Current of Electricity

CHAPER 14

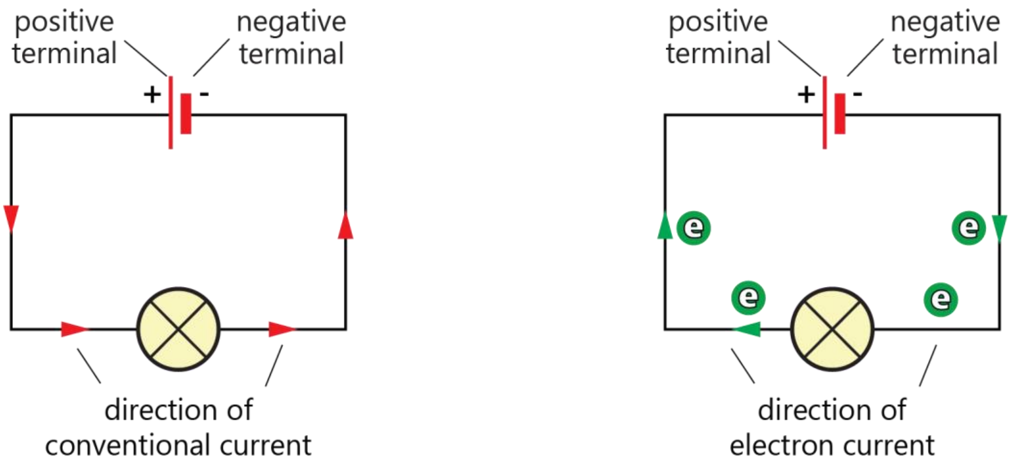
At the end of the lesson, I can…

1. **STATE** that current is a rate of flow of charge and that it is measured in amperes	
2. **DISTINGUISH** between conventional current and electron flow	
3. **RECALL** and **APPLY** the relationship *charge* = *current* × *time* to new situations or to solve related problems	
4. **STATE** that the electromotive force (e.m.f.) of an electrical source is the work done per unit charge by the source in driving charges around a complete circuit and that it is measured in volts	
5. **STATE** that the electromotive force (e.m.f.) of a source is the work done per unit charge by the source in driving charges around a complete circuit and that it is measured in volts	
6. **CALCULATE** the total e.m.f. where several sources are arranged in series	
7. **STATE** that the potential difference (p.d.) across a component in a circuit is the work done per unit charge in driving charges through the component and that it is measured in volts	
8. **STATE** that *resistance* = *p.d.* / *current*	
9. **APPLY** the relationship $R = V/I$ to new situations or to solve related problems	
10. **RECALL** and **APPLY** the relationship of the proportionality between resistance and the length and cross-sectional area of a wire to new situations or to solve related problems	
11. **DESCRIBE** the effect of temperature increase on the resistance of a metallic conductor	
12. **SKETCH** and **INTERPRET** the I/V characteristic graphs for a metallic conductor at constant temperature (ohmic conductor), for a filament lamp and for a semiconductor diode	

1. Electric Current and Charges

1.1 An electron current flows when electrons move through a conductor, such as a metal wire. Electrons flows from the positive terminal of a battery to its negative terminal.

1.2 Conventional current assumes that current flows out of the positive terminal of a source (e.g., battery), through the circuit and into the negative terminal of the source.



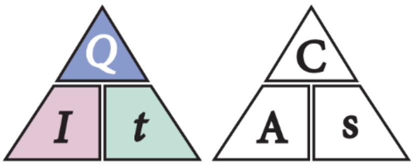
1.3 ***Unless otherwise stated, the term "electric current" means "conventional current", and directions indicated by the arrows in any circuit diagrams are that of convectional current.***

1.4 An ***electric current*** is the rate of flow of charges. DEFN

Symbols and units for current and charges:

quantity	current	charges	time
symbol	I	Q	t
unit	A	C	s
name of unit	ampere	coulomb	second

$$I = \frac{Q}{t} \text{ or } Q = It$$



1.5 One coulomb is the amount of charges passing any point in a circuit when a steady current of one ampere flows for one second.

QUESTION: When the starter motor of a car is switched on for 0.5 s, 16 C of charge passes through the wires in the motor. How large is the electric current?

$I = Q/t = 16/0.5 = 32$ A

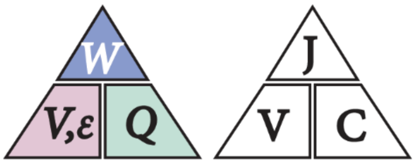
2. Electromotive Force and Potential Difference

2.1 ***Electromotive force (emf)*** of a power source (e.g., battery) is the work done by the source in driving a unit charge around a complete circuit. In this process, non-electrical energy is converted to electrical energy.

2.2 ***Potential difference (pd)*** across an electrical component (e.g., resistor) is the work done in driving a unit charge through the component. In this process, electrical energy is converted to non-electrical energy.

quantity	work done	charges	emf	pd
symbol	W, WD	Q	ε	V
unit	J	C	V	V
name of unit	joule	coulomb	volt	volt

emf, $\varepsilon = \dfrac{W}{Q}$ and pd, $V = \dfrac{W}{Q}$



QUESTION: A battery is labelled as "1.5 V". **(a)** Is the "1.5 V" stand for emf or pd? **(b)** What is the amount of electrical energy produced by the cell when 0.4 C of charge flow through it? **(c)** How many joules of energy is converted when a current of 2 A flows through it for 10 s?

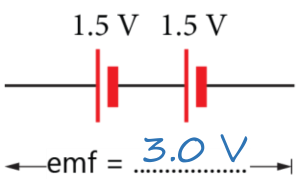
(a) emf

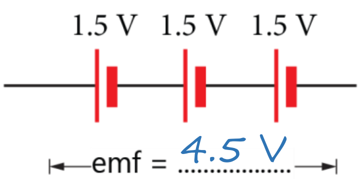
(b) $V = W/Q$; $W = 1.5 \times 0.4 = 6.0$ J

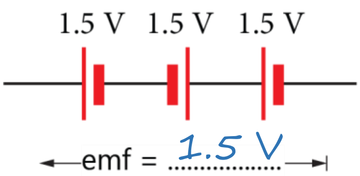
(c) $Q = It = 2 \times 0.4 = 0.80$ C

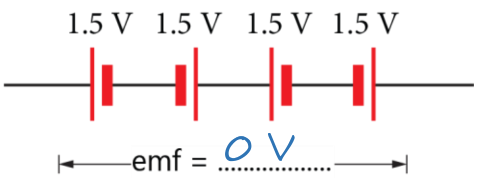
$W = 1.5 \times 0.8 = 1.2$ J

2.3 When more than one cell is connected in series, the total emf depends on how the cells are arranged.





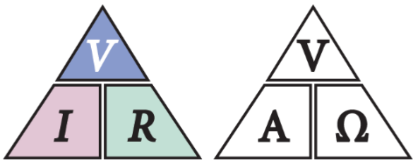




3. Resistors and Resistance

3.1 ***Resistance*** of an electrical component is the ratio of the potential different across it to the current flowing through it.

$$\boxed{\text{resistance, } R = \frac{V}{I}}$$



quantity	current	potential difference	resistance
symbol	I	V	R
unit	A	V	Ω
unit (name)	ampere	volt	ohm

QUESTION: A potential difference of 240 V applied across the heating coil of an electric kettle drives a current of 8 A through the coil. Calculate **(a)** the resistance of the coil, and **(b)** the current flowing through the coil if the p.d. applied is changed to 110 V.

(a) R = V/I = 240/8 = 30 Ω
(b) I = 110/30 = 3.7 A

3.2 ***Resistors*** are conductors in electrical circuits with known resistance. They are designed to control the currents in a circuit.

3.2 There are two types of resistors: fixed resistors and variable resistors with symbols:

fixed resistor   variable resistor

5. Factors Affecting Resistance

5.1 ***Temperature.*** When the wire is heated up, the positive ions in the conducting wire vibrate more vigorously because of increase in energy. This causes more collisions between the electrons and the particles and increases resistance.

5.2 ***Material.*** The more tightly an atom holds on to its outermost electrons the harder it is for the current flow.

5.3 ***Length.*** In longer wires, electrons must travel longer distances and will have more collisions. Resistance of a wire is directly proportional to its length.

5.4 ***Cross-sectional Area.*** With larger cross-sectional area, there is more space for the electrons to travel through and so fewer collisions. Resistance of a wire is inversely proportional to its cross-sectional area.

Simulation of factors affecting resistance

5.5 Combining the factors of length and cross-sectional area, the resistance of a wire R:

$$\boxed{R \propto \frac{L}{A}}$$

QUESTION: A wire has a resistance of 7.5 Ω. what is its resistance when **(a)** its length is halved? **(b)** cross-sectional area is doubled? **(c)** length is halved, and cross-sectional area is doubled?

(a) $7.5/2 = 3.8\ \Omega$
(b) $7.5/2 = 3.8\ \Omega$
(c) $7.5/(2 \times 2) = 1.9\ \Omega$

6. Ohm's Law

6.1 ***Ohm's Law*** states that the ratio of the potential difference across a conductor to the current flowing in it is always a constant, provided its physical conditions, such as temperature, remain unchanged.

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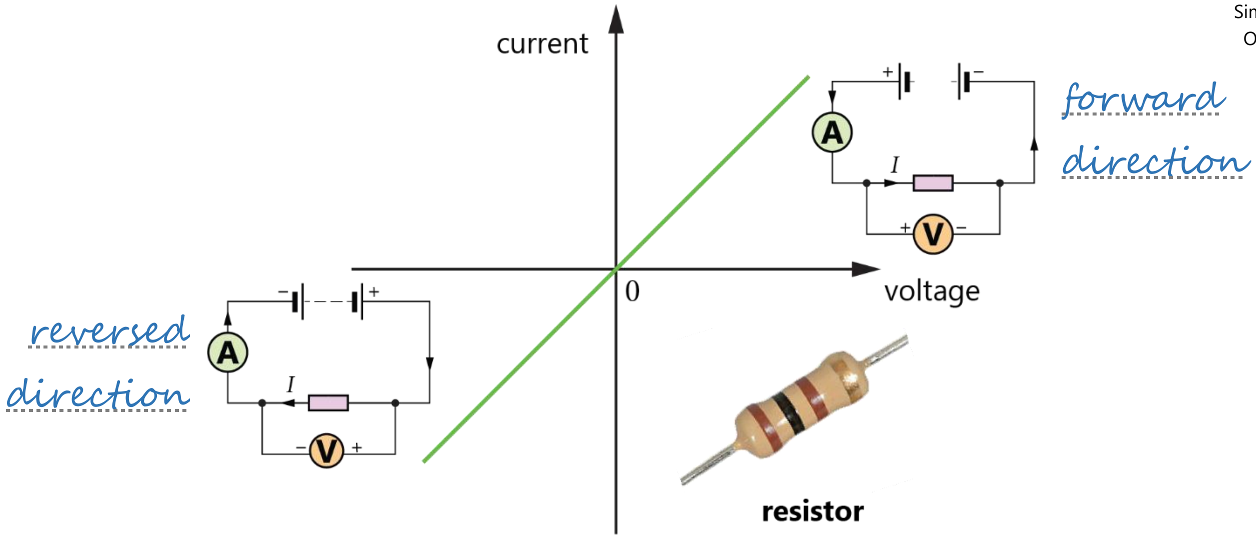
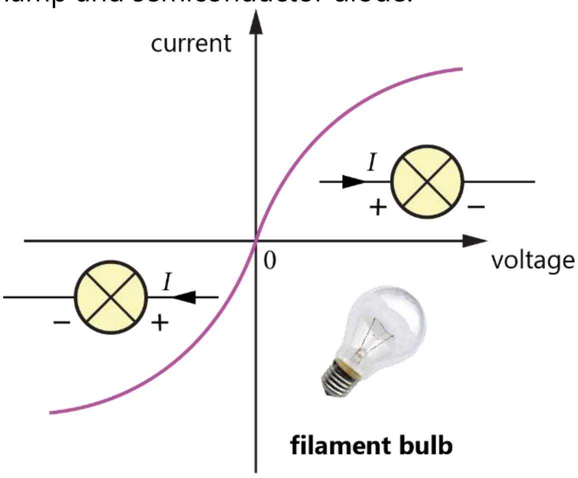
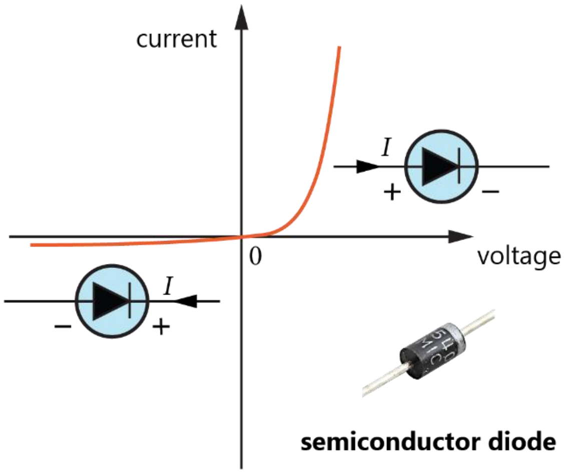
6.2 ***Ohmic conductors*** are conductors which obey Ohm's Law. The I-V characteristic graph of an ohmic conductor is a straight line passing through the origin. The resistance of an ohmic conductor is a constant.

Simulation of Ohm's Law

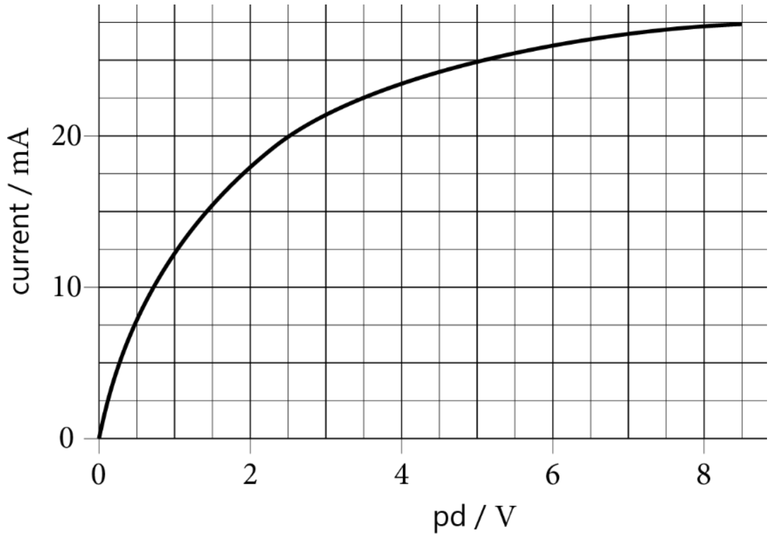


6.3 ***Non-ohmic conductors*** are conductors which do not obey Ohm's Law, e.g., filament lamp and semiconductor diode.





6.4 ***Resistance of a non-ohmic conductor.*** From the ***I-V*** **characteristics graph** of a non-ohmic conductor,



resistance at a point (I, V) on the graph is $R = \frac{V}{I} = \frac{V - 0}{I - 0}$, which is the gradient of the reciprocal of the line joining (0, 0) and (I, V). Since this gradient decreases as pd increases, the resistance of the this resistor increases.

QUESTION: The graph shows how the currents in a lamp **L** and in a wire **W** vary with the potential difference (p.d.) applied. Find the resistance of **L** and **W** when the potential difference across them is **(a)** 5.0 V, and **(b)** 10 V.

(a) L: R = 5.0/1.5 = 3.3 Ω
W: R = 5.0/0.35 = 14 Ω

(b) L: R = 10/1.95 = 5.1 Ω
W: R = 10/0.35 = 14 Ω