TOPIC 18

D.C. Circuits

Objectives

Candidates should be able to:

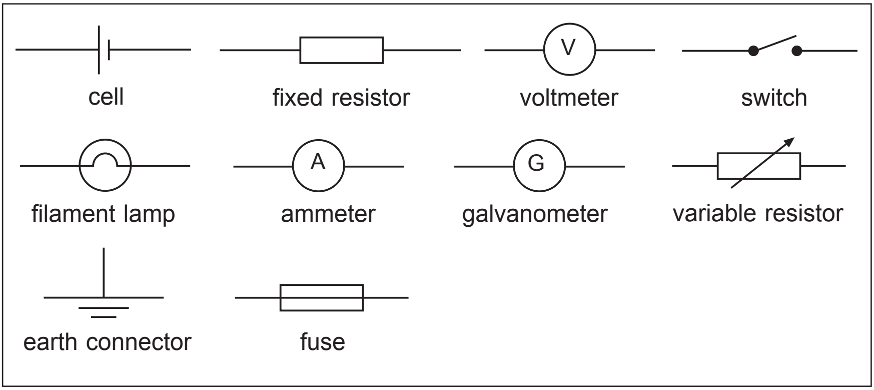
(a) draw circuit diagrams with power sources (cell, battery, d.c. supply or a.c. supply), switches, lamps, resistors (fixed and variable), variable potential divider (potentiometer), fuses, ammeters and voltmeters, bells, light-dependent resistors, thermistors and light-emitting diodes
(b) state that the current at every point in a series circuit is the same and apply the principle to new situations or to solve related problems
(c) state that the sum of the potential differences in a series circuit is equal to the potential difference across the whole circuit and apply the principle to new situations or to solve related problems
(d) state that the current from the source is the sum of the currents in the separate branches of a parallel circuit and apply the principle to new situations or to solve related problems
(e) state that the potential difference across the separate branches of a parallel circuit is the same and apply the principle to new situations or to solve related problems
(f) recall and apply the relevant relationships, including $R = V/I$ and those for current, potential differences and resistors in series and in parallel circuits, in calculations involving a whole circuit
(g) describe the action of a variable potential divider (potentiometer)
(h) describe the action of thermistors and light-dependent resistors and explain their use as input transducers in potential dividers
(i) solve simple circuit problems involving thermistors and light-dependent resistors

NOTES

18.1 Current and Potential Difference in Circuits

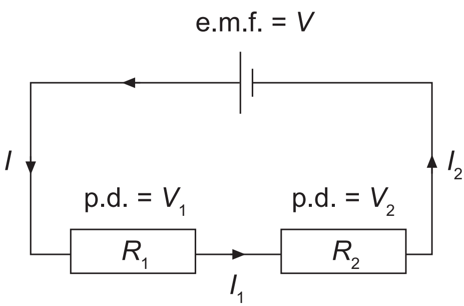
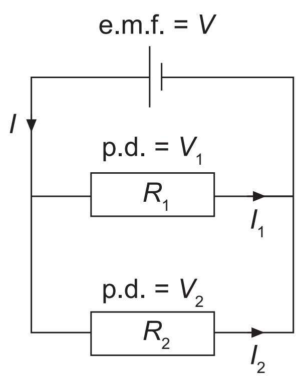
1. Current can only flow in a **closed** circuit.

2. The following table shows some of the electrical symbols used in circuit diagrams:

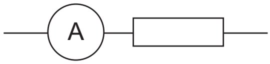
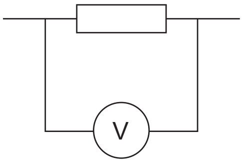


18.2 Series and Parallel Circuits

1. Comparison between a series circuit and a parallel circuit:

Series Circuit	Parallel Circuit
 • Only 1 path for current flow • The current is the same at all points in a series circuit. $I = I_1 = I_2$ • The potential difference across each resistor is different based on their resistance. • The sum of the potential differences across the resistors gives the e.m.f. of the cell. $V = V_1 + V_2$ • Effective resistance: $R_{eff} = R_1 + R_2$	 • There is more than 1 path for the current to flow. • Current: $I = I_1 + I_2$ • The potential difference across each resistor is the same and is equal to the e.m.f. of the cell. $V = V_1 = V_2$ Effective resistance: $\frac{1}{R_{elf}} = \frac{1}{R_1} + \frac{1}{R_2}$

2. Ammeter and Voltmeter

Component	Use	Characteristic
Ammeter	Measures the current flowing through resistor. To be connected in series. 	Very small resistance (so that the potential difference arоss it is negligible).
Voltmeter	Measures the potential difference across resistor. To be connected in parallel. 	Very high resistance (so that negligible amount of current will flow through it).

Example 18.1

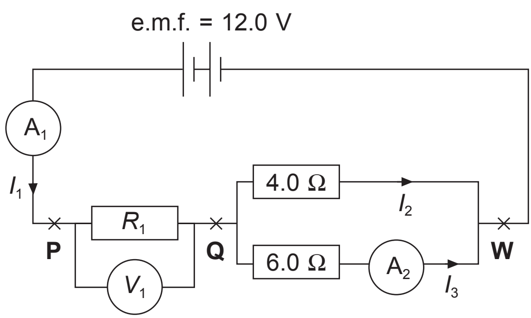
In the following circuit diagram, the effective resistance of the circuit is 5.4 Ω. Find:

(a) the resistance of R_1

(b) the reading of ammeter 1

(c) the voltmeter reading

(d) the reading of ammeter 2



Solution

(a) Effective resistance across **QW** = $\left(\frac{1}{4.0} + \frac{1}{6.0}\right)^{-1}$ = 2.4 Ω

Hence, R_1 = 5.4 – 2.4 = 3.0 Ω

(b) Let the current reading in A_1 be I_1:

Using Ohm's Law: $V = IR$

$12.0 = I_1(5.4)$

$I_1 = 2.222$ A

$= 2.22$ A (to 3 s.f.)

(c) Current through $R_1 = I_1 = 2.222$ A

Potential difference (p.d.) across $R_1 = V$

$V = I_1 R_1 = 2.222 \times 3.0$

(d) Let the current reading in A_2 be I_3:

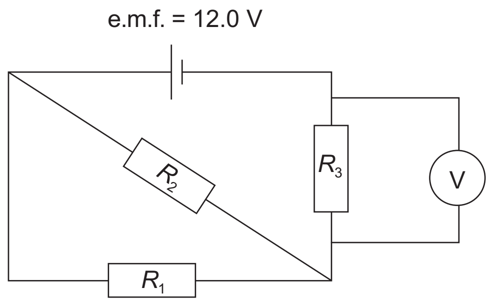
p.d. across **QW** = 12.0 – 6.67 = 5.33 V

$5.33 = I_3(6.0)$

$I_3 = 0.888$ A (to 3 s.f.)

Example 18.2

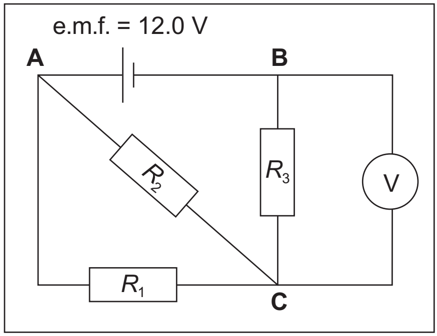
Three resistors are connected to a 12.0 V battery as shown in the circuit below:



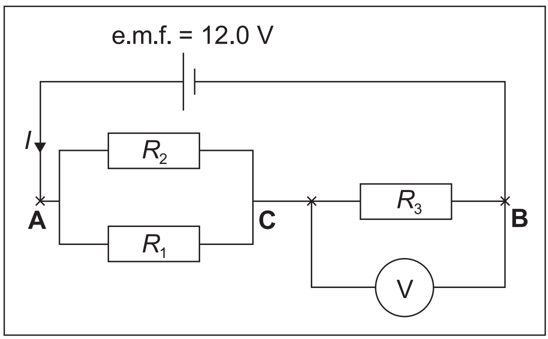
Given that $R_1 = 4.0\ \Omega$, $R_2 = 1.0\ \Omega$, $R_3 = 3.0\ \Omega$, find the voltmeter reading.

Solution

Let us add points **A**, **B**, **C** to the circuit diagram and redraw it.
Observe that R_1 and R_2 are parallel across points **A** and **C**:



Original



Redrawn

Effective resistance across **AC** = $\left(\frac{1}{4.0} + \frac{1}{1.0}\right)^{-1}$ = 0.8 Ω

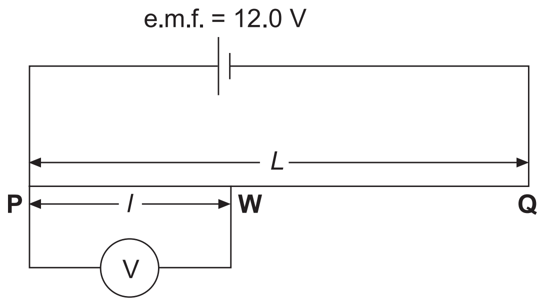
Effective resistance of the whole circuit = 0.8 + R_3 = 0.8 + 3.0 = 3.8 Ω
Let the current through whole circuit be I.
Using Ohm's Law,
12.0 = I × 3.8
I = 3.158 A (to 4 s.f.)
p.d. across R_3 = IR_3 = 3.158 × 3.0 = 9.47 V
Voltmeter reading = 9.47 V (to 3 s.f.)

18.3 Potential Divider Concept

1. Recall that resistance is directly proportional to length:

   $R = \dfrac{\rho l}{A}$.

2. Let us use a uniform wire *PQ* of length *L* to replace the box resistors for the circuit below:



Let the resistance of the wire **PQ** be $R_{PQ} = \dfrac{\rho l}{A}$ --------- Equation (1)

Take a point **W** which is the distance *l* from **P**:

$R_{PW} = \dfrac{\rho l}{A}$ --------- Equation (2)

From Equation (1), $\dfrac{\rho}{A} = \dfrac{R_{PQ}}{L}$. Substitute into Equation (2).

$$R_{PW} = \left(\frac{R_{PQ}}{L}\right) l = \left(\frac{l}{L}\right) R_{PQ}$$

$$\left(\frac{R_{PW}}{R_{PQ}}\right) = \left(\frac{l}{L}\right)$$

Current *I* through a series circuit is the same.

$$V_{PW} = IR_{PW} = \left(\frac{l}{L}\right) IR_{PQ}$$

Thus,

$$V_{PW} = \left(\frac{l}{L}\right) V$$

When $l = L$, $V_{PW} = V$,

which tells us that (i) as *l* decreases, V_{PW} also decreases,

(ii) as *l* increases, V_{PW} also increases,

(iii) $\dfrac{V_{PQ}}{L}$ = constant.

Example 18.3

The wire PQ used in the circuit below has a length of 3.0 m. The resistance of PQ is 4.0 Ω. Find l for the voltmeter to register a reading of 4.0 V.

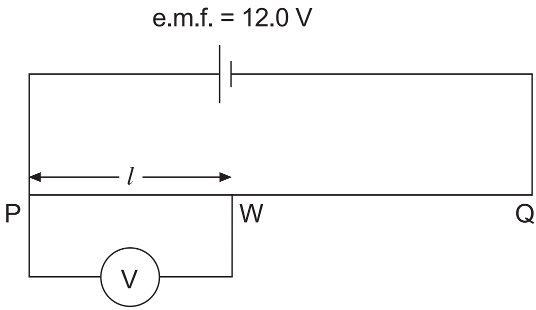
Solution

$$\frac{R_{PW}}{R_{PQ}} = \left(\frac{l}{L}\right)$$

$$\frac{R_{PW}}{R_{PQ}} = \frac{IR_{PW}}{IR_{PQ}} = \left(\frac{l}{L}\right)$$

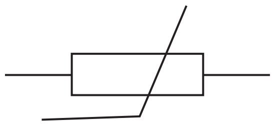
$$\frac{4.0}{12.0} = \left(\frac{l}{3.0}\right)$$

$$l = 1.0 \text{ m}$$



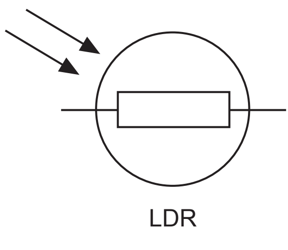
18.4 Thermistors and Light-Dependent Resistors (LDR)

1. A thermistor is a non-ohmic conductor. As it gets hotter, its resistance decreases. Thermistors are used for the control of temperature.



thermistor

2. An LDR is a semiconductor device (cadmium sulphide). Its resistance decreases as the intensity of light on it increases. LDRs are used in illumination control.



LDR