1. A battery has an emf of 5.30 V and negligible internal resistance.

(a) State what is meant by an emf of 5.30 V for this battery.

_____

_____

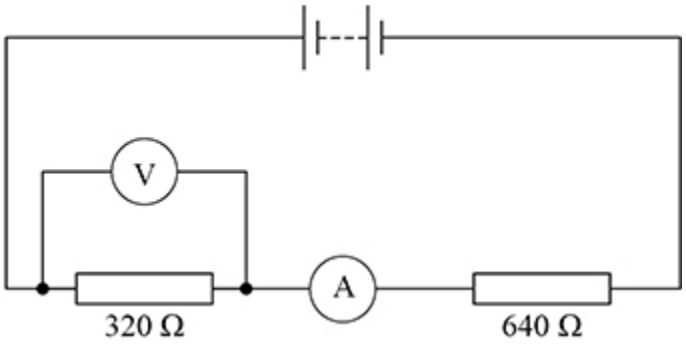
_____

_____

(2)

(b) **Figure 1** shows the battery connected into a circuit.

Figure 1



The ammeter is ideal.

The voltmeter is non-ideal and has a resistance R.

The reading on the voltmeter is 1.05 V when it is connected across the 320 Ω resistor.

Show that the reading on the ammeter is approximately 7 mA.

(2)

(c) Show that the resistance R of the voltmeter is approximately 300 Ω.

(3)

(d) The voltmeter is now connected across the battery terminals.

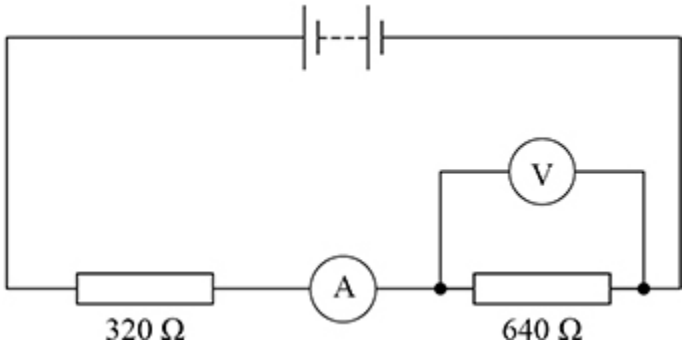
Calculate the power dissipated in the voltmeter.

power = _____ W

(2)

(e) The voltmeter is now connected across the 640 Ω resistor as shown in **Figure 2**.

Figure 2



The reading on the voltmeter is 2.10 V.

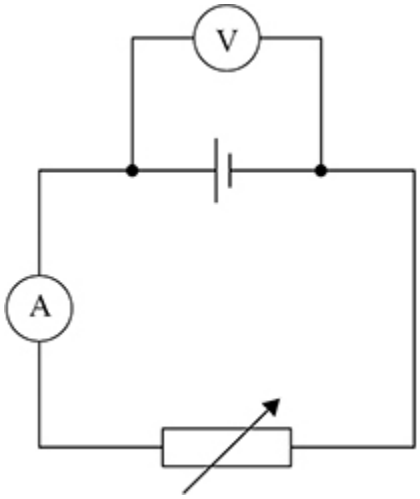
When the voltmeter was connected across the 320 Ω resistor, as shown in **Figure 1**, the reading on the voltmeter was 1.05 V.

Explain why the sum of these voltmeter readings does **not** equal the emf of the battery.

(2)

(Total 11 marks)

2. In the circuit shown, the cell has an emf of 12 V and an internal resistance which is not negligible.



When the resistance of the variable resistor is 10 Ω the voltmeter reads 10 V and the ammeter reads 1.0 A.

The resistance of the variable resistor is changed to 5 Ω.

What is the new reading on the ammeter?

A 1.4 A ⬭

B 1.7 A ⬭

C 2.0 A ⬭

D 2.4 A ⬭

(Total 1 mark)

3. **Figure 1** shows a conveyor used to raise concrete blocks on a building site. The blocks do not slip on the belt at any time.

Figure 1

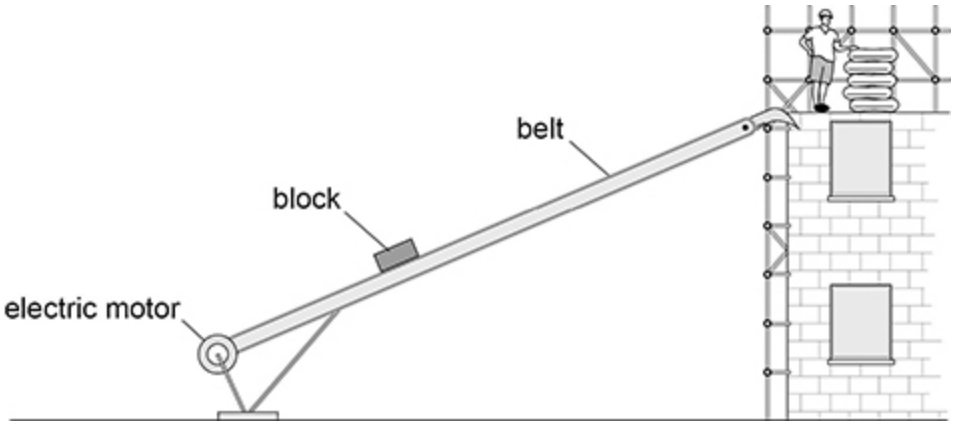
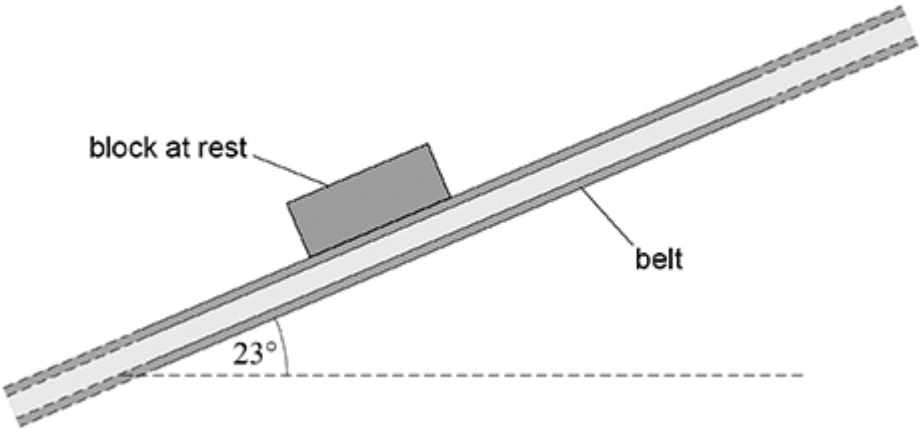


Figure 2 shows an enlarged view of one block on the belt. The belt is inclined at 23° to the horizontal. The mass of the block is 19 kg.

Figure 2



The belt exerts a frictional force F on the block when the block is at rest.

(a) Draw an arrow on **Figure 2** to show the line of action of F.

(1)

(b) Show that the magnitude of F is approximately 70 N.

(1)

(c) The belt is driven by an electric motor. When the motor is switched on, the belt and the block accelerate uniformly from rest to a speed of 0.32 m s^{-1} in a time of 0.50 s.

Calculate the magnitude of the frictional force of the belt on the block during this acceleration.

frictional force = _____ N

(3)

(d) The motor is connected to a 110 V dc supply that has negligible internal resistance. The maximum operating current in the motor is 5.0 A.

The efficiency of the motor and drive system of the conveyor is 28%. The belt travels at 0.32 m s^{-1} and is 8.0 m long.

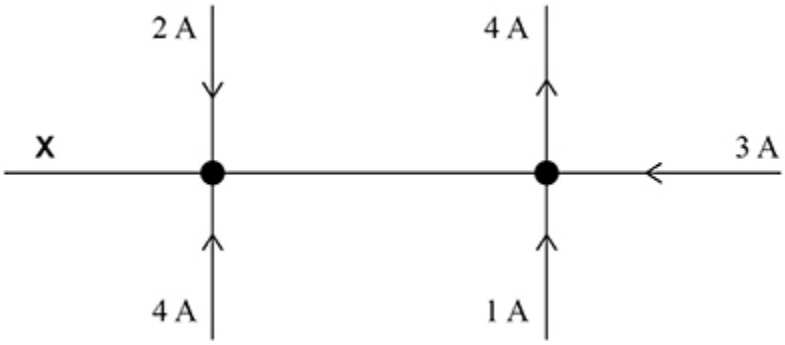
Deduce the maximum number of blocks that can be moved on the belt at one time.

maximum number of blocks = _____

(4)

(Total 9 marks)

4. The diagram shows the currents in a set of wires.



What is the magnitude of the current at **X**?

A zero ⬭

B 2 A ⬭

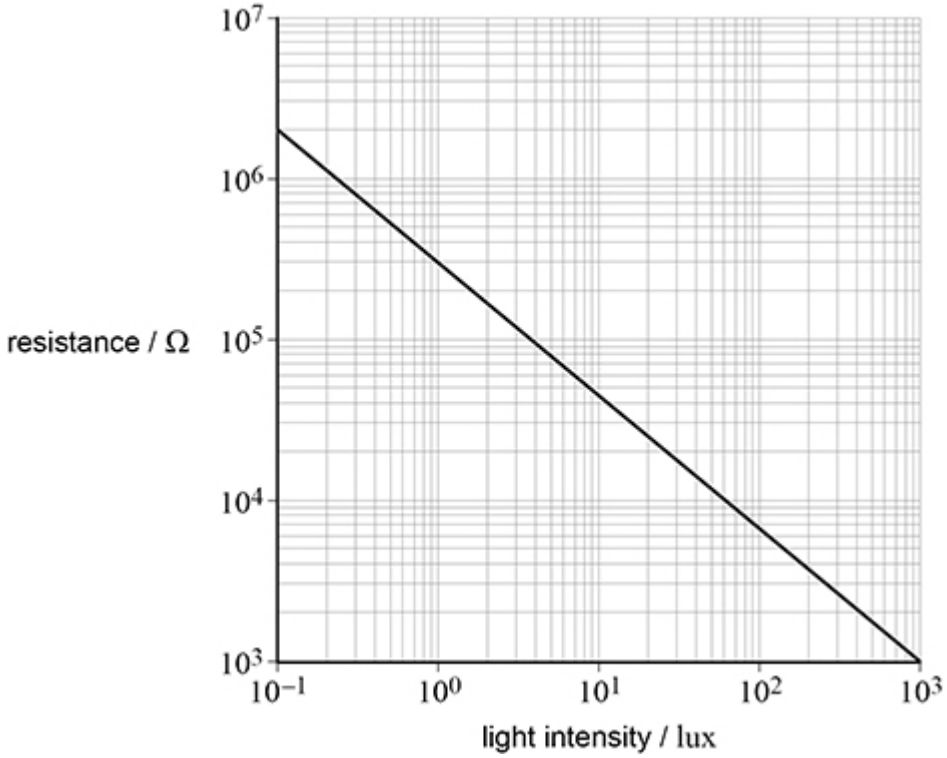
C 3 A ⬭

D 6 A ⬭

(Total 1 mark)

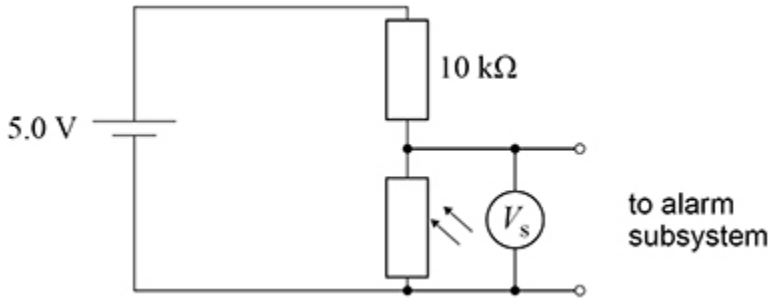
5. **Figure 1** shows how the resistance of an LDR varies with light intensity.

Figure 1



The LDR is used as part of an alarm system in a dim room. **Figure 2** shows one proposal for a sensor circuit for this system.

Figure 2



The power supply to the sensor has an emf of 5.0 V and a negligible internal resistance. A negligible current is drawn from the sensor circuit by the alarm subsystem.

A light beam illuminates the LDR. When the light beam is broken the LDR is not illuminated by the light beam. This causes the alarm to sound.

The table below shows how the light intensity at the LDR changes.

	Light intensity / lux
LDR illuminated by light beam	4.0
LDR **not** illuminated by light beam	1.0

(a) Show that the current in the sensor circuit when the LDR is **not** illuminated by the light beam is approximately 16 μA.

(2)

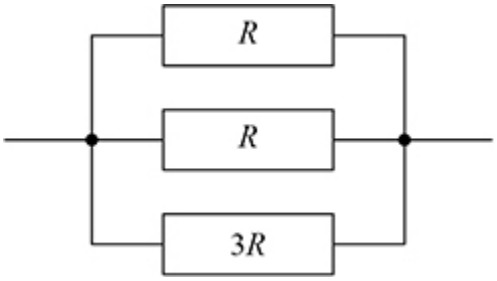
(b) The alarm sounds when the potential difference Vs across the LDR changes by more than 25% of the power supply emf.

Discuss whether the circuit shown in **Figure 2** is suitable.
Support your answer with a calculation.

(3)

(Total 5 marks)

6. Resistors of resistance R, R and $3R$ are connected as shown.



What is the resistance of the arrangement?

A $\frac{3R}{7}$ ⬭

B $\frac{7R}{3}$ ⬭

C $\frac{5R}{6}$ ⬭

D $\frac{6R}{5}$ ⬭

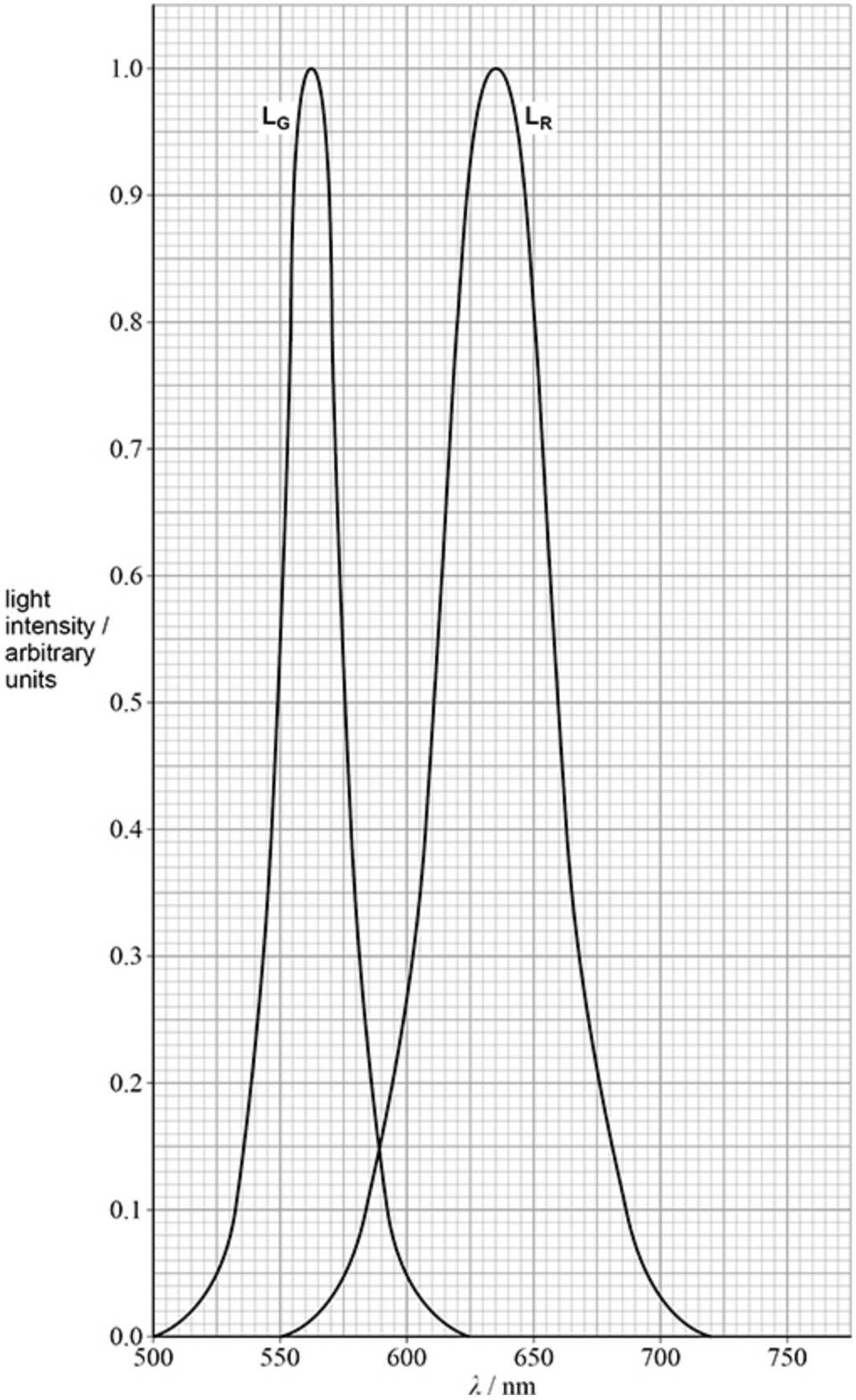
(Total 1 mark)

7. A light-emitting diode (LED) emits light over a narrow range of wavelengths. These wavelengths are distributed about a peak wavelength λ_p.

Two LEDs $\mathbf{L_G}$ and $\mathbf{L_R}$ are adjusted to give the same maximum light intensity. $\mathbf{L_G}$ emits green light and $\mathbf{L_R}$ emits red light.

Figure 1 shows how the light output of the LEDs varies with the wavelength λ.

Figure 1


1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
light intensity / arbitrary units
L_G
L_R
500
550
600
650
700
750
λ / nm

(a) Light from **L_R** is incident normally on a plane diffraction grating.
The fifth-order maximum for light of wavelength λ_p occurs at a diffraction angle of 76.3°.

Determine N, the number of lines per metre on the grating.

N = _____ m^{-1}

(3)

(b) Suggest **one** possible disadvantage of using the fifth-order maximum to determine N.

_____

_____

_____

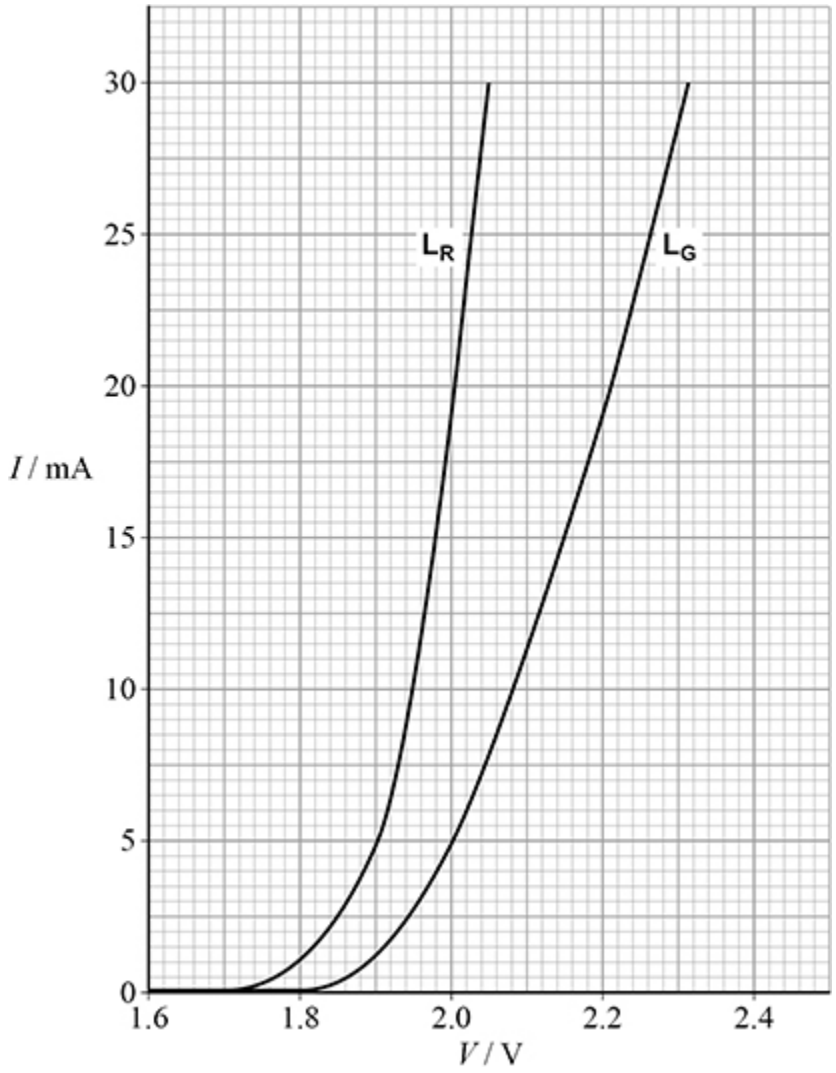
_____

_____

(1)

(c) **Figure 2** shows part of the current−voltage characteristics for $\mathbf{L_R}$ and $\mathbf{L_G}$.

Figure 2



When the linear part of the characteristic is extrapolated, the point at which it meets the horizontal axis gives the activation voltage V_A for the LED.
V_A for $\mathbf{L_G}$ is 2.00 V.

Determine, using **Figure 2**, V_A for $\mathbf{L_R}$.

V_A for $\mathbf{L_R}$ = _____ V

(2)

(d) It can be shown that:

$$V_A = \frac{hc}{e\lambda_p}$$

where h = the Planck constant.

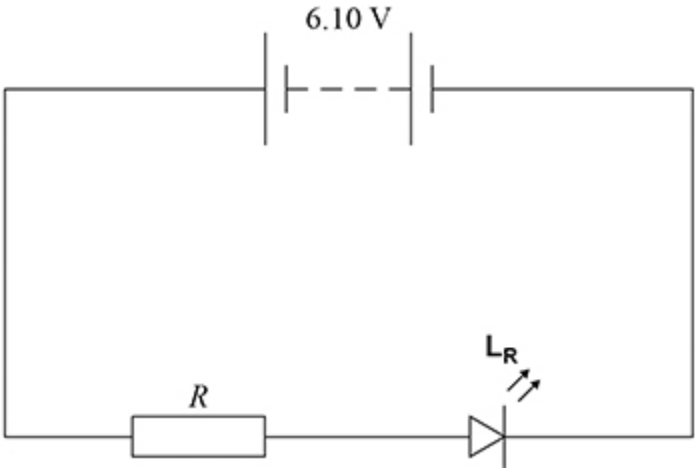
Deduce a value for the Planck constant based on the data given about the LEDs.

h = _____ J s

(2)

(e) **Figure 3** shows a circuit with $\mathbf{L_R}$ connected to a resistor of resistance R.

Figure 3



The power supply has emf 6.10 V and negligible internal resistance.
The current in $\mathbf{L_R}$ must not exceed 21.0 mA.

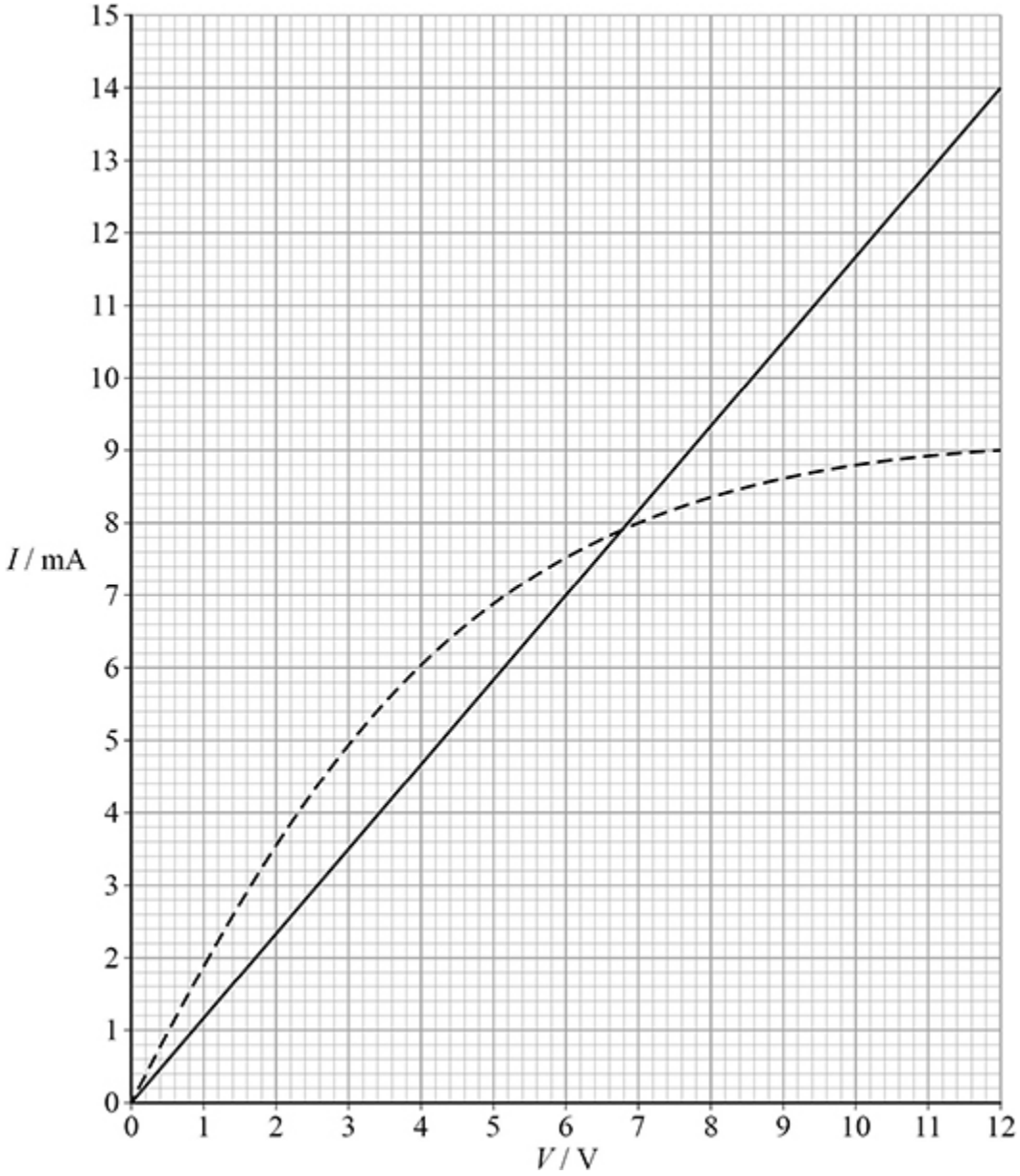
Deduce the minimum value of R.

minimum value of R = _____ Ω

(2)

(Total 10 marks)

8. The graph shows the current–voltage (I–V) characteristics for two components.



The two components are connected in parallel with a 12 V battery that has negligible internal resistance.

What is the current in the battery?

A 7.9 mA ⬭

B 14.5 mA ⬭

C 15.8 mA ⬭

D 23.0 mA ⬭

(Total 1 mark)

9. Measurements are taken to determine the resistivity of a uniform metal wire. The table shows the quantities measured and their percentage uncertainties.

Quantity	Percentage uncertainty
potential difference across wire	0.3%
current in wire	5.0%
diameter of wire	4.0%
length of wire	0.2%

What is the percentage uncertainty in the calculated value for the resistivity of the metal of the wire?

A 1.6% ⬭

B 9.5% ⬭

C 13.5% ⬭

D 21.5% ⬭

(Total 1 mark)

10. A cell has an emf of 1.5 V and an internal resistance of 0.65 Ω.
The cell is connected to a resistor **R**.

(a) State what is meant by an emf of 1.5 V.

_____

_____

_____

_____

(2)

(b) The current in the circuit is 0.31 A.

Show that the total power output of the cell is approximately 0.47 W.

(1)

(c) Calculate the energy dissipated per second in resistor **R**.

energy dissipated per second = _____ J s^{-1}

(2)

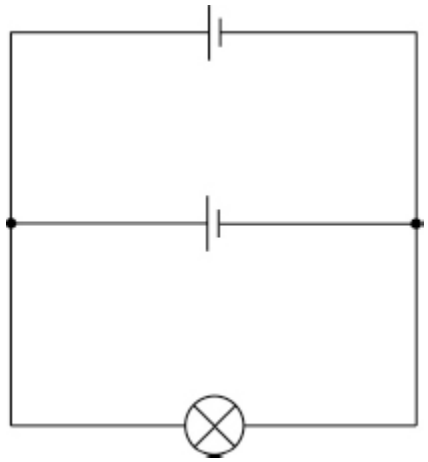
(d) The cell stores 14 kJ of energy when it is fully charged. The cell's emf and internal resistance are constant as the cell is discharged.

Calculate the maximum time during which the fully-charged cell can deliver energy to resistor **R**.

maximum time = _____ s

(2)

(e) A student uses two cells, each of emf 1.5 V and internal resistance 0.65 Ω, to operate a lamp. The circuit is shown in the diagram.



The lamp is rated at 1.3 V, 0.80 W.

Deduce whether this circuit provides the lamp with 0.80 W of power at a potential difference (pd) of 1.3 V.
Assume that the resistance of the lamp is constant.

(4)

(f) The lamp operates at normal brightness across a pd range of 1.3 V to 1.5 V.

State and explain how more of these cells can be added to the circuit to make the lamp light at normal brightness for a longer time.
No further calculations are required.

(3)

(Total 14 marks)

11. Superconductors are used to

A increase the strength of electricity cables. ⬭

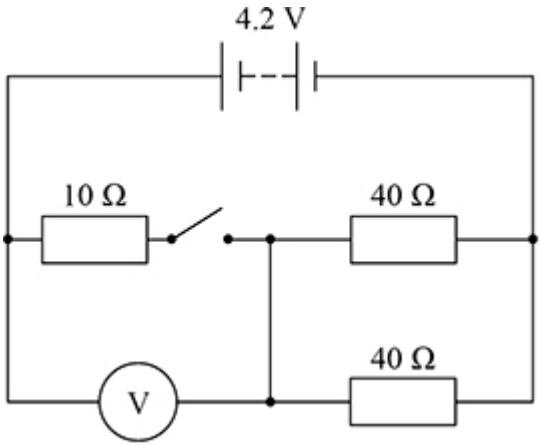
B make light dependent resistors. ⬭

C produce strong magnetic fields. ⬭

D increase the rate of heat energy transfer. ⬭

(Total 1 mark)

12. The battery in this circuit has an emf of 4.2 V and negligible internal resistance.



What are the readings on the voltmeter when the switch is open (off) and when the switch is closed (on)?

	Open	Closed	
A	0 V	2.1 V	⬭
B	4.2 V	2.1 V	⬭
C	0 V	1.4 V	⬭
D	4.2 V	1.4 V	⬭

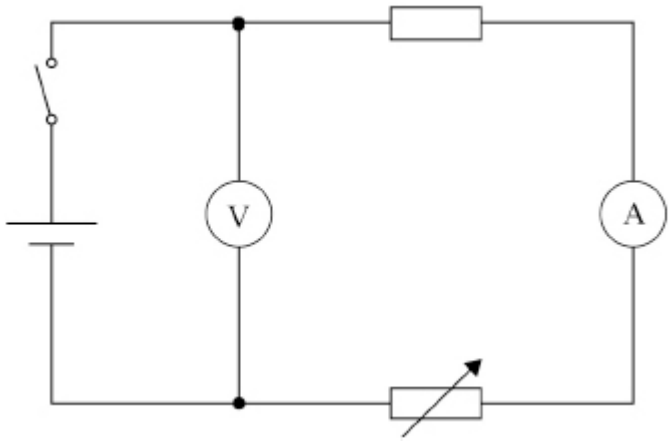
(Total 1 mark)

13. **Figure 1** shows a circuit used by a student to determine the emf and the internal resistance of a cell.

The cell is connected to a switch, a fixed resistor and a variable resistor.
When the switch is closed, a voltmeter measures the potential difference V across the cell.
An ammeter measures the current I in the circuit.

Readings of V and I are taken as the resistance of the variable resistor is changed from zero to its maximum value.

Figure 1

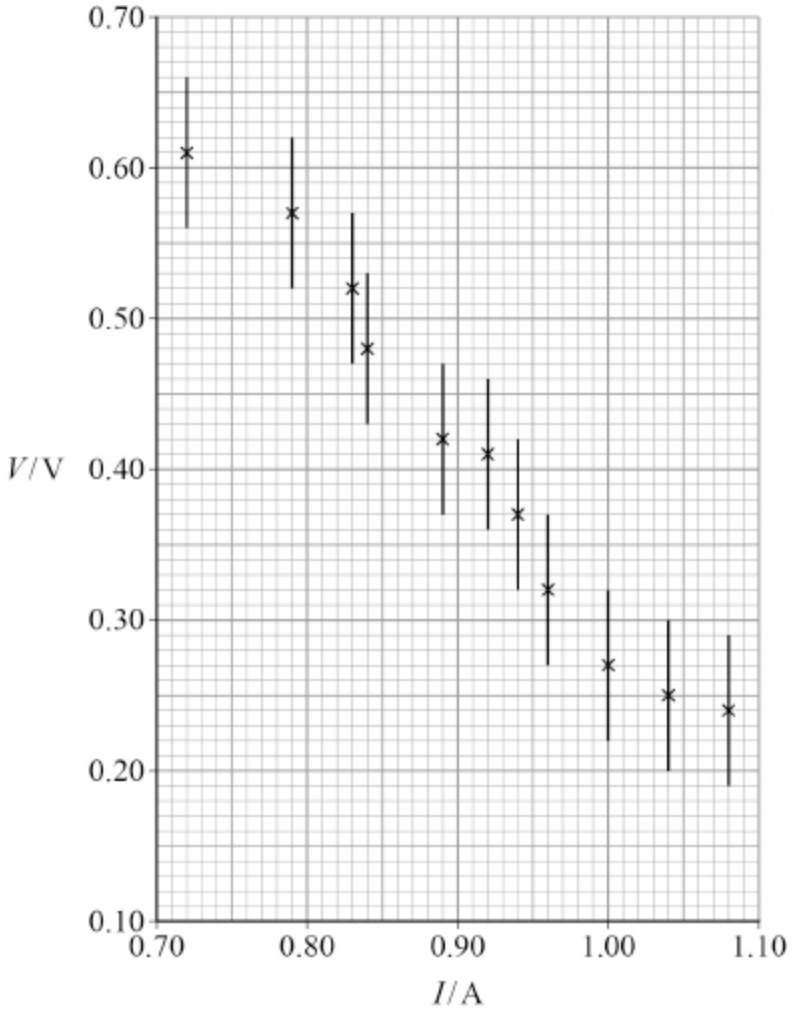


(a) Explain why the student included the fixed resistor in this circuit.

(2)

Figure 2 is a graph of the data recorded for this experiment.

Figure 2



(b) Determine the magnitude of the minimum gradient G_{min} of a line that passes through all the error bars in **Figure 2**.

magnitude of G_{min} = _____

(3)

(c) The maximum gradient G_{max} / V A^{-1} of a line passing through all the error bars in **Figure 2** is –1.3

Determine, using G_{max} and G_{min}, the internal resistance of the cell.

internal resistance = _____ Ω

(2)

(d) The line of best fit passes through the data point (0.94, 0.37).

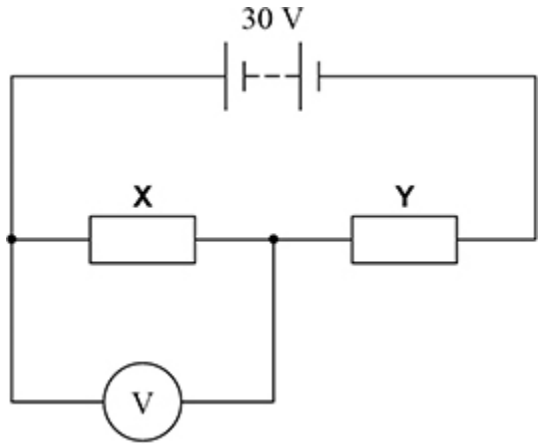
Determine the emf of the cell.

emf = _____ V

(3)

(Total 10

14. Two resistors **X** and **Y** are connected in series with a power supply of emf 30 V and negligible internal resistance.
The resistors are made from wire of the same material. The wires have the same length. **X** uses wire of diameter d and **Y** uses wire of diameter $2d$.



What is the reading on the voltmeter?

A 10 V ⬭

B 15 V ⬭

C 20 V ⬭

D 24 V ⬭

(Total 1 mark)

15. The table shows corresponding values of potential difference V and current I for four electrical components **A**, **B**, **C** and **D**.

	A	**B**	**C**	**D**
V / V	I / A	I / A	I / A	I / A
0	0.0	0.0	0.0	0.0
2	0.0	0.3	0.4	0.3
4	0.1	0.6	0.8	0.6
6	0.7	0.9	1.2	0.9
8	1.4	1.2	1.6	1.1
10	2.1	1.5	2.0	1.3
12	2.8	1.8	2.4	1.4

Which component is an ohmic conductor with the greatest resistance?

A ⬭

B ⬭

C ⬭

D ⬭

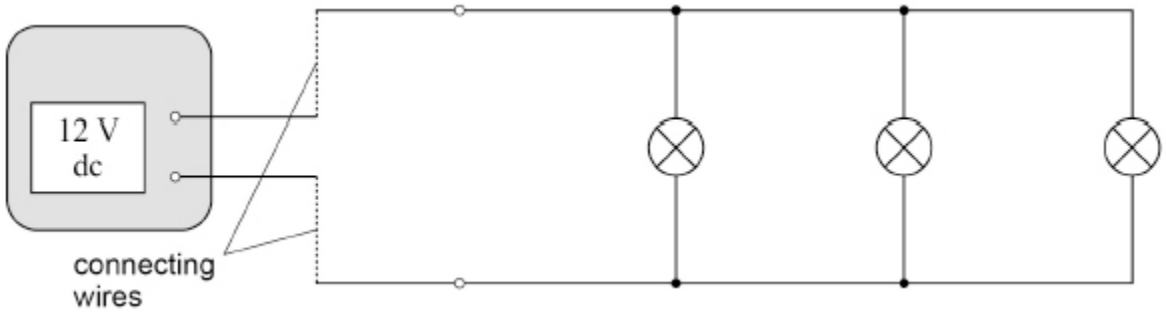
(Total 1 mark)

16. Which row shows the resistances of an ideal ammeter and an ideal voltmeter?

	Ideal ammeter	**Ideal voltmeter**	
A	infinite	infinite	⬭
B	infinite	zero	⬭
C	zero	infinite	⬭
D	zero	zero	⬭

(Total 1 mark)

17. The diagram shows some of the apparatus used in a demonstration of electrical power transmission using a dc power supply.



A power supply of emf 12 V and negligible internal resistance is connected to three identical 12 V, 1.5 W lamps in parallel.

(a) Show that the resistance of one of the lamps when it is operating at 12 V is about 100 Ω.

(1)

(b) Initially the power supply is connected to the lamps using two short copper wires of negligible resistance.

Calculate the current in the power supply.

current = _____ A

(2)

(c) The two short copper wires are replaced with two long constantan wires.

Show that the resistance of each length of constantan wire is about 50 Ω.

length of each constantan wire	= 2.8 m
diameter of constantan wires	= 0.19 mm
resistivity of constantan	= 4.9×10^{-7} Ω m

(3)

(d) The demonstration is intended to show that the lamps are significantly dimmer when connected using the long constantan wires than when using the short copper wires.

Discuss whether the demonstration achieves this.
Support your answer with suitable calculations.

(4)

(e) Scientists and engineers are investigating the use of superconductors in electrical transmission.

Discuss **one** advantage and **one** difficulty when using superconductors in electrical transmission over long distances.

Advantage _____

_____

_____

_____

Difficulty _____

_____

_____

_____

(3)

(Total 13 marks)

18. The capacity of a portable charger is rated in ampere hours (A h). A charger of capacity 1 A h can provide 1 A for 1 hour at its working voltage.

One charger has a capacity of 1800 mA h at a working voltage of 3.7 V.

What is the energy stored in this charger?

A 6.5 kJ ⬭

B 24 kJ ⬭

C 400 kJ ⬭

D 24 kJ ⬭

(Total 1 mark)

19. A filament lamp with resistance 12 Ω is operated at a power of 36 W.

How much charge flows through the filament lamp during 15 minutes?

A 26 C ⬭

B 1.6 kC ⬭

C 2.7 kC ⬭

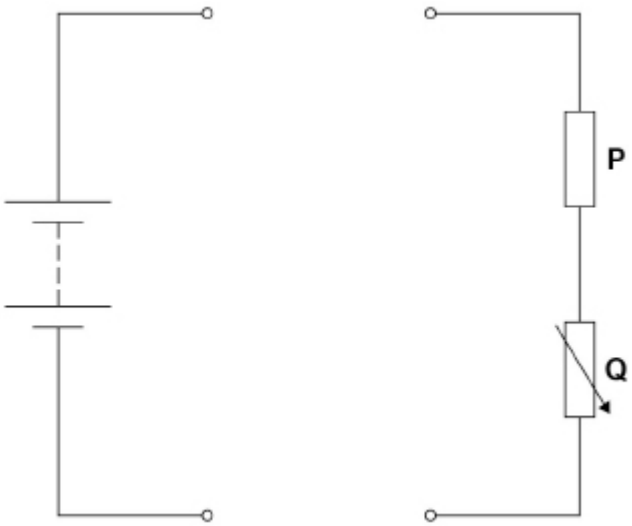
D 6.5 kC ⬭

(Total 1 mark)

20. **Figure 1** shows a partly-completed circuit used to investigate the emf ε and the internal resistance r of a power supply.

The resistance of **P** and the maximum resistance of **Q** are unknown.

Figure 1



(a) Complete **Figure 1** to show a circuit including a voltmeter and an ammeter that is suitable for the investigation.

(1)

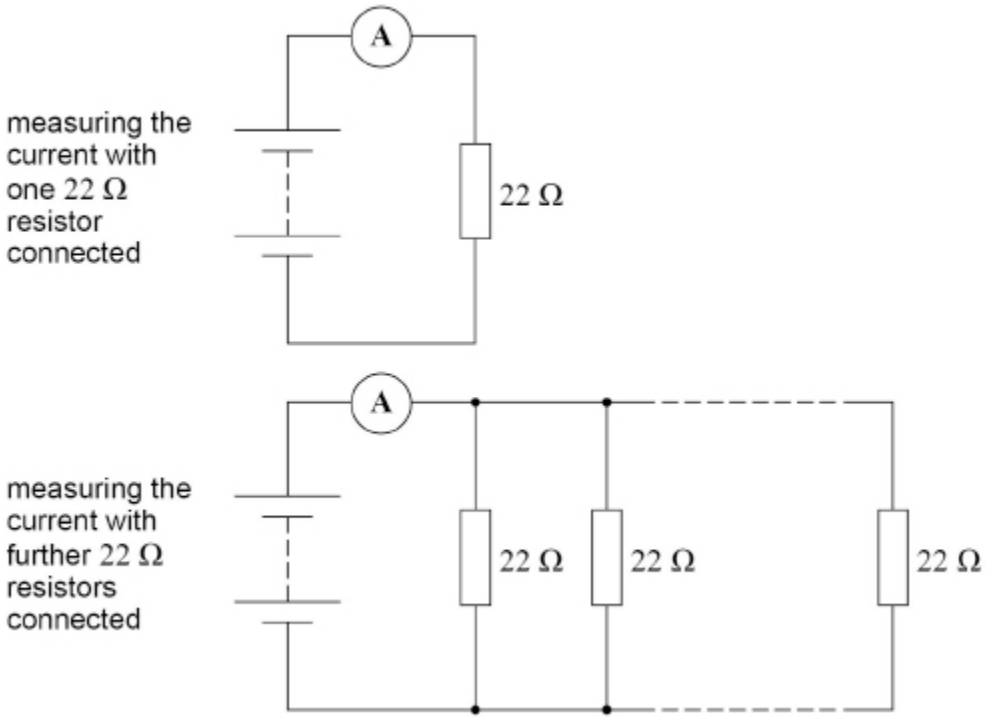
(b) Describe

- a procedure to obtain valid experimental data using your circuit
- how these data are processed to obtain ε and r by a graphical method.

(4)

Figure 2 shows a different experiment carried out to confirm the results for ε and r.

Figure 2



Initially the power supply is connected in series with an ammeter and a 22 Ω resistor. The current I in the circuit is measured.

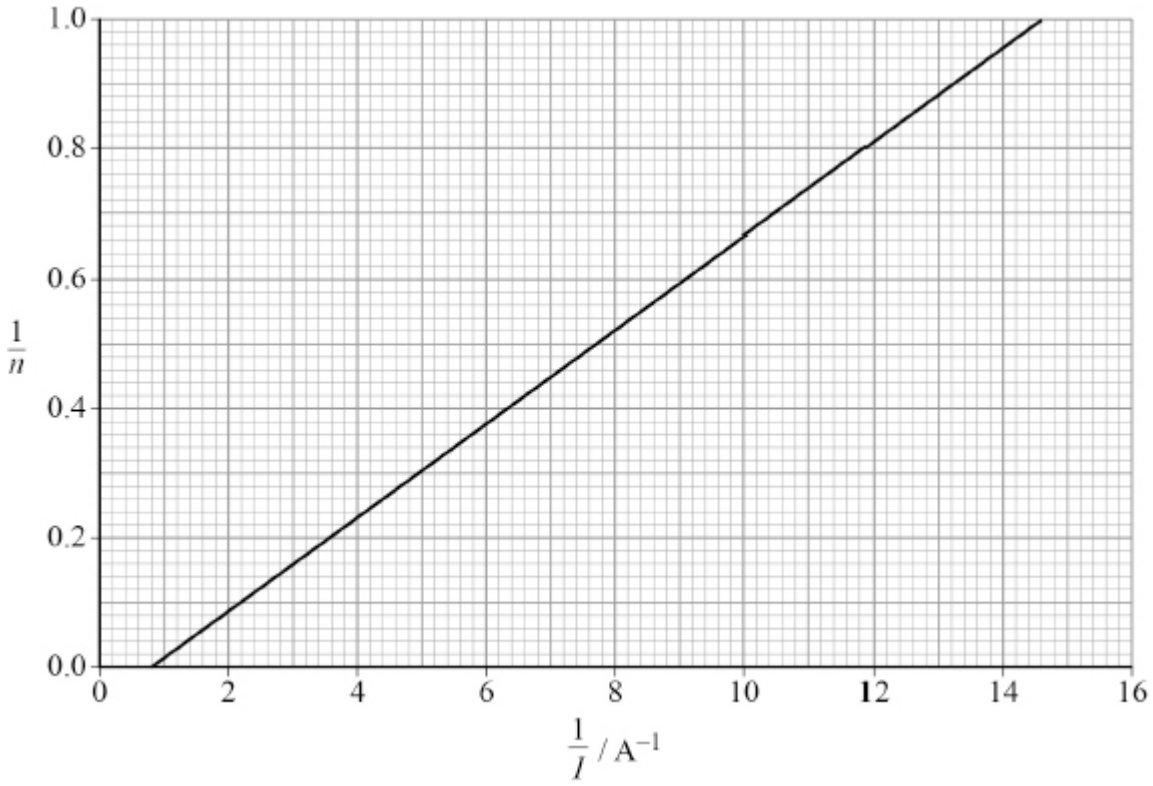
The number n of 22 Ω resistors in the circuit is increased as shown in **Figure 2**. The current I is measured after each resistor is added.

It can be shown that

$$\frac{22}{n} = \frac{\varepsilon}{I} - r$$

Figure 3 shows a graph of the experimental data.

Figure 3

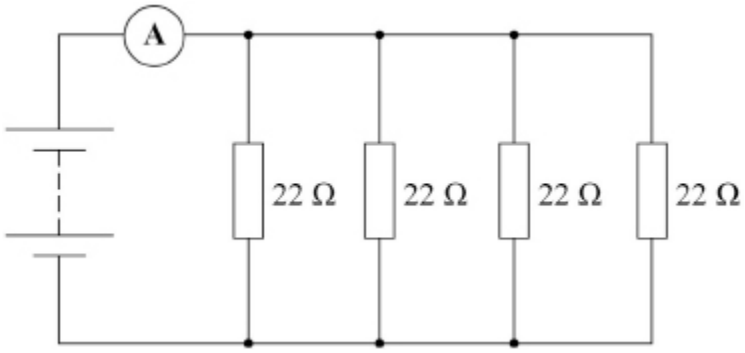


(c) Show that ε is about 1.6 V.

(2)

(d) **Figure 4** shows the circuit when four resistors are connected.

Figure 4



Show, using **Figure 3**, that the current in the power supply is about 0.25 A.

(1)

(e) Deduce, for the circuit shown in **Figure 4**,

- the potential difference (pd) across the power supply
- r.

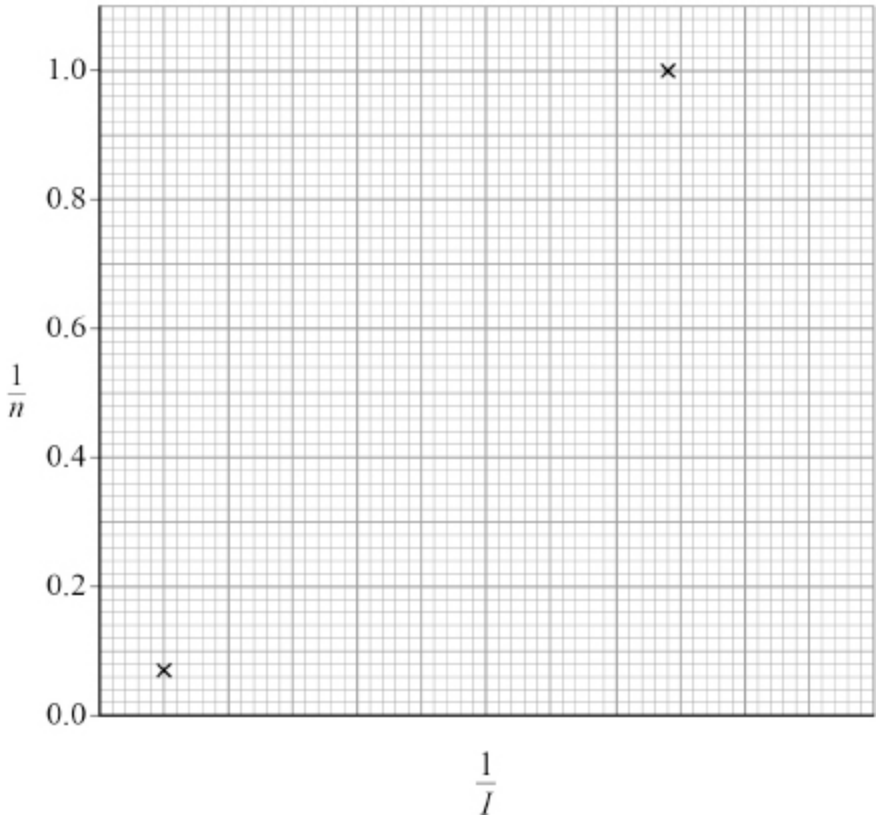
pd = _____ V

r = _____ Ω

(4)

(f) **Figure 5** shows the plots for $n = 1$ and $n = 14$

Figure 5



Three additional data sets for values of n between $n = 1$ and $n = 14$ are needed to complete the graph in **Figure 5**.

Suggest which additional values of n should be used.
Justify your answer.

(3)

(g) The experiment is repeated using a set of resistors of resistance 27 Ω.

The relationship between n and I is now

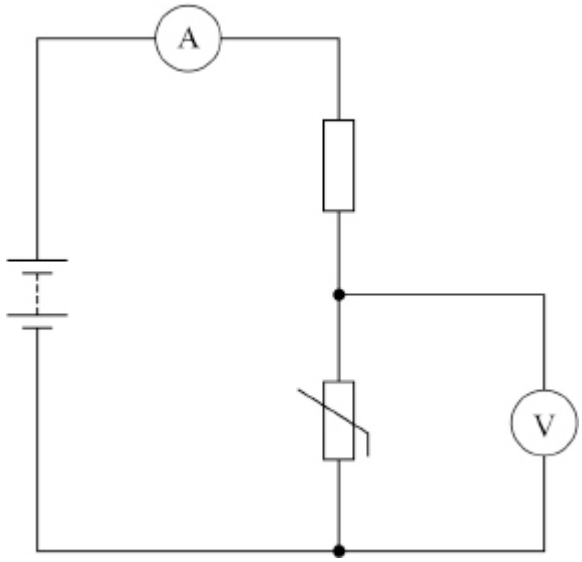
$$\frac{27}{n} = \frac{\varepsilon}{I} - r$$

Show on **Figure 5** the effect on the plots for n = 1 and n = 14
You do **not** need to do a calculation.

(2)

(Total 17 marks)

21. The diagram shows a temperature-sensing circuit.



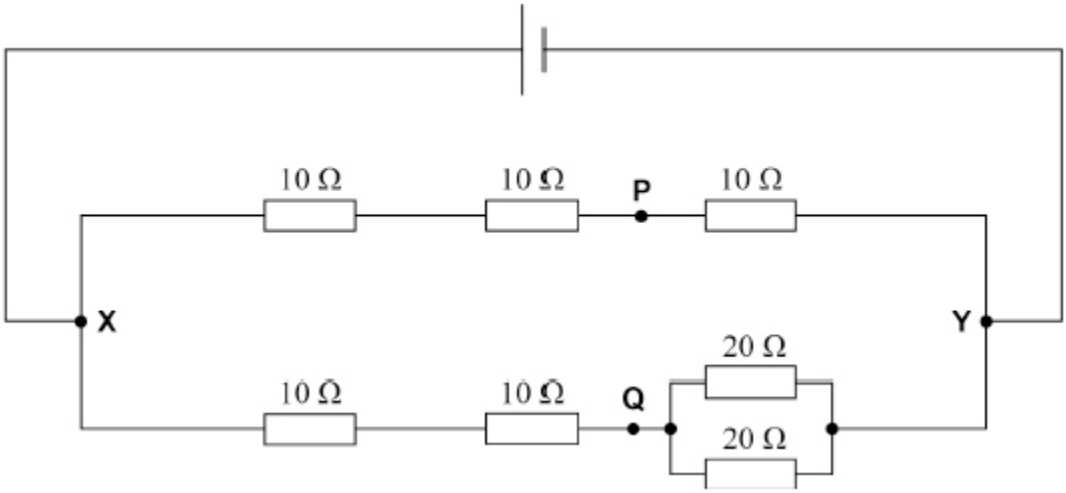
The temperature of the thermistor is decreased.

Which row shows the changes to the ammeter reading and the voltmeter reading?

	Ammeter reading	Voltmeter reading	
A	increases	increases	⬭
B	increases	decreases	⬭
C	decreases	decreases	⬭
D	decreases	increases	⬭

(Total 1 mark)

22. The potential difference between points **X** and **Y** is V.



What is the potential difference between **P** and **Q**?

A zero ⬭

B $\frac{V}{3}$ ⬭

C $\frac{V}{2}$ ⬭

D $\frac{2V}{3}$ ⬭

(Total 1 mark)

23. A resistor with resistance R is made from metal wire of resistivity ρ. The length of the wire is L.

What is the diameter of the wire?

A $\sqrt{\frac{2\rho R}{\pi L}}$ ⬭

B $\sqrt{\frac{2\rho L}{\pi R}}$ ⬭

C $2\sqrt{\frac{\rho L}{\pi R}}$ ⬭

D $2\sqrt{\frac{\rho R}{\pi L}}$ ⬭

(Total 1 mark)

24. A battery of emf 7.4 V and negligible internal resistance is used to power a heating element inside a glove. The heating element has a resistance of 3.7 Ω.

(a) The designers state that the battery can produce a current of 2.0 A in the heating element for 240 minutes.

Calculate the energy dissipated in the heating element in this time.

energy dissipated = _____ J

(3)

(b) The length of the heating element needed is about 0.85 m.
The designer considers using a carbon fibre tape for the heating element.
The table gives information for the carbon fibre tape.

Cross-sectional area / m^2	**Resistivity / Ω m**
4.9×10^{-6}	2.0×10^{-5}

Deduce whether the carbon fibre tape is suitable for making the heating element for the glove.

(2)

(c) A light emitting diode (LED) is used to indicate that the switch in the glove is closed, as shown in **Figure 1**. Resistor R limits the current in the LED.

Figure 1

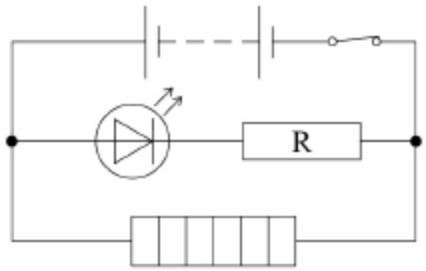
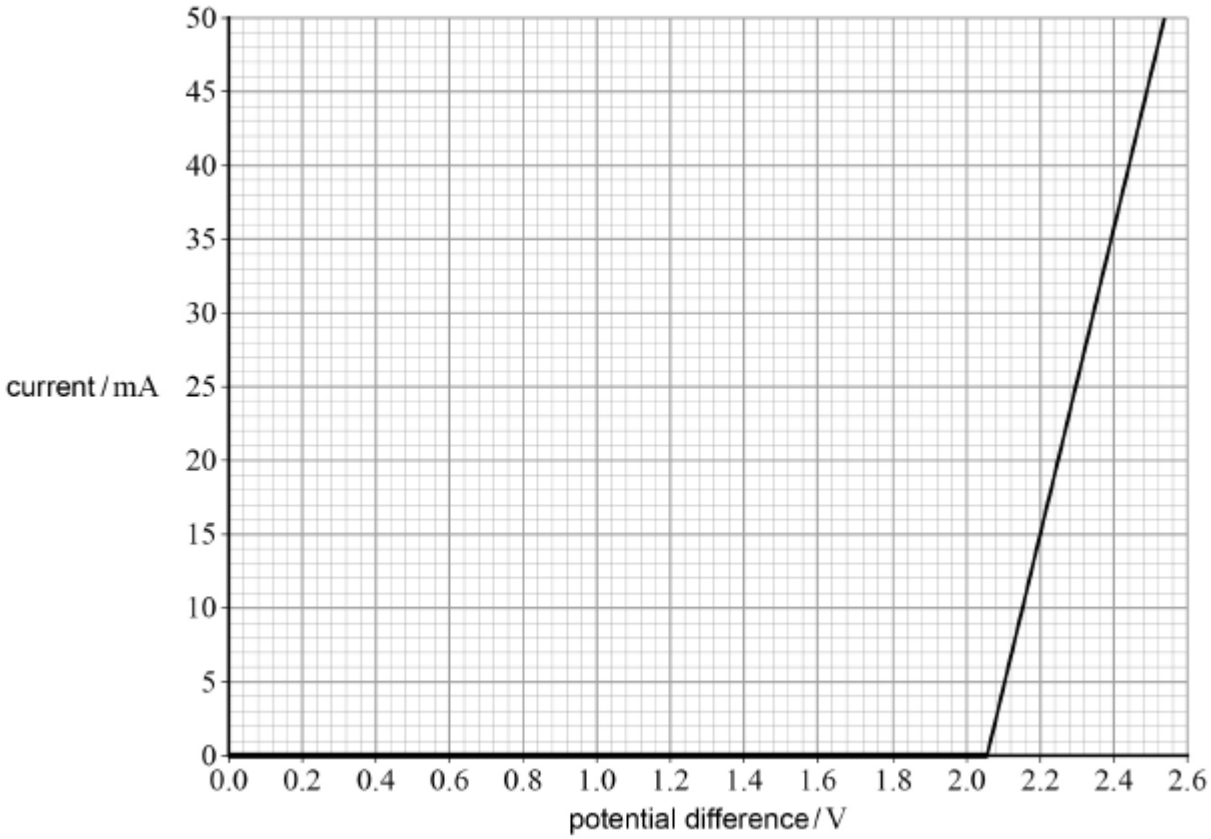


Figure 2 shows part of the characteristic graph for the LED.

Figure 2



The circuit is designed so that the potential difference across the LED is 2.2 V when the switch is closed.

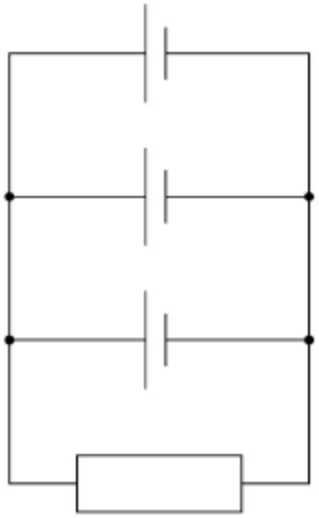
Calculate the resistance of R.

resistance = _____ Ω

(4)

(Total 9 marks)

25. A resistor of resistance R and three identical cells of emf E and internal resistance r are connected as shown.



What is the current in the resistor?

A $\frac{3E}{(3R+r)}$ ⬭

B $\frac{9E}{(3R+r)}$ ⬭

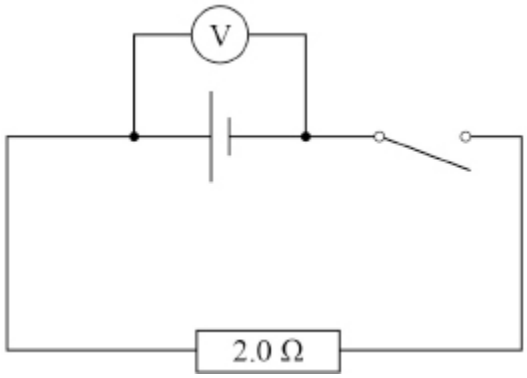
C $\frac{E}{R}$ ⬭

D $\frac{3E}{R}$ ⬭

(Total 1 mark)

26. In the circuit, the reading of the voltmeter is V.

When the switch is closed the reading becomes $\frac{V}{3}$.



What is the internal resistance of the cell?

A 0.33 Ω ⬭

B 0.67 Ω ⬭

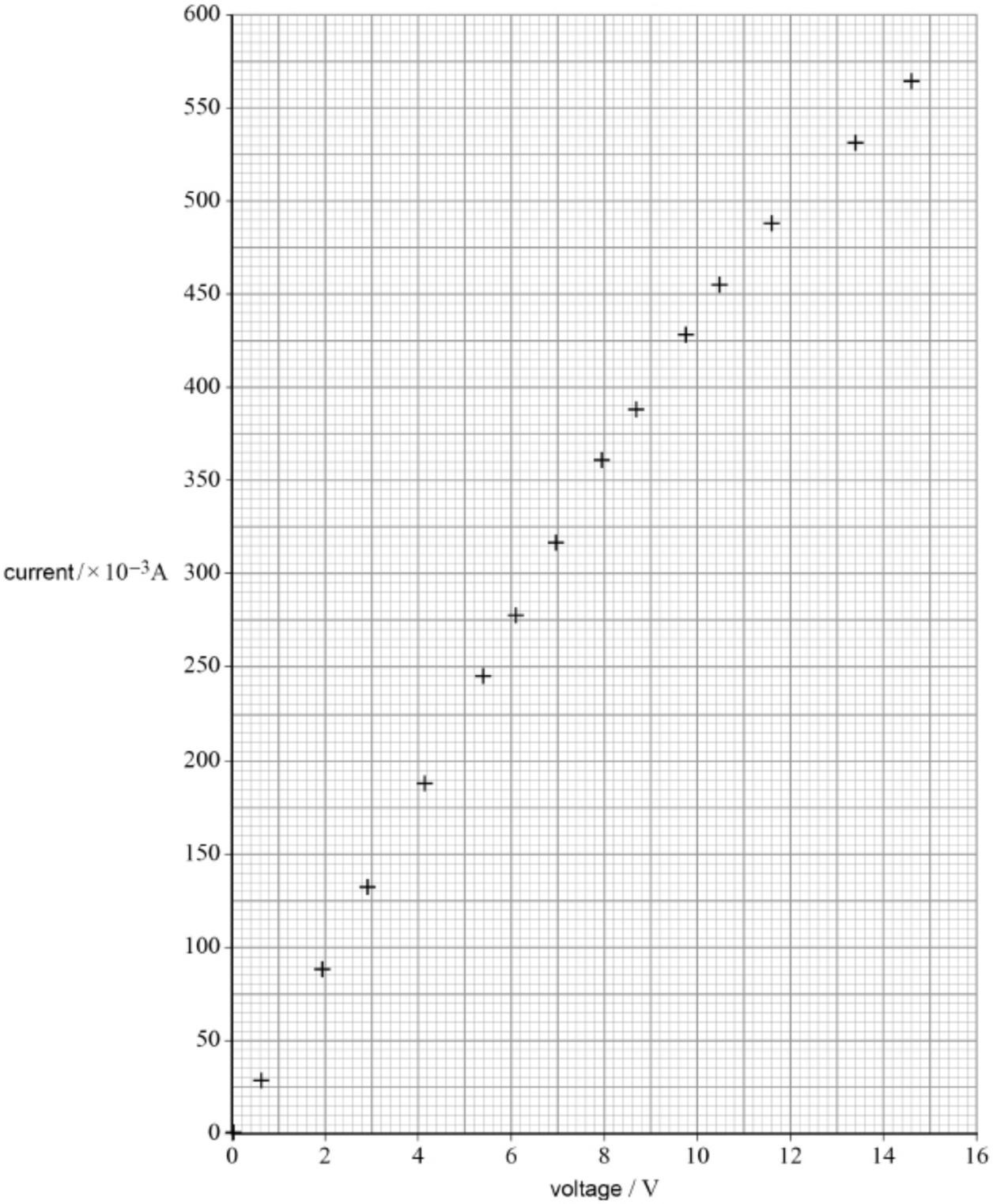
C 4.0 Ω ⬭

D 6.0 Ω ⬭

(Total 1 mark)

27. This question is about an experiment to obtain current–voltage data for a resistor **R**.
Figure 1 shows a plot of current–voltage data for **R**.

Figure 1



(a) Draw a best-fit line for the data on **Figure 1**.

(1)

(b) Identify the data point with the greatest value of current and voltage at which **R** obeys Ohm's law.

Draw a circle around this data point on **Figure 1**.

(1)

(c) When **R** obeys Ohm's law it has a resistance of 22.2 Ω.

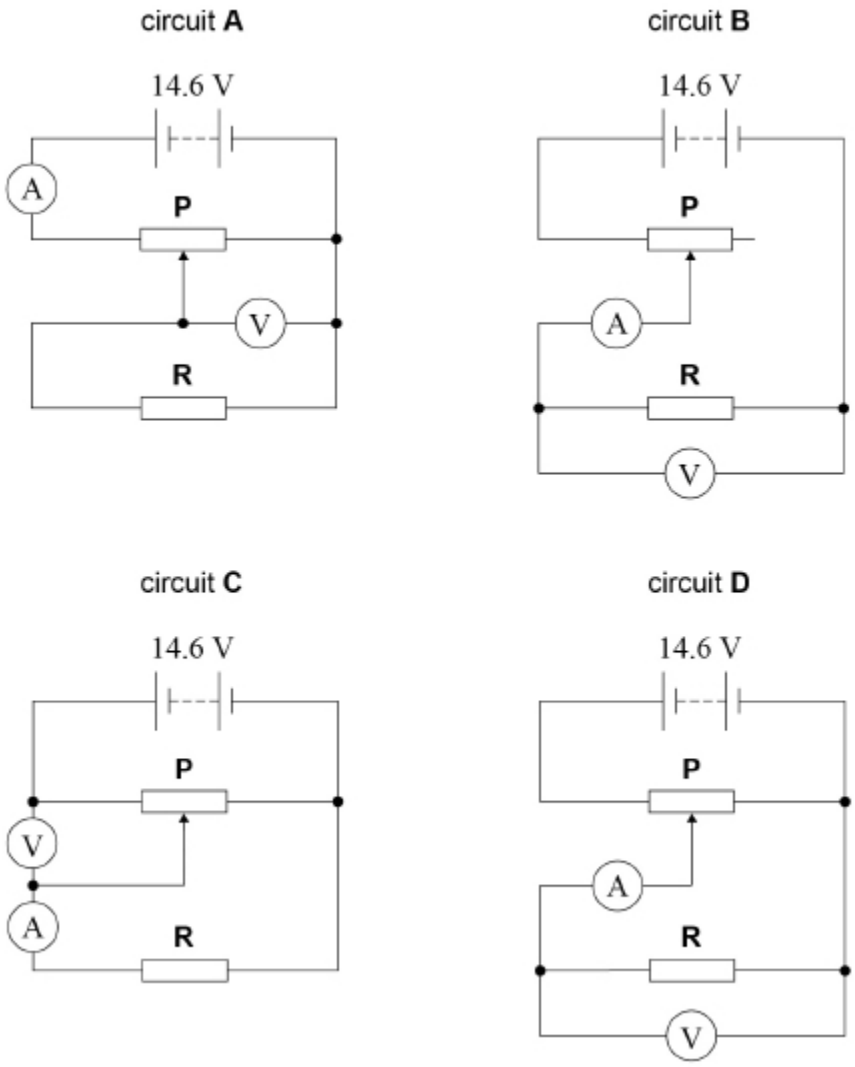
Determine the percentage increase in the resistance of **R** from its 22.2 Ω value to its value when the current is 550×10^{-3} A.

percentage increase = _____

(2)

(d) One of the circuits **A** to **D** shown in **Figure 2** was used to obtain the current–voltage data in **Figure 1**. The maximum resistance of resistor **P** is twice the resistance of **R**.
The battery has an emf of 14.6 V and negligible internal resistance.

Figure 2

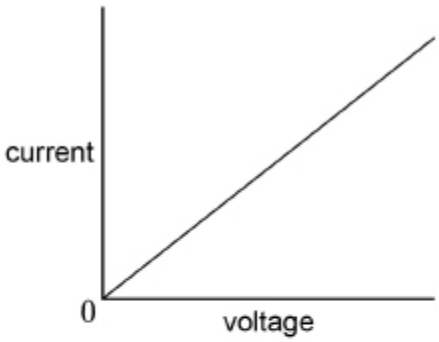


Deduce which **one** of these circuits was used to directly obtain the current–voltage data in **Figure 1**.
You should include in your answer an explanation of why each of the other circuits is **not** suitable to obtain the data directly from the voltmeter and ammeter readings.

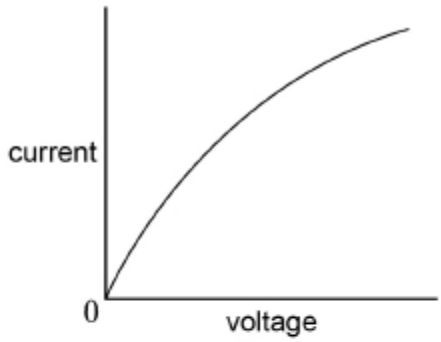
(4)
(Total 8 marks)

28. Which is the current–voltage characteristic graph for a filament lamp up to its working voltage?

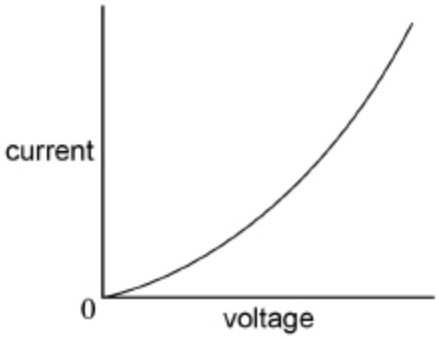
A



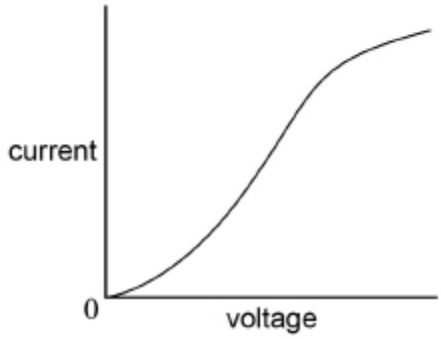
B



C



D



A ⬭

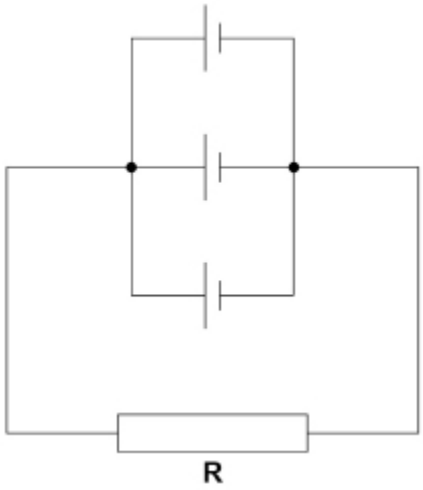
B ⬭

C ⬭

D ⬭

(Total 1 mark)

29. Three identical cells, each of emf 1.5 V and internal resistance 6.0 Ω, are connected to resistor **R**. The resistance of **R** is 6.0 Ω.



What is the current in **R**?

A 0.19 A ⬭

B 0.25 A ⬭

C 0.56 A ⬭

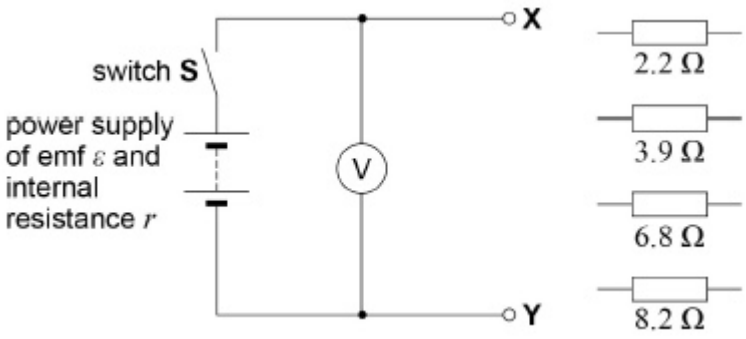
D 0.75 A ⬭

(Total 1 mark)

30. This question is about an experiment to determine the internal resistance of a power supply.

A student is given the circuit and the four resistors of known resistance shown in **Figure 1**.

Figure 1



The student can change the external resistance R of the circuit between terminals **X** and **Y**. This is done by connecting different combinations of **two** resistors in series or in parallel between **X** and **Y**.

This method can produce **12 different values** for R.

(a) Calculate the largest value of R that the student can obtain using **two** resistors.

largest value of R = _____ Ω

(1)

(b) Calculate the smallest value of R that the student can obtain using **two** resistors.

smallest value of R = _____ Ω

(2)

(c) With switch **S** closed (in the on position) and no resistors connected between **X** and **Y** the voltmeter reading V is 1.62 V.

The student concludes that this voltmeter reading equals the emf ε of the power supply.

State why the student's conclusion that ε = 1.62 V was correct.

_____

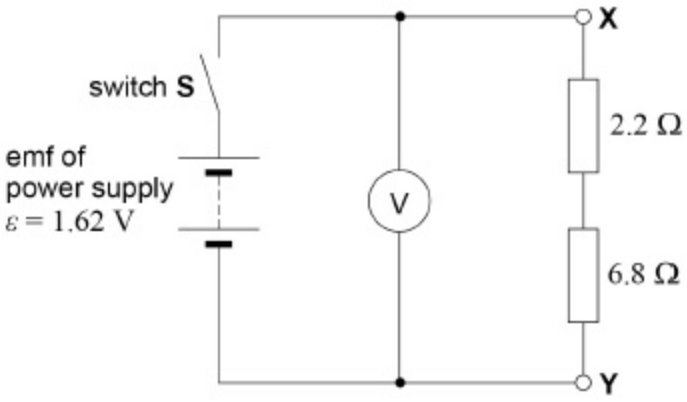
_____

_____

(1)

(d) **Figure 2** shows one particular combination and arrangement of two resistors that the student could use.

Figure 2



When **S** is closed the voltmeter reading V is 1.14 V.

Explain why V is less than 1.62 V when **S** is closed.

_____

_____

_____

(1)

(e) It can be shown that

$$\varepsilon - V = r \times \frac{V}{R}$$

where r is the internal resistance of the power supply.

Determine $(\varepsilon - V)$ and $\frac{V}{R}$ for this circuit using the data given in part (d).

$(\varepsilon - V)$ = _____ V

$\frac{V}{R}$ = _____ V Ω^{-1}

(1)

(f) The student obtains values of V for five further different values of R.

These data were used to produce the graph of ($\varepsilon - V$) against $\frac{V}{R}$ in **Figure 3**.

Plot the point you determined in part (e) on **Figure 3** and add a suitable best-fit line.

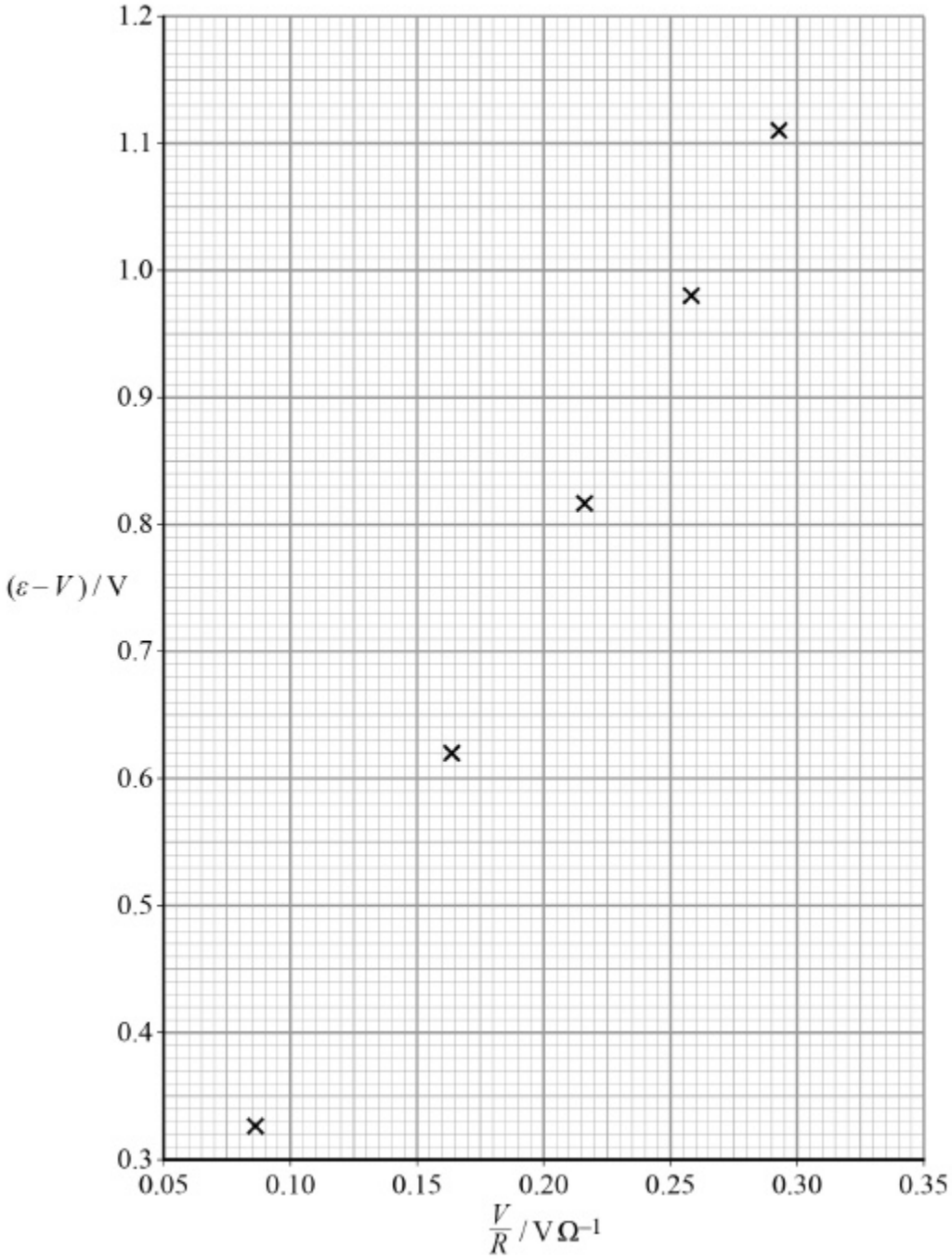
(1)

(g) Use **Figure 3** to determine *r*.

r = _____ Ω

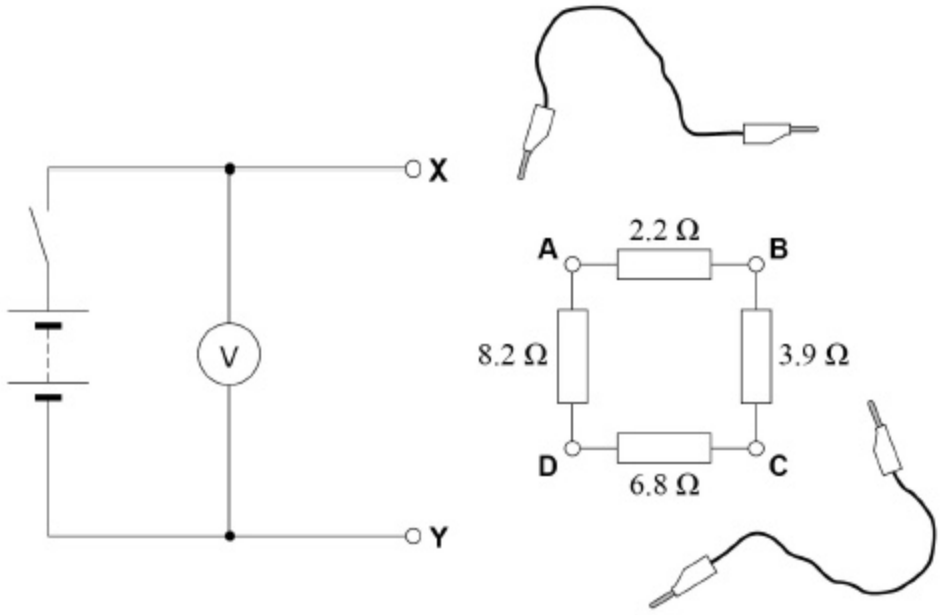
(2)

Figure 3



(h) **Figure 4** shows a different method for varying the resistance R described in part (a).

Figure 4



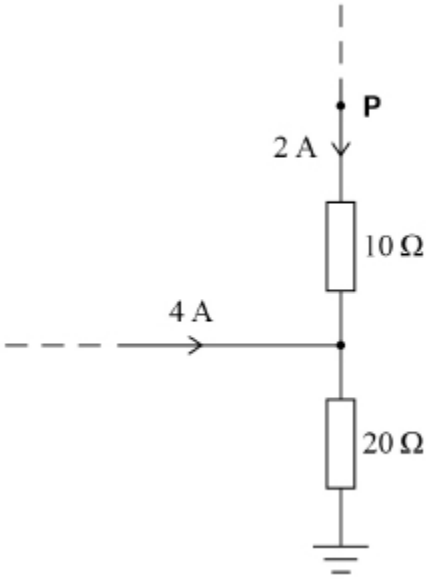
The four resistors are connected in a loop with sockets **A**, **B**, **C** and **D** at each junction. Two leads are used to connect the resistor loop to **X** and **Y**.

Discuss whether this method is an improvement over the method described in part (a). In your answer, you should refer to the number of different values that can be obtained for R.

(2)

(Total 11 marks)

31. The diagram shows part of a circuit and the currents in the circuit.



What is the potential difference between point P and earth?

A 60 V ⬭

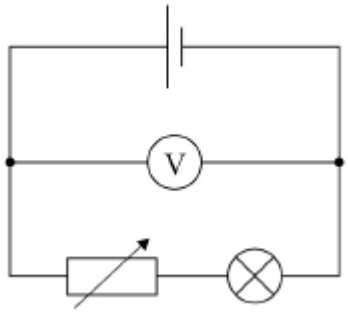
B 100 V ⬭

C 120 V ⬭

D 140 V ⬭

(Total 1 mark)

32. The diagram shows a practical circuit in which a variable resistor is used to control the brightness of a lamp. The voltmeter reading is monitored as the variable resistor is adjusted to make the lamp brighter.



(a) Explain why the reading on the voltmeter decreases as the brightness of the lamp increases.

(2)

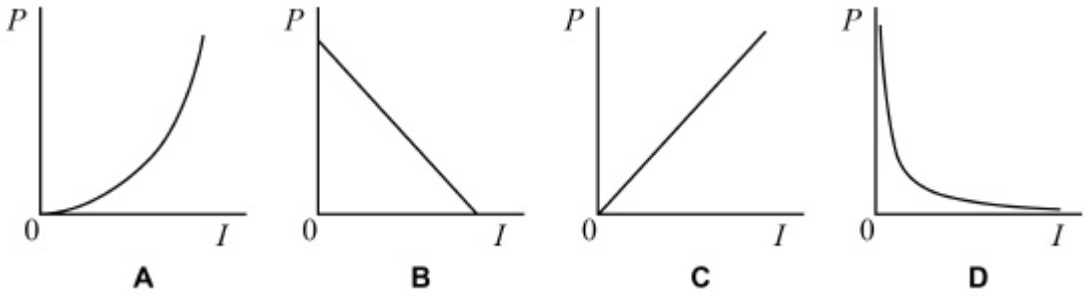
(b) The variable resistor is adjusted so that the lamp is at its brightest. The reading V_1 on the voltmeter is noted. A second identical cell is then connected in parallel with the cell in the diagram above. The new reading V_2 on the voltmeter is noted.

Explain why V_2 is greater than V_1.

(2)

(Total 4 marks)

33. Which graph shows how power dissipated P varies with current I in a component that obeys Ohm's law?



A ⬭

B ⬭

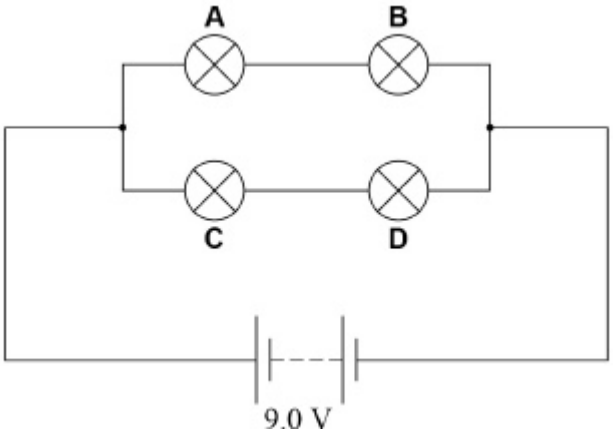
C ⬭

D ⬭

(Total 1 mark)

34. A student connects four lamps **A**, **B**, **C** and **D** in the circuit shown in **Figure 1**.
The battery has an emf of 9.0 V and negligible internal resistance.

Figure 1



(a) The table shows the operating conditions for the lamps when they are at normal brightness.

Lamps	Operating voltage / V	Power / W
A and **C**	6.0	6.0
B and **D**	3.5	4.1

The student observes that **two** of the lamps are at their normal brightness.
Assume that any changes in resistance of the lamps are negligible.

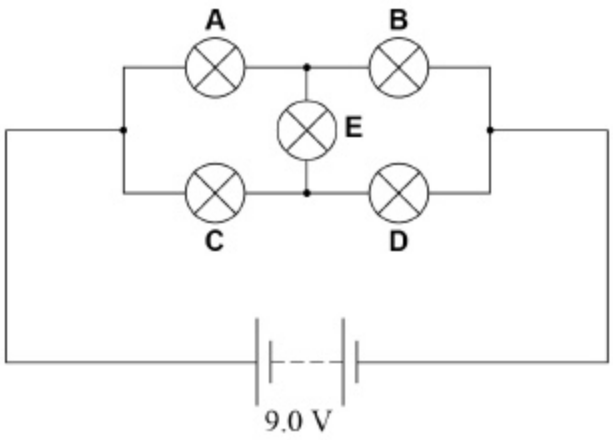
Determine which **two** lamps are at their normal brightness.

Use calculations to support your answer.

(4)

(b) The student connects another lamp **E** in the circuit as shown in **Figure 2**.
Lamp **E** is identical to lamps **A** and **C**.

Figure 2



Explain what the student would observe regarding the brightness of the lamps.

Refer to potential differences across lamp **E** in your answer.

(3)

(c) Lamp **B** in **Figure 2** fails so that it no longer conducts. This change does not affect the resistance of the other lamps.

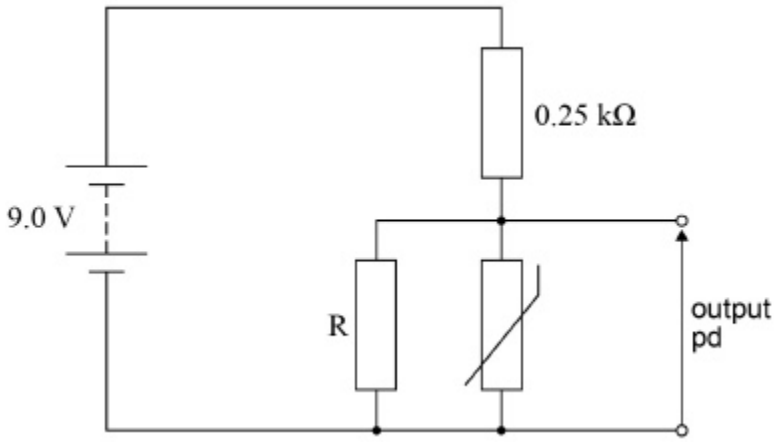
Deduce the effect on the current in the battery.

Use calculations to support your answer.

(3)

(Total 10 marks)

35. The diagram shows a circuit designed by a student to monitor temperature changes.



The supply has negligible internal resistance and the thermistor has a resistance of 750 Ω at room temperature. The student wants the output potential difference (pd) at room temperature to be 5.0 V

(a) The 0.25 kΩ resistor is made of 50 turns of wire that is wound around a non-conducting cylinder of diameter 8.0 mm

Resistivity of the wire = 4.2×10^{-7} Ω m

Determine the area of cross-section of the wire that has been used for the resistor.

area of cross-section = _____ m^2

(3)

(b) The student selects a resistor rated at 0.36 W for the 0.25 kΩ resistor in the diagram.

Determine whether this resistor is suitable.

_____

_____

_____

_____

_____

(2)

(c) Determine the value of R that the student should select.

Give your answer to an appropriate number of significant figures.

value of R = _____ Ω

(5)

(d) State and explain the effect on the output pd of increasing the temperature of the thermistor.

_____

_____

_____

_____

_____

(2)

(Total 12 marks)

36. A gas containing doubly-charged ions flows to give an electric current of 0.64 A

How many ions pass a point in 1.0 minute?

A 2.0×10^{18} ⬭

B 4.0×10^{18} ⬭

C 1.2×10^{20} ⬭

D 2.4×10^{20} ⬭

(Total 1 mark)

37. A mobile phone operates at a constant power of 200 mW
It has a 3.7 V lithium-ion battery that has a charge capacity of 9400 C

What is the time taken for the battery to discharge completely?

A 2 hours ⬭

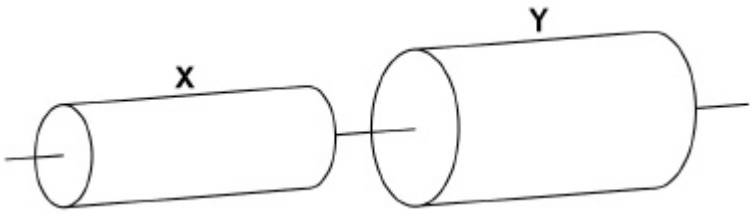
B 48 hours ⬭

C 120 hours ⬭

D 140 hours ⬭

(Total 1 mark)

38. The two resistors shown are both uniform cylinders of equal length made from the same conducting putty.



The diameter of **Y** is twice that of **X**. The resistance of **Y** is R.

What is the total resistance of the combination?

A $\frac{4R}{5}$ ⬭

B $3R$ ⬭

C $4R$ ⬭

D $5R$ ⬭

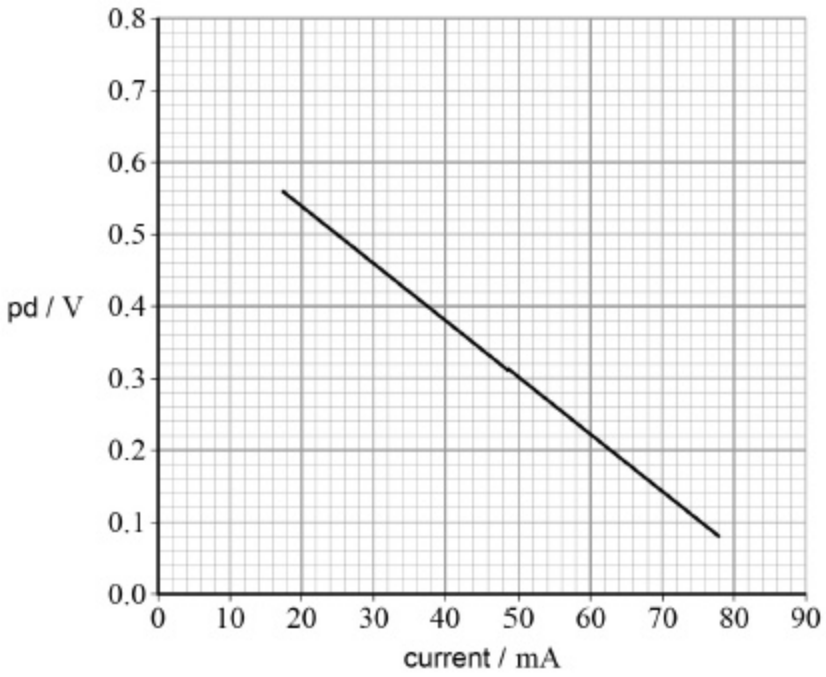
(Total 1 mark)

39. An engineer wants to use solar cells to provide energy for a filament lamp in a road sign.

The engineer first investigates the emf and internal resistance of a solar cell under typical operating conditions.

The engineer determines how the potential difference across the solar cell varies with current. The results are shown in the graph in **Figure 1**.

Figure 1



The engineer uses the graph to deduce that when operating in typical conditions a single solar cell produces an emf of 0.70 V and has an internal resistance of 8.0 Ω.

(a) Explain how the engineer uses the graph to obtain the values for the emf and internal resistance of the solar cell.

(2)

(b) To operate effectively the lamp in the road sign needs a minimum current of 75 mA. At this current the resistance of the filament lamp is 6.0 Ω.

The engineer proposes to try the two circuits shown in **Figure 2** and **Figure 3**.

Figure 2

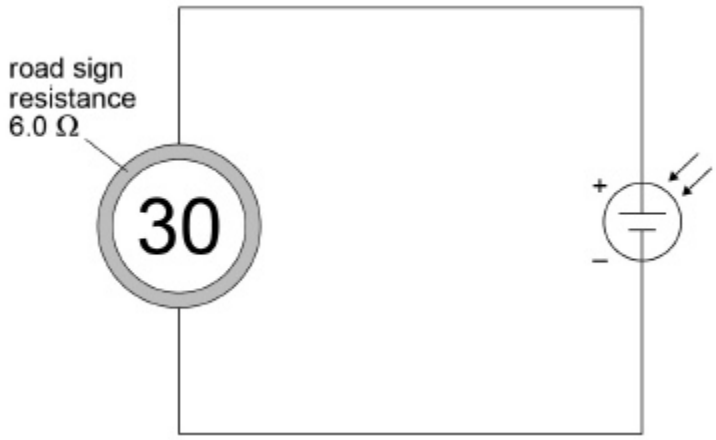
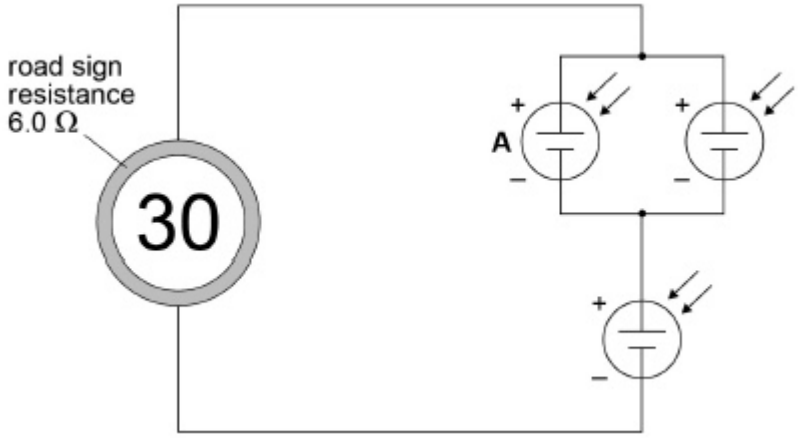


Figure 3



Deduce, using calculations, whether the circuits in **Figure 2** and **Figure 3** are suitable for this application.

(4)

(c) Solar cells convert solar energy to useful electrical energy in the road sign with an efficiency of 4.0%.
The solar-cell supply used by the engineer has a total surface area of 32 cm^2.

Calculate the minimum intensity, in W m^{-2}, of the sunlight needed to provide the minimum current of 75 mA to the road sign when it has a resistance of 6.0 Ω.

intensity = _____ W m^{-2}

(3)

(Total 9 marks)

40. The combined resistance of n identical resistors connected in parallel is R_n.

Which statement correctly describes the variation of R_n as n increases?

A R_n decreases linearly as n increases ⬭

B R_n decreases non-linearly as n increases ⬭

C R_n increases linearly as n increases ⬭

D R_n increases non-linearly as n increases ⬭

(Total 1 mark)