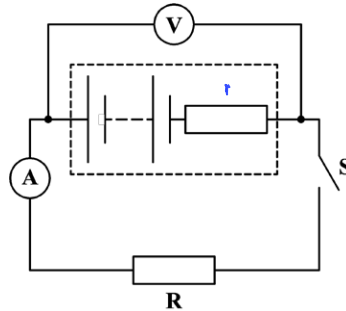


Electrical Circuits

1. A resistor **R**, an ammeter and a switch are connected in series to a battery.



The switch **S** is open. The voltmeter reading is 9.0 V and the ammeter reading is zero. With **S** closed, the voltmeter reading is 6.0 V and ammeter reading is 2.0 A.

What is the internal resistance of the battery?

- A. 1.5 Ω
- B. 3.0 Ω
- C. 4.5 Ω
- D. 6.0 Ω

$$\mathcal{E} = 9\text{ V} \quad I = 0 \rightarrow I_r = 0 \rightarrow V = \mathcal{E}$$

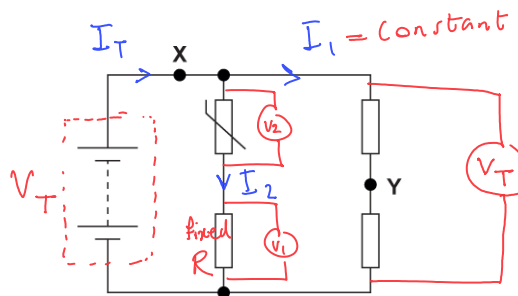
$$E = I(R + r)$$

$$E = V + Ir \rightarrow r = \frac{E - V}{I}$$

Your answer

[1] = 1.5 Ω

2. A circuit is shown below.



The battery has negligible internal resistance. The temperature of the NTC thermistor is **decreased**.

Which of the following statements is / are correct?

- 1 The current at **X** increases. X $\downarrow$
- 2 The current at **Y** remains the same. ✓
- ✓ 3 The potential difference across the thermistor increases. ✓

$$T \downarrow \Rightarrow R \uparrow \Rightarrow I_2 \downarrow$$

$$V_1 = R \times I_2$$

$\downarrow$
Const.

$$V_1 + V_2 = V_T \rightarrow \text{Const.}$$

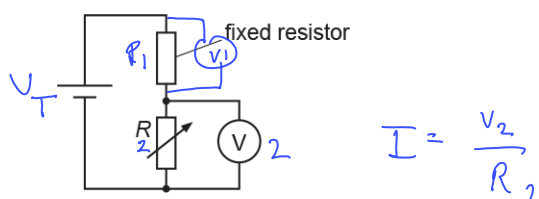
- A 1, 2 and 3
- B Only 2 and 3 ✓
- C Only 3
- D Only 2

Your answer

[1]

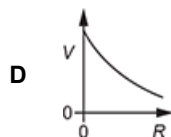
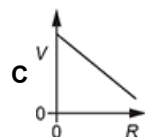
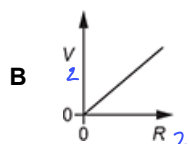
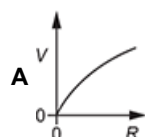
4.3 Electrical Circuits

3. A potential divider circuit is shown below.



The resistance of the variable resistor is R . The potential difference across the variable resistor is V .

Which graph shows the correct variation with R of V ?



$$R_2 \uparrow \Rightarrow I \downarrow \Rightarrow V_1 \downarrow \Rightarrow V_2 \uparrow$$

$$V_1 + V_2 = V_T$$

$$V_1 = IR_1 \quad V_2 = V_T - IR_1 = V_T - \frac{V_2}{R_2} R_1$$

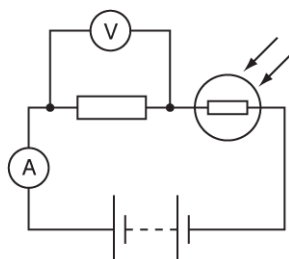
Your answer

☐

$$V_2 = V_T - \frac{R_1}{R_2} V_2$$

[1] $\rightarrow A$
 $\rightarrow$ not straight line

4. A potential divider circuit with a light-dependent resistor (LDR) is shown below.



The intensity of the light incident on the LDR is reduced.

Which row correctly describes the observed change on the ammeter and voltmeter readings?

	Ammeter reading	Voltmeter reading
A	decreases	decreases
B	decreases	increases
C	increases	stays the same
D	stays the same	decreases

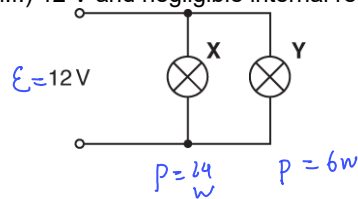
Your answer

☐

[1]

4.3 Electrical Circuits

5. Two filament lamps **X** and **Y** are connected in parallel to a supply. The power dissipated by lamp **X** is 24 W and the power dissipated by lamp **Y** is 6.0 W. The supply has electromotive force (e.m.f.) 12 V and negligible internal resistance.



What is the total current drawn from the supply by the lamps?

- A 0.4A
- B 0.5A
- C 2.0A
- D 2.5A

$$P = IV \rightarrow I_X = \frac{24}{12} = 2\text{A}$$

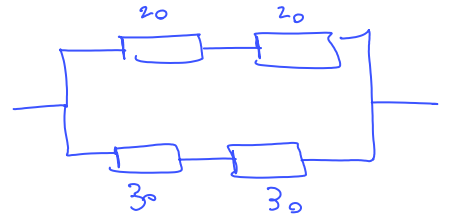
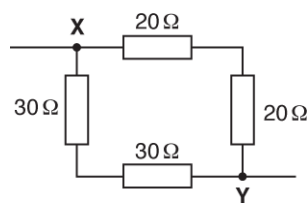
$$I_Y = \frac{6}{12} = 0.5\text{A}$$

$$I_T = 2.5\text{A} \rightarrow \text{D}$$

Your answer

[1]

6. The diagram below shows a circuit connected by a student.



What is the total resistance of the circuit between points **X** and **Y**?

- A 24Ω
- B 29Ω
- C 38Ω
- D 100Ω

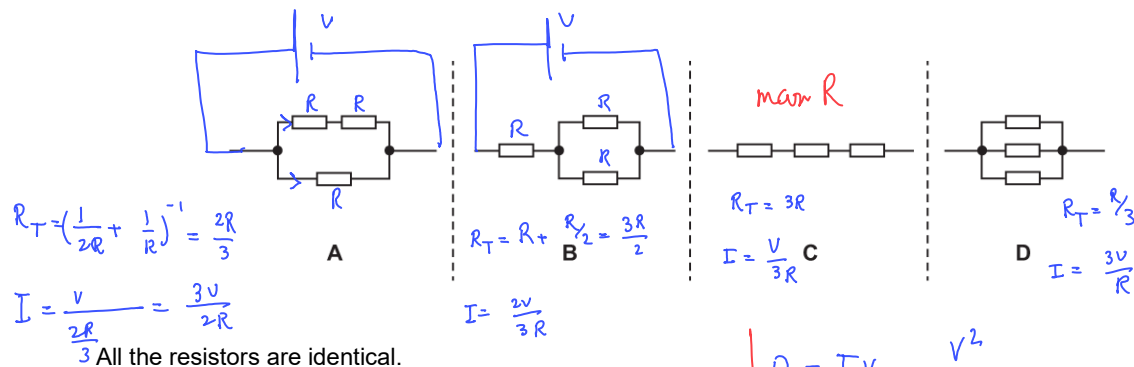
$$R_T = \left(\frac{1}{30+30} + \frac{1}{20+20} \right)^{-1} = 24\Omega \rightarrow \text{A}$$

Your answer

[1]

4.3 Electrical Circuits

7. Four electrical circuits are shown below.



Which circuit dissipates the **least** power?

Your answer

$$P = I^2 R$$

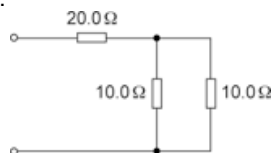
$$A: \left(\frac{3V}{2R}\right)^2 \frac{2R}{3} = \frac{9V^2}{4R^2} \times \frac{2R}{3} = \frac{3}{2} \frac{V^2}{R}$$

$$B: \left(\frac{2V}{3R}\right)^2 \times \frac{3R}{2} = \frac{4V^2}{9R^2} \times \frac{3R}{2} = \frac{2}{3} \frac{V^2}{R}$$

$$C: \frac{V^2}{9R^2} \times 3R = \frac{1}{3} \frac{V^2}{R} \text{ min}$$

$$D: \frac{9V^2}{R^2} \times \frac{R}{3} = 3 \frac{V^2}{R} \text{ max}$$

8. Three resistors are connected in a circuit.



The resistance of each resistor is shown in the circuit diagram.

What is the total resistance of this circuit?

$$\left(\frac{1}{10} + \frac{1}{10}\right)^{-1} + 20 = 25 \Omega \rightarrow C$$

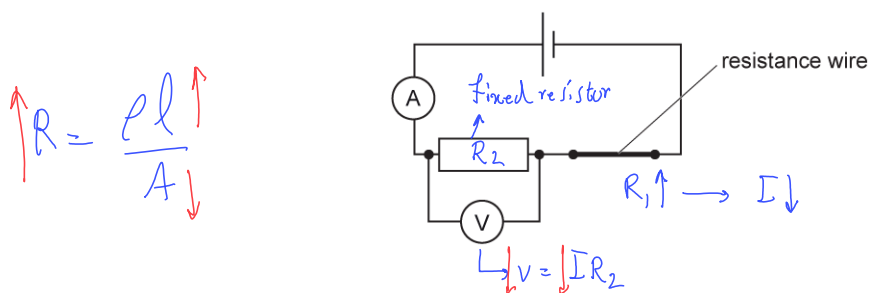
- A 10.0 Ω
- B 20.2 Ω
- C 25.0 Ω
- D 40.0 Ω

Your answer

[1]

4.3 Electrical Circuits

9. A resistance wire is part of an electrical circuit, as shown below.



The resistance wire is pulled so that it becomes longer and thinner.

Which statement is correct?

- A The ammeter reading increases. $R_1 \uparrow \Rightarrow I \downarrow$ X
- B The resistance of the wire decreases. X
- C The total resistance of the circuit remains constant. $R_T = R_1 + R_2$ X
- D The voltmeter reading decreases.

Your answer

☐

[1]

10. Stationary waves are produced in a flute when it is played. When all finger-holes are covered up, the flute can be treated as a pipe open at both ends. A flute is played so that it sounds the next harmonic above the fundamental frequency.

Which diagram correctly shows the node N and antinode A positions for the displacement of air for this harmonic?

- A

A	N	A
---	---	---
- B

N	A	N
---	---	---
- C

A	N	A	N	A
---	---	---	---	---
- D

N	A	N	A	N
---	---	---	---	---

Your answer

☐

[1]

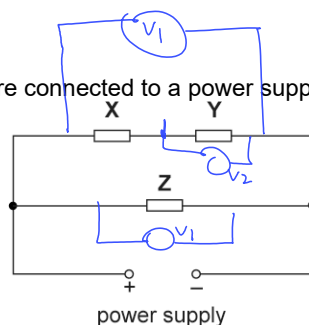
4.3 Electrical Circuits

11. Three identical resistors **X**, **Y** and **Z** are connected to a power supply.

$$P = I \cdot V$$

$$V_2 = \frac{V_1}{2}$$

$$V_Y = \frac{1}{2} V_Z$$



$$I_{XY} = \frac{1}{2} I_Z$$

The power dissipated in the resistor **Z** is 24 W.

What is the power dissipated in the resistor **Y**?

- A 6.0 W
- B 12 W
- C 24 W
- D 48 W

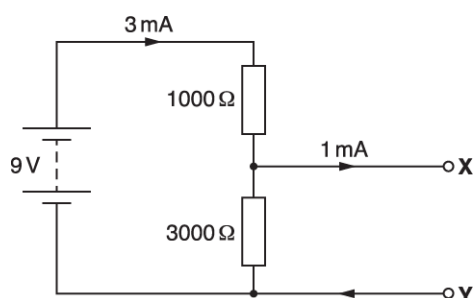
$$P_Z = I_Z V_Z = 24 \text{ W}$$

$$P_Y = \frac{I_Z}{2} \times \frac{V_Z}{2} = \frac{24}{4} = 6 \text{ W}$$

Your answer

[1]

12. A 9V battery is connected to two resistors as shown. The terminals **X** and **Y** are connected to another circuit that draws a current of 1 mA. The current from the battery is 3 mA.



What is the power supplied to the circuit connected between **X** and **Y**?

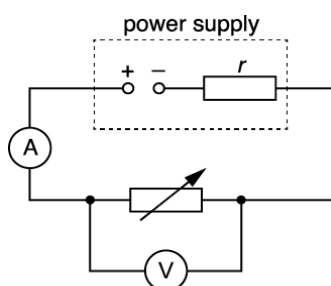
- A 6 mW
- B 12 mW
- C 18 mW
- D 27 mW

Your answer

[1]

4.3 Electrical Circuits

13. A variable resistor is connected across the terminals of a power supply of constant e.m.f. and internal resistance r .



The resistance of the variable resistor is changed from zero to its maximum value.

Which of the following statements is/are correct?

- 1 The current in the circuit decreases.
- 2 The p.d. across the internal resistance decreases.
- 3 A graph plotted of terminal p.d. against current has a negative gradient.

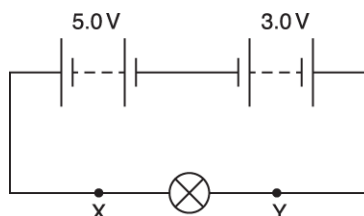
- A** Only 1
B Only 1 and 2
C Only 1 and 3
D 1, 2 and 3

Your answer

☐

[1]

14. Two batteries are connected in a circuit with a lamp as shown.



The batteries have e.m.f. 5.0 V and 3.0 V.
Which row is correct?

	Direction of conventional current	Magnitude of current
A	clockwise	greater at Y than at X
B	clockwise	same at Y and X
C	anticlockwise	greater at X than at Y
D	anticlockwise	same at X and Y

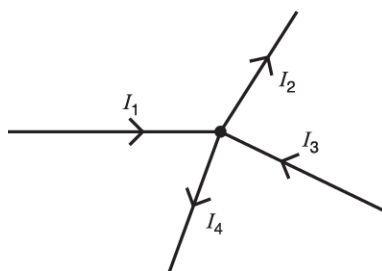
Your answer

☐

[1]

4.3 Electrical Circuits

15. The diagram shows the conventional currents entering and leaving a junction in an electric circuit. I_1 , I_2 , I_3 and I_4 are all positive.



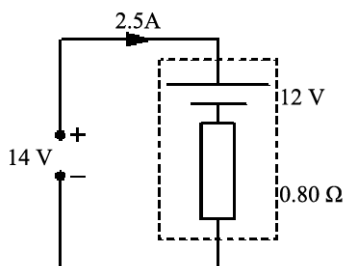
Which statement is always true?

- A** $I_1 + I_2 = I_3 + I_4$
- B** $I_1 - I_2 + I_3 - I_4 = 0$
- C** $I_1 = I_2$ and $I_3 = I_4$
- D** $I_1 + I_2 + I_3 + I_4 = 0$

Your answer

[1]

16. A 14 V d.c. supply is used to charge a 12 V car battery of internal resistance $0.80\ \Omega$ for 6.0 hours. The current in the circuit is 2.5 A.



How much electrical energy is provided by the charging supply?

- A.** 13 kJ
- B.** 110 kJ
- C.** 650 kJ
- D.** 760 kJ

Your answer

[1]

17. The graph in **Fig. 20.1** below shows the variation of force with extension for a single spring.

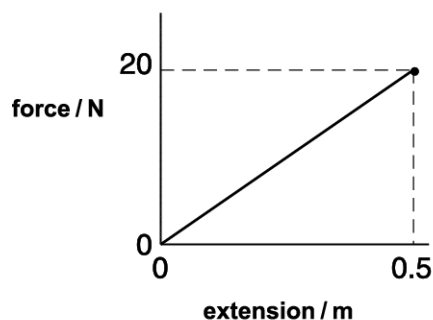


Fig. 20.1

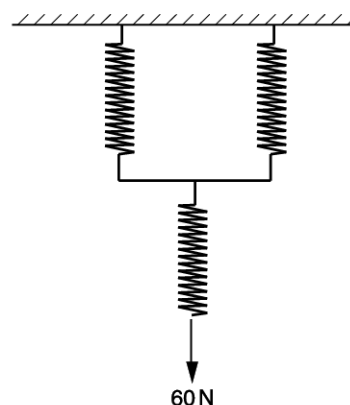


Fig. 20.2

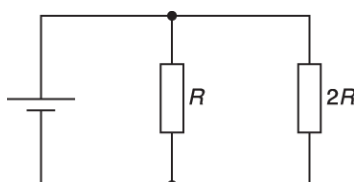
Three of these springs are joined together as shown in **Fig. 20.2** and a force of 60 N applied. What is the distance moved by the 60 N force (to 2 s.f.)?

- A. 1.5 m
- B. 2.0 m
- C. 2.3 m
- D. 3.0 m

Your answer

[1]

18. A resistor of resistance R is connected in parallel with a resistor of resistance $2R$. The combination of resistors is connected to a cell.



What is the ratio $\frac{\text{power dissipated in resistor of resistance } R}{\text{power dissipated in resistor of resistance } 2R}$?

- A $\frac{1}{4}$
- B $\frac{1}{2}$
- C 1
- D 2

Your answer

[1]

4.3 Electrical Circuits

19. A student is given two identical filament lamps. Each lamp is labelled as '12 V, 24 W'. The student connects the two lamps in series across a 12 V supply of negligible internal resistance.

Which of the following statements is / are true when the lamps are in **series**?

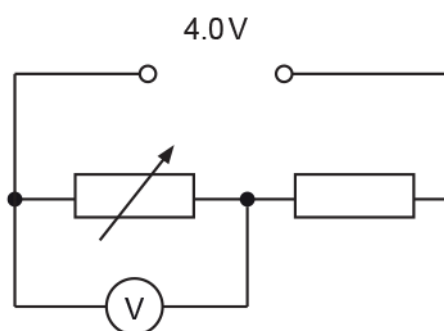
- 1 The resistance of each lamp is $6.0\ \Omega$
- 2 The current in the circuit is greater than 1.0 A.
- 3 The potential difference across each lamp is 6.0 V.

- A 1, 2 and 3
- B Only 2 and 3
- C Only 1 and 2
- D Only 2

Your answer

[1]

20. The diagram below shows a potential divider circuit.



The minimum resistance of the variable resistor is zero and its maximum resistance is $3R$, where R is the resistance of the fixed resistor.

The power supply has electromotive force (e.m.f.) 4.0 V and negligible internal resistance. The voltmeter has infinite resistance.

The resistance of the variable resistor is changed from its minimum to its maximum value.

How does the voltmeter reading change?

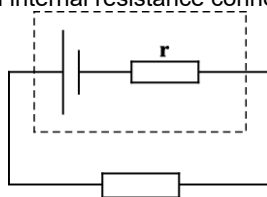
- A from 0 V to 1.0 V
- B from 0 V to 3.0 V
- C from 1.0 V to 4.0 V
- D from 3.0 V to 4.0 V

Your answer

[1]

4.3 Electrical Circuits

21. The diagram below shows a cell with an internal resistance connected to an external resistor.



Which of the following will increase the terminal p.d?

1. Increasing the e.m.f. of the cell.
2. Increasing the value of the external resistance.
3. Increasing the value of the internal resistance.

- A. 1, 2 and 3
B. Only 1 and 2
C. Only 2 and 3
D. Only 1

Your answer

☐

[1]

22. A battery of e.m.f. of 8.0 V and internal resistance 2.5 Ω is connected to an external resistor. The current in the resistor is 350 mA.

What is the power dissipated in the external resistor?

- A. 1.9 W
B. 2.5 W
C. 2.8 W
D. 3.1 W

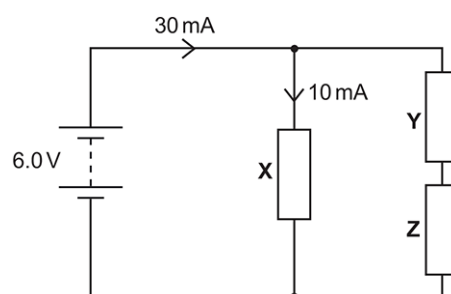
Your answer

☐

[1]

4.3 Electrical Circuits

23. A battery of electromotive force (e.m.f) 6.0 V and of negligible internal resistance is used in the circuit below.



The current from the battery is 30 mA. The current in the resistor **X** is 10 mA.
The resistors **Y** and **Z** are identical.

What is the power dissipated in the resistor **Z**?

- A** 30 mW
- B** 60 mW
- C** 120 mW
- D** 180 mW

Your answer

[1]

24. A student records the following data during an experiment to determine the internal resistance of a battery.

e.m.f. = (4.5 ± 0.2) V

terminal p.d. = (3.0 ± 0.1) V

current = (2.0 ± 0.1) A

What is the percentage uncertainty in the value for the internal resistance of the battery?

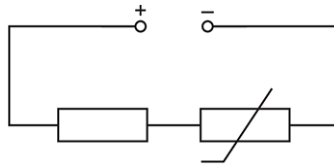
- A** 5.0 %
- B** 6.1 %
- C** 13 %
- D** 25 %

Your answer

[1]

4.3 Electrical Circuits

25. A circuit with a thermistor is shown below.



The resistance of the resistor is R and the resistance of the thermistor is $2.5R$.
The potential difference (p.d.) across the thermistor is 5.0 V .

What is the total p.d. across both components?

- A 2.0 V
- B 7.0 V
- C 12.5 V
- D 17.5 V

Your answer

[1]

26. A wire **X** has length L and radius r . Another wire **Y** made of the same material as **X** has length $2L$ and radius $3r$. The wires are connected in **parallel** to a battery.

What is the correct ratio of

$$\frac{\text{power dissipated in Y}}{\text{power dissipated in X}} ?$$

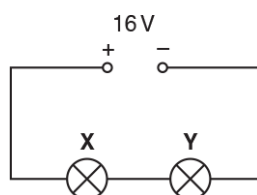
- A 0.22
- B 1.0
- C 4.5
- D 6.2

Your answer

[1]

4.3 Electrical Circuits

27. Two filament lamps **X** and **Y** are connected in series with a 16 V d.c. supply. The supply has negligible internal resistance.



Lamp **X** emits a power of 2.0 W and lamp **Y** emits a power of 6.0 W.

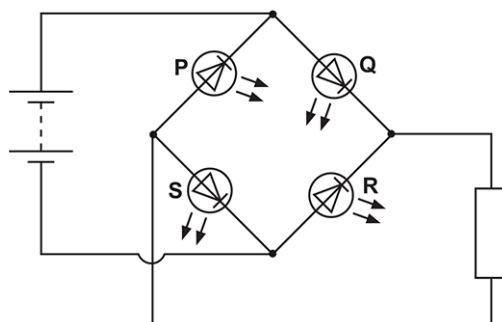
What is the potential difference across the lamp **X**?

- A** 1.0 V
- B** 4.0 V
- C** 12 V
- D** 16 V

Your answer

[1]

28. A circuit with four light-emitting diodes (LEDs) **P**, **Q**, **R** and **S** is shown below.



Two LEDs are lit in this circuit. Which **two** LEDs are lit?

- A** **P** and **Q**
- B** **P** and **R**
- C** **Q** and **R**
- D** **Q** and **S**

Your answer

[1]

4.3 Electrical Circuits

29. A battery of electromotive force (e.m.f.) 6.0 V is connected across a resistor of resistance $12\ \Omega$. The potential difference across the resistor is 4.5 V .

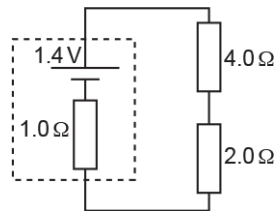
What is the internal resistance of the battery?

- A** $3\ \Omega$
- B** $4\ \Omega$
- C** $9\ \Omega$
- D** $10\ \Omega$

Your answer

[1]

30. Two resistors of resistances $2.0\ \Omega$ and $4.0\ \Omega$ are connected in series across the terminals of a cell of e.m.f. 1.4 V and internal resistance $1.0\ \Omega$.



What is the potential difference across the $2.0\ \Omega$ resistor?

- A** 0.40 V
- B** 0.47 V
- C** 0.80 V
- D** 0.93 V

Your answer

[1]

31 (a). A student is investigating the interference of microwaves after passing through two narrow slits.

The student sets up an experiment to demonstrate the interference of microwaves as shown in Fig. 2.

A microwave transmitter is placed in front of the two slits. A microwave detector is moved along the line **PQ**. Maxima are detected at points **A**, **C**, and **E**. Minima are detected at points **B** and **D**.

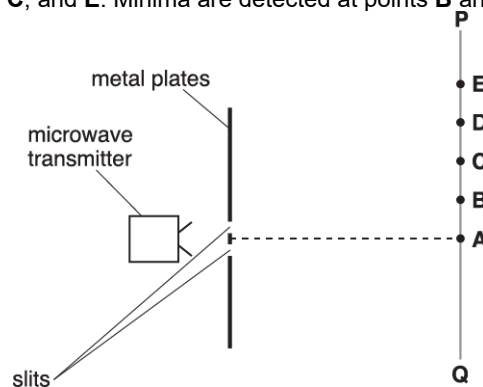


Fig. 2 (not to scale)

4.3 Electrical Circuits

The distance travelled by the microwaves from each slit to point **A** is the same.

State the path difference in terms of the wavelength λ of the microwaves from the two slits at

1 point C

path difference =

2 point D

path difference =

[2]

(b). The separation between the slits is increased.

State and explain the effect this has on the separation between adjacent maxima.

[2]

32(a). Fig. 17 shows a potential divider circuit consisting of a fixed resistor of resistance R and a negative temperature coefficient (NTC) thermistor.

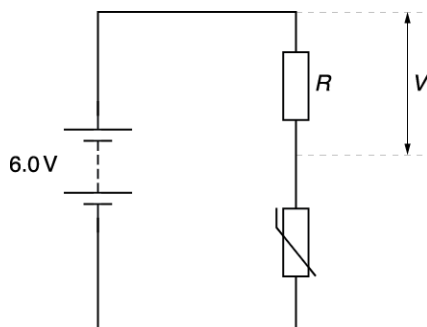


Fig. 17

The battery has electromotive force (e.m.f.) of 6.0 V and negligible internal resistance.

The thermistor is at room temperature. The resistance of the thermistor is $0.25 R$.

Calculate the potential difference V across the resistor.

$V = \dots\dots\dots$ V **[2]**

4.3 Electrical Circuits

(b). A voltmeter whose resistance is $5R$ is connected across the fixed resistor. The voltmeter reading is **less** than your answer in the previous question. Explain why the voltmeter reading is less and suggest an alternative measuring device.

[2]

33(a). Fig. 19.1 shows an electric circuit.

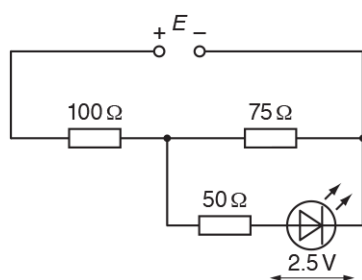


Fig. 19.1

The power supply has electromotive force (e.m.f.) E and negligible internal resistance.

The resistance values of the resistors are shown in Fig. 19.1. The I - V characteristic of the lightemitting diode (LED) is shown in Fig. 19.2.

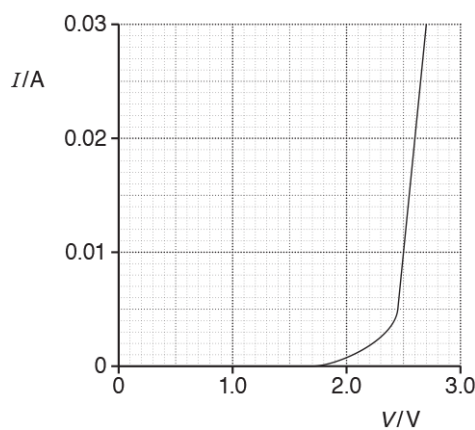


Fig. 19.2

The potential difference (p.d.) across the LED is 2.5 V.

Use Fig. 19.2 to show that the p.d. across the $50\ \Omega$ resistor is 0.50 V.

[2]

4.3 Electrical Circuits

(b). Calculate the e.m.f. E of the power supply.

$$E = \dots\dots\dots \text{V} \quad [3]$$

34. State Kirchhoff's second law **and** the physical quantity that is conserved according to this law.

[2]

35. A student connects a calibrated $10.0 \, \Omega$ resistor across a chemical cell of electromotive force (e.m.f.) $1.50 \, \text{V}$. The student expects the current in the resistor to be $0.150 \, \text{A}$.

Explain why the actual current will not be $0.150 \, \text{A}$.

[2]

36.

Fig. 24 shows a circuit with a battery and two resistors.

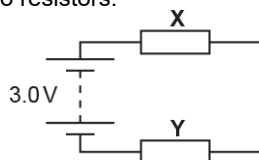


Fig. 24

The resistor **X** has length $8.0 \times 10^{-3} \, \text{m}$, cross-sectional area $1.2 \, \text{mm}^2$ and is made of a material of resistivity $1.5 \times 10^{-2} \, \Omega \text{m}$. The battery has e.m.f. $3.0 \, \text{V}$ and negligible internal resistance. The resistor **Y** has resistance $68 \, \Omega$.

Calculate the current I in the circuit.

$$I = \dots\dots\dots \text{A} \quad [3]$$

4.3 Electrical Circuits

37. A student is investigating the interference of microwaves after passing through two narrow slits.

- i. State the principle of superposition of waves.

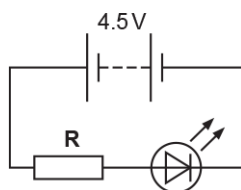
[1]

- ii. For interference effects to be observed, the waves from the two slits must be *coherent*. State what is meant by the term *coherent*.

[1]

38. A light-emitting diode (LED) emits red light when it is positively biased and has a potential difference (p.d.) greater than about 1.8 V.

An LED is connected into a circuit, as shown below.



The battery has electromotive force (e.m.f.) 4.5 V and negligible internal resistance.

The resistor **R** has resistance 150 Ω .

Assume the p.d. across the LED is 1.8 V.

Calculate the ratio $\frac{\text{power dissipated by LED}}{\text{power dissipated by resistor}}$.

ratio = [2]

39 (a). The circuit diagram shows a battery of e.m.f. E and internal resistance r connected to a variable resistor R .

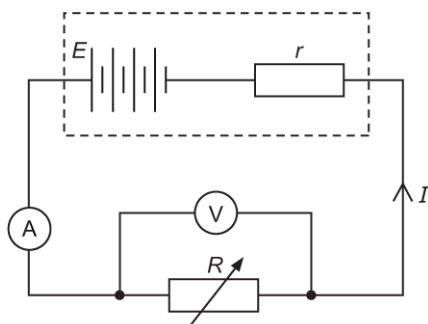


Fig. 5.1

The current I in the variable resistor is measured using an ammeter and the potential difference V across the variable resistor is measured using a voltmeter.

The resistance R of the variable resistor is varied. I and V are recorded for each value of R . A graph of V (y -axis) against I (x -axis) is plotted.

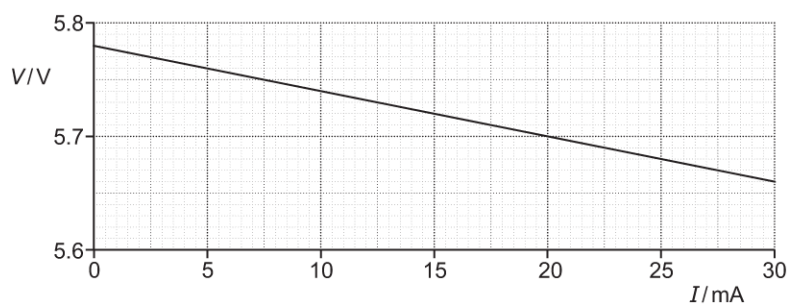


Fig. 5.2

Explain how values for E and r may be determined from the graph. No calculations are required.

[2]

(b). The resistance of the variable resistor is now fixed. The current is 25 mA.

- Use the graph to determine the resistance R of the variable resistor.

$R = \dots\dots\dots \Omega$ **[1]**

4.3 Electrical Circuits

- ii. Calculate the energy W dissipated in the variable resistor in 5.0 minutes.

$$W = \dots\dots\dots \text{ J [2]}$$

- iii. Calculate the charge Q passing through the variable resistor in 5.0 minutes. Include an appropriate unit.

$$Q = \dots\dots\dots \text{ unit } \dots\dots\dots \text{ [2]}$$

- (c). Use Kirchhoff's second law to show that $V = E - Ir$.

[2]

40. A student designs a circuit to vary the brightness of a filament lamp. The circuit is shown in **Fig. 17.2**.

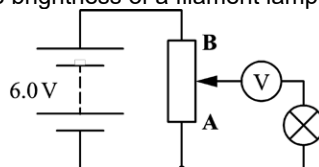


Fig. 17.2

The circuit is set up. Moving the slider from **A** to **B** changes the voltmeter reading from 0 V to 6.0 V but the lamp stays off. The lamp is not faulty.

Explain the observations above and refine the circuit design so that the brightness of the lamp can be varied as the slider is moved from **A** to **B**.

[3]

41. Fig. 6.1 shows the I - V characteristics for two electrical components **X** and **Y**.

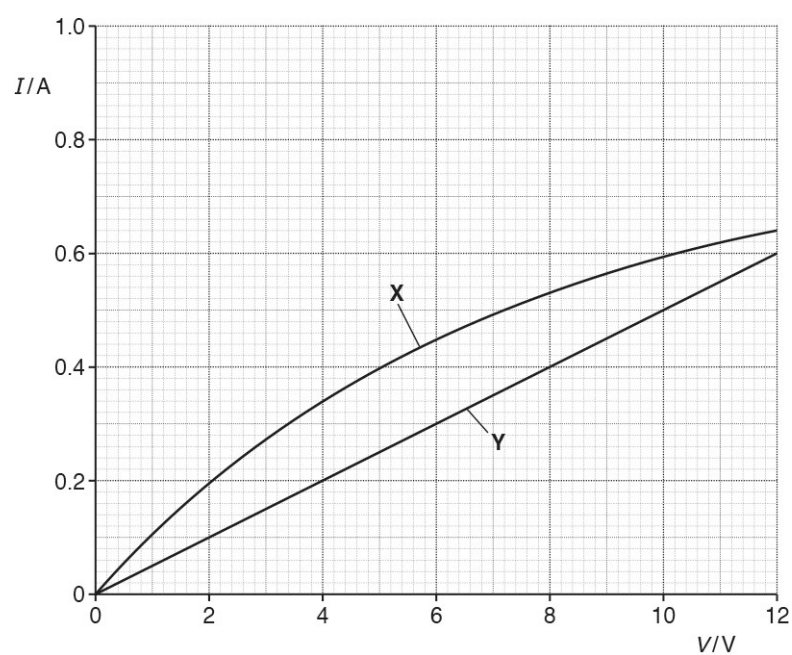


Fig. 6.1

Fig. 6.2 shows components **X** and **Y** connected in parallel to a battery of e.m.f. 9.6 V and internal resistance r .

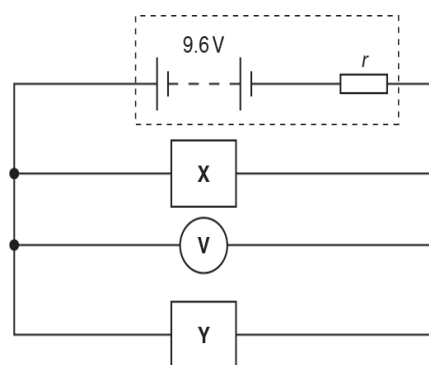


Fig. 6.2

The voltmeter reading is 7.2 V. Determine r .

$r =$

Ω
[3]

4.3 Electrical Circuits

42. A student conducts an experiment using two identical filament lamps and a variable power supply of negligible internal resistance. The lamps are connected in series to the supply. The current in the circuit is 0.030 A and the lamps are dimly lit.

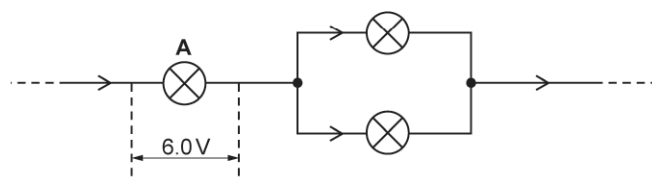
The e.m.f. of the power supply is then doubled and the experiment repeated.

The student expected the current to double, but the current only increased to 0.040 A. The lamps are brightly lit.

Use your knowledge of physics to explain these observations.

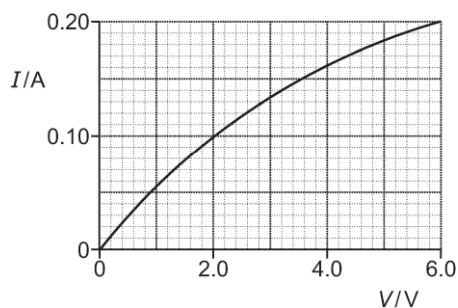
[3]

43. The diagram below shows part of an electrical circuit connected by a student.



The lamps are identical.

The graph below shows the I - V characteristic of one of the lamps.



The potential difference (p.d.) across lamp **A** is 6.0 V.

Use the graph to determine the total resistance of the lamps.

resistance = Ω [3]

44. A battery of negligible internal resistance is connected across two resistors of resistance values R and $2R$ as shown in **Fig. 24.1**.

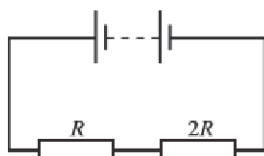


Fig. 24.1

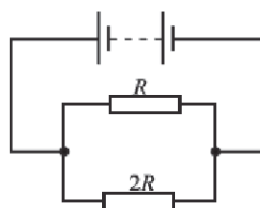


Fig. 24.2

The same battery is now connected to the same resistors as shown in **Fig. 24.2**.

Calculate the ratio

$$\frac{\text{current from battery in circuit of Fig. 24.1}}{\text{current from battery in circuit of Fig. 24.2}}$$

ratio = [3]

45. A student is investigating a potential divider circuit containing a light-dependent resistor (LDR). The student sets up the circuit shown in Fig. 4.

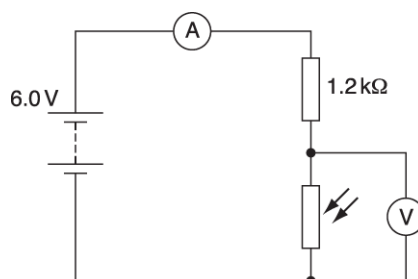


Fig. 4

The battery has an e.m.f. of 6.0 V and negligible internal resistance. The resistor has a resistance of 1.2 k Ω . In a dark room the voltmeter reading is 5.1 V.

- i. Show that the resistance R_{LDR} of the LDR is 6800 Ω .

[2]

- ii. Calculate the current I delivered by the battery.

$I = \dots\dots\dots$ A [1]

46. Fig. 27.1 shows the I - V characteristic of an LED designed to emit blue light.

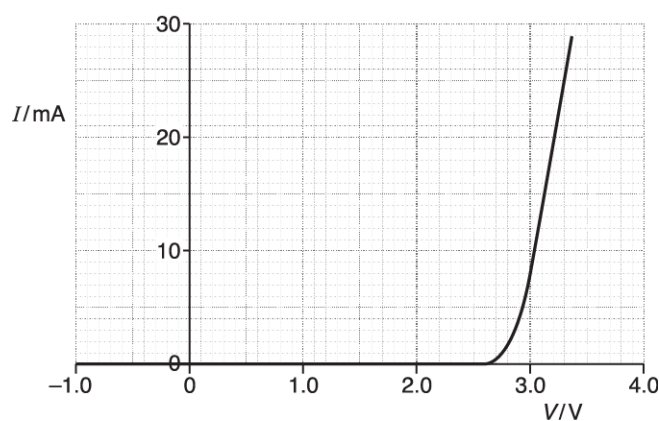


Fig. 27.1

A student uses the LED with the characteristic shown in Fig. 27.1 to construct the circuit shown in Fig. 27.2.

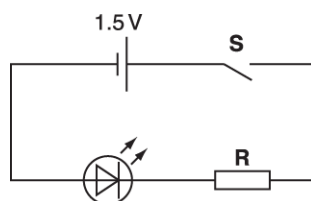


Fig. 27.2

A suitable resistor R is used in the circuit. The cell has electromotive force (e.m.f.) of 1.5 V and negligible internal resistance.

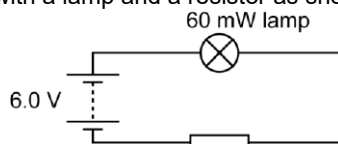
The LED fails to emit any light when the switch S is closed.

Explain why the circuit does not work and modify the design of the circuit so that the LED is lit when S is closed.

[3]

4.3 Electrical Circuits

47 (a). A battery is connected in series with a lamp and a resistor as shown.



The battery has e.m.f. 6.0 V and negligible internal resistance. The potential difference across the lamp is 2.4 V and it dissipates 60 mW. The resistor has cross-sectional area of 2.0 mm^2 . The number density of charge carriers (free electrons) within the resistor is $1.4 \times 10^{25} \text{ m}^{-3}$.

Calculate the resistance R of the resistor.

$$R = \dots\dots\dots \Omega \text{ [3]}$$

(b). Calculate the mean drift velocity v of the free electrons within the resistor.

$$v = \dots\dots\dots \text{ m s}^{-1} \text{ [3]}$$

(c). The number density of the free electrons in the connecting wires is greater than that of the resistor. The connecting wires have the same diameter as the resistor. State and explain whether the mean drift velocity of the free electrons would be smaller, the same, or larger than your value in **(b)**.

[2]

48. Fig. 17.1 shows a resistor and a diode connected in series to a cell.

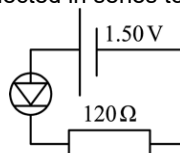


Fig. 17.1

The resistor has resistance 120Ω . The cell has e.m.f. 1.50 V and negligible internal resistance. The potential difference across the diode is 0.62 V.

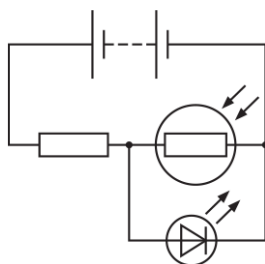
Calculate the total power dissipated in the circuit.

$$\text{power} = \dots\dots\dots \text{ W [3]}$$

4.3 Electrical Circuits

49. A light-emitting diode (LED) emits red light when it is positively biased and has a potential difference (p.d.) greater than about 1.8 V.

The diagram below shows a circuit designed by a student.



The LED is very close to, and facing the light dependent resistor (LDR). The circuit is taken into a dark room.

- i. The student thought that the LED would switch on. Instead, the LED was found to repeatedly switch on and off.

Explain this behaviour of the LED in this potential divider circuit.

[2]

- ii. Suggest a possible refinement so that the LED switches on permanently when taken into the dark room.

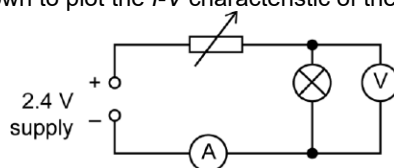
[1]

50. Two resistors of resistances R_1 and R_2 are connected in **parallel**. Show that the total resistance R of this combination is given by the equation

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}.$$

[3]

51. A student connects the circuit shown to plot the I - V characteristic of the filament lamp.



The current in the lamp is I and the potential difference across it is V . The supply has e.m.f. 2.4 V and negligible internal resistance. The maximum resistance of the variable resistor is about $60\ \Omega$.

- i. Explain why this circuit will provide data for large V values but not for small V values.

[2]

- ii. Complete Fig. 16 to design a circuit so that data may be obtained for V from zero to 2.4 V for the lamp.

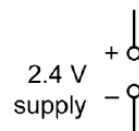


Fig. 16

[2]

52. This question is about two identical filament lamps. Fig. 23.2 shows the I - V characteristic of each lamp.

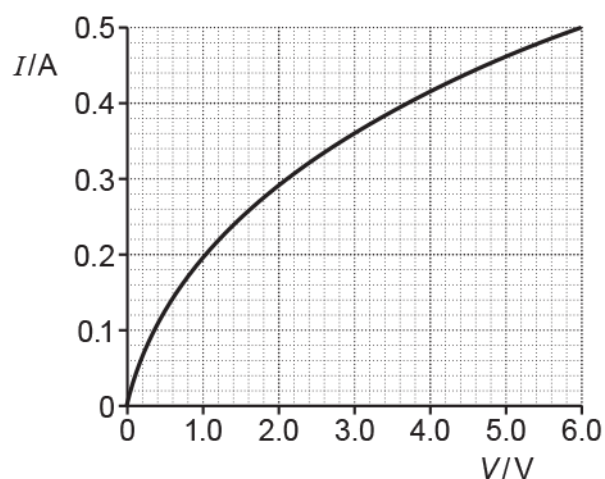


Fig. 23.2

The lamps are connected to a 6.0 V supply of negligible internal resistance in **series**, as shown in Fig. 23.3, and then in **parallel**, as shown in Fig. 23.4.

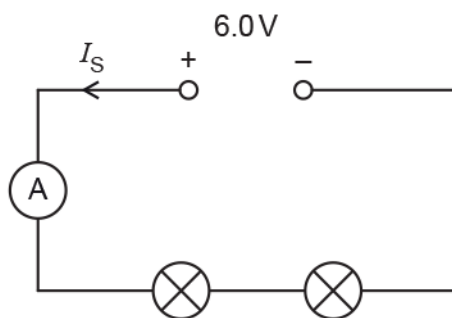


Fig. 23.3

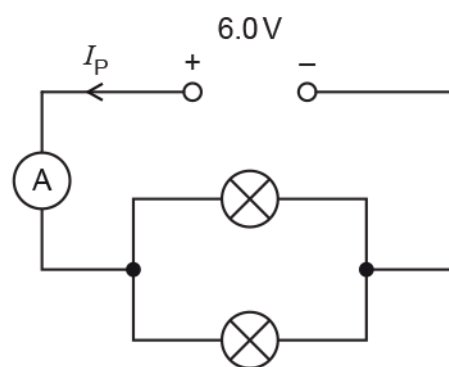


Fig. 23.4

The current from the supply in the series circuit is I_S and the current from the supply in the parallel circuit is I_P . I_P is found to be almost 3 times greater than I_S .

Use Fig. 23.2 to explain why I_P is almost 3 times greater than I_S . Show any calculations and your reasoning below.

Fig. 23.3

Fig. 23.4

53. The circuit in **Fig. 5.1** consists of a d.c. supply of e.m.f. 45 V and negligible internal resistance and three resistors.

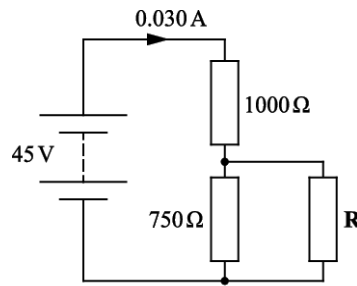


Fig. 5.1

Two of the resistors have resistances $1000\ \Omega$ and $750\ \Omega$ as shown.

The current drawn from the supply is $0.030\ \text{A}$. Calculate the resistance of **R**.

resistance = Ω **[4]**

54. A student is investigating a potential divider circuit containing a light-dependent resistor (LDR). The student sets up the circuit shown in Fig. 4.

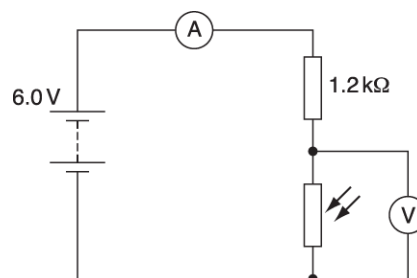


Fig. 4

The circuit is moved so that the LDR is now in sunlight.

Without reference to the potential divider equation, describe and explain how the readings on the ammeter and voltmeter will change.

[4]

55. Fig. 27.1 shows the I - V characteristic of an LED designed to emit blue light.

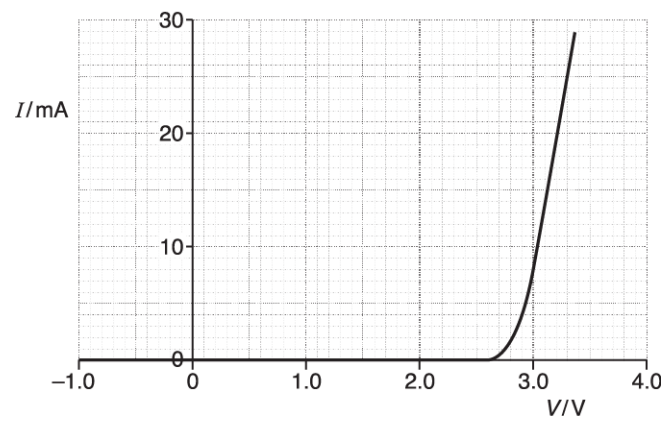


Fig. 27.1

Describe and justify the variation of resistance R of the LED as the potential difference V across the LED is increased from

- -1.0 V to 2.6 V

- 2.6 V to 3.0 V

- 3.0 V to 3.4 V

[4]

4.3 Electrical Circuits

56. A student is given a chemical cell, an ammeter, a voltmeter, a variable resistor and a number of connecting wires.

Design a laboratory experiment to determine the internal resistance r of the chemical cell using a graph. Start with a circuit diagram.

In your description pay particular attention to

- the circuit used
- the measurements taken
- how the data is analysed using a graph.

[4]

57. Fig. 17 shows a potential divider circuit consisting of a fixed resistor of resistance R and a negative temperature coefficient (NTC) thermistor.

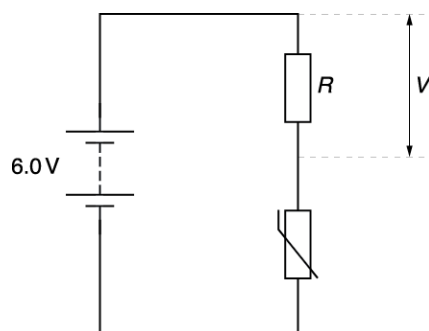


Fig. 17

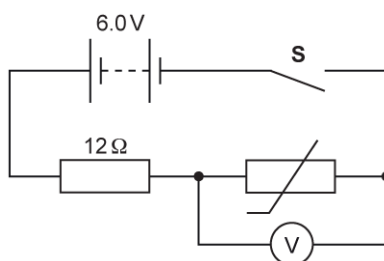
The battery has electromotive force (e.m.f.) of 6.0 V and negligible internal resistance. The thermistor is at room temperature. The resistance of the thermistor is $0.25 R$.

The circuit shown in Fig. 17 is now placed in a cold fridge. The temperature of the thermistor slowly decreases to a constant value. Describe and explain, in terms of current in the circuit, the variation of the potential difference V across the fixed resistor with time.

[4]

4.3 Electrical Circuits

58. A student connects a resistor and a thermistor in a circuit, as shown in the circuit diagram below.

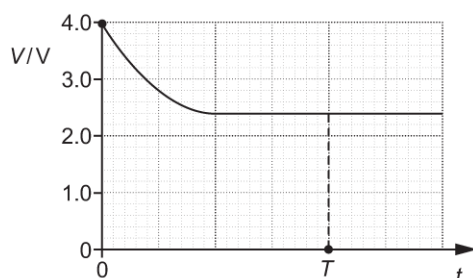


The battery has electromotive force (e.m.f.) 6.0 V and negligible internal resistance.

The resistor has resistance 12 Ω.

The thermistor is at room temperature. The student closes the switch **S** at time $t = 0$.

The student draws the following graph which shows potential difference (p.d.) V across the thermistor against time t .



- i. Explain why V decreases at the start.

[2]

- ii. Use the graph to calculate the resistance of the thermistor at $t = T$.

resistance = Ω [3]

59 (a). Fig. 18.1 shows a circuit.

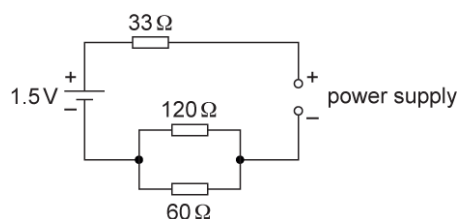


Fig. 18.1

The cell has e.m.f. 1.5 V. The cell and the variable power supply both have negligible internal resistance.

- i. The e.m.f. of the power supply is set at 4.2 V.
Calculate the current I in the $33\ \Omega$ resistor.

$I = \dots\dots\dots$ A [3]

- ii. The e.m.f. of the variable supply is now slowly decreased from 4.2 V to 0 V.
Describe the effect on the current I in the $33\ \Omega$ resistor.

[2]

- (b).**  A group of students are investigating the power dissipated in a variable resistor connected across the terminals of a cell. The cell has e.m.f. 1.5 V.
The students determine the power P dissipated in the variable resistor of resistance R .

Fig. 18.2 shows the data points plotted by the students on a graph of P (y-axis) against

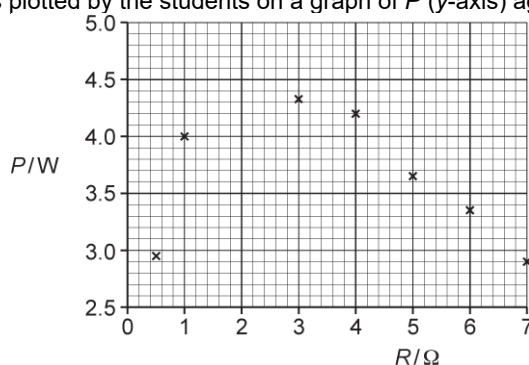


Fig. 18.2

The group of students know that **maximum power** is dissipated in the variable resistor when R is equal to the internal resistance r of the cell.

4.3 Electrical Circuits

Describe, with the help of a suitable circuit diagram, how the students may have determined P and R . Use Fig. 18.2 to estimate the internal resistance r of the cell and discuss any limitations of the data plotted by the group.

[illegible]

4.3 Electrical Circuits

60. A cell of electromotive force (e.m.f.) 1.4 V and internal resistance $0.62\ \Omega$ is connected to resistor **A** and wire **B** as shown in Fig. 23.1.

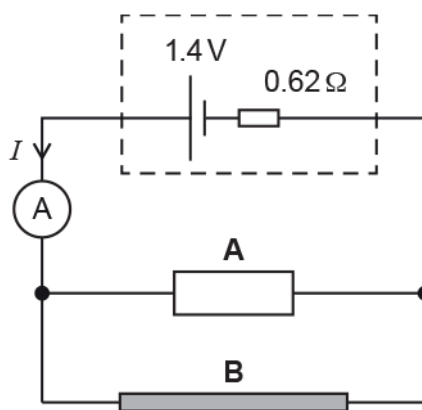


Fig. 23.1

The resistance of resistor **A** is $1.8\ \Omega$ and resistance per unit length of wire **B** is $9.5\ \Omega\text{m}^{-1}$. The length of wire **B** is 40 cm.

- i. Calculate the current I in the circuit. Write your value to an appropriate number of significant figures.

$I = \dots\dots\dots\text{ A [4]}$

- ii.

Calculate the ratio $\frac{\text{power dissipated in the internal resistance}}{\text{total power supplied by cell}}$

ratio = $\dots\dots\dots\text{ [2]}$

61. A student monitors the temperature in a room by using a potential divider circuit containing a negative temperature coefficient (NTC) thermistor. The student sets up the circuit shown in Fig. 4.2.

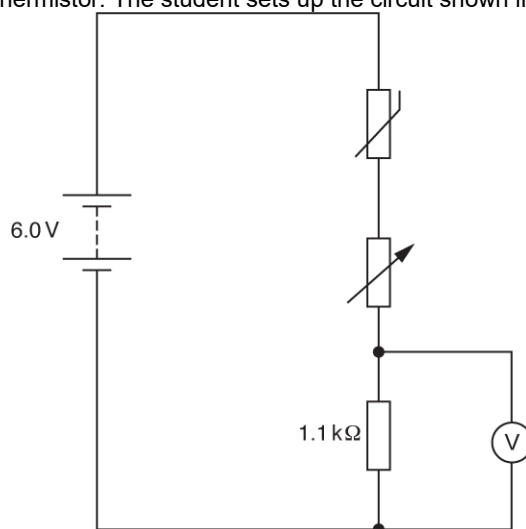


Fig. 4.2

The battery has an e.m.f. of 6.0 V and negligible internal resistance.

- i. When the temperature of the thermistor is 12 °C the thermistor has a resistance of 6.8 kΩ. The resistance of the variable resistor is set to a value of 1.4 kΩ. Calculate the reading V on the voltmeter.

$V = \dots\dots\dots$ V [2]

- ii. Explain how the reading on the voltmeter will change when the temperature of the thermistor increases.

[4]

4.3 Electrical Circuits

62 (a).  You are given an unmarked sealed square box which has four identical terminals at each corner.

Fig 4.1 shows the circuit diagram for the contents of the box with the four terminals labeled **A**, **B**, **C** and **D**.

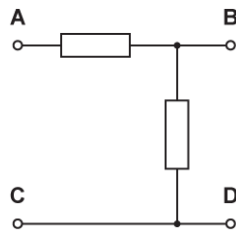


Fig. 4.1

One of the resistors in the box has resistance $220\ \Omega$. The other resistor has resistance $470\ \Omega$. Two of the terminals are connected by a wire.

The four terminals on your unmarked sealed box are **not** labelled.

You are given a 6.0 V d.c. supply, a $100\ \Omega$ resistor (labelled R) and a digital ammeter.

Plan an experiment to determine the arrangement of the components and identify which terminal of your unmarked sealed box is **A**, **B**, **C** and **D**.

A space has been left for you to draw circuit diagrams to illustrate your answer.

[illegible]

(b). A light-dependent resistor (LDR) is connected between points **X** and **Y** in the circuit of Fig. 4.2. The circuit is used to switch on a lamp during the hours of darkness.



- [1]

4.3 Electrical Circuits

- ii. Fig. 4.3 shows how the resistance of the LDR varies with light intensity. The electronic switch closes when V across **XY** is 4.0 V and opens when V across **XY** is 2.4 V. The electronic switch draws a negligible current.

Calculate

- 1** the resistance R of the resistor for the lamp to switch on at a light intensity of 0.80 W m^{-2}

$$R = \dots\dots\dots \Omega \text{ [3]}$$

- 2** the light intensity of the surroundings at which the lamp switches off.

$$\text{light intensity} = \dots\dots\dots \text{ W m}^{-2} \text{ [2]}$$

- 63.** Fig. 24.2 shows a circuit designed by a student.

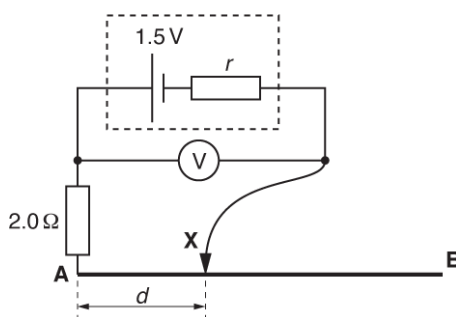


Fig. 24.2

The cell has e.m.f. 1.5 V and an internal resistance r .
The uniform wire **AB** has length 1.0 m and resistance 16 Ω .

- i. When the contact **X** is in the **middle** of the wire, the voltmeter reading is 1.2 V. Calculate the internal resistance r of the cell.

$$r = \dots\dots\dots \Omega \text{ [3]}$$

4.3 Electrical Circuits

- ii. The contact **X** is now moved along the wire from **A** to **B**.
The distance of the contact **X** from **A** is d .
Fig. 24.3 shows the variation of the potential difference V across the terminals of the cell.

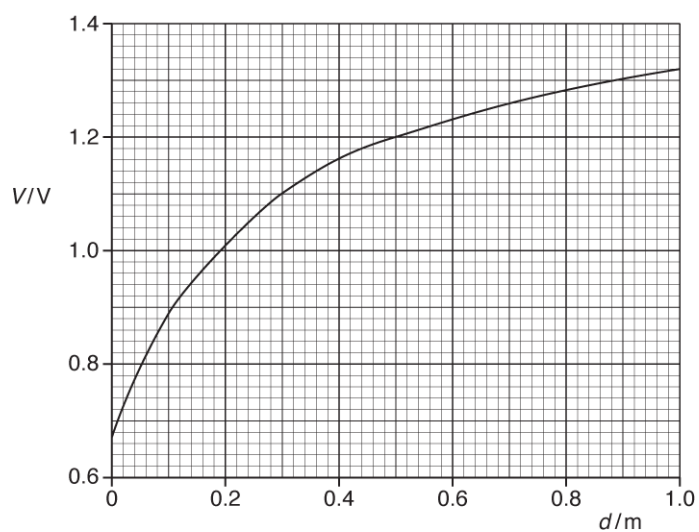


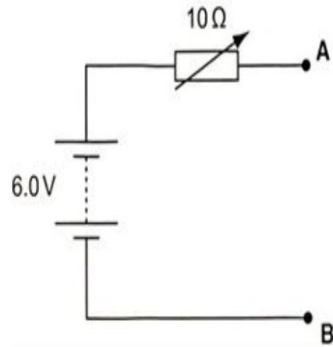
Fig. 24.3

Explain the variation of V with d in terms of the current in the circuit.

[3]

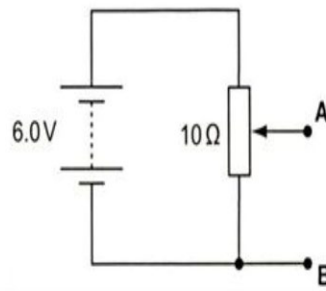
4.3 Electrical Circuits

64. *In order to determine the I - V characteristic for an LED, one student connects to the incomplete circuit **X** shown in **Fig. 4.2(a)** and a second student connects to the incomplete circuit **Y** shown in **Fig. 4.2(b)**. Each adds an LED with a resistor in series and suitable meters to take the measurements between terminals **A** and **B**.



Incomplete circuit X

Fig. 4.2(a)



Incomplete circuit Y

Fig. 4.2(b)

Only one of these circuits is suitable to carry out the task.

Draw an LED with a $100\ \Omega$ resistor in series and suitable meters to complete the correct circuit on **Fig. 4.2(a)** or **4.2(b)**.

Explain why only one of the circuits is suitable to carry out the task and why the $100\ \Omega$ resistor has been included.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

[6]

65.  A metal circular plate is rotated at a constant frequency by an electric motor. The plate has a small hole close to its rim. Fig. 17.1 shows an arrangement used by a student to determine the frequency of the rotating plate.

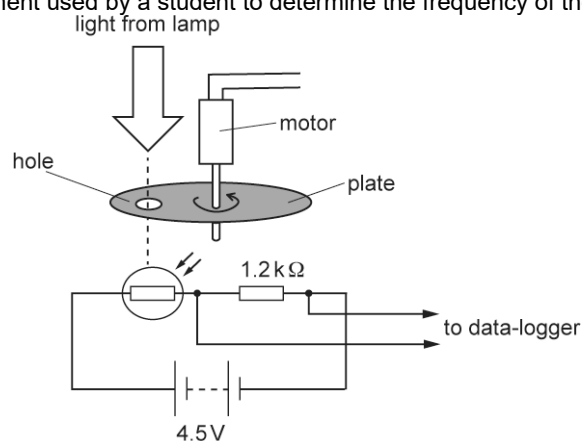


Fig. 17.1

A light-dependent resistor (LDR) and a fixed resistor of resistance 1.2 kΩ are connected in series to a battery. The battery has e.m.f. 4.5 V and has negligible internal resistance. The potential difference V across the resistor is monitored using a data-logger.

Fig. 17.2 shows the variation of V with time t .

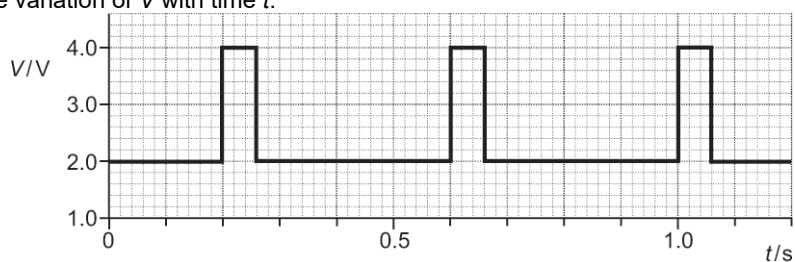


Fig. 17.2

4.3 Electrical Circuits

Use your knowledge and understanding of potential divider circuits to explain the shape of the graph shown in Fig. 17.2. Include in your answer the maximum and minimum values of the resistance of the LDR. Describe how the student can determine the frequency of the rotating plate.

This image shows a full page of white paper with horizontal dashed lines, typical of primary-ruled notebook paper. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

[6]

4.3 Electrical Circuits

66. * Students are given a light dependent resistor (LDR) and asked to design a circuit for a light meter to monitor changes in light intensity. The meter reading must rise when the light intensity increases.

The incident light may cause the resistance of the LDR to vary between $1500\ \Omega$ and $250\ \Omega$.

The students are asked to use the d.c. supply and one of the resistors from **(a)** above and either a voltmeter or ammeter.

Draw a suitable circuit.

Explain why the reading on the meter increases with increasing light intensity and which of the three fixed resistors gives the largest scale change on the meter for the change in light intensity.

This image shows a full page of white paper with horizontal dashed lines, typical of primary-ruled notebook paper. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

67. * Fig. 17.3 shows how the resistance of a thermistor varies with temperature.

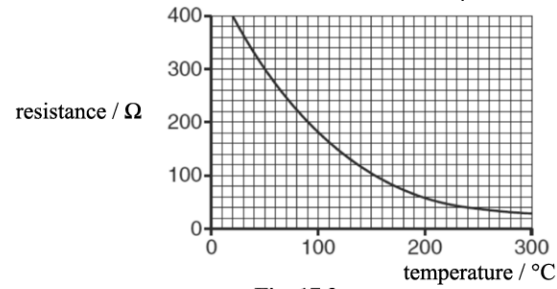


Fig. 17.3

Fig. 17.4 shows a potential divider circuit which uses this thermistor. The circuit is designed to monitor the changes in the temperature of an oven in the range 200 °C to 300 °C.

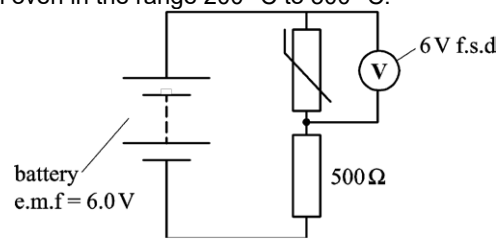


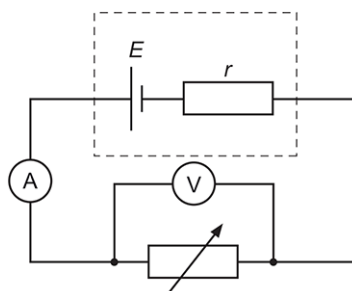
Fig. 17.4

The voltmeter has very high resistance and has a full scale deflection (f.s.d.) of 6.0 V.

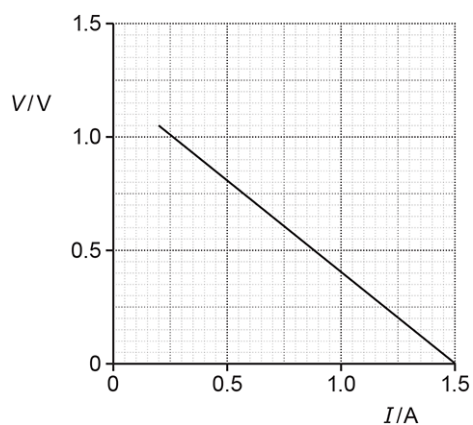
Explain how the circuit works and use calculations to discuss a significant limitation of this design.

[illegible]

68. A student is doing an experiment to determine the e.m.f. E of a cell and its internal resistance r . The circuit diagram of the arrangement is shown below.



The V against I graph plotted by the student is shown below.



V / V	I / A	R / Ω	P / W
0.20	1.25		
0.40	1.00		
0.60	0.75		
0.80	0.50		
1.00	0.25		

4.3 Electrical Circuits

There is an incomplete table next to the graph.

R is the resistance of the variable resistor and P is the power dissipated by the variable resistor.

- Use the graph to determine E and r . Explain your reasoning.
- Calculate R and P to complete the table. Describe how P depends on R .

[illegible]

4.3 Electrical Circuits

69. The table shows some of the properties of a light dependent resistor (LDR).

	Resistance of LDR/ Ω
Very bright	2.0×10^2
Daylight	2.0×10^3
Very dark	2.0×10^5

Design a circuit, using a potential divider with the LDR, so that the output potential difference from the circuit is

- greater than 5.0V when the LDR is in very bright light
- less than 1.0V when the LDR does not receive any light.

In your answer, include

- a circuit diagram with suggested component values
- an explanation of the operation of the circuit
- how the circuit could be adjusted to change the output potential difference for a different light intensity.

[illegible]

[6]

70. A cable consists of 17 tightly packed copper wires, see Fig. 6.3.

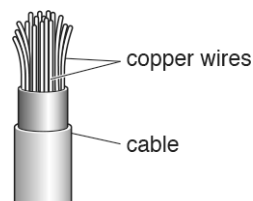


Fig. 6.3 (not to scale)

The student measures the diameter d of one of the copper wires as 0.12 ± 0.01 mm.

- i. Explain how the student should measure precisely the diameter of the wire.

[2]

The student measures the resistance R of the whole **cable** as $1.86 \pm 0.02 \Omega$.

The length L of the cable is 21.0 ± 0.1 m.

- ii. Determine the resistivity ρ of copper.

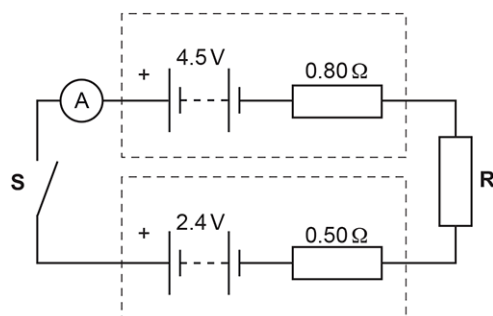
$\rho =$ $\Omega \text{ m}$ [3]

4.3 Electrical Circuits

- iii. Determine the percentage uncertainty in ρ .

percentage uncertainty = % **[2]**

71. The circuit diagram of an electrical circuit is shown below.



The positive terminals of the batteries are connected together.
 One battery has electromotive force (e.m.f.) 4.5 V and internal resistance 0.80 Ω.
 The other battery has e.m.f. 2.4 V and internal resistance 0.50 Ω.
R is a coil of insulated wire of resistance 1.2 Ω at room temperature.

The switch **S** is closed.

- i. On the diagram, draw an arrow to show the direction of the conventional current.

[1]

- ii. Calculate the current I shown by the ammeter.

$I = \dots\dots\dots$ A **[3]**

- iii. The insulated wire has diameter 4.6×10^{-4} m.
 The number density of charge carriers in **R** is $4.2 \times 10^{28} \text{ m}^{-3}$

Calculate the mean drift velocity v of the charge carriers in **R**.

$v = \dots\dots\dots$ m s⁻¹ **[2]**

4.3 Electrical Circuits

- iv. The current measured by the ammeter is smaller than that calculated in (ii). This is because the temperature of **R** increased due to heating by the current.

Without any changes to the circuit itself, state and explain what practically can be done to make the measured current the same as the calculated current..

[2]

- 72(a). State **one** S.I. base quantity other than length, mass and time.

[1]

- (b). Fig. 17 shows two resistors **X** and **Y** connected in series.

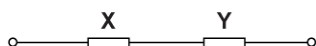


Fig. 17

The resistors are wires. Both wires have the same length L and diameter d . The material of **X** has resistivity ρ and the material of **Y** has resistivity 2ρ .

- i. Show that the total resistance R of the wires is given by the equation

$$R = \frac{12\rho L}{\pi d^2}.$$

[2]

4.3 Electrical Circuits

- ii. A student uses the equation in (i) to determine R .
The table below shows the data recorded by the student in her lab book.

Quantity	Value
ρ	$4.7 \times 10^{-7} \Omega\text{m}$
L	$9.5 \pm 0.1 \text{ cm}$
d	$0.270 \pm 0.003 \text{ mm}$

1. Name the likely instruments used by the student to measure L and d .

L :

d :

[1]

2. Use the data in the table and the equation in (i) to determine R and the absolute uncertainty.
Write your answer to the correct number of significant figures.

$R = \dots\dots\dots \pm \dots\dots\dots \Omega$ [4]

3. The instrument used to measure d has a zero-error. The measured d is much **larger** than the actual value.
Discuss how the actual value of R compares with the value calculated above.

[1]

73. Fig. 18.1 shows a circuit used by a student to determine the resistivity of the material of a wire.

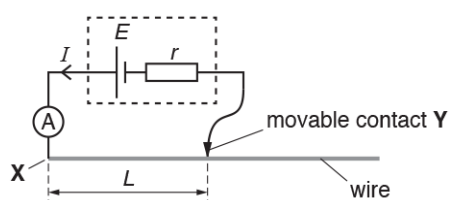


Fig. 18.1

The wire is uniform and has diameter 0.38 mm. The cell has electromotive force (e.m.f.) E and internal resistance r . The length of the wire between X and Y is L .

The student varies the length L and measures the current I in the circuit for each length.

Fig. 18.2 shows the data points plotted by the student.

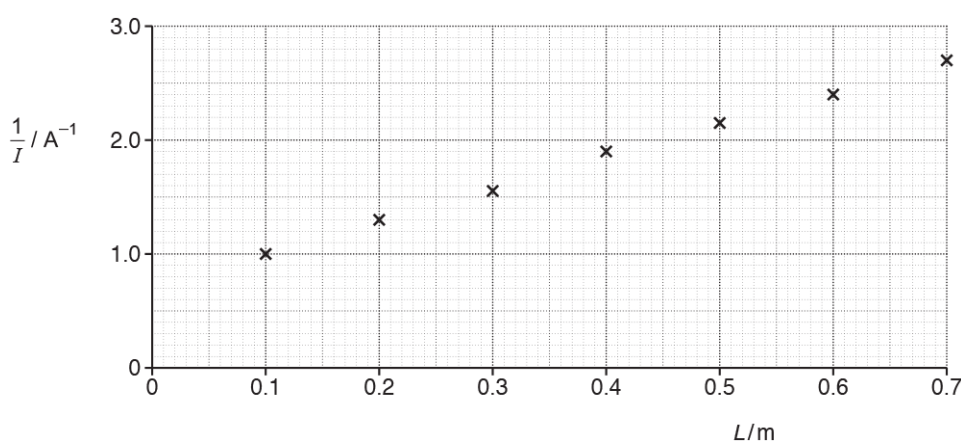


Fig. 18.2

- i. On Fig. 18.2 draw the straight line of best fit. Determine the gradient of this line.

gradient = $\text{A}^{-1} \text{m}^{-1}$ [2]

- ii. Show that the gradient of the line is $\frac{\rho}{AE}$, where ρ is the resistivity of the material of the wire, A is the area of cross-section of the wire and E is the e.m.f. of the cell.

[2]

- iii. The e.m.f. E of the cell is 1.5 V. The diameter of the wire is 0.38 mm.

Use your answer to (i) and the equation given in (ii) to determine ρ .

ρ = Ωm [2]

4.3 Electrical Circuits

- iv. Fig. 18.3 illustrates how the student had incorrectly measured all the lengths L of the wire.

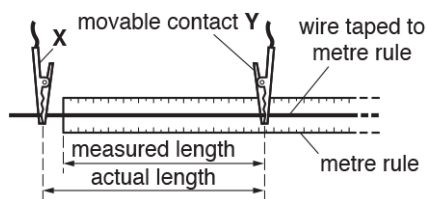


Fig. 18.3

According to the student, re-plotting the data points using the **actual** lengths of the wire will not affect the value of the resistivity obtained in (iii).

Explain why the student is correct.

[2]

74 (a). Fig. 4 shows a circuit with five identical $60\ \Omega$ resistors. The battery has electromotive force (e.m.f.) $9.0\ \text{V}$ and negligible internal resistance.

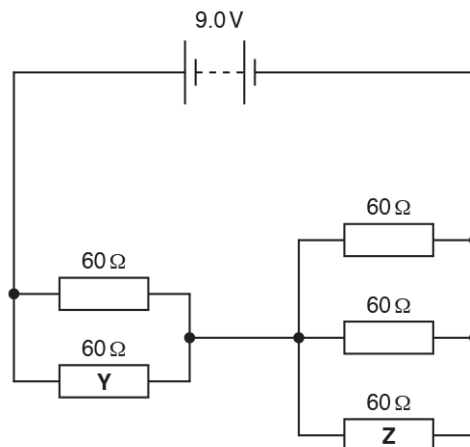


Fig. 4

- i. Show that the total resistance in the circuit is $50\ \Omega$.
Make your reasoning clear.

[2]

4.3 Electrical Circuits

- ii. Calculate the potential difference V across resistor **Y**.

$V = \dots\dots\dots$ V [2]

- iii. Calculate the charge Q passing through resistor **Y** in two minutes (include an appropriate unit).

$Q = \dots\dots\dots$ unit: $\dots\dots\dots$ [3]

- iv. Calculate the energy W dissipated in resistor **Y** in two minutes.

$W = \dots\dots\dots$ J [1]

(b). Explain how the mean drift velocity of electrons in resistor **Y** compares with the mean drift velocity of electrons in resistor **Z**.

.....

.....

.....

.....

.....

[3]

75. A filament lamp **X** is part of an electrical circuit. The circuit has a battery of electromotive force (e.m.f.) 6.0 V and negligible internal resistance. The potential difference across the lamp can be increased **continuously** from 0 to 6.0 V. This potential difference is measured using a voltmeter. The lamp glows brightly at 6.0 V.

- i. Draw a circuit diagram for this electrical arrangement.

[2]

4.3 Electrical Circuits

- ii. Describe and explain the variation of the resistance of this lamp as the potential difference across it is changed from 0 to 6.0 V.

[4]

- iii. The filament lamp **X** is now connected in a different circuit as shown in Fig. 16.

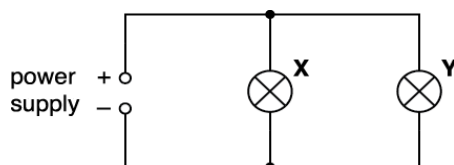


Fig. 16

The power dissipated in **X** is three times more than the power dissipated in the filament lamp **Y**. The filament wire of lamp **X** has a diameter half that of lamp **Y**. The filament wires of **X** and **Y** are made of the same material and are at the same temperature.

Calculate the ratio

$$\frac{\text{mean drift velocity of charge carriers in lamp X}}{\text{mean drift velocity of charge carriers in lamp Y}}$$

ratio = [3]

76. Fig. 16.1 shows the I - V characteristics of two electrical components **L** and **R**.

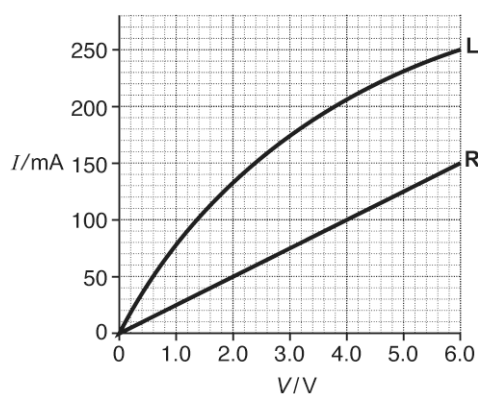


Fig. 16.1

The component **L** is a filament lamp and the component **R** is a resistor.

i. Show that the resistance of **R** is $40\ \Omega$.

ii. Fig. 16.2 shows the components **L** and **R** connected in series to a battery of e.m.f. 6.0 V .

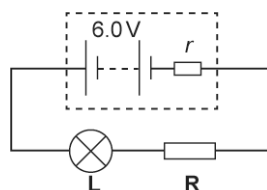


Fig. 16.2

The resistor **R** is a cylindrical rod of length 8.0 mm and cross-sectional area $2.4 \times 10^{-6}\text{ m}^2$. The current in the circuit is 100 mA .

1 Use Fig. 16.1 to determine the internal resistance r of the battery.

$r =$ Ω
[3]

- 2** Calculate the resistivity ρ of the material of the resistor **R**.

$$\rho = \quad \quad \quad \Omega \text{ m} \text{ [2]}$$

- 3** There are 6.5×10^{17} charge carriers within the volume of **R**.
Calculate the mean drift velocity v of the charge carriers within the resistor **R**.

$$v = \quad \quad \quad \text{m s}^{-1} \text{ [3]}$$

END OF QUESTION PAPER