9. Electricity

9.3 Resistance and resistivity

Paper 2

Question Paper

1 Lightning occurs when charge builds up in the atmosphere, creating a potential difference between the ground and the atmosphere.

During a lightning strike there is an average current of 3.3×10^4 A for a time of 2.6×10^{-5} s.

(c) A lightning rod is attached to a tall building to conduct charge safely to the ground. The lightning rod is modelled as a uniform cylindrical copper cable of total length 95 m that runs from the ground to the top of the building, as shown in Fig. 3.1.

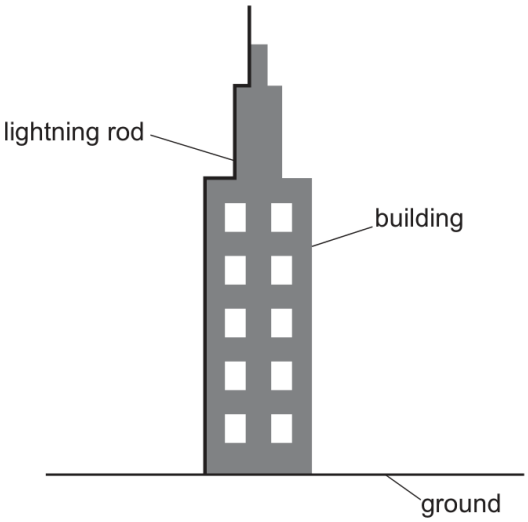


Fig. 3.1

(i) The resistance of the lightning rod is 9.6 Ω.
The resistivity of copper is 1.7×10^{-8} Ω m.

Determine the radius of the lightning rod.

radius = ... m [3]

(ii) The radius of the copper lightning rod is doubled with no change to its length.

State the effect of this change on the resistance of the lightning rod.

..... [1]

2 **(b)** A battery of electromotive force (e.m.f.) 9.0 V and negligible internal resistance is connected in series with a variable resistor X and a thermistor Y as shown in Fig. 5.1.

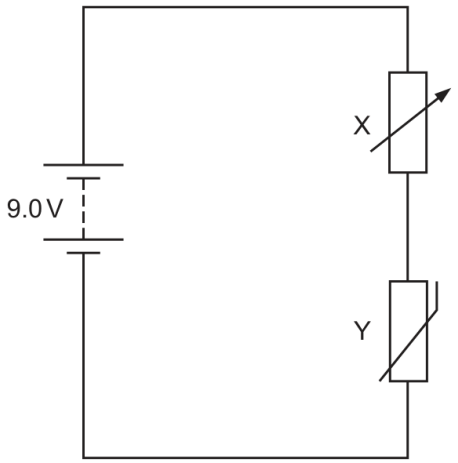


Fig. 5.1

Fig. 5.2 shows the relationship between temperature and resistance for the thermistor.

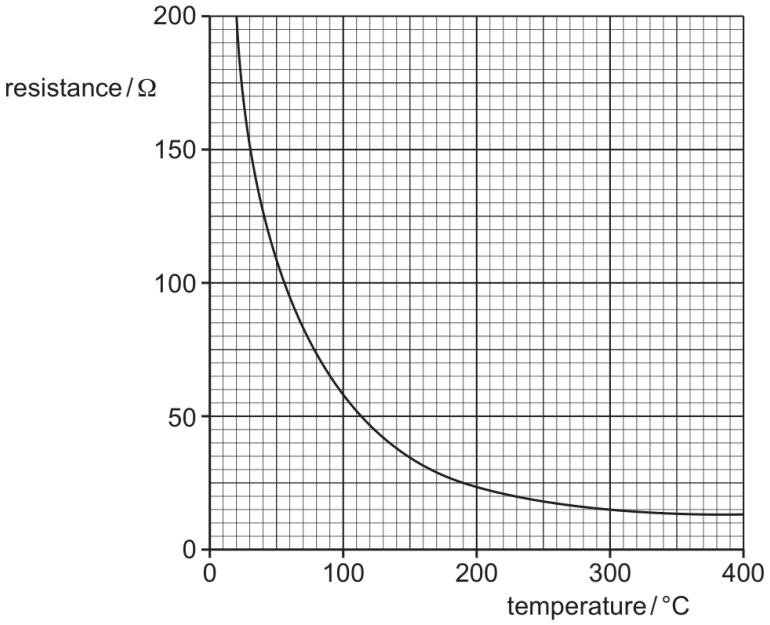


Fig. 5.2

(i) The current in the circuit is 1.1×10^{-2} A. The potential difference across Y is 4.0 V.

Calculate the resistance of X.

resistance = ... Ω [2]

(ii) The temperature of Y is changed to 190 °C. The resistance of X remains unchanged.

Determine the new potential difference across Y.

potential difference = ... V [3]

3 **(c)** An electric motor has an input power of 900 W. The motor takes 1.0 minute to lift a load of weight 240 N at constant speed through a vertical height of 150 m. Resistive forces are negligible.

(iv) Some of the power wasted in the motor is dissipated by the resistance of its coil. This dissipated power is 280 W.

The coil of the motor is made from wire of total length 23 m. The wire has a cross-sectional area of $2.6 \times 10^{-8}\,m^2$ and is made from metal of resistivity $1.7 \times 10^{-8}\,\Omega m$.

Calculate the current in the coil.

current = ...A [3]

4 **(a)** Fig. 7.1 shows two resistors connected in series with a cell of electromotive force (e.m.f.) 1.50 V and internal resistance 0.28 Ω.

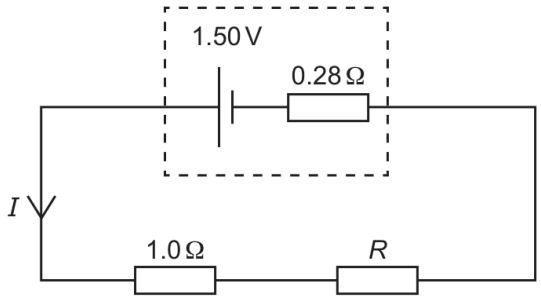


Fig. 7.1

One of the resistors has resistance 1.0 Ω. The other resistor has resistance *R*.
The terminal potential difference (p.d.) across the cell is 1.36 V.

(ii) Calculate the combined resistance of the two resistors.

resistance = ... Ω [2]

5 **(b)** A power supply, three resistors and a component X are connected in the circuit shown in Fig. 5.1.

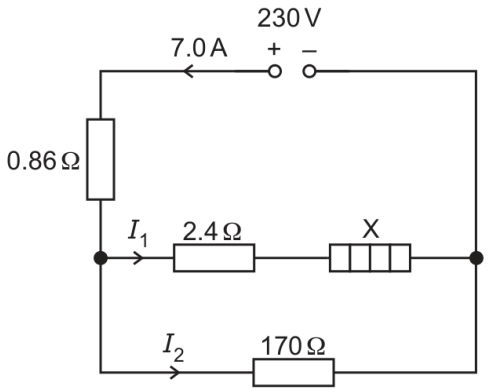


Fig. 5.1

The power supply has an electromotive force (e.m.f.) of 230 V and negligible internal resistance. The current in the power supply is 7.0 A.

(ii) Show that the p.d. across the resistor of resistance 0.86 Ω is 6.0 V.

[1]

6 A battery of electromotive force (e.m.f.) 9.6 V and negligible internal resistance is connected in series with two fixed resistors and a thermistor, as shown in Fig. 7.1.

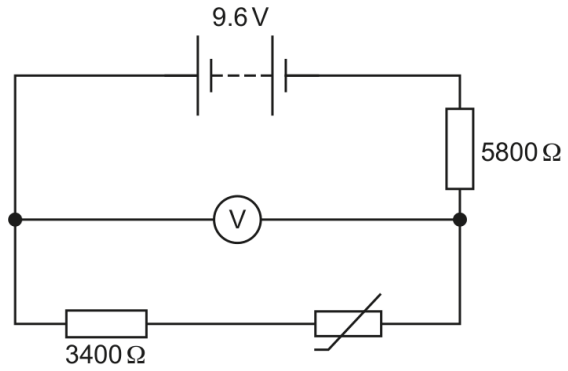


Fig. 7.1

The fixed resistors have resistances of 3400 Ω and 5800 Ω. The reading on the voltmeter in the circuit is 6.0 V.

(a) Calculate the current in the resistor of resistance 5800 Ω.

current = ...A [2]

(d) The environmental conditions change causing an increase in the resistance of the thermistor.

State whether there is a decrease, increase or no change to:

(i) the temperature of the thermistor

..... [1]

7 **(a)** The current in a filament lamp decreases.

State and explain how the resistance of the lamp changes.

.....

..... [1]

(b) A cylindrical wire has length L and resistance R. The **total** number of free electrons (charge carriers) contained in the volume of the wire is N. Each free electron has charge e. The potential difference between the ends of the wire is V.

Determine expressions, in terms of some or all of the symbols e, L, N, R and V for:

(i) the current in the wire

current = ... [1]

8 **(b)** The circuit in **(a)** is now modified by adding a uniform resistance wire XY and a galvanometer, as shown in Fig. 7.2.

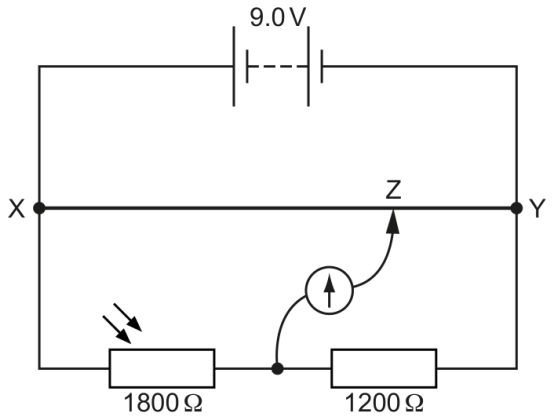


Fig. 7.2 (not to scale)

The length of the wire XY is 1.2 m. The movable connection Z is positioned on the wire XY so that the galvanometer reading is zero.

(ii) The environmental conditions change causing a decrease in the resistance of the LDR. The temperature of the LDR remains constant.

State whether there is a decrease, increase or no change to:

- the intensity of the light illuminating the LDR

.....

- the total power produced by the battery

.....

- the length XZ so that the galvanometer reads zero.

.....

[3]

9 A battery is connected in a circuit with a light-dependent resistor (LDR), two fixed resistors and a voltmeter, as shown in Fig. 6.1.

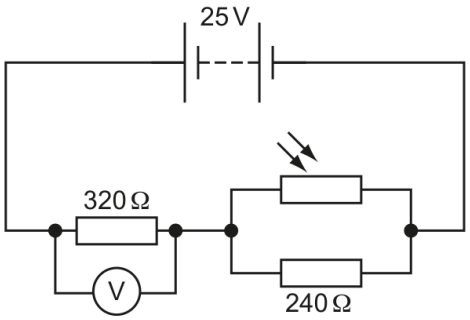


Fig. 6.1

The battery has an electromotive force (e.m.f.) of 25 V and negligible internal resistance.
The resistors have resistances of 320 Ω and 240 Ω.

(a) The voltmeter displays a reading of 16 V.

(i) Show that the current in the battery is 0.050 A.

[1]

(b) The intensity of the light incident on the LDR increases.

State and explain what happens to the voltmeter reading.

.....

.....

.....

..... [3]

10 **(a)** A metal wire has a resistance per unit length of $0.92\,\Omega\,m^{-1}$. The wire has a uniform cross-sectional area of $5.3 \times 10^{-7}\,m^2$.

Calculate the resistivity of the metal of the wire.

resistivity = ... Ω m [2]

(b) A battery of electromotive force (e.m.f.) *E* and negligible internal resistance is connected in series with a fixed resistor and a light-dependent resistor (LDR), as shown in Fig. 6.1.

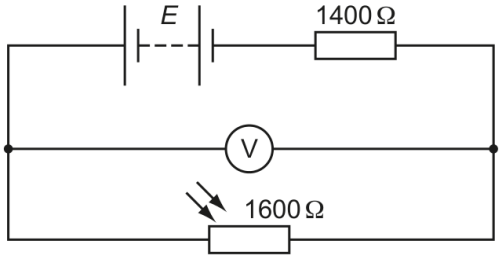


Fig. 6.1

The resistance of the fixed resistor is 1400 Ω. The intensity of the light illuminating the LDR causes it to have a resistance of 1600 Ω. A voltmeter connected across the LDR reads 6.4 V.

(i) Show that the current in the LDR is 4.0×10^{-3} A.

[1]

(c) The environmental conditions change causing a decrease in the resistance of the LDR in **(b)**. The temperature of the environment does not change.

State whether there is a decrease, increase or no change to:

(i) the intensity of the light illuminating the LDR

..... [1]

11 (b) A battery is connected to two resistors X and Y, as shown in Fig. 6.1.

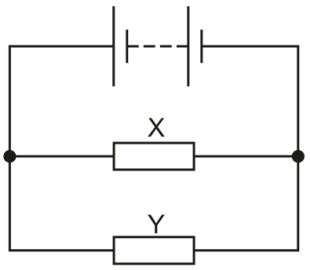


Fig. 6.1

The resistance of resistor X is greater than the resistance of resistor Y.

(ii) The two resistors are made of wires that have the same length. Both wires are made from metal of the same resistivity.

State and explain which resistor is made of wire with the larger cross-sectional area.

.....

.....

..... [2]

(c) A battery of electromotive force (e.m.f.) 9.0 V and negligible internal resistance is connected in series with a light-dependent resistor (LDR) and a fixed resistor of resistance 1800 Ω, as shown in Fig. 6.2.

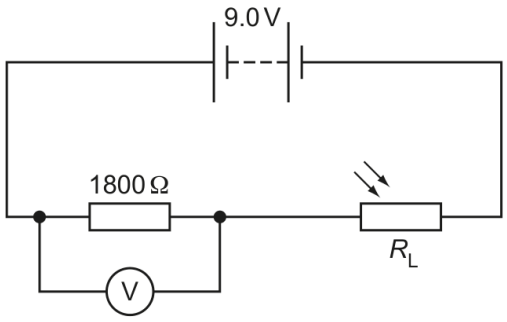


Fig. 6.2

A voltmeter is connected across the fixed resistor. The reading on the voltmeter is 5.4 V.

(i) Calculate the current in the circuit.

current = ... A [1]

(ii) Calculate the resistance R_L of the LDR.

R_L = ... Ω [2]

(iii) The intensity of the light illuminating the LDR increases.

By reference to the current in the circuit, state and explain the change, if any, to the voltmeter reading.

.....

.....

.....

..... [2]

12 (b) A battery of electromotive force (e.m.f.) 8.0 V and negligible internal resistance is connected to a thermistor, a switch X and two fixed resistors, as shown in Fig. 6.2.

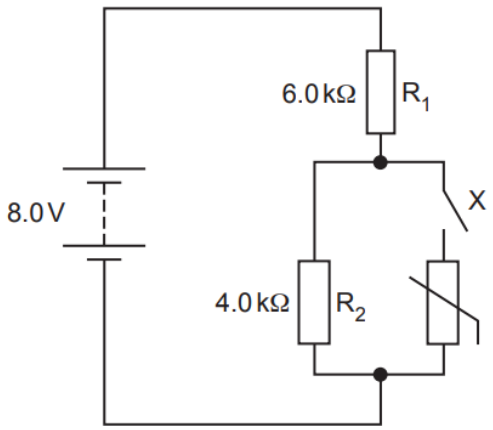


Fig. 6.2

Resistor R_1 has resistance 6.0 kΩ and resistor R_2 has resistance 4.0 kΩ.

(c) The switch X in the circuit in **(b)** remains closed. The temperature of the thermistor decreases.

By reference to the current in the battery, state and explain the effect, if any, of the decrease in temperature on the power produced by the battery.

.....

.....

.....

.....

..... [3]

13 **(a)** State Ohm's law.

.....

.....

..... [2]

(b) The variation of current I with potential difference V for a filament lamp is shown in Fig. 5.1.

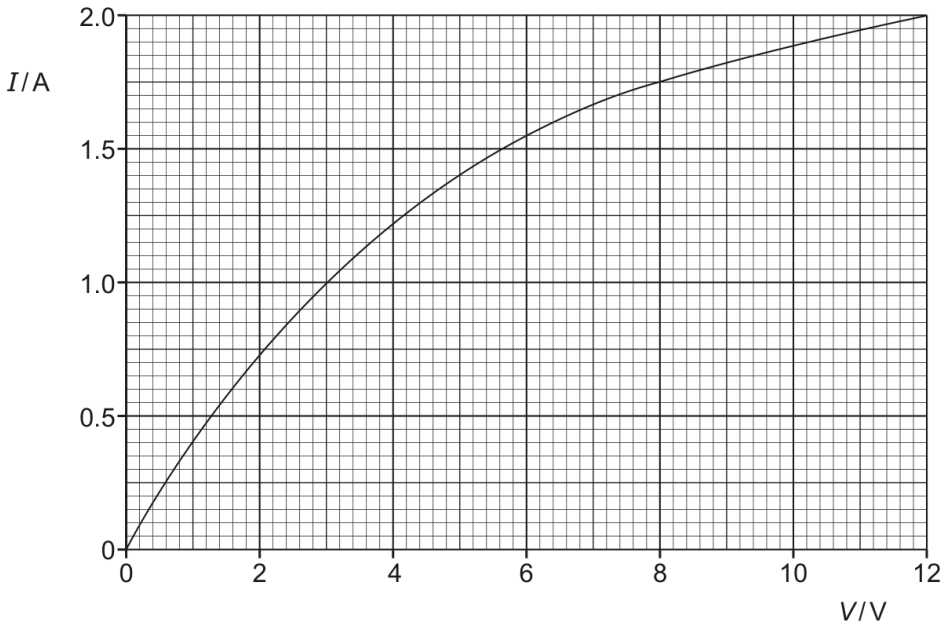


Fig. 5.1

The resistance of the filament lamp increases with potential difference.

(i) State how Fig. 5.1 shows this.

.....

..... [1]

(ii) Explain why the resistance varies in this way.

.....

..... [1]

(c) Fig. 5.2 shows a circuit with a battery of electromotive force (e.m.f.) 12.0 V connected to a linear potentiometer AB and two identical filament lamps P and Q.

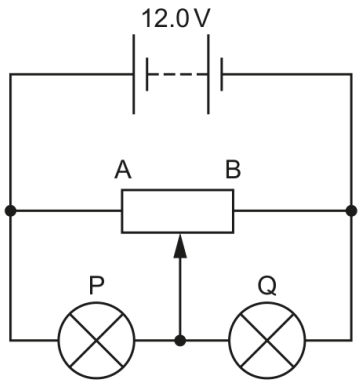


Fig. 5.2

The battery has negligible internal resistance and the lamps each have the same I–V characteristic shown in Fig. 5.1.

When the slider of the potentiometer is at its midpoint, as shown in Fig. 5.2, the current I in the battery is 1.78 A.

Determine:

(i) the current in lamp P

current = ... A [1]

(iii) the resistance of the potentiometer between its ends A and B.

resistance = ... Ω [2]

14 (b) A battery has electromotive force (e.m.f.) 4.0 V and internal resistance 0.35 Ω. The battery is connected to a uniform resistance wire XY and a fixed resistor of resistance *R*, as shown in Fig. 5.1.

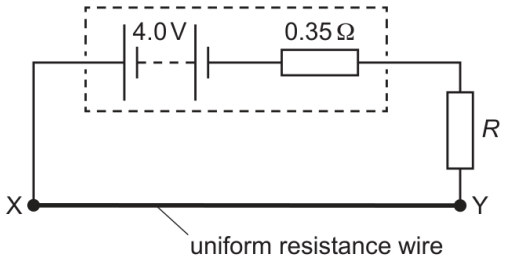


Fig. 5.1

Wire XY has resistance 0.90 Ω. The potential difference across wire XY is 1.8 V.

Calculate:

(i) the current in wire XY

current = ... A [1]

15 (a) Define the *ohm*.

.....

..... [1]

(b) A wire is made of metal of resistivity ρ. The length *L* of the wire is gradually increased. Assume that the volume *V* of the wire remains constant as its length is increased.

Show that the resistance *R* of the extending wire is proportional to L^2.

[2]

16 (b) The circuit shown in Fig. 5.1 contains a battery of electromotive force (e.m.f.) *E* and negligible internal resistance connected to four resistors R_1, R_2, R_3 and R_4, each of resistance *R*.

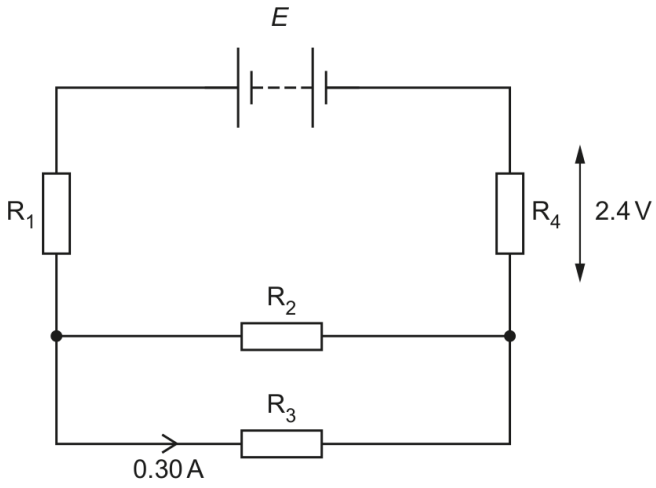


Fig. 5.1

The current in R_3 is 0.30 A and the potential difference (p.d.) across R_4 is 2.4 V.

(i) Show that *R* is equal to 4.0 Ω.

[2]

(d) The resistors in the circuit of Fig. 5.1 are made from nichrome wire of uniform radius 240 μm. The length of this wire needed to make each resistor is 0.67 m.

Calculate the resistivity of nichrome.

resistivity = ... Ω m [3]

17 **(a)** Metal wire is used to connect a power supply to a lamp. The wire has a total resistance of 3.4 Ω and the metal has a resistivity of 2.6×10^{-8} Ωm. The total length of the wire is 59 m.

(i) Show that the wire has a cross-sectional area of 4.5×10^{-7} m^2.

[2]

(ii) The potential difference across the total length of wire is 1.8 V.

Calculate the current in the wire.

current = ... A [1]

18 One end of a wire is attached to a fixed point. A force F is applied to the wire to cause extension x. The variation with F of x is shown in Fig. 5.1.

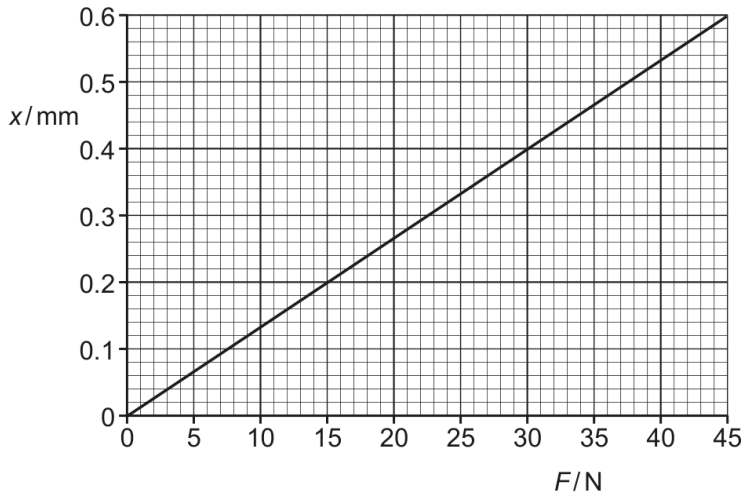


Fig. 5.1

The wire has a cross-sectional area of $4.1 \times 10^{-7}\,m^2$ and is made of metal of Young modulus $1.7 \times 10^{11}\,Pa$. Assume that the cross-sectional area of the wire remains constant as the wire extends.

(c) The resistivity of the metal of the wire is $3.7 \times 10^{-7}\,\Omega m$.

Determine the change in resistance of the wire when the extension x of the wire changes from $x = 0.48\,mm$ to $x = 0.60\,mm$.

change in resistance = ... Ω [3]

19 **(a)** Define the *ohm*.

.....

..... [1]

(b) A uniform wire has resistance 3.2 Ω. The wire has length 2.5 m and is made from metal of resistivity 460 nΩ m.

Calculate the cross-sectional area of the wire.

cross-sectional area = ... m^2 [3]

20 A battery of electromotive force (e.m.f.) E and internal resistance r is connected to a variable resistor of resistance R, as shown in Fig. 6.1.

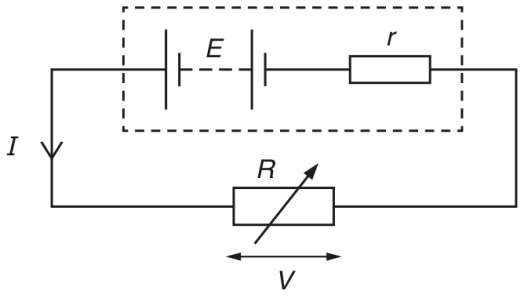


Fig. 6.1

The current in the circuit is I and the potential difference across the variable resistor is V.

(c) The resistance R of the variable resistor is varied. The variation with I of V is shown in Fig. 6.2.

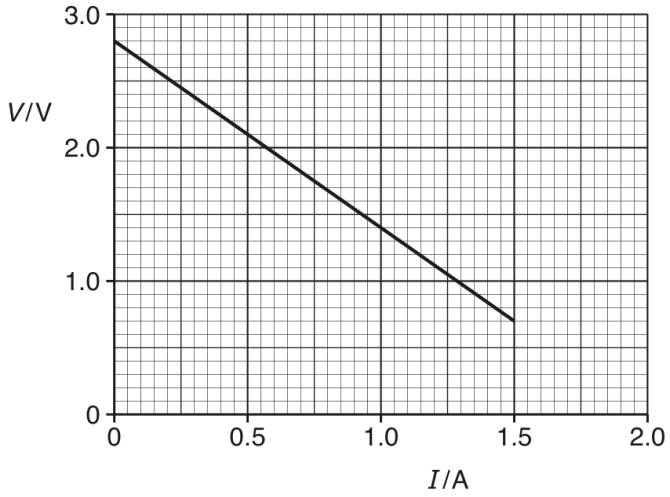


Fig. 6.2

(d) The battery stores 9.2 kJ of energy. The variable resistor is adjusted so that $V = 2.1$ V. Use Fig. 6.2 to:

(i) calculate resistance R

$R =$ ..... Ω [1]

21 (b) The variation with potential difference V of the current I in a semiconductor diode is shown in Fig. 6.1.

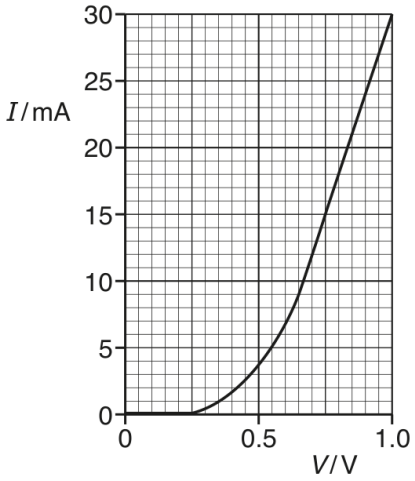


Fig. 6.1

Use Fig. 6.1 to describe qualitatively the variation of the resistance of the diode as V increases from 0 to 1.0 V.

.....

.....

.....

..... [2]

(c) The diode in **(b)** is part of the circuit shown in Fig. 6.2.

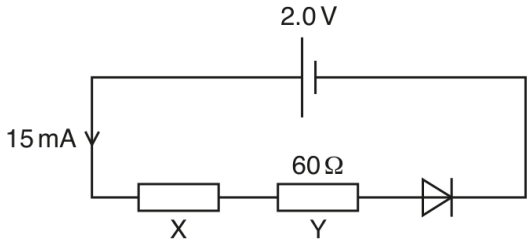


Fig. 6.2

The cell of electromotive force (e.m.f.) 2.0 V and negligible internal resistance is connected in series with the diode and resistors X and Y. The resistance of Y is 60 Ω. The current in the cell is 15 mA.

(i) Use Fig. 6.1 to determine the resistance of the diode.

resistance = ... Ω [3]

22 **(b)** The variations with potential difference V of the current I for a resistor X and for a semiconductor diode are shown in Fig. 6.1.

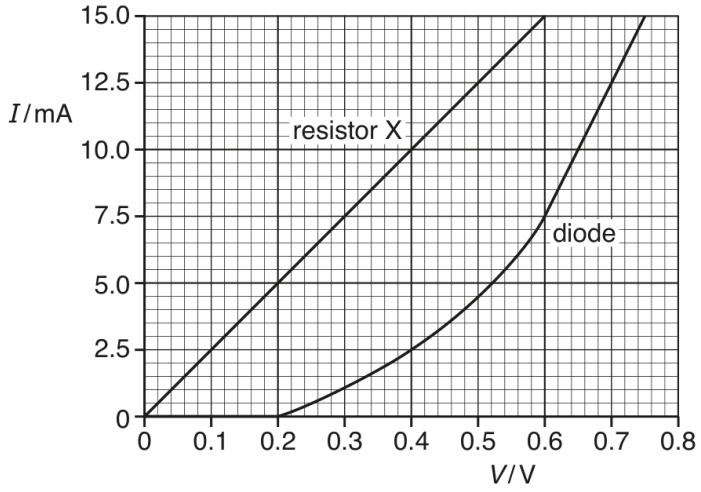


Fig. 6.1

(i) Determine the resistance of the diode for a potential difference V of 0.60 V.

resistance = ... Ω [3]

(ii) Describe, qualitatively, the variation of the resistance of the diode as V increases from 0.60 V to 0.75 V.

..... [1]

(c) The diode and the resistor X in **(b)** are connected into the circuit shown in Fig. 6.2.

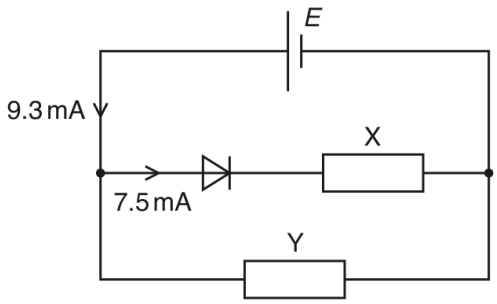


Fig. 6.2

The cell has electromotive force (e.m.f.) *E* and negligible internal resistance. Resistor Y is connected in parallel with resistor X and the diode. The current in the cell is 9.3 mA and the current in the diode is 7.5 mA.

(i) Use Fig. 6.1 to determine *E*.

E = ...V [1]

(iv) The cell is now replaced by a new cell of e.m.f. 0.50 V and negligible internal resistance. Use Fig. 6.1 to determine the new current in the diode.

current = ...mA [1]

23 (b) A battery of electromotive force (e.m.f.) 4.5 V and negligible internal resistance is connected to two filament lamps P and Q and a resistor R, as shown in Fig. 6.1.

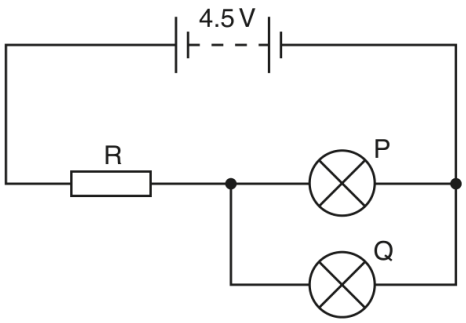


Fig. 6.1

The current in lamp P is 0.15 A.
The I–V characteristics of the filament lamps are shown in Fig. 6.2.

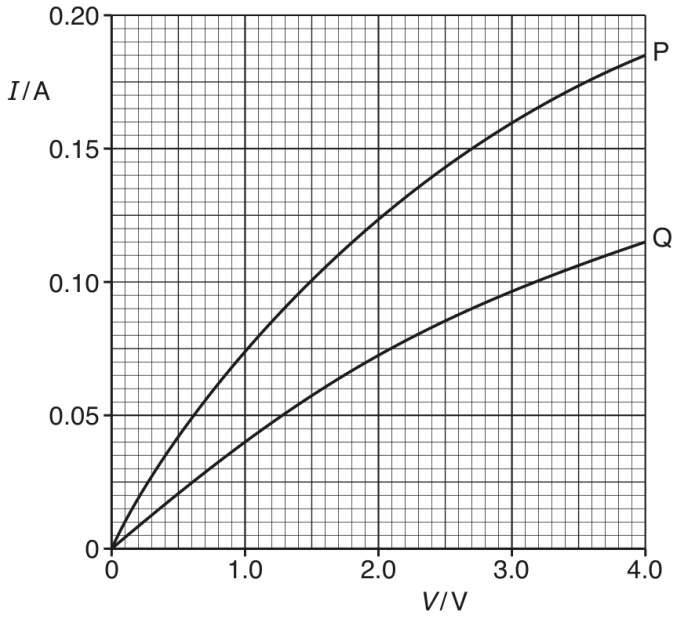


Fig. 6.2

(i) Use Fig. 6.2 to determine the current in the battery. Explain your working.

current = ... A [2]

(ii) Calculate the resistance of resistor R.

resistance = ... Ω [2]

(iii) The filament wires of the two lamps are made from material with the same resistivity at their operating temperature in the circuit. The diameter of the wire of lamp P is twice the diameter of the wire of lamp Q.

Determine the ratio

$$\frac{\text{length of filament wire of lamp P}}{\text{length of filament wire of lamp Q}}.$$

ratio = ... [3]

(iv) The filament wire of lamp Q breaks and stops conducting.

State and explain, qualitatively, the effect on the resistance of lamp P.

.....

.....

.....

.....[2]

24 (b) A battery of electromotive force (e.m.f.) 8.0 V and internal resistance 2.0 Ω is connected to a resistor X and a wire Y, as shown in Fig. 6.1.

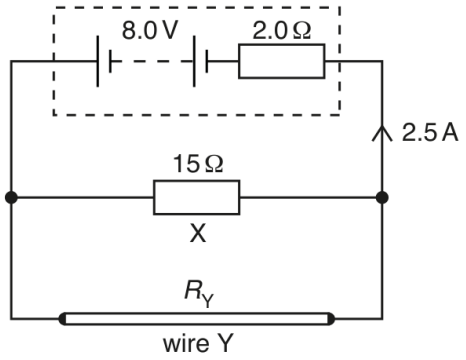


Fig. 6.1

The resistance of X is 15 Ω. The resistance of Y is R_Y. The current in the battery is 2.5 A.

(iii) A new wire Z has the same length but less resistance than wire Y.

1. State two possible differences between wire Z and wire Y that would separately cause wire Z to have less resistance than wire Y.

first difference: .....

.....

second difference: .....

.....
[2]

2. Wire Y is replaced in the circuit by wire Z. By considering the current in the battery, state and explain the effect of changing the wires on the total power produced by the battery.

.....

.....

.....[2]

25 (b) An electric heater containing two heating wires X and Y is connected to a power supply of electromotive force (e.m.f.) 9.0 V and negligible internal resistance, as shown in Fig. 6.1.

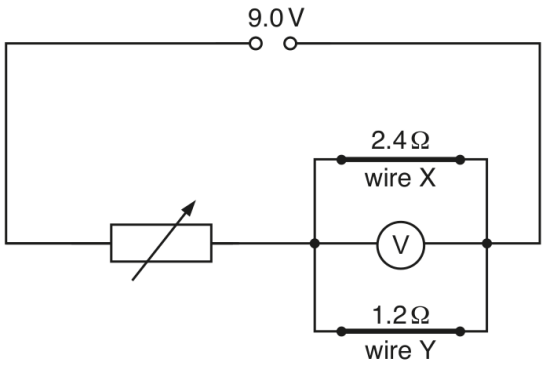


Fig. 6.1

Wire X has a resistance of 2.4 Ω and wire Y has a resistance of 1.2 Ω. A voltmeter is connected in parallel with the wires. A variable resistor is used to adjust the power dissipated in wires X and Y.

The variable resistor is adjusted so that the voltmeter reads 6.0 V.

(iii) The cross-sectional area of wire X is three times the cross-sectional area of wire Y. Assume that the resistivity and the number density of free electrons for the metal of both wires are the same.

Determine the ratio

1. $\frac{\text{length of wire X}}{\text{length of wire Y}}$,

ratio = ... [2]

2. $\frac{\text{average drift velocity of free electrons in wire X}}{\text{average drift velocity of free electrons in wire Y}}$.

ratio = ... [2]

26 (b) A battery of electromotive force (e.m.f.) 7.0 V and negligible internal resistance is connected in series with three components, as shown in Fig. 6.1.

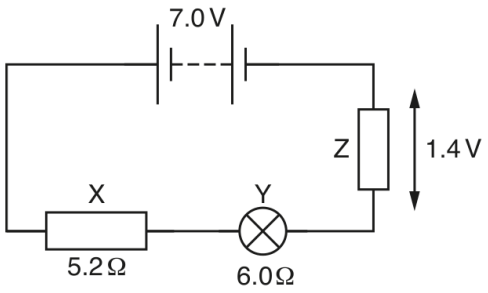


Fig. 6.1

Resistor X has a resistance of 5.2 Ω. The resistance of the filament wire of lamp Y is 6.0 Ω. The potential difference across resistor Z is 1.4 V.

(i) Calculate the current in the circuit.

current = ... A [2]

(iv) The filament wire of the lamp is made of metal of resistivity $3.7 \times 10^{-7}\,\Omega\,\text{m}$ at its operating temperature in the circuit.

Determine, for the filament wire, the value of α where

$$\alpha = \frac{\text{cross-sectional area}}{\text{length}}.$$

α = ... m [2]