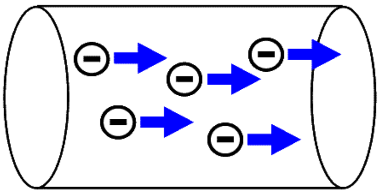
CHAPTER 7: ELECTRICITY

7.1 Electric Field and Charge Flow

7.1.1 Electric Current



Electric current is *the rate of flow of charge*.

$$I = \frac{Q}{t}$$

where I = electric current [Ampere, A]

Q = charge [Coulomb, C]

t = time [seconds, s]

$$Q = ne$$

where Q = total charge [C]

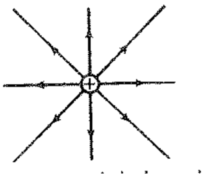
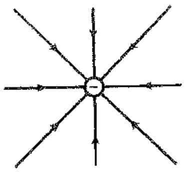
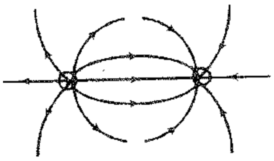
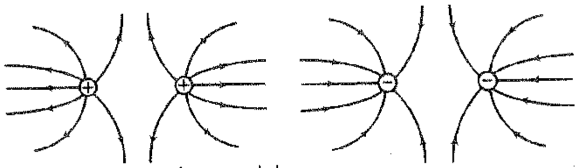
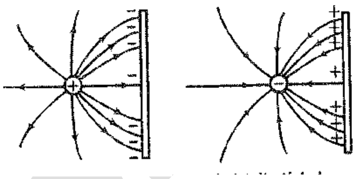
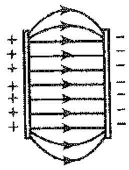
n = number of electrons

e = charge of an electron (1.6×10^{-19} C)

7.1.2 Electric Field

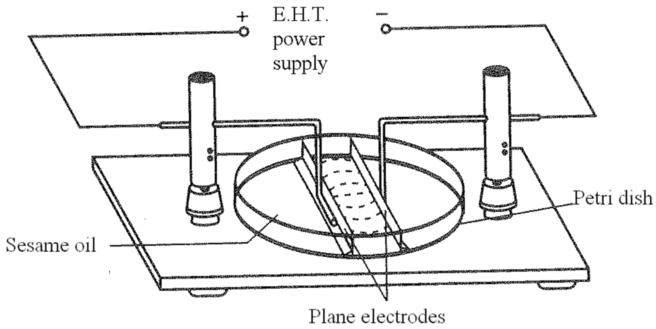
An **electric field** is *the region which an electric charge experiences a force*.

Same charges *repel* whereas opposite charges *attract*.

 *Positive charge*	 *Negative charge*
 *Two opposite charges*	 *Two same charges*
 *Two non-uniform fields*	 *Two uniform fields*

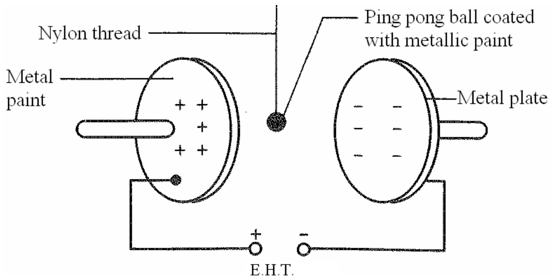
7.1.3 Effect of an Electric Field

A) Observing Pattern of Electric Fields



- When the power supply is turned on, the lycopodium powder will map the electrical field lines.
- Oil is used because it is *a poor conductor of electricity*.
- Water cannot be used because it is a good conductor of electricity. The electrical field will not exist between the two electrodes.

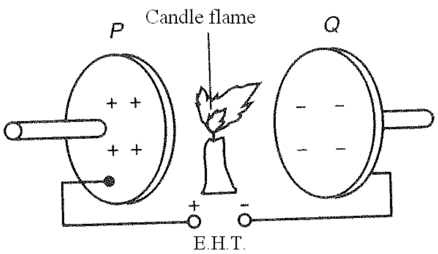
B) Observing Effect of Electric Fields on a Metallic Ball



- A ping pong ball coated with metallic point is placed centrally between two metallic plates connected to a very high voltage source.The ball is suspended with nylon string which is an electrical insulator.
- When the power supply is turned on, the ball will not move as it is initially **neutral**. The attractive forces on both sides of the ball are equal.
- When the ball is pushed to one of the plates, the ball will **oscillate** between the plates until the power supply is turned off.
  - At the **negative** plate, the electrons will move from the plate to the ball. The ball will repel and be attracted to the positive plate.
  - At the **positive** plate, the electrons will move from the ball to the plate. The ball will repel and be attracted to the negative plate.

The frequency of oscillation increases if:
- the distance between the two plates is decreased.
- the voltage of the EHT power supply is increased.

C) Observing Effect of Electric Fields on a Candle Flame



- A candle is placed centrally between two metallic plates connected to a high voltage power source.
- The candle flame splits into two and is biased towards the negative plate.
- This is because the mass of the positive charges is greater than the mass of the negative charges. The positive charges are attracted to the negative plate while the negative charges are attracted to the positive plate.

7.2 Relationship Between Current and Potential Difference

7.2.1 Potential Difference

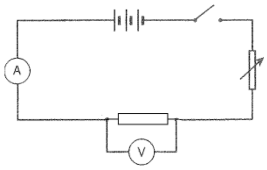
The **potential difference** between two points is *the work done to move 1 C of charge from one point to another in a circuit*.

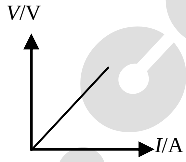
$$V = \frac{W}{Q}$$

where V = potential difference [V]
W = work done [J]
Q = charge [C]

7.2.2 Relationship Between Current and Potential Difference

Ohm's Law states that *the current flowing through an ohmic conductor* is directly proportional to the potential difference across its ends, provided that its temperature and all other physical conditions remain constant*.

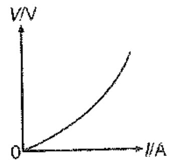




** Ohmic conductors are conductors which obey Ohm's Law*

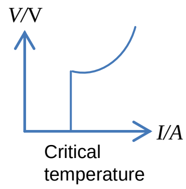
<u>**Non-ohmic conductors**</u>

- Non-ohmic conductors are conductors which do not obey Ohm's Law.
- E.g., a light bulb whose resistance increases over time due to temperature increase (heating effect of current)



<u>**Superconductors**</u>

Superconductors are conductors which the resistance drops to zero below critical temperature.



7.2.3 Resistance

Resistance is the *ratio of potential difference to current*.

$$R = \frac{V}{I}$$

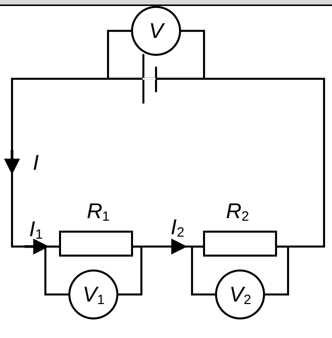
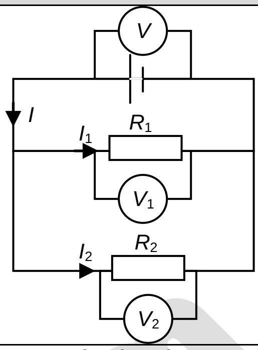
$$V = IR$$

where V = potential difference [V]
I = electric current [A]
R = resistance[Ω]

7.2.4 Factors Which Affect Resistance

Factor:	Influence
1. Length of conductor	Length ↑ Resistance ↑
2. Diameter / Cross-section area of conductor	Cross-section ↑ Resistance ↓
3. Temperature of conductor	Temperature ↑ Resistance ↑
4. Material of conductor	Depends on material

7.3 Series and Parallel Circuits

	Series	Parallel
Circuit		
Current	$I = I_1 = I_2$	$I = I_1 + I_2$
Potential difference	$V = V_1 + V_2$	$V = V_1 = V_2$
Total Effective Resistance	$R = R_1 + R_2$	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

7.4 Electromotive Force and Internal Resistance

7.4.1 Electromotive force and Potential difference

Electromotive force is *the work done by a source in moving a unit charge across a complete circuit*.

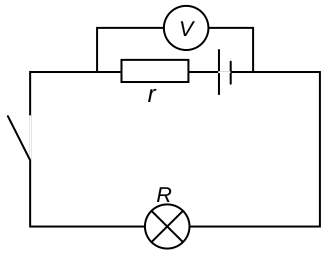
Note: Think of electromotive force as the ***total voltage supplied by the source****.*

7.4.2 Internal resistance

Internal resistance of a source or cell is *the resistance against a moving charge due to the electrolyte*.

Note: Think of internal resistance as the resistance inside the power source.

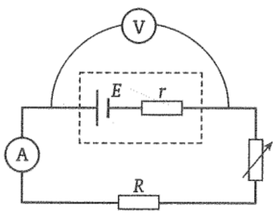
Understanding electromotive force and internal resistance:



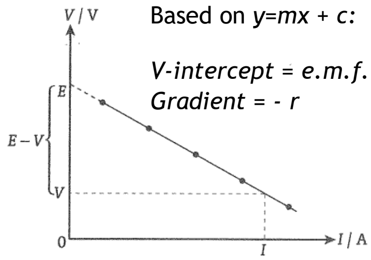
- Before the switch is turned on
  - The battery does not supply current to the light bulb
  - Voltmeter reading = E.m.f. of battery
- After the switch is turned on
  - The battery supplies current which flows around the circuit
  - Voltmeter measures the potential difference across the terminals of the battery
  - The voltmeter reading drops due to **internal resistance** of the battery

$$emf = IR + Ir$$
$$emf = V + Ir$$
$$emf = I(R + r)$$

where	emf	= electromotive force	[V]
	I	= current	[A]
	R	= external resistance	[Ω]
	r	= internal resistance	[Ω]
	V	= terminal potential difference	[V]



Circuit setup



Based on *y=mx + c:*

V-intercept = e.m.f.
Gradient = - r

7.5 Electric Energy and Power

7.5.1 Electric power

Electrical energy is *the energy carried by electrical charges which can be transformed to other forms of energy by the operation of an electrical appliance.*

Electric power is *the rate of electrical energy consumption*.

$$P = \frac{E}{t}$$

$$P = IV$$

where P = power [Watt, W]
E = energy [Joule, J]
t = time [seconds, s]
I= current [Ampere, A]
V= potential difference [Volt, V]

From $P = IV$ and $V = IR$,

$$P = I^2R$$

Usually used to calculate power loss

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

7.5.2 Power Rating Electrical Appliances

- Electrical appliances are usually labeled by its voltage and power rating
  - Voltage – required potential difference to operate the appliance
  - Power rating – power used by the appliance when the correct voltage is supplied
- For example:
  - A light bulb labeled 12 V, 36 W:When connected to a 12 V voltage source, the light bulb will use 36 W of power. It will shine with **normal brightness**.
  - A heater labeled 240 V, 1 500 W: When connected to a 240 V voltage source, the heater will use 1 500 W of power.

7.5.3 Energy Consumption and Cost of using electricity

$$\text{Energy consumed} = \text{Power rating} \times \text{Time}$$

$$\text{Total cost} = \text{Units} \times \text{Cost per unit}$$

where 1 unit = 1 kW-hour = 1 kW × 1 hour

Example:
Air conditioner with a power rating of 1 500 W is used for 20 hours. Cost per unit is RM0.20.

Number of units = 1.5 kW × 20 hours = 30 kW-hours
Total cost = 30 × RM0.20 = **RM6.00**

7.5.4 Efficiency

$$\text{Efficiency} = \frac{\text{Output power}}{\text{Input power}} \times 100\%$$

END OF CHAPTER