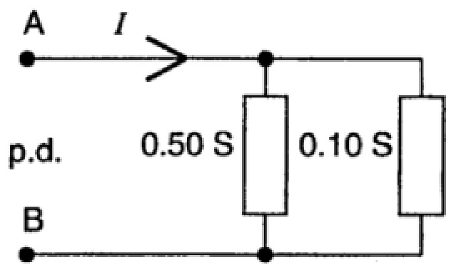
Sensing Questions from Paper 2860 for years 2001 to 2009

Jan 2001

1 Two conductors of conductance 0.10 S and 0.50 S are connected in parallel as shown in Fig. 1.



(a) What is the conductance of the parallel combination?

conductance = ...S [1]

The p.d. across terminals A B in Fig. 1 is 1.5 V.

(b) Calculate the current *I* passing through the combination.

current I = ...A [2]

6 A motor bike battery delivers a current of 2.5 A for two hours.

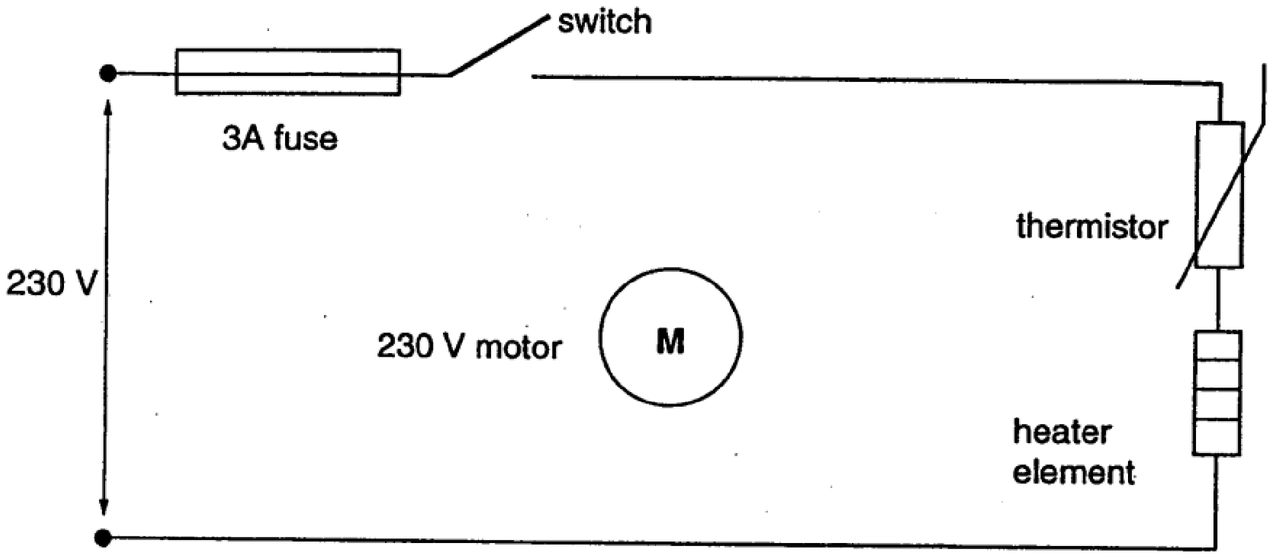
(a) Show that the total charge flowing is 18 kC.

[1]

(b) This charge transfers 108 kJ of electrical energy. Calculate the emf of the battery.

emf of battery = …………………… V [2]

8 Part of the circuit for a hair dryer is shown in Fig. 8.1.
The hair dryer has a 230 V motor.
A thermistor is close to the heater element in the hot air stream.



(a) Draw on Fig. 8.1 to show how the motor should be connected.

(b) The resistance of the heater element changes during the first few seconds of operation as shown in Fig. 8.2.

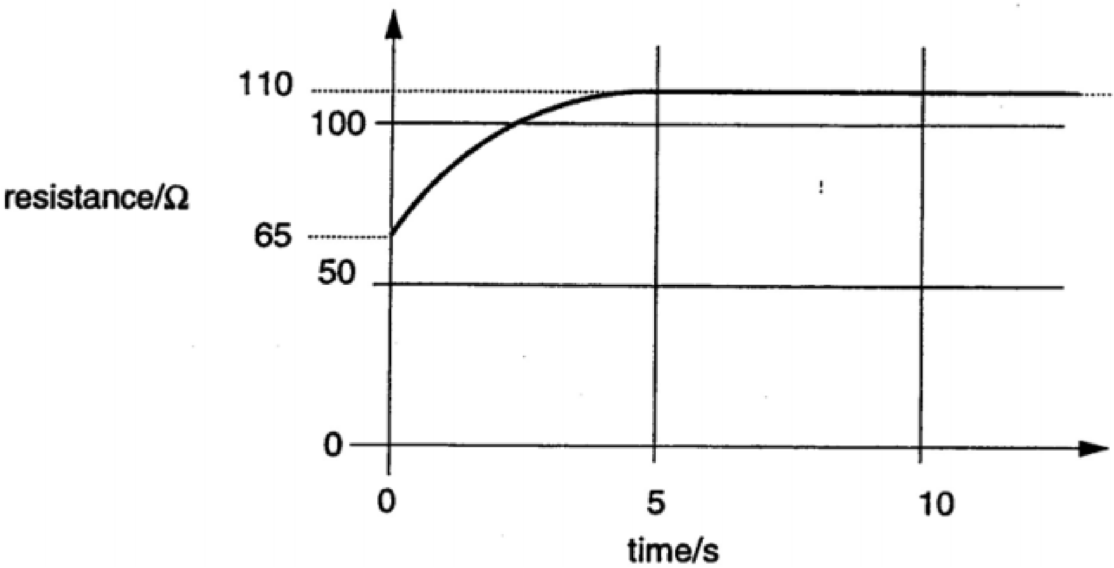


Fig. 8.2

(i) Describe how the resistance of the heater element changes with time.

[2]

(ii) Give one reason why the resistance changes when the dryer is first turned on.

[1]

(c) A thermistor is in the hot air stream, close to the heater element. The thermistor is chosen to maintain a constant current of 2.0 A in the heater circuit.

(i) Describe how the resistance of the thermistor needs to change during the first few seconds.

[1]

(ii) After the first few seconds, the resistance of the heater element is 110Ω, and the current in the heater circuit is 2.0 A.
Show that the resistance of the thermistor at this time is 5.0Ω.

[3]

(iii) On the graph, Fig. 8.2, show how the resistance of the thermistor changes.

[2]

June 2001

4 A resistor is rated at 470 Ω and 0.25 W.

(a) Why is the resistor given a maximum power rating?

[1]

(b) Calculate the potential difference across the resistor, when the maximum power is 0.25 W.

potential difference = ... V [3]

6 Fig. 6 shows the variation of potential difference with current for three electrical conductors A, B and C.

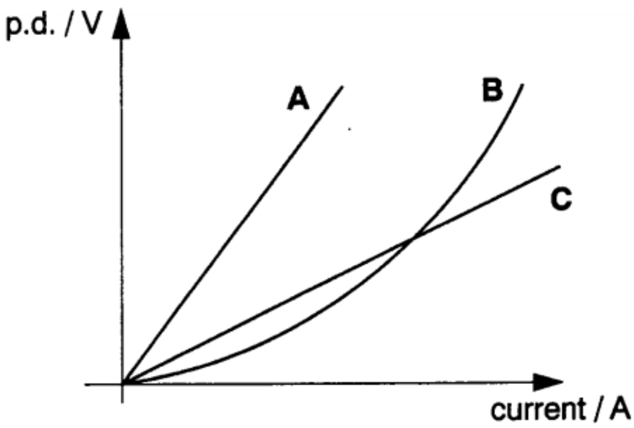


Fig. 6

(a) Which graph illustrates Ohm's Law for the largest resistance?

[1]

(b) How do the resistances of conductors B and C compare, at the point where the graphs B and C cross. Explain your answer.

[2]

7 A position sensor is needed on a greenhouse window.
The potentiometer is mounted at the window hinge as shown in Fig. 7.1. When the window opens, it rotates the wiper arm of a rotary potentiometer.

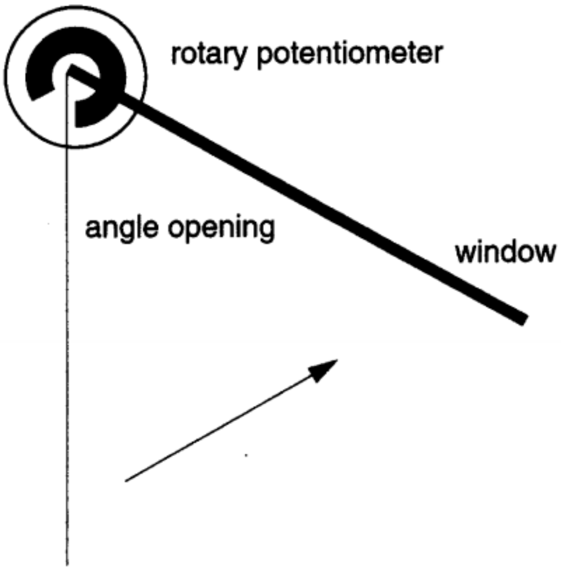


Fig. 7.1

The window may be opened between 0 and 60 degrees, but the rotary potentiometer has a 0 to 300 degree range.
The table in Fig. 7.2 shows the relationship between window position and potentiometer angle.

window position	potentiometer wiper angle / degree	output p.d. / V
shut vertical	0	0.0
fully open	60	
	300	3.0

Fig. 7.2

(a) A sensitivity of 10 mV / degree is required from the sensor.
Use this information to complete the third column in the table in Fig. 7.2. [1]

(b) The sensor circuit proposed is shown in Fig. 7.3.

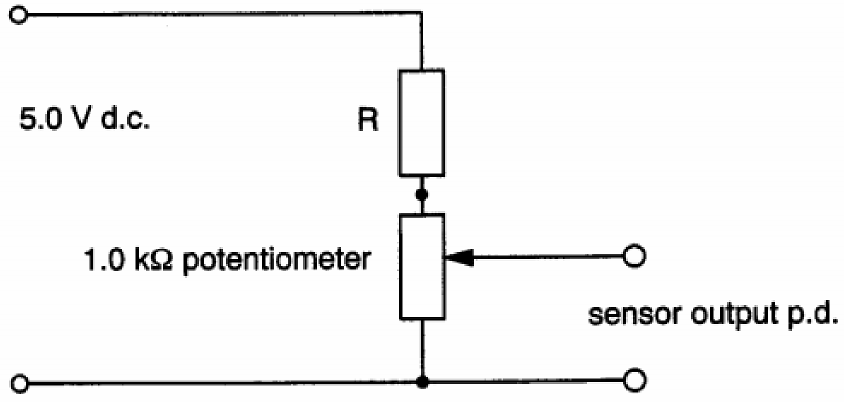


Fig. 7.3

(i) On Fig. 7.3 draw a circle around the variable wiper of the potentiometer. [1]

(ii) The sensor circuit is to run from a 5.0 V d.c. supply.
Explain the need for the fixed resistor R in the circuit.

[2]

(iii) Using data from the table in Fig. 7.2, calculate the value of R required if the potentiometer has a resistance of 1.0 kΩ.

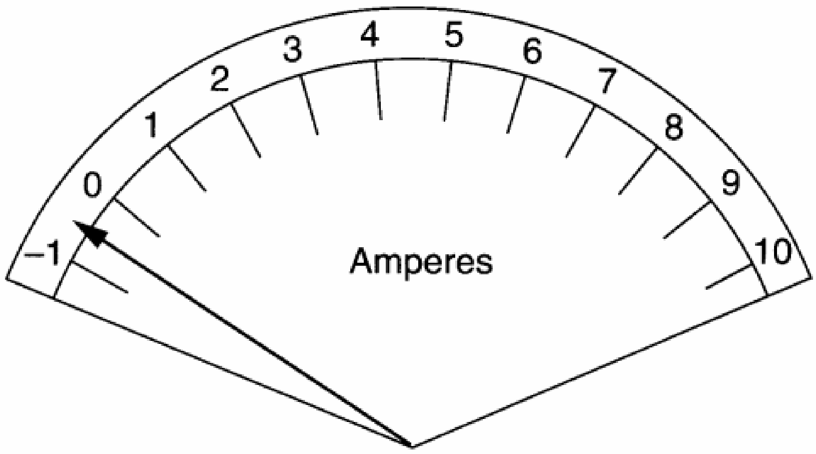
[3]

(c) The potentiometer and the fixed resistor are made from the same composition carbon. The resistivity of carbon falls as the temperature rises. The window is fully open.
State and explain the effect on the sensor's output p.d. if the fixed resistor R is warmer than the potentiometer.

[3]

June 2002

1 The moving coil ammeter scale illustrated below is to be used to measure a current. The full scale deflection is 10 A.



The meter has a systematic zero-error as shown, when the current is zero.

(a) Use this example to explain the meaning of **systematic error** in instrumentation.

[1]

(b) When the meter indicates a reading of 6.5 A, what is the actual current?

current = ... A [1]

10 A solar cell generates electrical power in constant bright sunlight.
A circuit is required to measure the p.d. and current delivered into a variable load resistor.

(a) Complete the circuit in Fig. 10.1 showing the connection of a variable load resistor and a voltmeter to measure the output p.d. across the load.

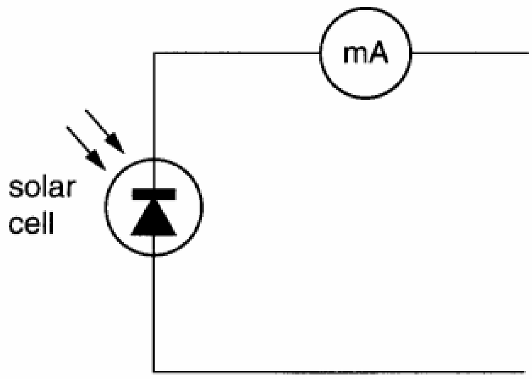


Fig. 10.1

[3]

The solar cell is placed in constant bright sunlight.
The graph in Fig. 10.2 shows this variation of p.d.

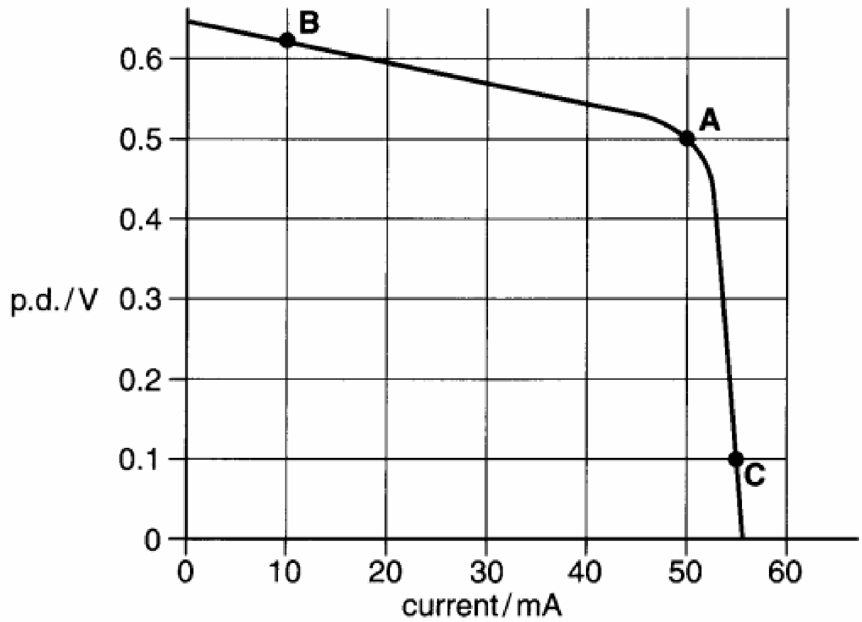


Fig. 10.2

(b) (i) Using the graph Fig. 10.2 describe how the p.d. of the solar cell varies, as more current is drawn from it.

[2]

(ii) Suggest a reason for the variation you have described in **(b)(i)**.

[1]

(c) (i) The maximum power from the cell is gained at the point **A** indicated in Fig. 10.2. Calculate this maximum power delivered.

maximum power delivered = ... W [3]

(ii) At both points **B** and **C** in Fig. 10.2, how do the values on the graph suggest that the power delivered is lower than at **A**?

[2]

June 2003

3 A thermistor, fixed resistor and voltmeter are connected in three different potential divider circuits **A, B, C** as shown in Fig. 3.1.

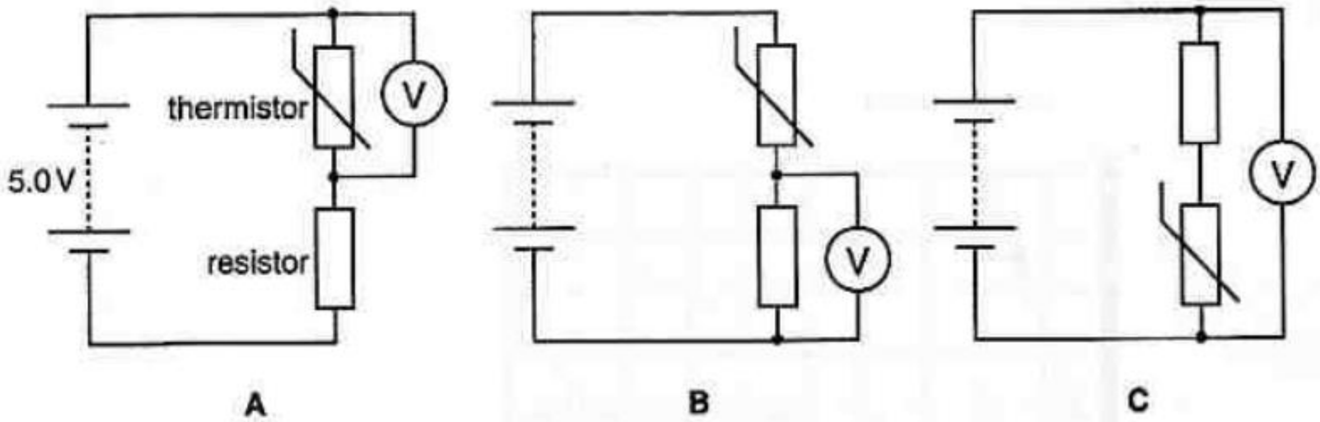


Fig. 3.1

Each divider is connected to a 5.0 V supply of negligible internal resistance.
The resistance of the thermistor decreases as the temperature increases.

State in which of the circuits **A, B, C** there is

(a) no change in p.d. recorded by the voltmeter as the temperature increases ....

(b) an increasing reading on the voltmeter as the temperature increases. ....

[2]

6 The graphs in Fig. 6.1 show how the potential difference across each of three cells **A, B** and **C** varies with current drawn from the cell.

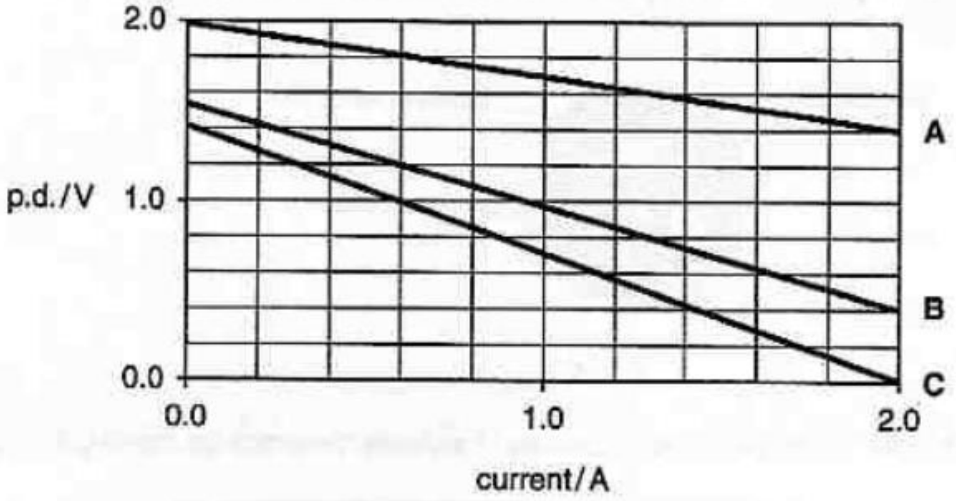


Fig. 6.1

State the cell **A, B** or **C** which

(a) has the greatest e.m.f. ....

(b) has the greatest internal resistance ....

(c) supplies a current of 2.0 A when the cell is short-circuited. .... [3]

8 This question is about aspects of a portable, flexible electrical extension cable, shown in cross-section in Fig. 8.1.

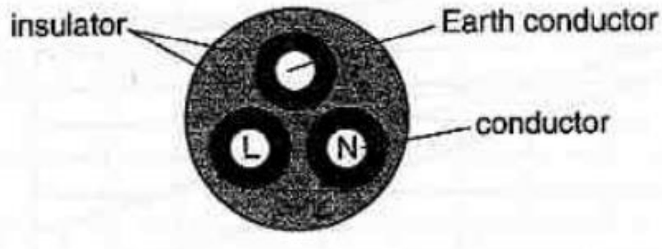


Fig. 8.1

(a) Complete the table for the required properties of suitable materials for making the cable.

	conductor	**insulator**
electrical conductivity		very low
suitable material	copper	

[2]

(b) The live **L** and neutral **N** conductors are connected in series with the load and the supply as shown in Fig. 8.2.

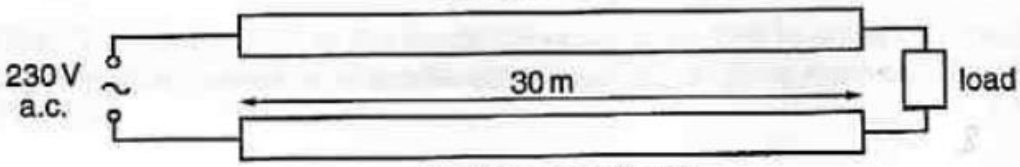


Fig. 8.2

(i) The cable is 30 m long, so that in total 60 m of conductor in the cable are in series with the load.
Each conductor has a cross-sectional area of $1.8 \times 10^{-6}\,m^2$.
Copper has a conductivity of $5.9 \times 10^{7}\,S\,m^{-1}$.

Show that the conductance of the cable is about 1.8 S.

[2]

(ii) The cable has a maximum current rating of 13 A.

Calculate the voltage dropped across the total resistance of the 60 m of conductor when there is a current of 13 A.

voltage dropped = ... V [2]

(iii) Show that the power dissipated in the cable under these conditions is of the order of 100 W.

[1]

(iv) The cable is stored by being tightly wound on a reel. The makers recommend that if the cable is used coiled on its reel, the current in it should be significantly less than 13 A.

Use the data from **(b)(iii)** to suggest and explain a reason for this recommendation.

[2]

Jan 2004

6 The electrical power P dissipated in a resistor R, with a potential difference V across it, can be calculated using

$$P = \frac{V^2}{R}.$$

Here is a list of multiplying factors.

$\times 2$ $\times \frac{1}{2}$ $\times 4$ $\times \frac{1}{4}$ $\times 1$

Choose the factor that best completes each of the two statements given below.

(a) When resistance R is kept constant, and the p.d. V is halved,

the power P will be multiplied by .... [1]

(b) When p.d. V is kept constant, and the resistance R is halved,

the power P will be multiplied by .... [1]

8 Fig. 8.1 shows how the resistance of a thermistor varies with temperature.

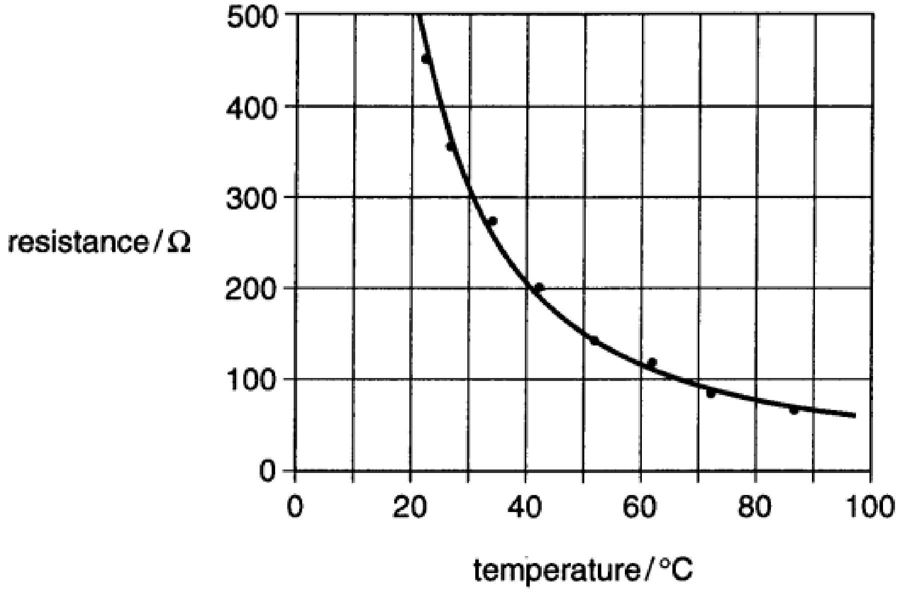


Fig. 8.1

(a) Complete the following description of the graph.

As the temperature of the thermistor rises, its resistance ....

The change in resistance between 80 °C and 90 °C is about 15 Ω, the change in resistance between 30 °C and 40 °C is about .... Ω.

On Fig. 8.1, the thermistor shows **greatest** sensitivity to temperature change when the temperature is .... [3]

(b) Fig. 8.2 shows this thermistor together with a resistor in a temperature sensing potential divider circuit.

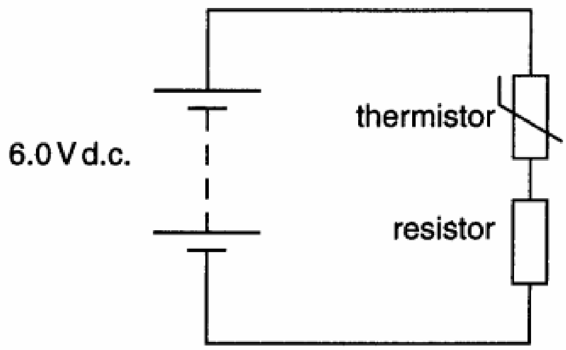


Fig. 8.2

(i) A voltmeter is to be connected to the circuit to indicate an **increasing** p.d. when the sensor detects an increasing temperature.

On Fig. 8.2, draw the circuit connections for a voltmeter to measure a p.d. that **rises** with increasing temperature. [1]

(ii) The value of the resistor in Fig. 8.2 is 200 Ω. The thermistor is at 65 °C.

Show that the current drawn from the 6.0 V supply is about 0.02 A.
Use data from Fig. 8.1.

[3]

(iii) Calculate the p.d. across the 200 Ω resistor at 65 °C.

p.d. across resistor = ... V [1]

(c) The graphs **X**, **Y** and **Z** in Fig. 8.3 show how the p.d. across the resistor varies with temperature, for three different values of the resistor.

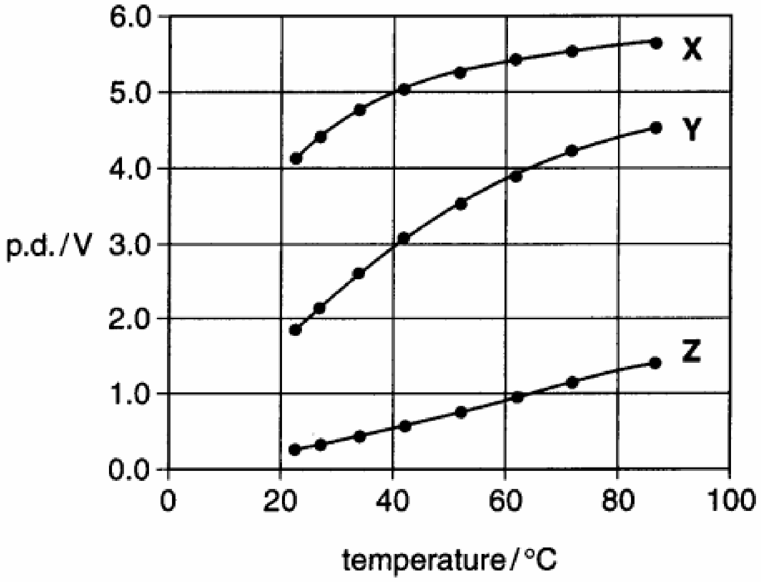


Fig. 8.3

(i) The values of resistance used are 20 Ω, 200 Ω and 1000 Ω.

State which graph, **X**, **Y** or **Z**, is the curve for the 1000 Ω resistor. .... [1]

(ii) State **one** advantage and **one** disadvantage of using output **Z** for the temperature sensing circuit.

advantage

disadvantage

[2]

4 Fig. 4.1 shows a light sensing circuit using an LDR, a fixed resistor of resistance 220 Ω and a 6.0 V battery.

The battery in the potential divider circuit is of negligible internal resistance.

The p.d. across the resistor is measured by a digital voltmeter.

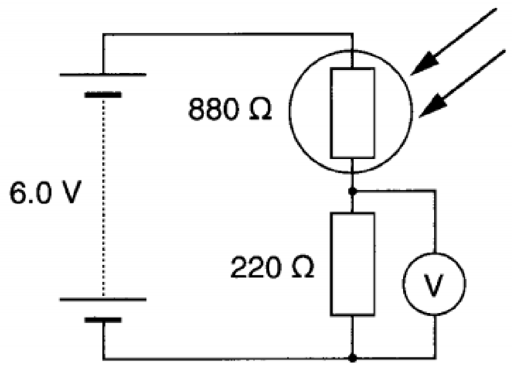


Fig. 4.1

In bright daylight, the resistance of the LDR is 880 Ω.

(a) Calculate the ratio = $\frac{\text{p.d across resistor}}{\text{p.d. across LDR}}$.

ratio = ... [1]

(b) Calculate the voltmeter reading in bright daylight.

p.d. = ... V [2]

5 Here are two relationships for electrical components.

$$P = I\,V \qquad\qquad V = I\,R$$

(a) **Show how** to combine these two relationships to produce an equation for the electrical power P in terms of the current I and resistance R only.

[1]

(b) Complete the following statement.

When the current is doubled in a constant resistance, the power dissipated is increased

by a factor of .... [1]

(c) The rear surface of the mirror can be heated electrically to clear frost and demist the mirror. A current I is passed through the reflecting alloy at the back of the mirror, as shown in Fig. 8.4.

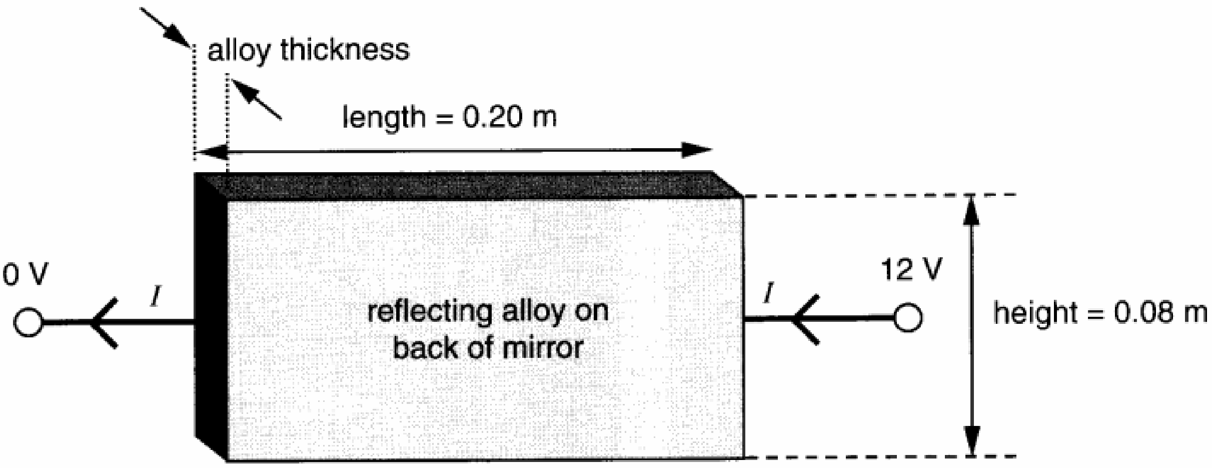


Fig. 8.4

(i) The heater dissipates 50 W from the 12 V car battery.

Show that the current I drawn by the heater is about 4 A.

[2]

(ii) Show that the conductance G of the heater is about 0.3 S.

[2]

(iii) The dimensions of the mirror are length = 0.20 m and height = 0.08 m as shown in Fig. 8.4.

Calculate the thickness of the reflecting alloy film used to heat the mirror.

conductivity of reflecting alloy = $3.1 \times 10^5\,\text{S m}^{-1}$

thickness = ... m [3]

10 A battery is being tested. Fig. 10.1 shows the battery connected to a variable load resistor **R** and two meters.

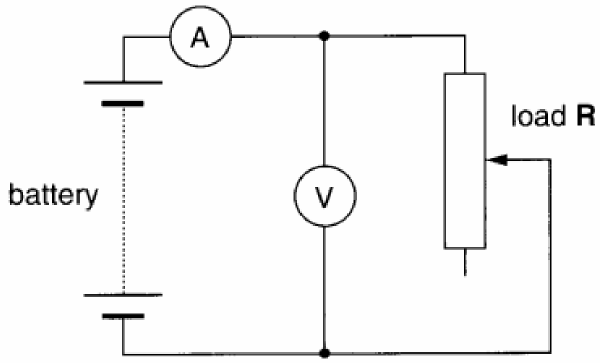


Fig. 10.1

Fig. 10.2 is a plot of the p.d. *V* across the battery against the current *I*, as **R** is varied.

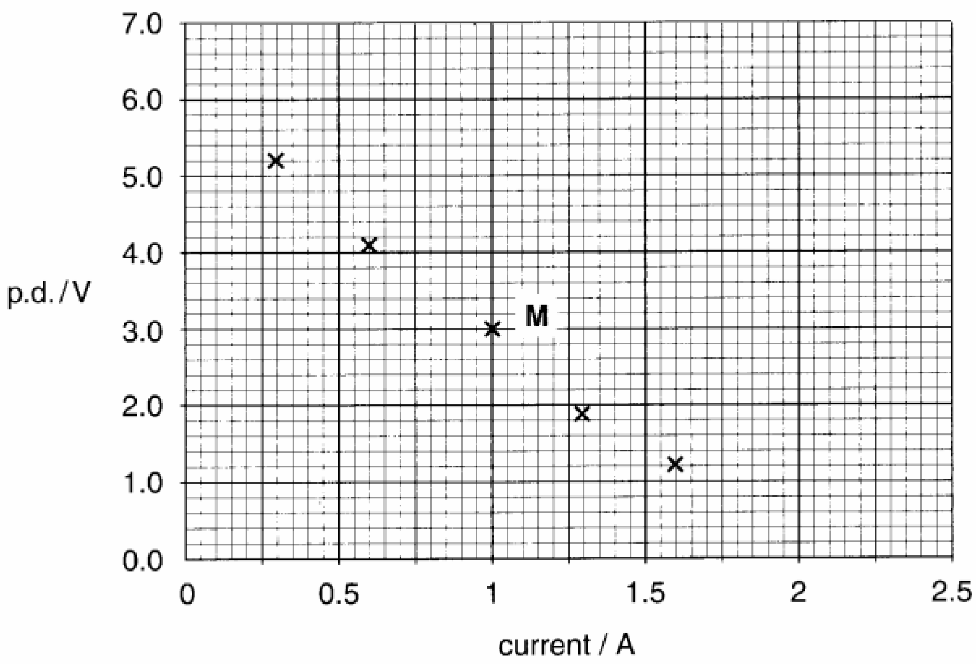


Fig. 10.2

(a) **(i)** Draw the line of best fit on Fig. 10.2. [1]

(ii) Use your line of best fit to

1. estimate the e.m.f. $\mathcal{E}$ of the battery $\mathcal{E}$ = ... V [1]

2. calculate the internal resistance *r* of the battery. Show your working clearly.

r = ... Ω [3]

(b) When the equation $V = \mathcal{E} - I\,r$

is multiplied throughout by the current I, an equation for the power, $I\,V$, delivered to the load resistance is

$$I\,V = I\,\mathcal{E} - I^2\,r.$$

Complete the gaps in the following sentence to explain the physical meaning of the second equation.

The electrical power delivered to the external load resistance is equal to

the power .... minus

the power ....[2]

(c) **(i)** Using point **M** on Fig. 10.2, where $I = 1.0$ A and p.d. $V = 3.0$ V, calculate

1. the resistance of the variable load resistor **R**

$R =$ .... Ω [1]

2. the power dissipated in **R**.

power = ... W [1]

(ii) The efficiency of a battery under load can be defined as follows

$$\text{efficiency} = \frac{\text{useful power}}{\text{total power}}\ .$$

Calculate the efficiency of the battery operating at point **M** on the graph.

efficiency = ... [1]

(iii) Choose **one** other data point from the graph Fig. 10.2.

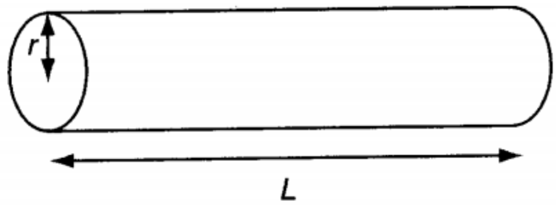
Show that the power dissipated in **R** at this point is smaller than the power at point **M**, calculated in **(c)(i)**.

[1]

Jan 2005

3 This question is about the conductance G of a cylindrical wire given by the following equation.

$$G = \frac{\sigma A}{L} = \frac{\sigma \pi r^2}{L}$$



(a) State what the term πr^2 in the equation represents.

[1]

(b) Here is a list of multiplying factors.

$\times 4$ $\times 2$ $\times 1$ $\times \frac{1}{2}$ $\times \frac{1}{4}$

Select the factor that best describes the variations given below.

If the length L of the wire is doubled, the conductance G will be ....

If the radius r of the wire is halved, the conductance G will be ....

[2]

4 Fig. 4.1 shows a ladder of conductivity values on a logarithmic scale, for three classes of conducting material.

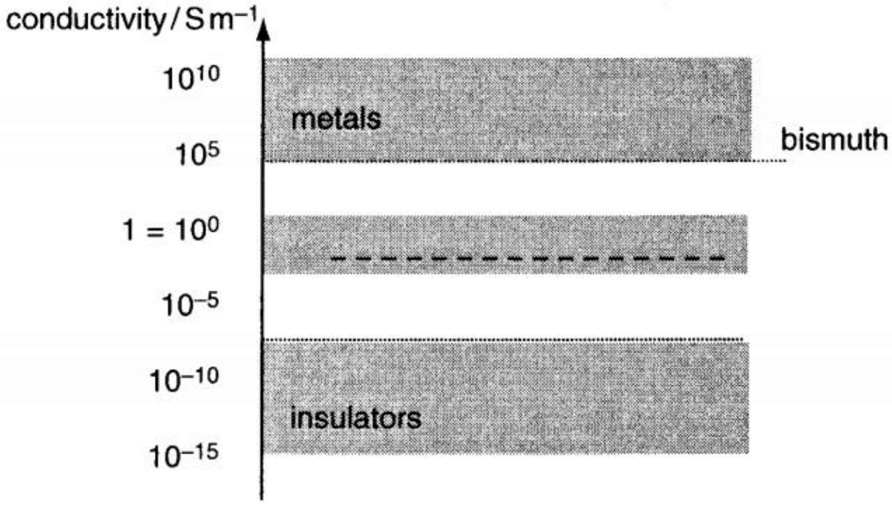


Fig. 4.1

(a) Label on Fig. 4.1 on the dashed line, the third class of conducting material. [1]

(b) The lowest conductivity of a metal indicated on the ladder is $9 \times 10^{5}\,\mathrm{S\,m^{-1}}$ for the metal bismuth.

Calculate the **resistivity** of bismuth. Give a suitable unit.

resistivity = ... unit .... [3]

6 Three equal resistors each of 100 Ω resistance are connected in the circuit shown in Fig. 6.1.

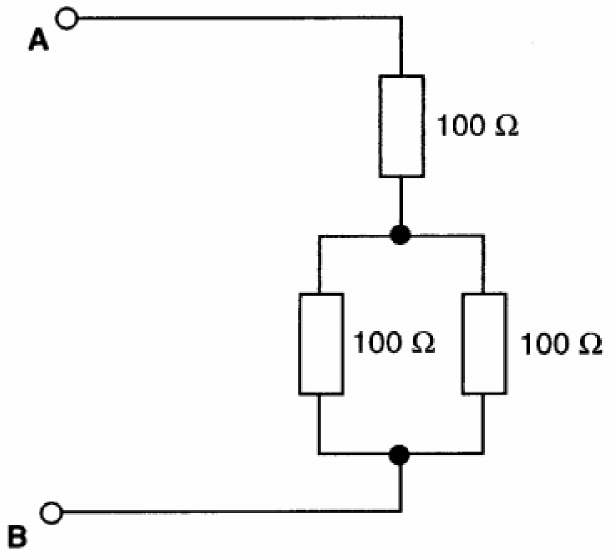


Fig. 6.1

(a) Calculate the total resistance of the circuit between points **A** and **B**.
Show your working.

resistance = ... Ω [2]

(b) The circuit is connected across a 12 V battery of negligible internal resistance.

Calculate the current drawn from the battery.

current = ... A [1]

8 An active temperature sensor produces an emf $\mathcal{E}$ which depends on temperature. The points in Fig. 8.1 show how the emf varies with temperature. A straight line fitting the data up to 40 °C has been added to the graph.

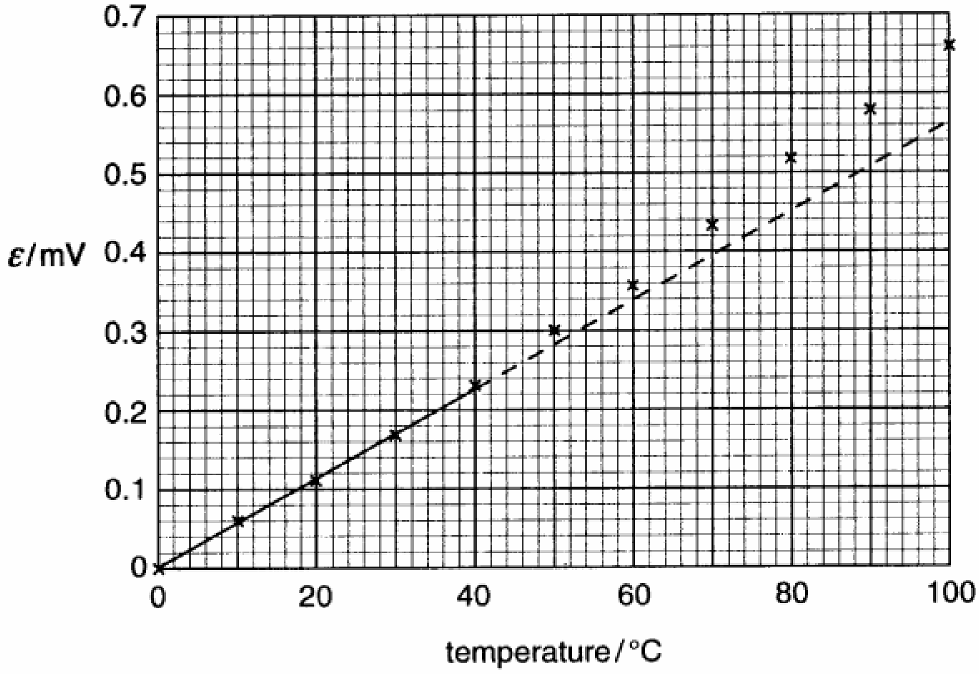


Fig. 8.1

(a) (i) Describe the relationship between the emf $\mathcal{E}$ and the temperature in °C shown by all the data points of Fig. 8.1.

[2]

(ii) Estimate the **sensitivity** of the temperature sensor in the range 0 °C to 40 °C from the data points in Fig. 8.1.
Use units of $\mu V\ °C^{-1}$ for the sensitivity.
Make your method of estimating the sensitivity clear.

sensitivity = ... $\mu V\ °C^{-1}$ [2]

(b) (i) Fig. 8.2 shows an active sensor of internal resistance r producing an emf $\mathcal{E}$ connected to an external resistance R.

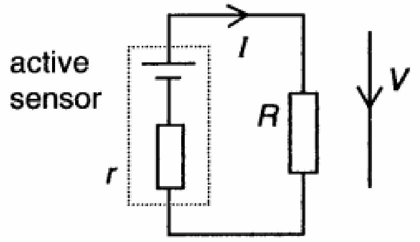


Fig.8.2

The p.d. V across the sensor, and the current I in the circuit are given by the equations

$$V = \mathcal{E} - Ir \quad \text{and} \quad I = \frac{\mathcal{E}}{(R+r)}.$$

Combine the equations to show that $V = \dfrac{\mathcal{E}R}{(R+r)}$.

[2]

(ii) The active temperature sensor has internal resistance $r = 0.2\,\Omega$.
Using **(b)(i)**, show that if an instrument of external resistance $R = 10\,\Omega$ is used to measure the p.d. across the sensor, it will show a reading that is about 98% of the emf $\mathcal{E}$.

[2]

(c) Instruments available to measure the output from the temperature sensor are given in the table below.

instrument	full scale deflection	sensitivity	internal resistance
moving coil meter	300 mm	$10\,\mu V\,mm^{-1}$	$10\,\Omega$
cathode ray oscilloscope	100 mm	$1.0\,mV\,mm^{-1}$	$25\,M\Omega$
digital voltmeter	$200\,\mu V$	$0.1\,\mu V$ steps	$2.0\,M\Omega$

The most suitable of these instruments to use for this sensor in the temperature range 0 to 100 °C is the **moving coil meter**.
Give **two** reasons why the **moving coil meter** is the most suitable, using the data in the table.

[2]

June 2005

1 Here is a list of electrical units.

A s   C s^{-1} J s^{-1} J C^{-1} V A^{-1}

Choose the correct unit for

(a) electric current ....

(b) resistance ....

(c) potential difference. ....

[3]

5 Fig. 5.1 shows an aluminium conductor on the surface of a computer chip.
It has a cross-sectional area $A = 2.0 \times 10^{-10}\,\text{m}^2$ and a length $L = 8.5 \times 10^{-4}\,\text{m}$.

conductivity σ of aluminium $= 3.8 \times 10^7\,\text{S m}^{-1}$

Calculate the conductance G of this conductor.

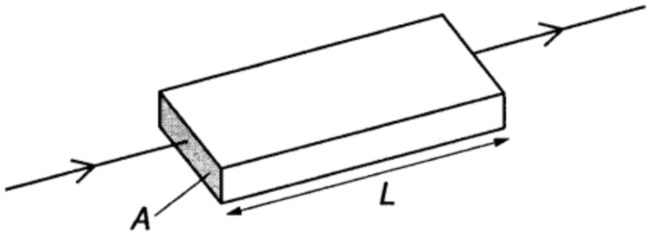


Fig. 5.1

G = ...S [1]

7 An ion beam delivers a charge of 60 nC during a time of 30 s.

(a) Calculate the current carried by the beam.

current = ...nA [1]

(b) Calculate the number of ions passing per second.

charge on each ion = 1.6×10^{-19} C

number of ions per second = ...[2]

9 A solar cell is being tested as a source of electrical power.

(a) The solar cell is connected in a circuit with a load resistor, an ammeter and a voltmeter in order to measure its power output.

Complete the circuit diagram Fig. 9.1 to show the ammeter and the voltmeter correctly connected into the circuit.

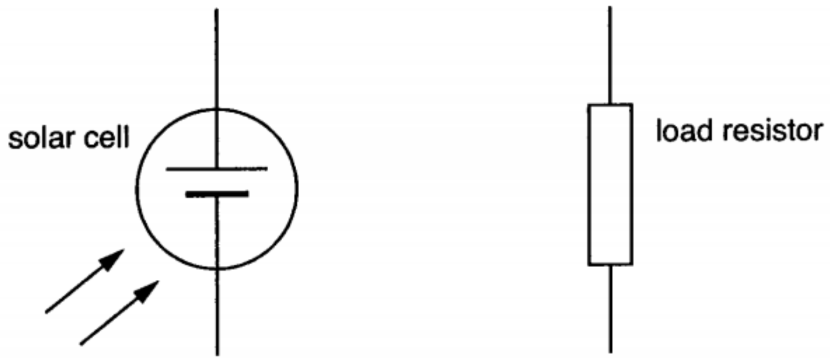


Fig. 9.1

[2]

Jan 2006

4 A battery of emf E of 6.0 V and internal resistance $R_{internal}$ is connected across a variable load resistor R_{load} as shown in Fig. 4.1.

The graph in Fig. 4.2 shows how the p.d. V across the load varies with current drawn from the battery.

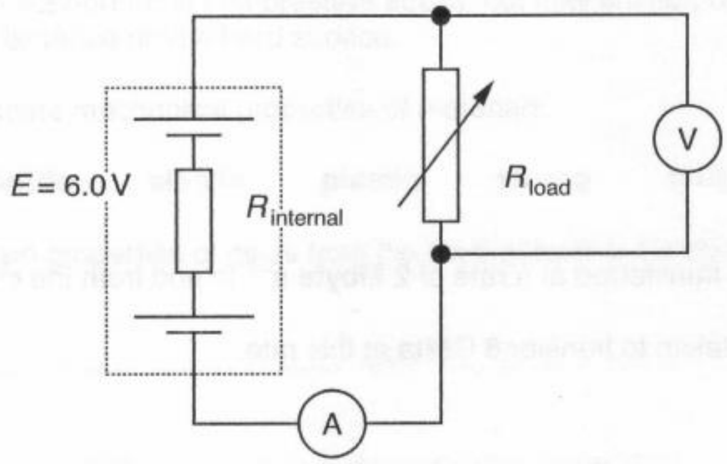


Fig. 4.1

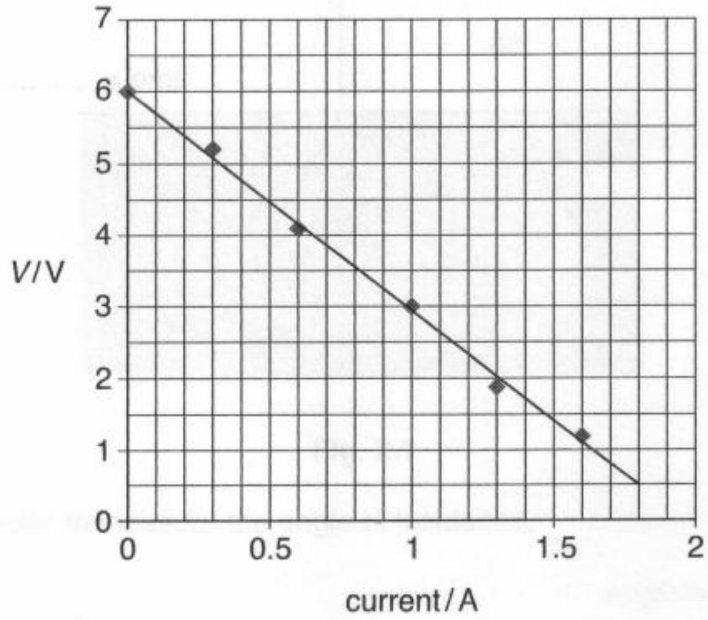


Fig. 4.2

Use data from the graph to calculate the internal resistance $R_{internal}$ of the battery. Make your method clear.

internal resistance $R_{internal}$ = ... Ω [3]

5 **(a)** To demonstrate some ideas in electricity, a teacher connects two different lamps **A** and **B** in parallel with a car battery as shown in Fig. 5.1.

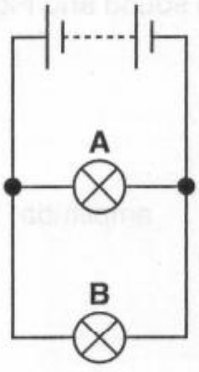


Fig. 5.1

Lamp **B** glows brighter than lamp **A**.

Complete the following sentences by adding one phrase from the list below.

greater than **equal to** **less than**

The current in lamp **B** is .... that in lamp **A**.

The p.d. across lamp **B** is .... that across lamp **A**. [2]

(b) The teacher then connects the lamps **A** and **B** in series with the car battery as shown in Fig. 5.2.

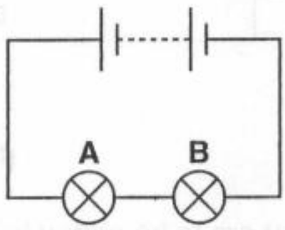


Fig. 5.2

Lamp **A** now glows brighter than lamp **B**.

Complete the following sentences by adding one phrase from the list below.

greater than **equal to** **less than**

The current in lamp **B** is .... that in lamp **A**.

The p.d. across lamp **B** is .... that across lamp **A**. [2]

9 The conductance G of a wire is related to its length L and cross-sectional area A by the relationship

$$G = \frac{\sigma A}{L}$$

where σ is the electrical conductivity of the material.

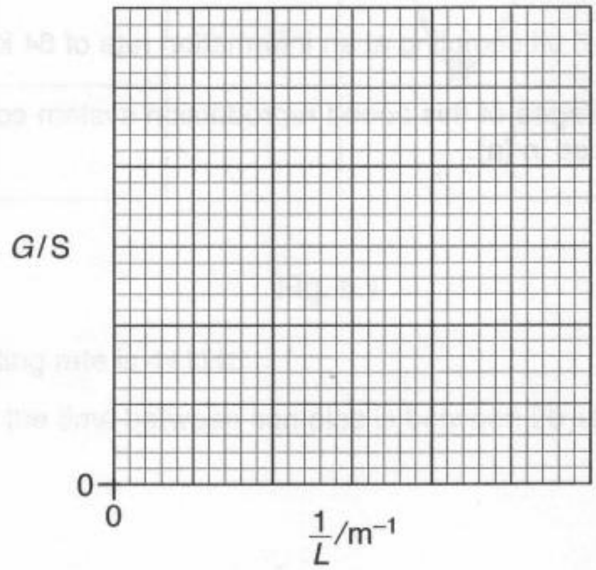
(a) In an experiment to investigate this relationship, a student gathers the following data for wires of the same material and of the same cross-sectional area.

conductance G / S	length L / m	$\frac{1}{L}$ / m^{-1}
0.50	0.20	5.00
0.20	0.50	
0.11	0.90	1.11
0.07	1.50	

(i) Complete the third column. [2]

(ii) Plot the data on a suitably scaled graph of G against $\frac{1}{L}$ below.

Draw the line of best fit.



[3]

(iii) Explain how your graph shows that G is **inversely proportional** to L.

[2]

(b) (i) Calculate the gradient of the graph, making your method clear.

gradient = ... S m [2]

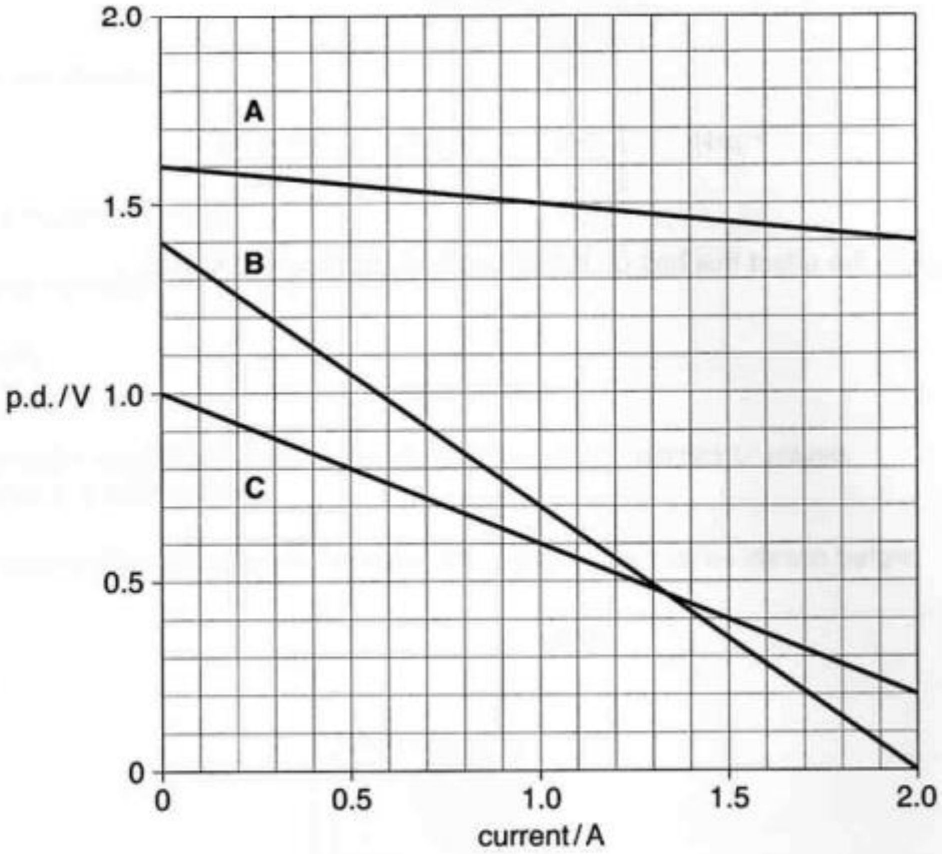
(ii) Show that the conductivity of the material is about $4 \times 10^4\,\mathrm{S\,m^{-1}}$.
Use your data from **(b)(i)**.

Take the cross-sectional area A as $2.3 \times 10^{-6}\,\mathrm{m^2}$.

[2]

June 2006

3 The graph below shows how the p.d. across three different cells **A**, **B**, and **C** decreases as more current is drawn from each.



State which of the cells **A**, **B** or **C**

(a) has the smallest emf ....

(b) will deliver the most electrical power at a current of 1.0 A ....

(c) has the smallest internal resistance. ....

[3]

4 Fig. 4.1 shows part of a scanning tunnelling microscope (STM).
Electrons flow between a fine tip and the surface.

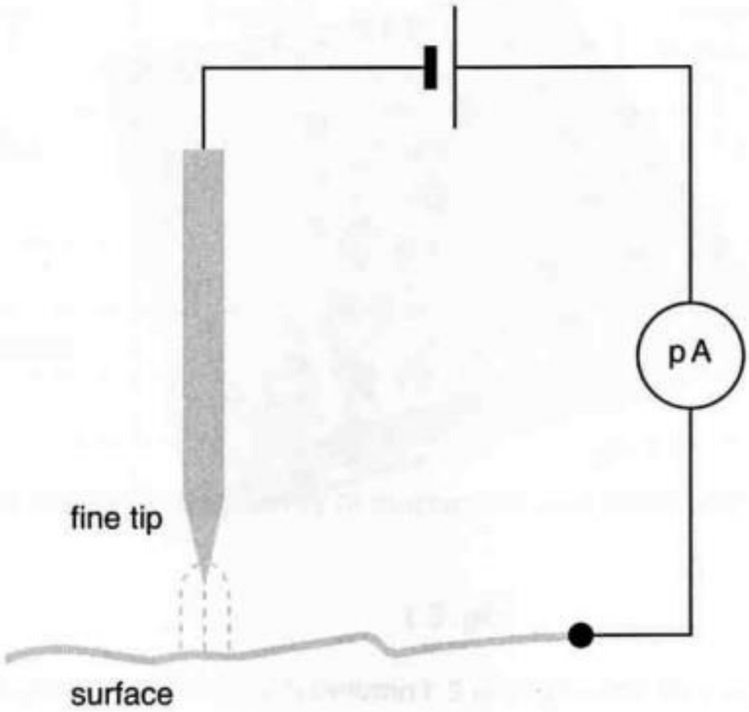


Fig. 4.1

20 million electrons per second flow between the tip and the surface.

Calculate the current in the circuit.

charge on electron, $e = 1.6 \times 10^{-19}$ C

current = ... A [2]

8 This question is about the heated **front windscreen** of a car.
The heater consists of resistance wires which are embedded in the glass.

(a) The power of the heater needs to be 180W for satisfactory de-misting.

A car battery of negligible internal resistance supplies 12V to operate the heated screen.

(i) Calculate the current required to deliver a power of 180W.

current = ... A [2]

(ii) Show that the resistance of the heater when operating is about 1 Ω.

[2]

(b) The heater consists of 200 wires inside the glass.
These wires are connected in parallel to the 12 V supply as shown in Fig. 8.1.

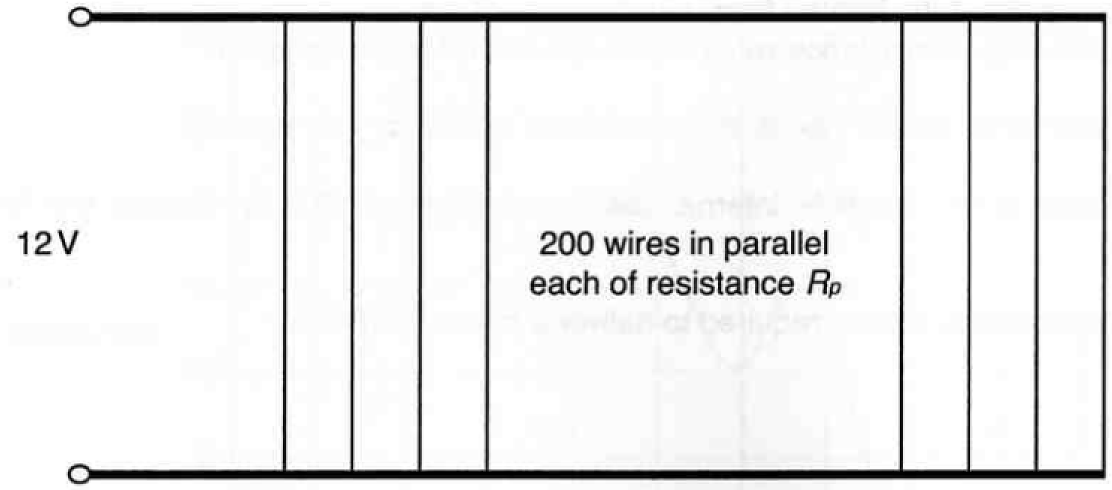


Fig. 8.1

Each of the 200 wires has a length of 0.70 m and resistance R_p of 160 Ω.

The material of the wire has resistivity $\rho = 6.0 \times 10^{-7}\,\Omega\,m$.

Calculate the **diameter** of the wire.

diameter = ... m [4]

(c) An alternative design has a heater of the **same power** rating.
The wires are connected in **series** as shown in Fig. 8.2.

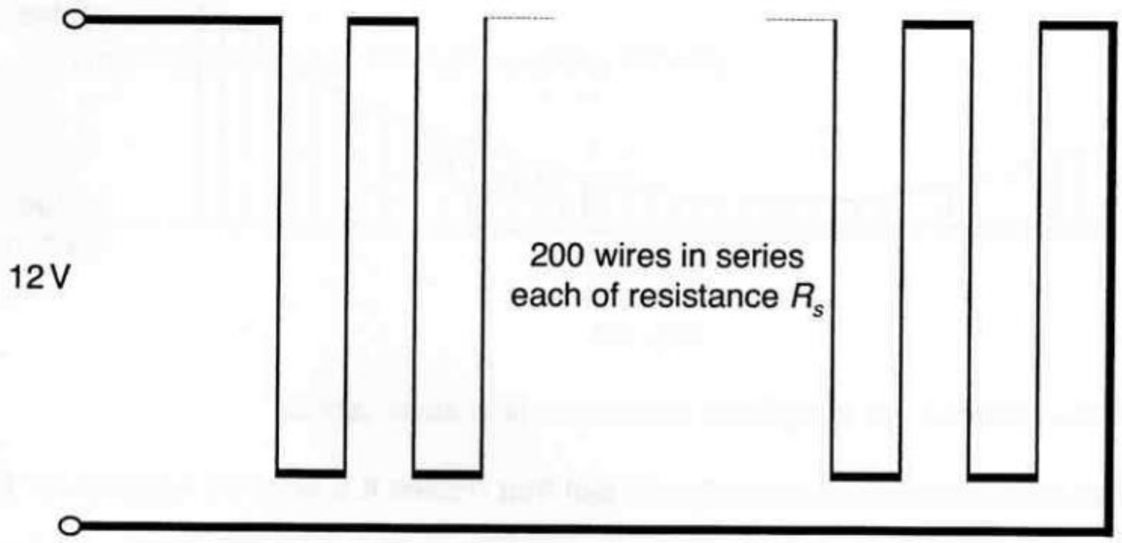


Fig. 8.2

The 200 wires are made of the **same material**, are each of length 0.7 m, but of resistance R_s.

(i) Calculate the resistance R_s of each wire in this series arrangement, required to keep the resistance of the heater about 1 Ω.

R_s = ... Ω [1]

(ii) This series design would not work in this application, because the wires would have to be so thick that they would block the driver's vision.

Justify this statement.

[2]

Jan 2007

1 Here is a list of electrical units.

A s **J s^{-1}** **S m^{-1}** **Ω m** **Ω**

Choose a correct unit for

(a) power ....

(b) charge ....

(c) resistivity. ....

[3]

5 Fig. 5.1 shows two conductors connected in parallel.
The conductors have conductances of 1.0 mS and 3.0 mS as shown.

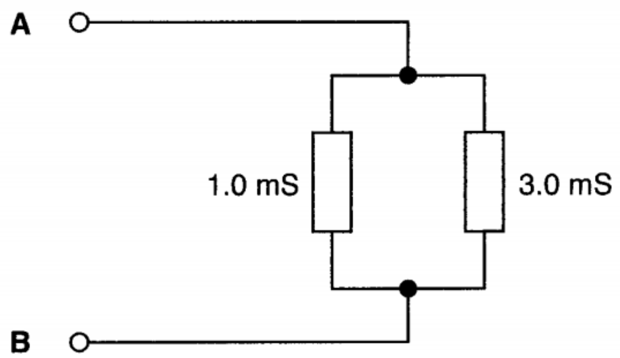


Fig. 5.1

(a) State the total conductance of the parallel conductors.

total conductance = ... mS [1]

(b) A battery of emf 6.0 V and negligible internal resistance is connected between **A** and **B**.

Calculate the current drawn from the battery.

current = ... A [2]

9 This question is about the resistances of ammeters and voltmeters.

(a) (i) A battery of emf 12.0V and negligible internal resistance is connected to a resistor of resistance 2.5 Ω, as shown in Fig. 9.1.

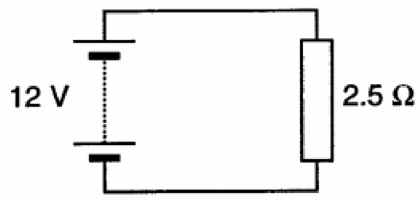


Fig. 9.1

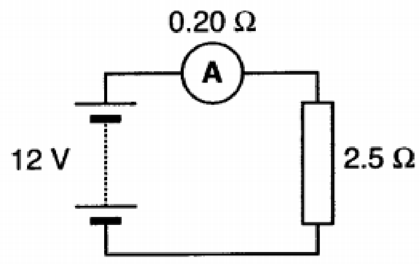


Fig. 9.2

Calculate the current in the circuit of Fig. 9.1.

current = ... A [1]

(ii) An ammeter of resistance 0.20 Ω is connected in series in the circuit as shown in Fig. 9.2 to measure this current.

1 Calculate the current in the circuit of Fig. 9.2 after the ammeter is added.

current = ... A [2]

2 Explain why the current is **lower** in Fig. 9.2.

[1]

(iii) A good quality ammeter alters the current it is measuring by as little as possible.

Suggest the best value of the resistance of an ammeter to make it perfect.

[1]

(b) A battery of emf 12.0V and negligible internal resistance is connected across two resistors in series as shown in Fig. 9.3.

Each resistor has a resistance of 25 kΩ.

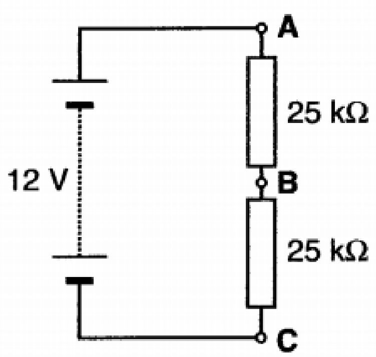


Fig. 9.3

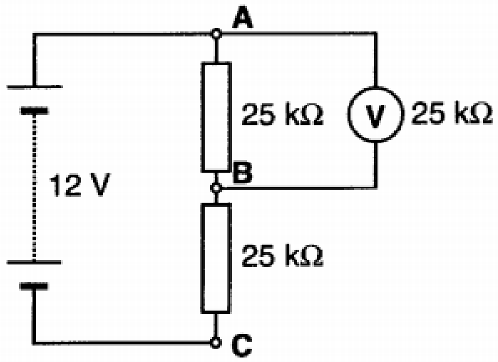


Fig. 9.4

(i) Explain why the potential difference V_{AB} between points **A** and **B** in Fig. 9.3 is 6.0V.

[1]

(ii) A voltmeter of resistance 25 kΩ is now connected across **AB** as shown in Fig. 9.4, to measure V_{AB}.

1 Explain why two identical resistors connected in parallel have a combined resistance of **half** the value of one resistor on its own.

[1]

2 Calculate V_{AB} in the circuit of Fig. 9.4.

V_{AB} = ... V [2]

3 Explain why V_{AB} is **lower** in the circuit in Fig. 9.4.

[1]

(iii) A good quality voltmeter alters the p.d. it is measuring by as little as possible.

Suggest the best value for the resistance of a voltmeter that makes it perfect.

[1]

2 A student is measuring the conductance of a component.

He measures the current in the component as $I = 0.24 \pm 0.01$ A
and the p.d. across the component as $V = 5.4 \pm 0.1$ V.

(a) Calculate the best estimate for the conductance G.

Give your answer to a sensible number of significant figures.

G = ... S [1]

(b) Use the largest current and smallest p.d. within his uncertainty range.

Calculate the maximum value of G consistent with the data.

maximum value of G = ... S [1]

(c) State an estimated value for the $\pm$ uncertainty in the measurement of G.

uncertainty in $G = \pm$ .... S [1]

3 Here is a list of units.

A s **C s^{-1}** **J C^{-1}** **V A^{-1}** **J s^{-1}**

Write down the units from the list that are equivalent to the units below:

W .... A ....

Ω .... V .... [4]

8 This question is about the properties of an LDR.

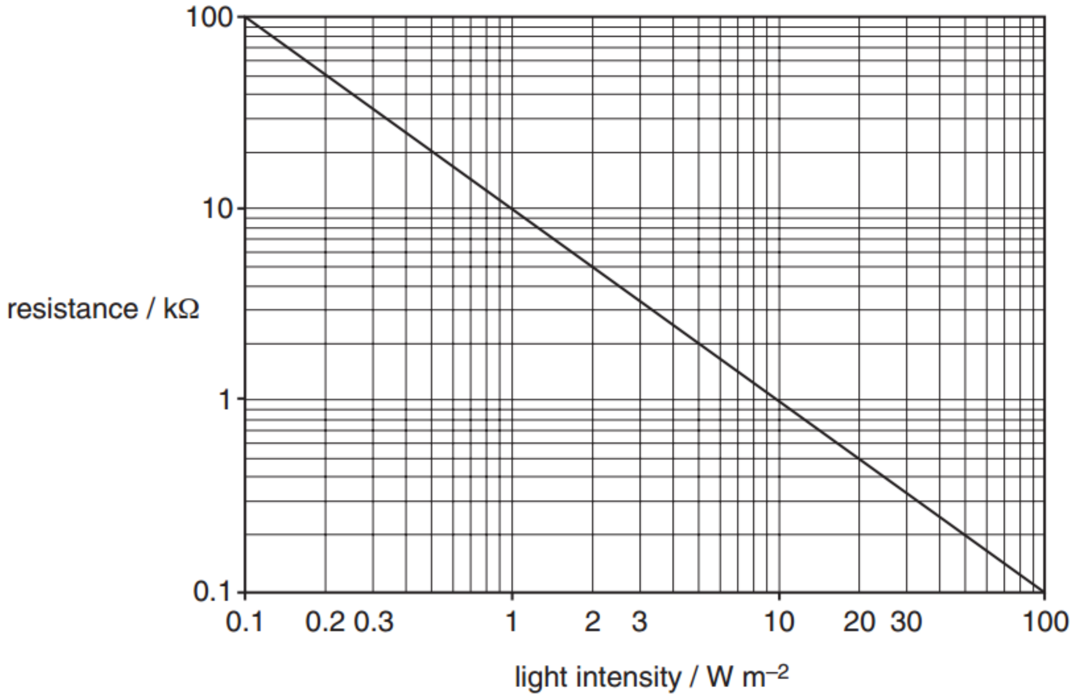


Fig. 8.1

The graph in Fig. 8.1 shows how the resistance of the LDR varies with incident light intensity.

(a) The unit of light intensity is $W\,m^{-2}$.

Complete an equation for the incident light intensity I, in terms of the power P of the light and the area A through which the light passes normally.

$$I =$$

[1]

(b) **(i)** State how you recognise that the scales of the graph in Fig. 8.1 are **logarithmic**.

[1]

(ii) Use Fig. 8.1 to find the resistance of the LDR at a light intensity of $2.0\,W\,m^{-2}$.

resistance of LDR = ... Ω [2]

(c) **(i)** The line in Fig. 8.1 obeys the relationship

resistance × intensity = constant.

Calculate the value and state the units of this constant.

constant = ... units .... [2]

(ii) Graphs **A**, **B**, **C**, **D** in Fig. 8.2 show possible variations for the resistance *R* of the LDR plotted against light intensity *I*, but now using **linear** scales.

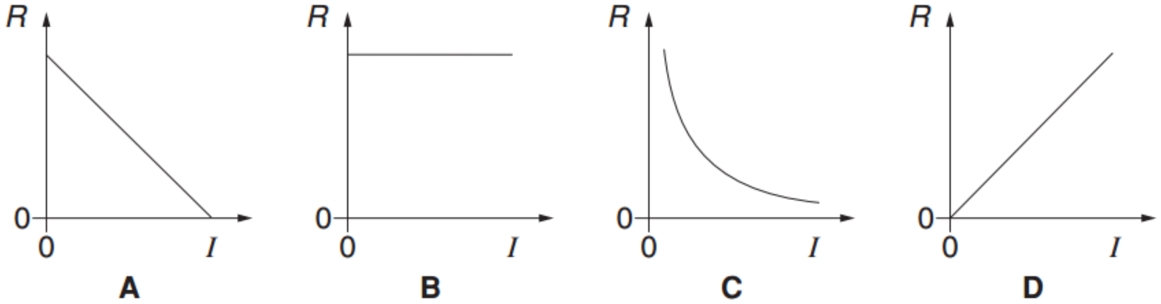


Fig. 8.2

State which of the graphs **A**, **B**, **C**, **D** represents the data plotted in Fig. 8.1.

.... [1]

(d) Electrons are released from bonds in the material of the LDR by absorbing incident photons. They remain free to conduct for about 50 ms before returning to be localised in bonds again.

Imagine an LDR which is brightly illuminated, which is suddenly plunged into darkness.

Suggest why the resistance of the LDR also takes about 50 ms to respond.

[1]

(e) **(i)** Suggest a reason why the charge carrier density in the LDR material **doubles** when the incident light intensity **doubles**.

[1]

(ii) Explain why it is expected that the resistance of the LDR is **inversely proportional** to the light intensity incident on it.

[2]

10 This question is about a strain gauge.

(a) **(i)** Fig. 10.1 shows a metallic wire conductor used to form the strain gauge.

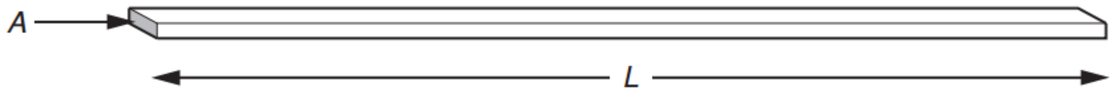


Fig. 10.1

A is the cross-sectional area and *L* the length of the wire.

ρ is the resistivity of the wire material.

Complete the equation for the resistance *R* of a wire, in terms of *A, L* and ρ.

R =

[1]

(ii) The cross-sectional area of the wire is 8.0×10^{-10} m^2.

The resistivity of the wire material is 4.8×10^{-7} Ω m.

Calculate the length *L* of wire needed to achieve a resistance of 120 Ω.

L = ... m [2]

Jan 2008

8 This question is about the choice of materials to construct the overhead power cables for the National Grid.
Fig. 8.1 shows cables suspended from pylons.

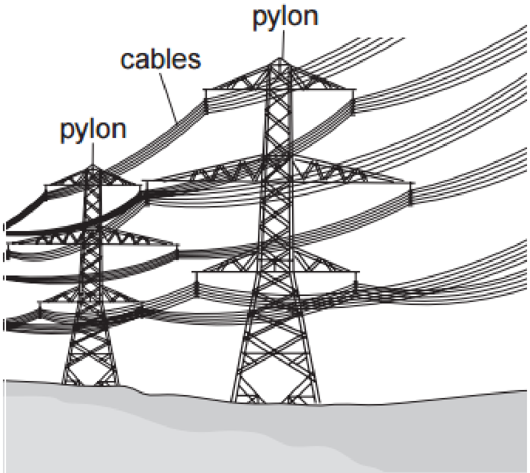


Fig. 8.1

(a) (i) Each cable operates at a p.d. of 400 kV above Earth voltage.

Calculate the power transmitted by each cable if the current in it is 100 A.

power = ... W [1]

(ii) Power cables inevitably lose some energy during transmission.

State where this energy goes.

[1]

(iii) An acceptable power loss is 1.4 kW per km length of cable at a current of 100 A.

Show that the conductance *G* of a 1.0 km length of the cable must be greater than about 7 S, so that it does not lose more power than 1.4 kW per km.

[2]

(b) (i) The mass m of the cable is given by $m = A L \rho$

where A is the cross-sectional area, L is the length and ρ the density of the cable material.

The conductance G of the cable is given by $G = \frac{\sigma A}{L}$

where σ is the conductivity of the cable material.

Combine these two relationships to show that $m = \frac{G L^2 \rho}{\sigma}$.

[1]

(ii) Aluminium and steel are used for making the cables.
Fig. 8.2 shows the ratios (steel / aluminium) of conductivity, density, yield stress, and Young Modulus for these two materials.

conductivity of steel / conductivity of aluminium	0.18
density of steel / density of aluminium	2.9
yield stress of steel / yield stress of aluminium	6.0
Young modulus of steel / Young modulus of aluminium	3.0

Fig. 8.2

Using these data and the formula in **(i)**

calculate the ratio $\frac{\text{mass of steel cable}}{\text{mass of aluminium cable}}$

for cables of length 1.0 km and conductance of 7 S.

ratio = ... [2]

(c) The cables are made from a combination of steel and aluminium strands.

Fig. 8.3 shows a composite cable made of 7 central steel strands surrounded by 30 aluminium strands.

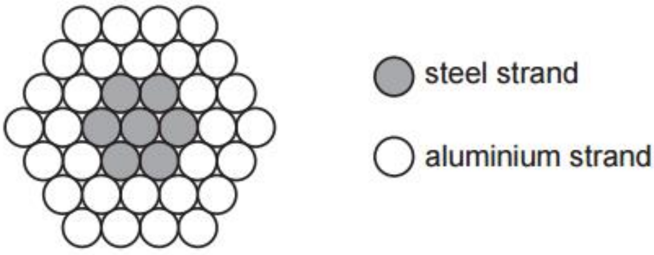


Fig. 8.3

(i) The conductance G_{steel} of 1.0 km of the 7 steel strands is 0.29 S.
Use data from table Fig. 8.2 to show that the conductance of 1.0 km of the 30 aluminium strands is close to 7 S.
All the strands have the same cross-sectional area.

[3]

(ii) Calculate the conductance of 1.0 km of the composite cable.

conductance = ... S [1]

(iii) Suggest **one** reason why a composite conductor composed of steel and aluminium strands is chosen for the National Grid.

[1]

June 2008

1 Here is a list of units for electrical quantities.

A s **A V^{-1}** **J C^{-1}** **J s^{-1}**

Select the correct unit for

electrical charge ....

potential difference ....

electrical conductance ....

[3]

5 Fig. 5.1 shows a graph of how the potential difference, p.d., across a cell varies with increasing current.

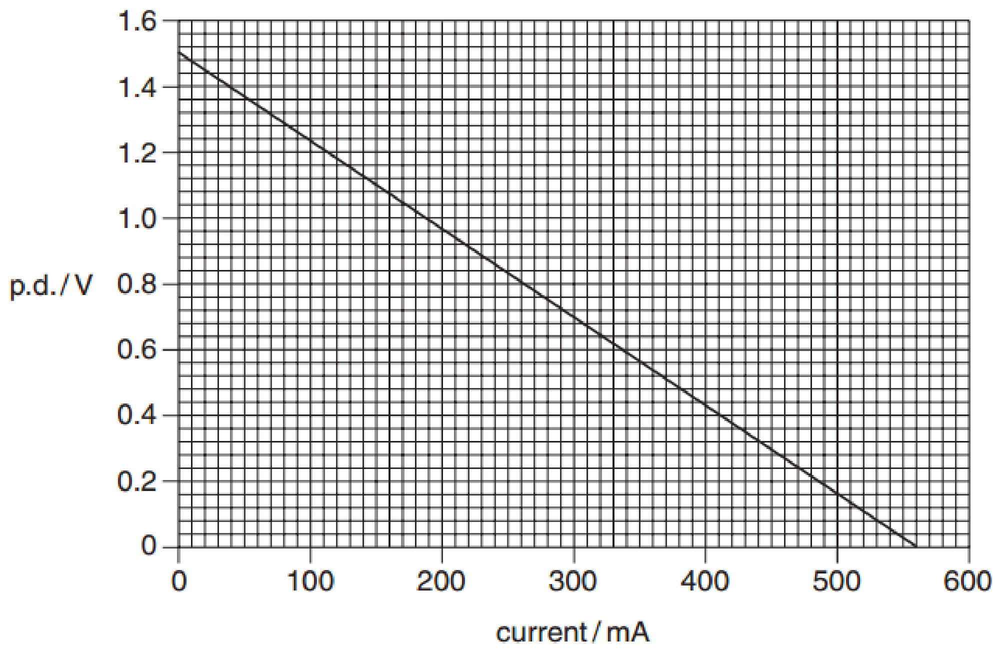


Fig. 5.1

(a) From the graph read and record the following values:

the e.m.f. of the cell = ... V

the maximum current obtainable from the cell = ... mA [2]

(b) Use these data to calculate the internal resistance of the cell.

Make your method clear.

internal resistance = ... Ω [2]

9 Fig. 9.1 shows how the resistance R of a light dependent resistor (LDR) in a circuit varies with light intensity incident upon it.

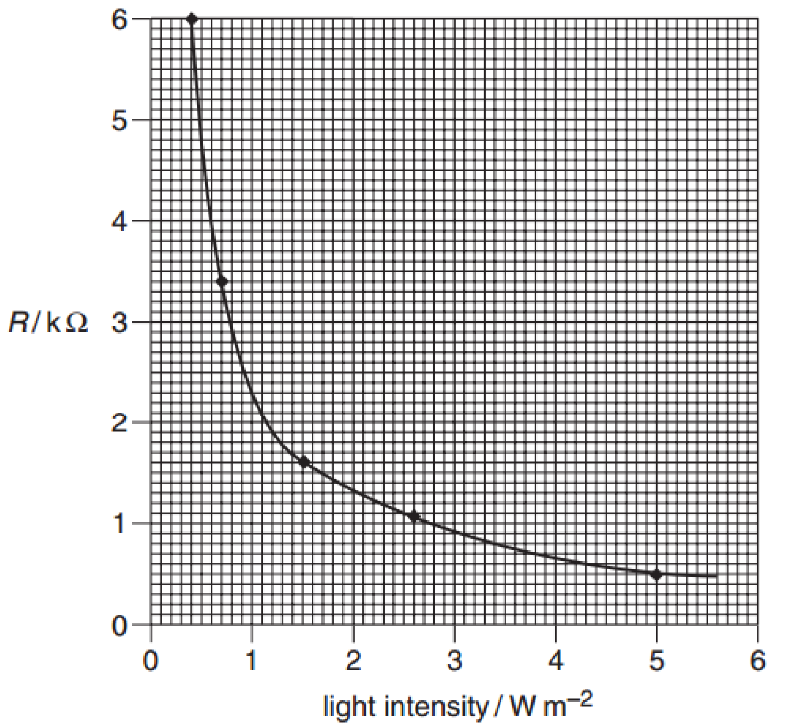


Fig. 9.1

(a) Complete the following description of the graph.

As the light intensity incident upon the LDR decreases, its resistance ....

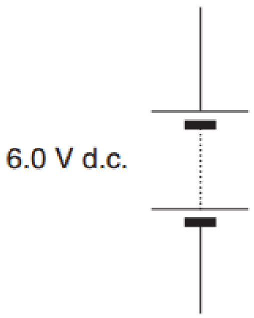
The change in resistance between 1.0 and 1.5 W m^{-2} is less than 1 kΩ

The change in resistance between 0.5 and 1.0 W m^{-2} is about .... kΩ

On Fig. 9.1 the LDR shows **greatest** sensitivity to light intensity change

when the light intensity is .... [3]

(b) **(i)** The LDR and a fixed resistor are connected as a potential divider to the 6.0 V battery shown in Fig. 9.2 to make a circuit.
Draw the potential divider on Fig. 9.2 to complete the circuit. The internal resistance of the battery can be neglected.



[1]

Fig. 9.2

(ii) A voltmeter is to be connected to the circuit to indicate an **increasing** output p.d. when the sensor detects an **increasing** light intensity.

Add to Fig. 9.2 a voltmeter with the correct circuit connections to achieve this.

[1]

(iii) An output p.d. of 3.0V is required from the circuit at a light intensity of $1.0\,\mathrm{W\,m^{-2}}$.

Calculate the value of the fixed resistor needed in the potential divider circuit to achieve this. Explain your reasoning.

resistance = ... Ω [3]

(c) For the same circuit, use Fig. 9.1 to predict the light intensity that would cause the output p.d. to rise to 4.0V. Explain your reasoning.

light intensity = ... $\mathrm{W\,m^{-2}}$ [3]

11 This question is about the use of high-power light emitting diodes (LEDs) in traffic lights.

Fig. 11.1 shows the graph of current against potential difference for a high-power red LED.

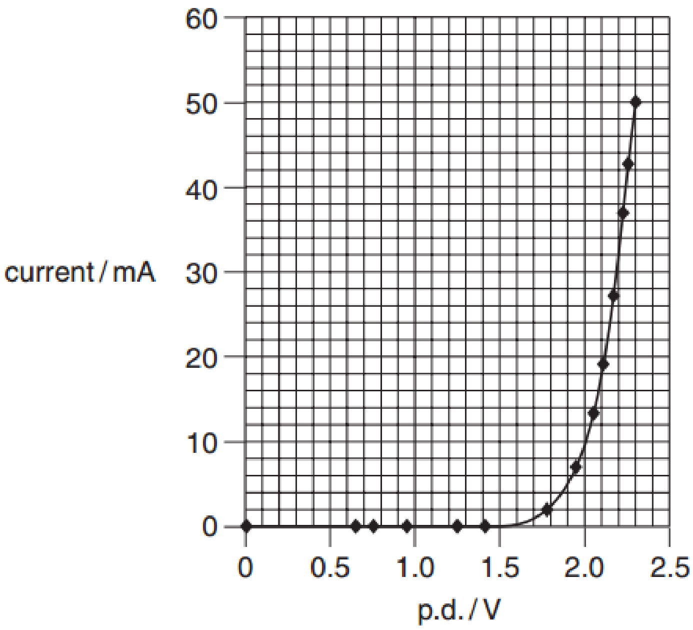


Fig. 11.1

(a) **(i)** Describe the variation of current with p.d. shown in Fig. 11.1.

[2]

(ii) Use data from the graph to show that the electrical power supplied to the red LED when operating at 50 mA is greater than 100 mW.

[2]

(iii) State where the energy of the electrons passing through the LED goes.

[1]

(b) Fig. 11.2 shows part of the array of 105 red LEDs that make the red disc of a traffic light.

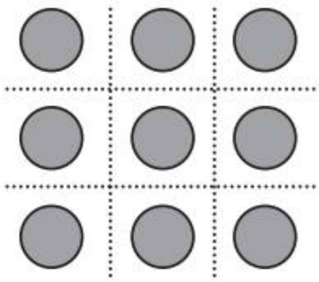


Fig. 11.2

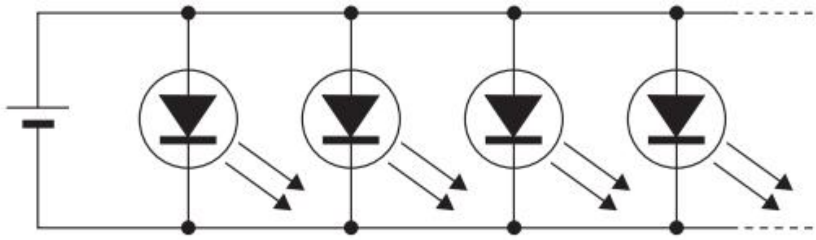


Fig. 11.3

(i) The 105 LEDs are connected in a parallel circuit as shown in Fig. 11.3.
Suggest a reason why the LEDs are connected in parallel.

[1]

(ii) Calculate the total power in W for all 105 LEDs when each is operating at 50 mA.

total power = ... W [1]

(iii) 150 W of electrical power is required by a filament lamp to give a similar power output of red light.

Suggest **two** reasons why a filament lamp requires so much more power to give the same red light output.

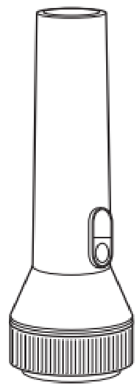
[2]

(iv) Filament lamps are often used in traffic lights. Suggest a benefit to society of substituting LEDs for filament lamps in traffic lights.

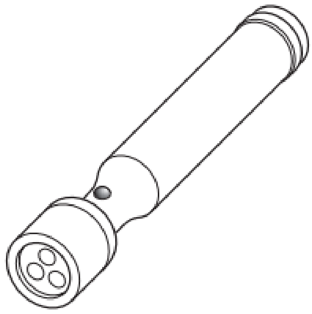
[1]

Jan 2009

5 Two torches produce similar intensities of illumination using different light sources.



filament lamp torch



LED torch

Each torch has an identical rechargeable cell which can store 14 000 J of energy.
The cell in the filament lamp torch draws power from its cell at 0.80 W and the LED torch at 0.10 W

(a) Calculate the maximum time in hours the cell can run the filament lamp.

maximum time = ... hours **[2]**

(b) Suggest one advantage of using LEDs rather than the filament lamp in a torch.

[1]

11 Three lamps **A**, **B** and **C** are all rated at 12V and 24W but take the following currents when operating at 12V.

lamp	**A**	**B**	**C**
current / A	2.0	2.0	2.1

(a) (i) Calculate the working resistance of lamp **A** when operating at 12V.

working resistance = ... Ω **[1]**

(ii) Lamp filaments are made from long thin uniform coiled wires of tungsten as shown in Fig. 11.1.

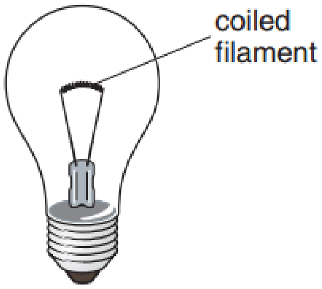


Fig. 11.1

In operating conditions the wire used has a resistance of 300 Ω per metre length.

Calculate the length of wire needed to construct the filament of lamp **A**.

length = ... unit .... **[1]**

(iii) Manufactured lamps labelled with the same power rating vary in their actual power, due to small differences in filament dimensions.

State **two** possible differences in the dimensions of the filament wire of lamp **C** that would result in it operating at more power than 24W at 12V.

[2]

(b) Fig. 11.2 shows the p.d. versus current graph for the identical lamps **A** and **B**.

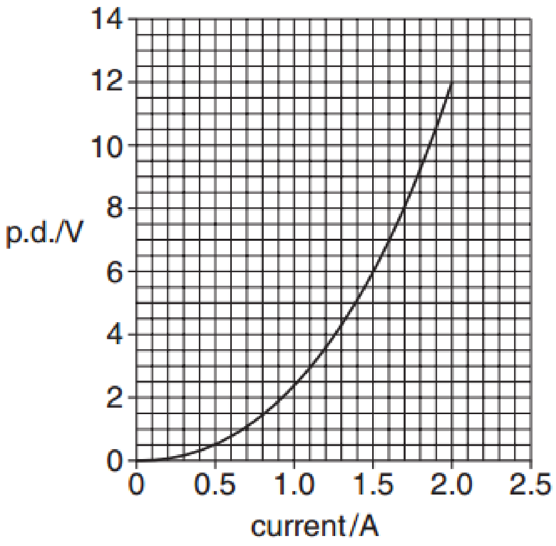


Fig. 11.2

(i) State and explain what the graph shows about the resistance of the lamps as the current increases.

[2]

(ii) Identical lamps **A** and **B** are connected in series with the 12V supply.
Use data from Fig. 11.2 to predict the total power of the two lamps in series.
Explain your reasoning.

total power = ... W **[2]**

(iii) On Fig. 11.2 sketch the graph you would expect for lamp **C** in **(a)**. **[1]**

(iv) Lamps **A** and **C** are now connected in series with the 12V supply.
State and explain which lamp will have the greater voltage across it.

[2]

June 2009

8 An electrical resistance thermometer consists of a sensor made from a platinum wire. The resistance of the wire increases with temperature.

Temperatures can be measured reliably by monitoring the resistance of the wire.

(a) A calibration temperature for the thermometer is melting ice at 0 °C.

The length of the platinum wire is 0.100 m and its radius is 19 μm.

Show that the resistance of the platinum wire sensor is about 10 Ω at 0 °C.

resistivity of platinum at 0 °C = $1.10 \times 10^{-7}\,\Omega\,m$

[3]

(b) It is found that the resistance of the sensor increases **linearly** between 0 °C and 100 °C.

At 100 °C the resistance of the sensor is 13.5 Ω; at 0 °C it is 9.7 Ω.

Draw a (linear) calibration graph for the sensor on Fig. 8.1 by displaying its resistance against temperature in the range 0 °C to 100 °C.

Add a suitable temperature scale to the axis of the graph.

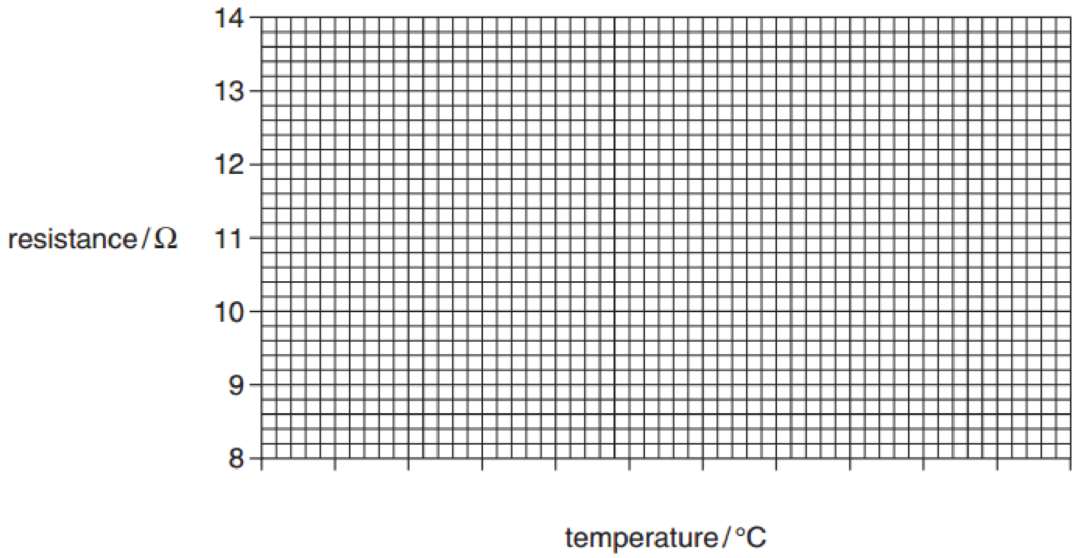


Fig. 8.1

[2]

(c) Using your calibration graph Fig. 8.1

(i) find the resistance of the sensor at a temperature of 45.0 °C

resistance = ... Ω **[1]**

(ii) estimate the value of the sensitivity of this resistance thermometer.

Make your method clear.

sensitivity = ... unit .... **[3]**

(d) An ohmmeter is used to measure the sensor resistance.

It measures the resistance to an uncertainty of ± 0.05 Ω.

Calculate the uncertainty in the measurement of temperature over the range 0 °C to 100 °C.

uncertainty in temperature = ± .... °C **[2]**

10 Fig. 10.1 shows the principle of operation of a Scanning Tunnelling Microscope (STM). The gap between the sample and tip, both made of metal, is only a few atomic diameters in size. When a potential difference *V* is applied across the gap, there is a tunnelling current through the vacuum.

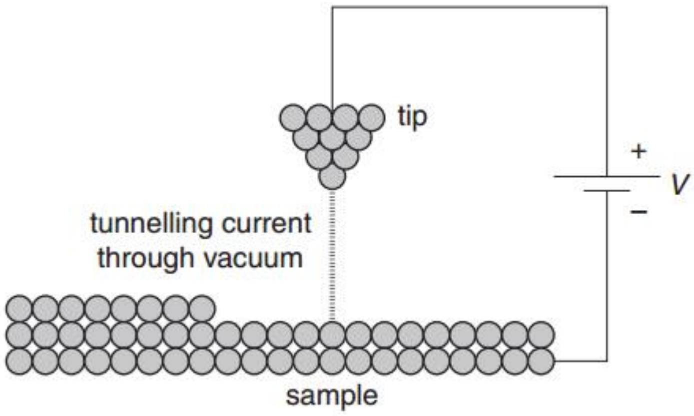


Fig. 10.1

(a) **(i)** A typical tunnelling current in this device is 2.0 nA.

Calculate the number of electrons crossing the gap every second at 2.0 nA.

$e = 1.6 \times 10^{-19}$ C

number = ... s^{-1} **[2]**

11 A set of Christmas lights has 46 lamps in a series circuit connected across the 230 V mains. One of the lamps is shown in Fig. 11.1.

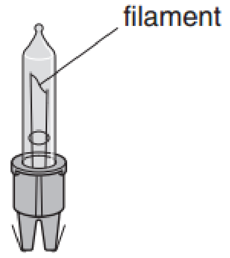


Fig. 11.1

(a) Show that the potential difference across each lamp is 5 V when lit normally.

[1]

(b) The p.d. against current relationship for the filament is shown in Fig. 11.2.

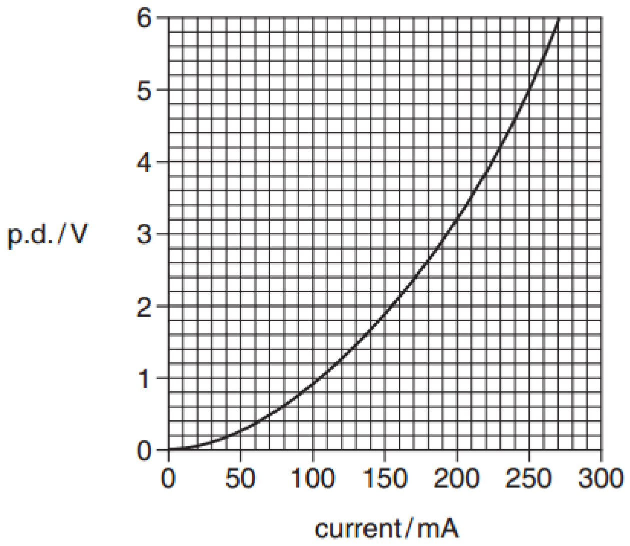


Fig. 11.2

(i) Calculate the power of each lamp filament when lit normally.

power = ... W **[1]**

(ii) Calculate the resistance of each lamp filament when lit normally.

resistance = ... Ω **[2]**

(c) In another set of 46 Christmas lights the same lamps are used, but a 60 Ω resistor in the lamp holder is connected in parallel with each lamp as shown in Fig. 11.3.

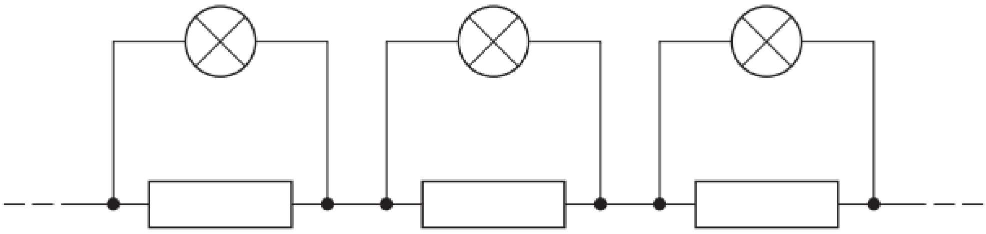


Fig. 11.3

(i) Suggest a reason for this design with a resistor in parallel with each filament.

[1]

(ii) Calculate the current drawn from the mains supply by this set of lamps.

current = ... A **[3]**

(iii) The filament breaks in one of the lamps.

State and explain what will happen to the brightness of the other 45 lamps.

[2]

(d) In another set of lights which are meant to be identical to the set in part **(c)** there is a manufacturing fault. The 60 Ω resistor has been omitted from one of the lamp holders.

Suggest and explain what will happen to the brightness of the lamp in this holder compared to the other 45 lamps.

[1]

You can now go onto the G491 papers from 2009 to 2015