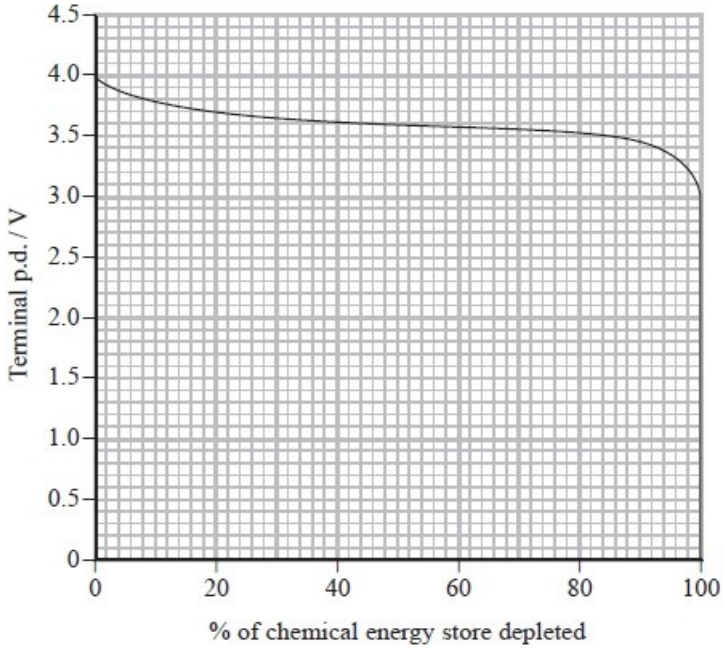
Q15.

A student is investigating how the internal resistance of a dry cell varies over time. She sets up the circuit shown to draw current from the cell.



The student proposes to use a data logger to monitor the terminal potential difference (p.d.) of the cell over a period of time.

The graph shows how the terminal p.d. varies as the chemical energy store in the cell is depleted.



(i) Explain, using the graph, why the current drawn from the cell decreases as the chemical energy store in the cell is depleted.

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(ii) Determine the internal resistance of the cell when its chemical energy store is 80% depleted. Assume that the e.m.f. of the cell remains constant at 4.0 V.

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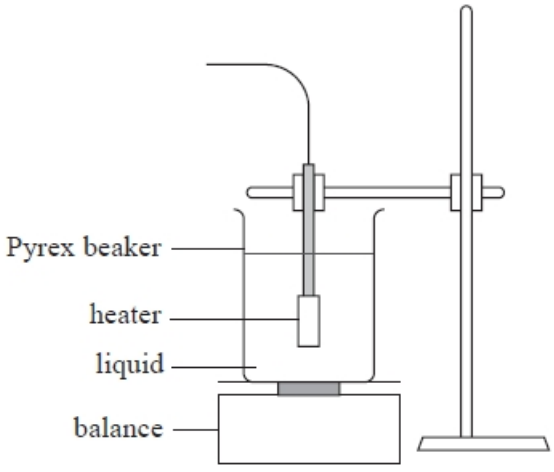
Internal resistance = ...

(Total for question = 5 marks)

Q16.

A student determined the latent heat of vaporisation of a liquid using an electrical heater to boil the liquid in a Pyrex beaker.

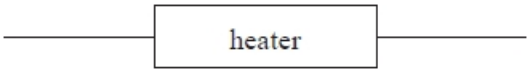
The apparatus used is shown below.



She connected the heater into a circuit and took measurements of the potential difference *V* and the current *I* for the heater.

Complete the circuit diagram to show a suitable circuit.

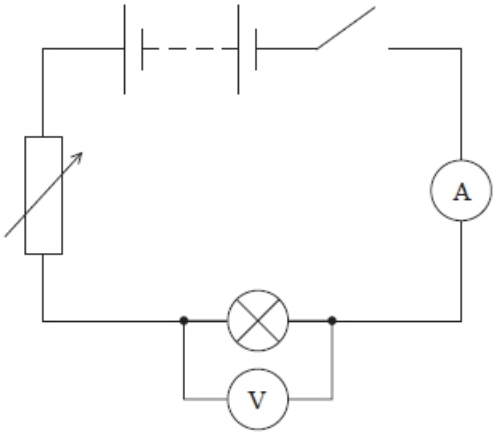
(2)



(Total for question = 2 marks)

Q17.

A student set up the circuit shown and measured the current *I* through the filament lamp for a range of values of potential difference (p.d.) *V*.



The student's data is shown in the table.

V / V	*I* / A
3.0	0.6
4.0	0.75
6.0	1.00
8.0	1.20
10.0	1.35
12.0	1.5

Using the circuit shown the student was unable to obtain data for p.d.s less than 2.5 V.

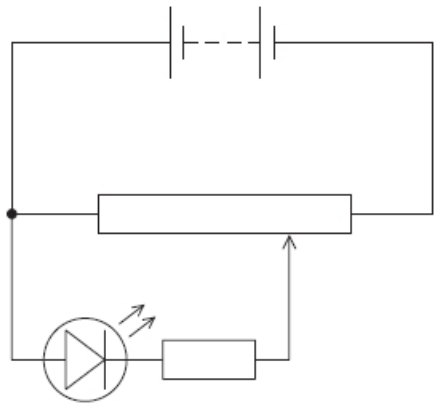
Draw a diagram of a circuit the student could have used to enable a full range of p.d.s from 0 to 12 V to be investigated.

(2)

(Total for question = 2 marks)

Q18.

A student wanted to plot a graph of current against potential difference for a light emitting diode (LED). He used the circuit shown.



Add an ammeter and a voltmeter to the circuit diagram that would enable the data to be collected.

(1)

(Total for question = 1 mark)

Q19.

A student is deriving an equation for the total resistance of resistors in series.

She writes the following steps but does not justify them.

Step 1 $V = V_1 + V_2$
Step 2 $but\ V = IR$
Step 3 $so\ IR = I_1R_1 + I_2R_2$
Step 4 $but\ I = I_1 = I_2$
Step 5 $Therefore\ R = R_1 + R_2$

Which step is justified using conservation of charge?

(1)

☒ **A** Step 1

☒ **B** Step 2

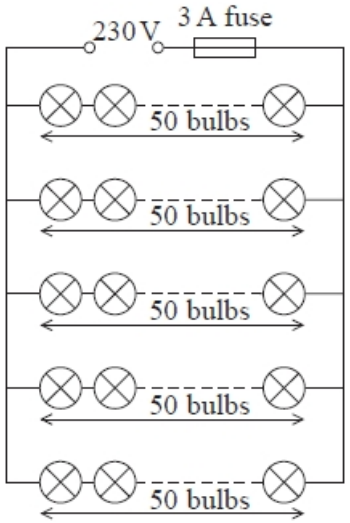
☒ **C** Step 3

☒ **D** Step 4

(Total for question = 1 mark)

Q20.

A set of festive lights is made up of five parallel strands of filament bulbs. Each strand contains 50 bulbs in series as shown.



(a) When a bulb is working normally its resistance is 8.0 Ω. If the filament of the bulb breaks, the lamp is designed to still conduct and its resistance becomes 3.0 Ω.

(i) The filament of one bulb on a strand breaks.
By considering the effect this has on the remaining bulbs in that strand, explain why it is recommended that broken bulbs are replaced as soon as possible.

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(ii) The set of festive lights are fitted with a 3 A fuse. Five bulbs in one strand break.
Determine whether the fuse blows.

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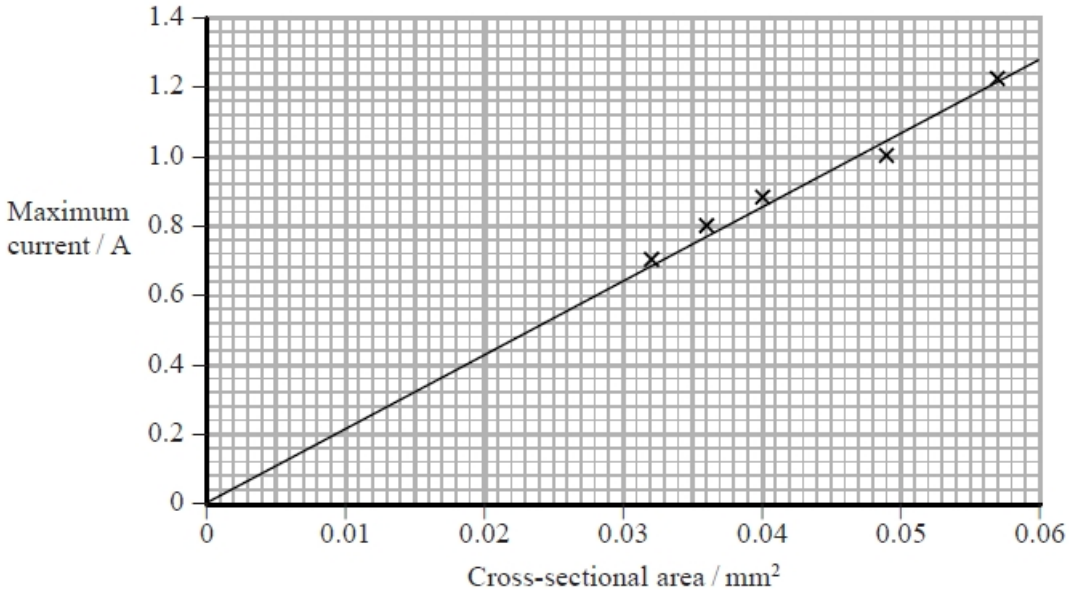
(b) A student investigates how the cross-sectional area of a fuse wire affects the current at which the fuse blows. She uses pieces of wire of the same material and length, but different cross-sectional areas. She steadily increases the current through each piece of wire and records the maximum current through the wire before it breaks.

She then plots a graph of maximum current against cross-sectional area.



(i) Describe how the student should determine the cross-sectional area of the wire.

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(ii) State the relationship between the maximum current and the cross-sectional area of the wire.

(1)

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(iii) The student chooses a piece of wire, of the same material and length as used in the investigation. The piece of wire has a diameter of 0.40 mm.

Use the graph to determine whether the piece of wire is suitable to use as the 3A fuse wire for the set of festive lights.

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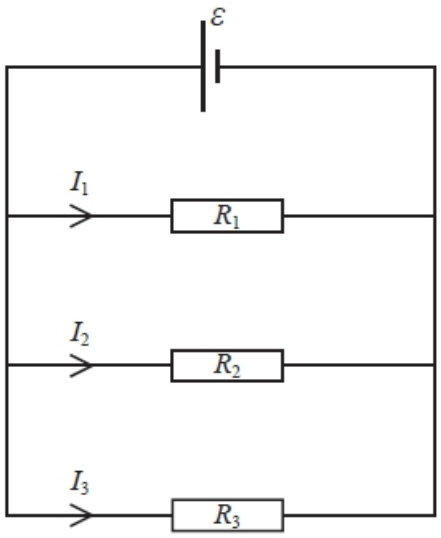
(Total for question = 14 marks)

Q21.

Three resistors, of resistance R_1, R_2 and R_3 respectively, are connected in parallel across a cell. The cell has negligible internal resistance and electromotive force ε.



Use the principle of conservation of charge to show that the total resistance R_T of the three resistors can be found using the expression

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

(3)

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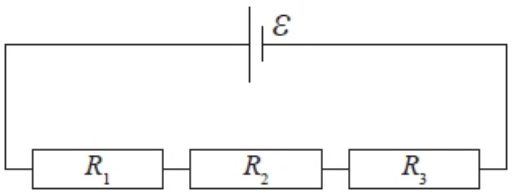
(Total for question = 3 marks)

Q22.

Three resistors, of resistance R_1, R_2 and R_3, are connected in series across a cell. The cell has electromotive force (e.m.f.) ε with negligible internal resistance. The current through the cell is I.



Derive the formula for the total resistance R_T of the circuit in terms of R_1, R_2 and R_3.

(3)

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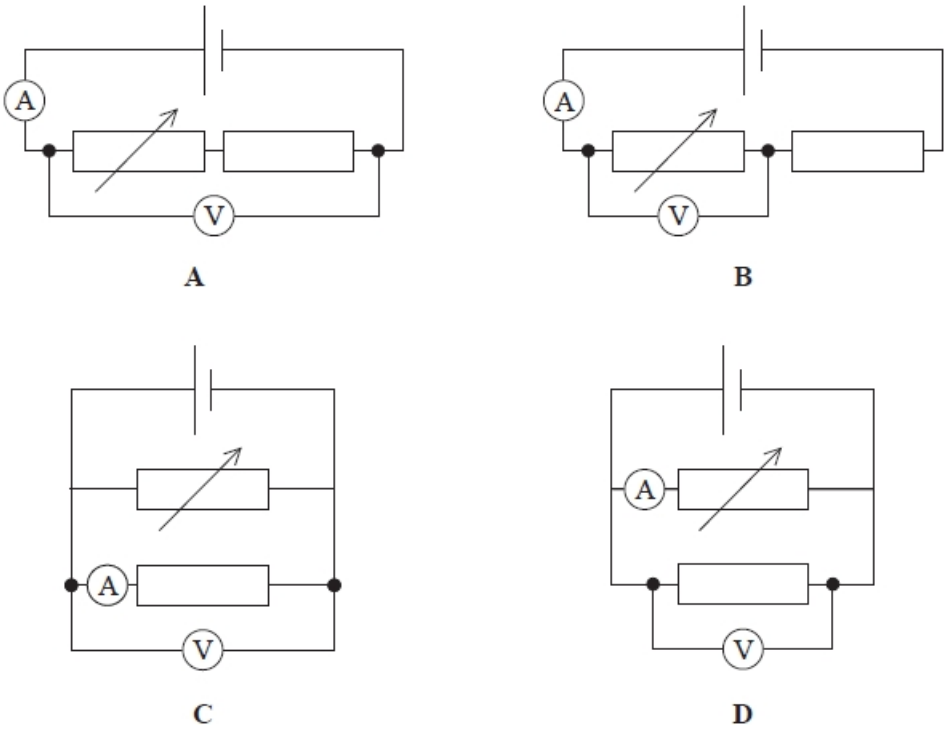
(Total for question = 3 marks)

Q23.

A student carried out an experiment to determine the electromotive force (e.m.f.) of a cell. The current in a circuit was changed by adjusting a variable resistor. A graph was plotted of the voltmeter reading on the *y*-axis against the ammeter reading on the *x*-axis.

Using the data obtained, the value of the intercept on the *y*-axis was the e.m.f. of the cell.

Which of the following circuits should have been used?



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

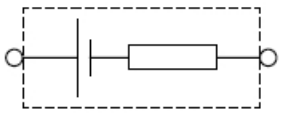
(Total for question = 1 mark)

Q24.

A student is asked to determine the e.m.f. and internal resistance of a cell using standard laboratory apparatus and a graphical method.

(a) The diagram below shows a cell with internal resistance. Add to the diagram to show the circuit she could use.

(2)



(b) Explain how she should determine the e.m.f. and internal resistance of the cell. Your answer should include a sketch of the graph.

(5)

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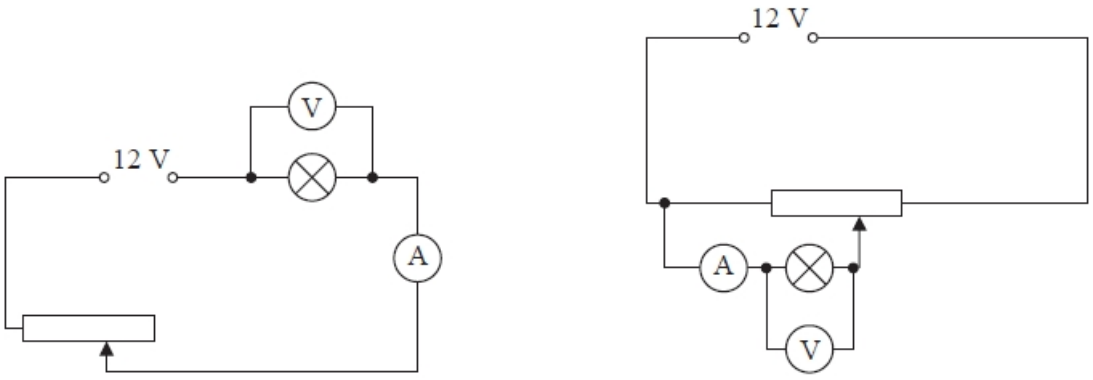
(Total for question = 7 marks)

Q25.

Students are investigating how the current through a filament lamp depends upon the potential difference across the lamp. They are provided with a power supply of 12 V and a variable resistor.

Two students set up different circuits as shown.



Circuit A Circuit B

Evaluate the effectiveness of the circuit used by each student in obtaining data for a current-potential difference characteristic graph. Assume that the voltmeters have infinite resistance.

(5)

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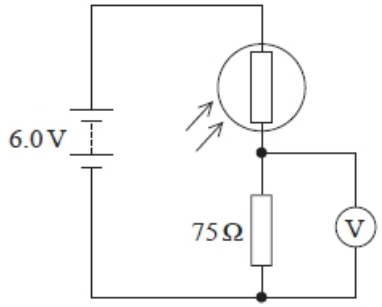
(Total for question = 5 marks)

Q26.

A student set up a circuit containing a light dependent resistor (LDR) in series with a fixed resistor as shown.



As the student moved a lamp towards the circuit she observed the potential difference (p.d.) changing across the fixed resistor.

With reference to the electrons in the LDR explain this observation.

(5)

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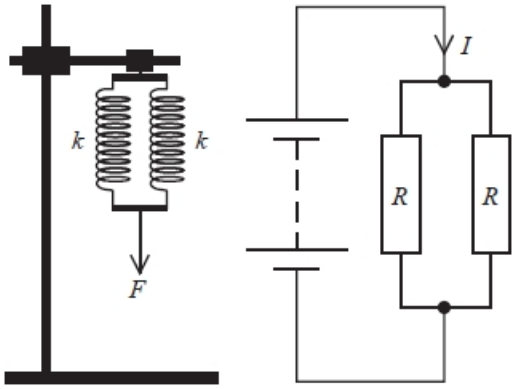
(Total for question = 5 marks)

Q27.

A student is experimenting with different combinations of springs and recalls that in physics it is often possible to model different physical situations in similar ways.

The student suggests that a parallel combination of springs could be a model for a parallel combination of resistors in a circuit.



Derive an expression for the effective resistance R_{eff} of two resistors R_1 and R_2 connected in parallel in a circuit.

(3)

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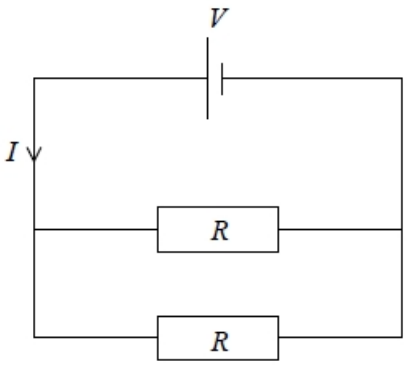
(Total for question = 3 marks)

Q28.

A potential difference, *V*, is applied to two resistors in parallel, each of resistance *R*.
A current, *I*, flows through the whole circuit.



The correct expression for the power developed in each resistor is given by

☒ **A** $P = IV$

☒ **B** $P = IV/4$

☒ **C** $P = V^2/2R$

☒ **D** $P = I^2R/4$

(Total for question = 1 mark)

Q29.

Read the following press release and then answer the question that follows.

"Lockheed Martin Demonstrates Weapons Grade High Power Fiber Laser

BOTHELL, Wash., Jan. 28, 2014 – Lockheed Martin has demonstrated a 30-kilowatt electric fiber laser, the highest power ever documented while retaining beam quality and electrical efficiency.

The internally funded research and development program culminated in this demonstration, which was achieved by combining many fiber lasers into a single, nearperfect quality beam of light – all while using approximately 50 percent less electricity than alternative solid-state laser technologies. The unique process, called Spectral Beam Combining, sends beams from multiple fiber laser modules, each with a unique wavelength, into a combiner that forms a single, powerful, high quality beam."

(Source: Lockheed Martin Demonstrates Weapons Grade High Power Fiber Laser Wash Bothell, Jan 28, 2014)

A student uses a laser pointer to measure the internal resistance of a cell.
The laser uses a battery of three small cells.
The student obtains the following results:

Laser switched off	
Potential difference across cells	4.1 V
Current in cells	0 mA
Laser switched on	
Potential difference across cells	3.7 V
Current in cells	14 mA

(i) Calculate the internal resistance of the battery of cells.

(2)

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Internal resistance = ...

(ii) The student notices that the manufacturer of the laser pointer claims it is as efficient as industrial lasers. At a distance of several metres the laser pointer produces a circular spot of diameter 6 mm and intensity 140 W m^{-2}.

Max power output < 5mW

Use this data and the data in the passage to evaluate the manufacturer's claim.

(5)

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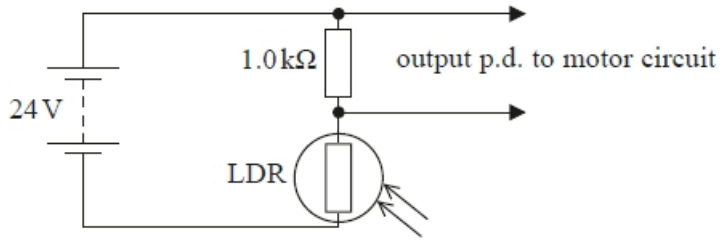
(Total for question = 7 marks)

Q30.

A solar panel uses electromagnetic radiation from the Sun to generate electricity.
In one installation a sensor in the solar panel measures the intensity of radiation arriving from different directions. A motor rotates the solar panel so that it always faces the brightest part of the sky.

The circuit diagram shows how a light dependent resistor (LDR) can be used to produce an output potential difference (p.d.) that is dependent on the intensity of light. This output p.d. is connected to a motor circuit that operates the movement of the solar panel.



Initially the motor is switched off. The light intensity increases and the resistance of the LDR decreases to 750 Ω.

The motor switches on when the output p.d. is above 13 V.

Deduce whether this change in light intensity causes the motor to switch on.

(3)

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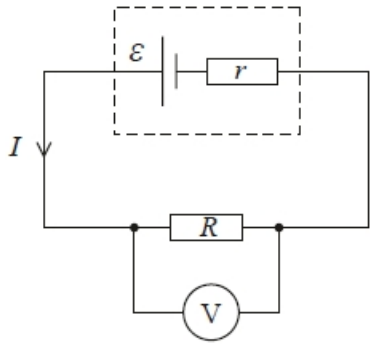
(Total for question = 3 marks)

Q31.

A cell of e.m.f ε and internal resistance r is connected across a fixed resistor of resistance R. There is a current I in the circuit and a potential difference V across the fixed resistor.



The term 'lost volts' refers to the difference between the e.m.f. and the terminal potential difference.

Which of the following is an expression for the lost volts?

☒ **A** $I\,(R + r)$

☒ **B** Ir

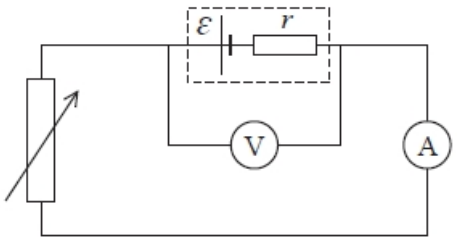
☒ **C** IR

☒ **D** $I(R - r)$

(Total for question = 1 mark)

Q32.

A cell of e.m.f. ε and internal resistance r is connected across a variable resistor as shown.



A student varied the current in the circuit using the variable resistor.
The current I and the corresponding potential difference V across the cell were recorded.
A graph was plotted of V against I.

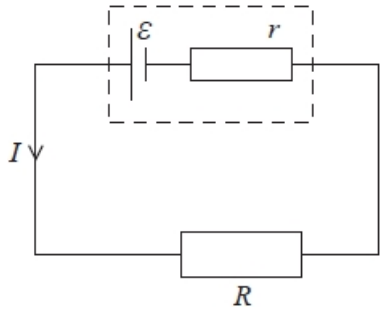
Which of the following statements about the graph is correct?

	Gradient	Intercept on y-axis
☒ **A**	positive	r
☒ **B**	positive	ε
☒ **C**	negative	r
☒ **D**	negative	ε

(Total for question = 1 mark)

Q33.

A cell of e.m.f. ε and internal resistance r is connected across an external resistor of resistance R.



Which is the correct expression for the terminal potential difference V of the cell?

☒ **A** $V = \varepsilon + Ir$

☒ **B** $V = \varepsilon - Ir$

☒ **C** $V = \varepsilon + IR$

☒ **D** $V = \varepsilon - IR$

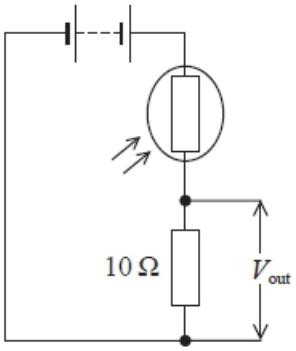
(Total for question = 1 mark)

Q34.

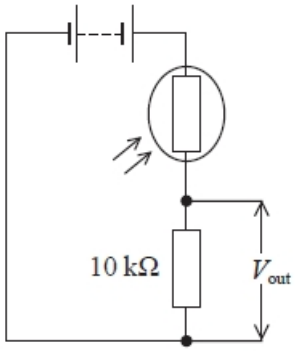
When a light dependent resistor is illuminated, its resistance falls from 1000 kΩ to 0.1kΩ.

The light dependent resistor is connected in series with a fixed resistor.

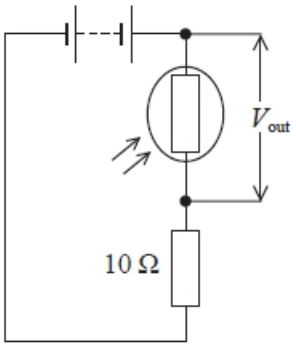
Which of the circuits shown would produce the greatest output potential difference V_{out} when illuminated?



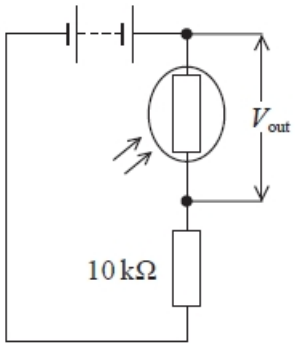
☒ **A**



☒ **B**



☒ **C**



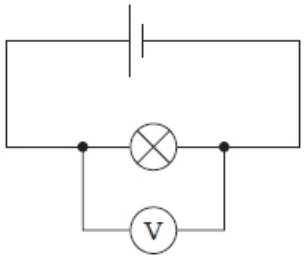
☒ **D**

(Total for question = 1 mark)

Q35.

A torch uses a 1.5 V dry cell. Over time, the light intensity produced by the torch decreases as the cell 'goes flat'.

Student A sets up the following circuit in an attempt to measure the e.m.f. of a cell.



Explain why the voltmeter reading will **not** be the e.m.f. of the cell.

(2)

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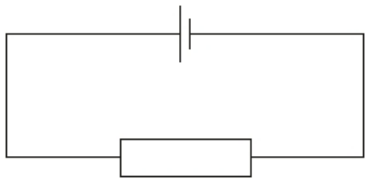
(Total for question = 2 marks)

Q36.

A cell of e.m.f. 1.5 V is connected to a 5.0 Ω resistor. The terminal potential difference across the cell is 1.0 V.



Which of the following is the current in the circuit?

☒ **A** 0.1 A

☒ **B** 0.2 A

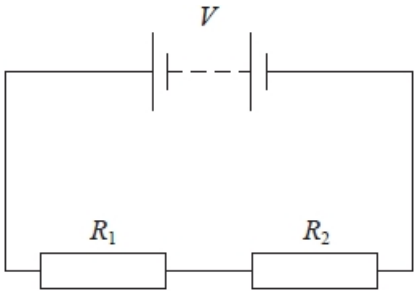
☒ **C** 0.3 A

☒ **D** 0.5 A

(Total for question = 1 mark)

Q37.

Two resistors of resistance R_1 and R_2 are connected to a battery as shown.
The terminal potential difference of the battery is V.



Which of the following gives the potential difference across the resistor of resistance R_1?

☒ **A** $\frac{R_1}{R_2} \times V$

☒ **B** $\frac{R_1}{R_1 + R_2} \times V$

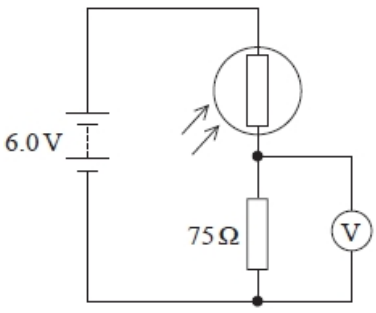
☒ **C** $\frac{R_2}{R_1} \times V$

☒ **D** $\frac{R_2}{R_1 + R_2} \times V$

(Total for question = 1 mark)

Q38.

A student set up a circuit containing a light dependent resistor (LDR) in series with a fixed resistor as shown.



When the lamp was at a distance of 10 cm from the LDR, the reading on the voltmeter was 2.4V.

Calculate the resistance of the LDR at this distance.

(3)

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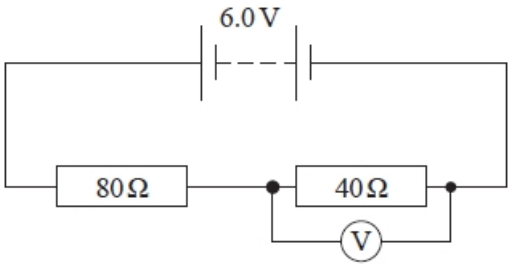
Resistance of the LDR = ...

(Total for question = 3 marks)

Q39.

The circuit diagram shows two resistors in series across a battery of e.m.f. 6.0 V and negligible internal resistance. A voltmeter with low resistance is connected across the 40 Ω resistor.



The reading on the voltmeter is 1.8 V.

Calculate the resistance of the voltmeter.

(3)

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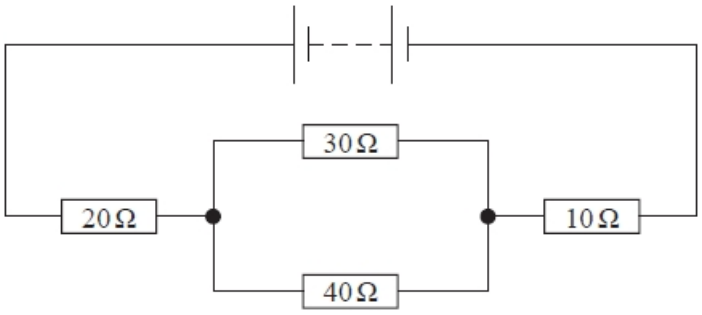
Resistance of voltmeter = ...

(Total for question = 3 marks)

Q40.

A circuit was constructed as shown.



Calculate the total resistance of the resistors in the circuit.

(3)

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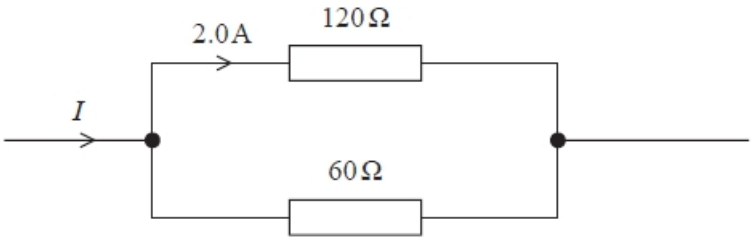
Total resistance = ...

(Total for question = 3 marks)

Q41.

Two resistors are connected in parallel and the current in one of them is 2.0 A, as shown.



Which of the following is the total resistance of the resistors in parallel?

☒ **A** 20 Ω

☒ **B** 40 Ω

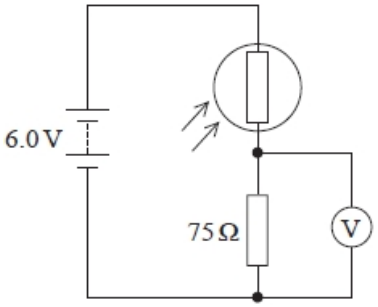
☒ **C** 90 Ω

☒ **D** 180 Ω

(Total for question = 1 mark)

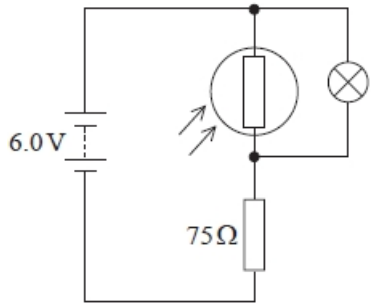
Q42.

A student set up a circuit containing a light dependent resistor (LDR) in series with a fixed resistor as shown.



The student wants to modify the circuit so that a light bulb lights up when the room goes dark.

She modifies the circuit as shown below. When working normally the resistance of the light bulb is 3Ω and the p.d. across it is 3V.



Explain, without further calculation, whether this circuit would work as intended.

(3)

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(Total for question = 3 marks)

Mark Scheme – Electrical Circuits and Internal Resistance

Q1.

Question number	Acceptable answers	Additional guidance	Mark
(i)	A description that makes reference to the following points: Circuit diagram showing: • Cell, variable resistor and ammeter in series and voltmeter in parallel with cell **(1)** • Recording pairs of readings of terminal p.d. and current **(1)** • Use the variable resistor to obtain 5 other pairs of readings **(1)**	Should be between 5 and 10 other pairs	**3**
(ii)	A description that makes reference to the following points: • Plot a graph of terminal potential difference on the y-axis and current on the x-axis **(1)** • Intercept on the y-axis equals e.m.f. **(1)** • And gradient = -r **(1)**		**3**

Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of $R = V/I$ **(1)** • $V = 2.2$ V **(1)**	Example of calculation $VV = 17.5 \times 10^{-3}\ \text{A} \times 560\ \Omega = 9.8$ V $\therefore VV_{\text{LED}} = (12 - 9.8)\text{V} = 2.2$ V	**2**

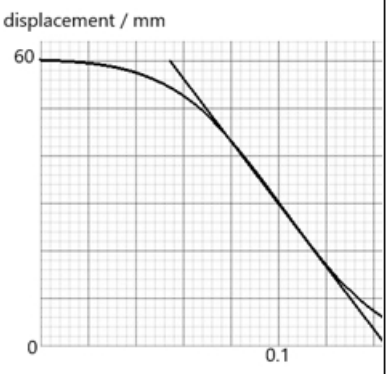
(ii)	An explanation that makes reference to the following points: **Either** • The effective resistance of the combination is less than the resistance of the lamp **(1)** • The combination has a smaller fraction of the total circuit resistance **(1)** • Hence a smaller fraction of the supply p.d. falls across the lamp **(1)** **OR** • The effective resistance of the combination is less than the resistance of the lamp **(1)** • The total circuit resistance decreases and the current increases **(1)** • So the p.d. across the resistor increases (so the p.d. across the lamp must decrease) **(1)** **OR** • Current flows through voltmeter **(1)** • So circuit current increases **Or** current through resistor increases **(1)** • So the p.d. across the resistor increases **(1)**		**3**

Q3.

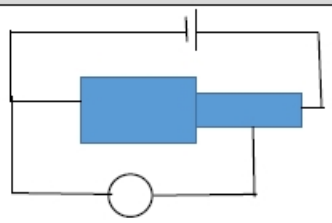
Question Number	Acceptable Answer	Additional Guidance	Mark
*	This question assesses a student's ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning. Indicative content: IC1 Both circuits are suitable because they allow readings of p.d./current for the lamp IC2 For circuit 1 the minimum p.d. across the lamp is 0 V (when the slider is at the left) **Or** For circuit 2 the minimum p.d. across the lamp is greater than 0 V For circuit 1 the maximum p.d. across the lamp is the supply p.d (when the slider is at the right) IC3 For circuit 1 the maximum p.d. across the lamp is the supply p.d	Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. Number of indicative marking points seen in answer / Number of marks awarded for indicative marking points 6 / 4 5–4 / 3 3–2 / 2 1 / 1 0 / 0 Number of marks awarded for structure of answer and sustained line of reasoning Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout / 2 Answer is partially structured with some linkages and lines of reasoning / 1 Answer has no linkages between points and is unstructured / 0 Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning IC points / IC mark / Max linkage mark / Max final mark 6 / 4 / 2 / 6 5 / 3 / 2 / 5 4 / 3 / 1 / 4 3 / 2 / 1 / 3 2 / 2 / 0 / 2 1 / 1 / 0 / 1 0 / 0 / 0 / 0	6

		(when the slider is at the right)		
	IC4	For circuit 2 adjusting the resistor changes the circuit resistance (so the current is varied) **Or** for circuit 2 the battery p.d. is shared between lamp and variable resistor		
	IC5	So for circuit 2 the minimum p.d. depends upon the resistance of the variable resistor,		
	IC6	Circuit 1 is better because it allows a bigger range **Or** Circuit 1 is better because it allows p.d.s down to 0 V to be used		

Q4.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• uses ratio of lengths to determine p.d. across potentiometer • V = 9.6 (V)	(1) (1)	Example of calculation: p.d. across potentiometer = $\frac{115\text{ mm}}{60\text{ mm}} \times 5\text{ V} = 9.6\text{ V}$	2
(ii)	• determines p.d. across R • apply $V = IR$ to potentiometer to determine current **Or** uses ratio of resistances = ratio of p.d.s • $R = 3000\ \Omega$	(1) (1) (1)	Example of calculation: current in circuit = $\frac{9.6\text{ V}}{12000\ \Omega} = 8.0 \times 10^{-4}$ A p.d. across $R = 12 - 9.6 = 2.4$ V $R = {}^{2.4\text{ V}}/_{8.0 \times 10^{-4}\text{A}}$ R = 3000 Ω (show that value gives 2400 Ω)	3
(iii)	• A battery has internal resistance • There is a p.d. across the internal resistance • Terminal p.d. less (than e.m.f.) **Or** refers to $V = E - Ir$	(1) (1) (1)	Accept "lost volts" for MP2 V must be the subject	3
(iv)	• tangent drawn on the curve • uses a triangle base of at least 0.06 s • attempt to find a gradient • velocity = 0.68 m s^{-1} so velocity not exceeded allow range from to 0.60 m s^{-1} to 0.80 m s^{-1}	(1) (1) (1) (1)	MP2 dependent on MP1  v = gradient = $\frac{60\text{ mm}}{0.144 - 0.056}$ v = 682 mm s^{-1}	4

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	• cell connected to both ends of paper with correct polarity (1) • voltmeter with one end connected to 0V end of paper and other to halfway along narrow strip of paper (1)		2

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is D A *is not correct because as it is 2A + 1A* B *is not correct because 2A +2A* C *is not correct because 2A + 3A*	6 A	1

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $E_{grav} = mgh$ (1) • Use of $P = IV$ and $P = \frac{E}{t}$ (1) • Use of Efficiency = $\frac{\text{useful power output}}{\text{total power input}}$ **Or** • Use of Efficiency = $\frac{\text{useful energy output}}{\text{total energy input}}$ (1) (1) • Efficiency = 0.74	Example of Calculation $E_P = 0.55\ kg \times 9.81\ ms^{-2} \times 0.20\ m$ $E_P = 1.08\ J$ Useful power = $\frac{1.08\ J}{15\ s} = 0.072\ W$ $P = 8.1 \times 10^{-3}\ A \times 12\ V$ Input power = 0.0972 W Input energy = 0.0972 × 15 = 1.46 J Efficiency = $\frac{1.08\ J}{1.46\ J} = 0.74$	4

Q8.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• V at top/start = 0V **Or** recognition "potential divider" **Or** V increases (by implication) **Or** V at bottom = 1.5V	(1)	**Alternative MS** Constant Current (I) in wire (1) p.d. across section of wire = Ir between A and loop (1) Increases from 0V to 1.5V linearly (1)	3
	• Two sections of wire act as series resistors **Or** $R=\rho l/A$ **Or** comment about R proportional to length **Or** $\frac{V}{1.5}=\frac{R}{R_T}$	(1)		
	• potential difference proportional to length of wire	(1)		

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• Tangent drawn at 1.5 s	(1)	Example of calculation	4
	• Scales p.d. to give distance	(1)	Gradient = $\frac{1.1\text{V}-0.2\text{V}}{1.0\text{s}}=0.9\text{Vs}^{-1}$ As 1.5 V represents 2.00 m	
	• Gradient determined using a base of triangle of at least 1.0 s **Or** use of $s=\frac{(u+v)}{2}t$ **and** correct V read from graph	(1) (1)	$v = 0.9\ \text{Vs}^{-1} \times \frac{2.00\text{m}}{1.5\text{V}} = 1.2\ \text{ms}^{-1}$	
	• velocity = 1.0 m s^{-1} – 1.3 m s^{-1}			

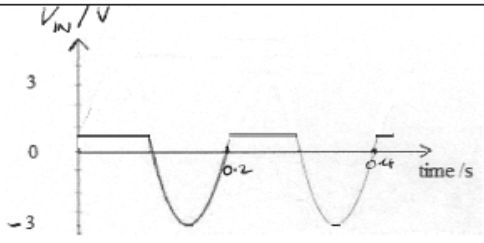
Question Number	Acceptable answers		Additional guidance	Mark
(c)	• Use of $v=u+at$	(1)	Example of calculation $1.5\,\text{ms}^{-1}=1.2\,\text{m s}^{-1}+\text{a}\times 0.5\,\text{s}$ $a=\frac{0.3\,\text{m s}^{-1}}{0.5}=0.6\,\text{m s}^{-2}$	4
	• Use of $a=g\sin\theta$	(1)		
	• Calculates a value for a, θ or v (using a SUVAT AND $a=g\sin\theta$)	(1)		
	• Valid comparison of their calculated quantity and the stated quoted uncertainty.	(1)	$0.6\,\text{m s}^{-2}=9.81\,\text{m s}^{-2}\sin\theta$ $\theta=3.6°$	

Q9.

Question Number	Answer	Additional Guidance	Mark
	• Use of $V = IR$ **(1)** • Use of $P = I^2R$ **(1)** • Use of $P = \frac{E}{t}$ **(1)** • $E = 320$ J ECF from (a) **(1)** [show that answer gives 323 J] **Or** • Use of $V = IR$ to find I **(1)** • Use of $V = IR$ to find terminal pd **(1)** • Use of $W = VIt$ **(1)** • $E = 320$ J ECF from (a) **(1)** [show that answer gives 323 J]	Example of calculation $I = \frac{9\text{ V}}{(72+2.5)\ \Omega} = 0.121\text{ A}$ $P = (0.121\text{ A})^2 \times 72\ \Omega$ $= 1.05\text{ W}$ $E = 1.05\text{ W} \times 300\text{ s}$ $= 316\text{ J}$	**4**

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of $V_{rms} = \frac{V_o}{\sqrt{2}}$ **(1)** • $V_{rms} = 2.4$ V **(1)**	Example of calculation: $V_{rms} = \frac{3.4}{\sqrt{2}} = 2.4$ V	**(2)**

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• Energy is conserved **Or** Kirchoff's law **Or** potential difference is energy per unit charge **(1)** • So the sum of p.d.s in a series circuit must equal the e.m.f. applied **(1)** (MP2 is dependent on MP1)	accept work done for energy accept V_{in} for emf Alternative: Current is the same in both components (1) $IV_{IN} = IV_R + IV_D$ and I cancels (1)	**(2)**
(iii)	• Alternate half cycles of sine curve (with peak about 3 V) **(1)** • Horizontal line in 1st half cycle and negative half cycle of a sine curve in 2nd half cycle **(1)** • horizontal lines/spaces at a value of potential difference of 0.6 V to 0.8 V **(1)**		**(3)**

Q11.

Question Number	Acceptable answers	Additional guidance	Mark
	• Calculates p.d. across internal resistance (1) • Use of $R = V / I$ (1) • Internal resistance = 6 Ω (1)	Example of calculation: $V_r = 8.2\text{V} - 5.5\text{V} = 2.7\text{V}$ $r = \frac{2.7\ \text{V}}{0.45\ \text{A}}$ $r = 6.0\ \Omega$	3

Q12.

Question Number	Answer	Mark
	B	1

Q13.

Question Number	Answer	Mark
	D	1

Q14.

Question Number	Answer	Mark
	B	1

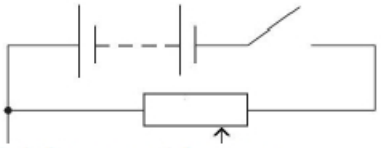
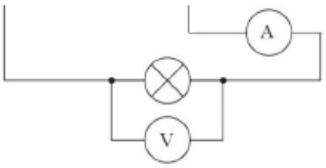
Q15.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following: • The (terminal) p.d. (of the cell) decreases. (1) • $I = \frac{V}{R}$, so the current decreases as the (external) resistance in the circuit stays constant (1)	In MP1 do not accept voltage for p.d. MP2: Accept $I \propto V$ because (external) resistance in the circuit is constant, so the current decreases	2
(ii)	• Use of $I = \frac{V}{R}$ with $R = 220\ \Omega$ or (220 + r) (1) • (Sum of e.m.f. = sum of p.d. leading to) use of $r = \frac{(\varepsilon - V)}{I}$ with I from MP1 (1) • $r = 30\ \Omega$ (allow answers in range $28\ \Omega - 32\ \Omega$) (1)	Answer in range with no working shown scores MP3 only Example of calculation $I = \frac{3.52\ \text{V}}{220\ \Omega} = 1.60 \times 10^{-2}\ \text{A}$ $r = \frac{\varepsilon - V}{I} = \frac{(4.0\text{-}3.52)\ \text{V}}{1.60 \times 10^{-2}\ \text{A}} = 30.0\ \Omega$	3

Q16.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Series circuit with power supply, heater and ammeter. (1) • Voltmeter connected in parallel with heater (1)		2

Q17.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• potential divider circuit diagram drawn as shown (1)	 Switch not essential, accept potential divider with arrow drawn through resistor	2
	• correctly incorporated into the given circuit (1)		

Q18.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Ammeter in series with LED **and** voltmeter in parallel with LED (1)		1

Q19.

Question Number	Answer	Mark
	D Step 4	1
	Incorrect Answers: A – this step uses the conservation of energy B – this step is just a statement of Ohm's law C – this step uses the conservation of energy	

Q20.

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(i)	An explanation that makes reference to the following points: • total resistance of strand decreases (1) • this increases the current in the strand OR remaining bulbs are brighter (1) • greater power / energy consumption with blown bulbs OR reduces the life of the remaining bulbs (1)		**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(ii)	• use of $V = IR$ and addition of resistances in series to determine current in strand with 5 blown bulbs (1) OR use of $V = IR$ and addition of resistances in series to determine current in healthy strands OR use of resistance in parallel and series to determine total resistance • $I = 2.9$ A (1) • 2.9 A < 3 A so fuse does not blow (1)	Example of calculation: Total current = sum of current in the four healthy strands + current in the unhealthy strand $I = 4\left(\frac{230\text{ V}}{50\times 8.0\ \Omega}\right) + \left(\frac{230\text{ V}}{(45\times 8.0\ \Omega)+(5\times 3.0\ \Omega)}\right)$ $I = 2.9$ A Allow credit for a consistent conclusion from an incorrect calculation of current	**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(i)	• use a micrometer (1) • $A = \pi\left(\frac{d}{2}\right)^2$ OR $A = \pi r^2$ and $r = \frac{d}{2}$ (1) • repeats readings in different planes/positions (1)		**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(ii)	• current directly proportional to cross-sectional area		**(1)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(iii)	• calculates area = $0.13\ (\text{mm}^2)$ **(1)** • use of $y = mx + c$ **(1)** • I = 2.8 A **(1)** • 2.8 A < 3 A so the wire is suitable to use as a fuse wire **(1)**	Example of calculation: $A = \pi\left(\frac{0.4\ \text{mm}}{2}\right)^2 = 0.13\ \text{mm}^2$ $I = \frac{1.28\ \text{A} \times 0.13\ \text{mm}^2}{0.06\ \text{mm}^2} = 2.8\ \text{A}$ Wire is suitable as I < 3 A Allow credit for a consistent conclusion from an incorrect calculation of current Accept converse working to find diameter of 3 A fuse wire	**(4)**

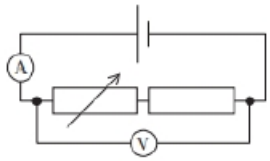
Q21.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• $Q_T = Q_1 + Q_2 + Q_3$ (1) • $Q/t = I$ hence $I_T = I_1 + I_2 + I_3$ (1) • $I = \varepsilon/R$ hence $\frac{\varepsilon}{R_T} = \frac{\varepsilon}{R_1} + \frac{\varepsilon}{R_2} + \frac{\varepsilon}{R_3}$ (1)		**(3)**

Q22.

Question Number	Acceptable answers	Additional guidance	Mark
	• A statement applying the conservation of energy to the circuit (1) • Use of Ohm's law for each term /individual pd leading to the cancelling of currents in the equation (1) • $R_T = R_1 + R_2 + R_3$ (1)	Example of calculation $\mathcal{E} = V_1 + V_2 + V_3$ $\mathcal{E} = IR_T = IR_1 + IR_2 + IR_3$ $R_T = R_1 + R_2 + R_3$	3

Q23.

Question Number	Answer	Mark
	A 	1
	Incorrect Answers: B – the ammeter would measure the current in the cell, but the voltmeter would not be measuring the p.d. across the cell C – the voltmeter would measure the p.d. across the cell but the ammeter would not be measuring the current in the cell D – the voltmeter would measure the p.d. across the cell but the ammeter would not be measuring the current in the cell	

Q24.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• Means of varying the current **(1)** • Ammeter, voltmeter and variable resistor correctly connected **(1)**	Accept a circuit that will allow correct measurements to be taken.	2
(b)	An explanation that makes reference to: • Vary the current using the variable resistor **(1)** • Record corresponding values for I and V **(1)** • Graph of V against I is a straight line with negative gradient **(1)** • The e.m.f. is given by the intercept on the V axis **(1)** • The internal resistance is given by the gradient **(1)**		5

Q25.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• in circuit A, $V = IR_{lamp}$ and $I = \frac{V}{(R_{lamp} + R_{resistor})}$	(1)		
	• when $R_{resistor}$ has its maximum value, $I \neq 0$	(1)		
	• hence using circuit A the current will never be zero which is a limitation OR range of p.d.s measured is limited	(1)		
	• in circuit B the supply p.d. is divided up in the ratio of the two circuit resistances OR $V_{lamp} = \frac{R_1}{R_1 + R_2} \times V$	(1)		
	• so by making R_1 equal to zero a full range of p.d. s (from 0 V to 12 V) can be applied which makes the circuit more suitable	(1)		**(5)**

Q26.

Question Number	Acceptable Answer		Additional Guidance	Mark
	An explanation that makes reference to the following:		MP1 e.g. If the frequency of the light is high enough the electrons will gain energy from the light (and jump to the conduction band)	
	• The idea that the <u>electrons</u> gain energy from the light	(1)		
	• (As the lamp is moved towards the LDR) the intensity/brightness/illumination of light falling on the LDR increases	(1)	MP2 assume the answer is in terms of the lamp moving towards the LDR unless stated otherwise	
	• This increased the number of (conduction) electrons	(1)	MP3 accept charge carrier (density) for electrons	
	• Which reduced the resistance of the LDR	(1)		
	• decreasing the potential difference across the LDR **Or** increasing the potential difference across the fixed resistor/voltmeter	(1)		5

Q27.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• See $I = I_1 + I_2$	(1)	If student assumes that $R_1 = R_2 = R \rightarrow R_{\text{eff}} = \frac{R}{2}$, then MP1 and MP2 only	
	• Use of $I = \frac{V}{R}$ with the same V for every term	(1)		
	• Algebra to show $\frac{1}{R_{\text{eff}}} = \frac{1}{R_1} + \frac{1}{R_2}$	(1)	For MP3, can assume algebra if equation seen <u>Example of derivation</u> $I = I_1 + I_2 \quad I = \frac{V}{R}$ $\therefore \frac{V}{R_{\text{eff}}} = \frac{V}{R_1} + \frac{V}{R_2}$	3

Q28.

Question number	Acceptable answers	Additional guidance	Mark
	D		1

Q29.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• state or use of $\mathcal{E} = V + Ir$ **(1)** • $r = 28.6\ \Omega$ **(1)**	Example of calculation: $4.1\ \text{V} = 3.7\ \text{V} + 0.014\ \text{A} \times r$ $r = 28.6\ \Omega$	**2**
(ii)	• use of $I = P/A$ **(1)** • use of $P = IV$ **(1)** • calculation of efficiency of pointer **(1)** • analysis of data in passage to give efficiency of laser as approximately 40% **(1)** • comparing data analysed to draw a conclusion that the claim is not justified. **(1)**		**5**

Q30.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Uses ratio of resistances to pd's **Or** uses $I = \frac{V}{R_{total}}$ **and** $V = IR$ (1) • Output pd =13.7 (V) (1) • Compares their answer to 13 (V) with conclusion consistent with their answer (1)	R_{total}=1750 Ω Example of Calculation $V_o = V_s\left(\frac{R_1}{R_1 + R_2}\right)$ $V_{LDR} = 24\ \text{V}\left(\frac{1000\ \Omega}{750\ \Omega + 1000\ \Omega}\right)$ $= 13.7\ \text{V}$ 13.7 > 13 so motor is on	**3**

Q31.

Question Number	Acceptable answers	Additional guidance	Mark
	B		**1**

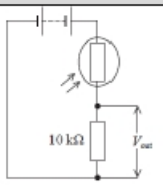
Q32.

Question Number	Answers	Additional Guidance	Mark
	D	**Gradient**: negative; **Intercept on y-axis**: ε	**(1)**

Q33.

Question Number	Acceptable Answer	Additional guidance	Mark
	B	V = ε – Ir	**(1)**

Q34.

Question Number	Answers	Additional Guidance	Mark
	B		**(1)**

Q35.

Question Number	Acceptable answers	Additional guidance	Mark
	• Due to the internal resistance of the cell **(1)** • There is a potential difference across the internal resistance of the cell **Or** there will be 'lost volts' **(1)** **Or** $V = \mathcal{E} . - Ir$		2

Q36.

Question Number	Acceptable answers	Additional guidance	Mark
	B		1

Q37.

Question Number	Answer	Additional Guidance	Mark
	B is the only correct answer	A is incorrect because this does not give the correct ratio C is incorrect because this does not give the correct ratio D is incorrect because this does not give the correct ratio	1

Q38.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• potential difference across the LDR = 3.6 V **Or** $\frac{R}{(R+75\ \Omega)}$ seen **Or** $\frac{75\ \Omega}{(R+75\ \Omega)}$ seen	(1)		
	• Use of $V = IR$ **Or** resistance ratio × 6.0 V = corresponding p.d.	(1)	MP2 use of $V = IR$ with 2.4 V or 3.6 V only	
	• $R = 110\ \Omega$	(1)	Example of calculation $I = 2.4\ V/75\ \Omega = 0.032\ A$ Voltage across LDR = 6.0 V – 2.4 V = 3.6 V $R = \frac{3.6\ V}{0.032A}$ $R = 112.5\ \Omega$ **Or** use of ratios $\frac{75\ \Omega}{(R+75\ \Omega)} \times 6.0\ V = 2.4\ V$ $R = 112.5\ \Omega$	3

Q39.

Question Number	Acceptable answers		Additional guidance	Mark
	Either • Use of equation(s) to determine the total resistance of the voltmeter and 40 Ω resistor in parallel (34.3 Ω) i.e. potential divider formula or Ohm's law	(1) (1)	Example of calculation $\left(\frac{R}{80\ \Omega+R}\right) 6\ V = 1.8\ V$ $R = 34.29\ \Omega$	
	• Use of $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$	(1)	$\frac{1}{34.29\ \Omega} = \frac{1}{40\ \Omega} + \frac{1}{R_V}$	3
	• $R_v = 240\ (\Omega)$		$R_V = 240.2\ \Omega$	
	Or • Use of Ohm's law to determine the current through voltmeter (0.0075 A) i.e. current in 40 Ω resistor calculated (0.045 Ω) **and** subtracted from current in 80 Ω resistor (0.0525 Ω)	(1) (1) (1)		
	• Use of Ohm's law with 1.8 V to calculate the resistance of the voltmeter			
	• $R_v = 240\ (\Omega)$			

Q40.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$ for resistors in parallel **(1)** • Use of $R_T = R_1 + R_2$ for resistors in series **(1)** • $R_T = 47\ \Omega$ **(1)**	Example Calculation $\frac{1}{R_P} = \frac{1}{30} + \frac{1}{40}$ $R_P = 17\ \Omega$ $R_T = 20+17+10 = 47\ \Omega$	**3**

Q41.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B A is not correct as 120 Ω / 3 = 40 Ω C is not correct as 120 Ω / 3 = 40 Ω D is not correct as 120 Ω / 3 = 40 Ω		**1**

Q42.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following: • Combined resistance of (light) bulb and LDR is about 3 Ω (in the dark) **Or** the combined resistance is less than the resistance of bulb/LDR **(1)** • The combined resistance is always much less than the (75 Ω) fixed resistance **(1)** • The p.d. across the bulb will be much less than 3 V and so the bulb will **not** come on (in the dark). **(1)**	MP3: accept the idea that the p.d. across the bulb is never high enough to make the bulb come on in the dark	**3**