Electric Charge

- The concept of electric charge is the physical basis for describing electrical phenomena.
- Charge is represented by the symbol \( q \). It is measured in coulombs (C).
- Charge is either positive or negative. Like charges repel, unlike charges attract:

Current

- The symbol used for current is \( i \) or \( i(t) \).
- Current is a measure of the flow of electric charge over time. It is defined as \( i = dq/dt \).
- The units of current are amperes (A).
- \( 1 \text{A} = 1 \text{C/s} \) (1 ampere = 1 coulomb/second). Since \( 1/(1.602\times10^{-19}) = 6.24\times10^{18} \), \( 1 \text{A} \) corresponds to the flow of 6.24 exa (\( 10^{18} \)) electrons per second!

Current

- Since charge can be positive or negative, current can be positive or negative.
- By convention, the direction of current is the direction of the net flow of positive charge. This is called conventional current.
- The flow of negative charge (electrons) in the opposite direction is called electronic current.

Energy

- Moving charge from a point A to a point B in a circuit requires energy.
- Energy is represented by the symbol \( w \). It is measured in joules (J).
- Conservation Law: Energy can neither be created nor destroyed, but it can be converted from one form to another, e.g., from electrical energy to heat.
Voltage

- Measuring energy directly is not convenient.
- In engineering the related signal variable voltage, denoted by v, is used.
- The voltage between two points A and B is defined as \( v_{AB} = v = \frac{dw}{dq} \), i.e., it is the change in energy per unit charge as a charge passes through a circuit from point A to point B.
- The units of voltage are volts (V). 1V = 1J/C.

- Voltage is independent of the exact path the charge takes from A to B.
- Example: Same \( v_{AB} \) through E2, or E3, or E1 and E4, or E1 and E5.

- Voltage can also be thought of as a measure of how much energy would be involved if a charge was moved from A to B.
- Thus, there can be a voltage between two points even if no charge is moved, in the same way that a ball at the top of a hill can have potential energy as opposed to kinetic energy when it rolls down the hill.

Power

- Power \( p \), measured in watts (W), is the time rate of change of energy: \( p = \frac{dw}{dt} \). 1W = 1J/s.
- Power is related to current and voltage through \( p = \frac{dw}{dt} = \frac{dw}{dq} \times \frac{dq}{dt} = \mathbf{v} \cdot \mathbf{i} \).

- Example: A microwave oven is rated 1 kW at 120 V. How many can run on a 15 A circuit?
- Ans: \( i = 8.33 \) A => Only one can run at a time.

Hydraulic Analogy

- Fluid flow systems and electrical circuits are analogous.
- Current \( \Leftrightarrow \) Flow rate of fluid through a pipe
- Voltage \( \Leftrightarrow \) Pressure difference between 2 points
- Charge \( \Leftrightarrow \) Quantity of fluid
- Conductor \( \Leftrightarrow \) Pipe through which fluid flows
- Battery \( \Leftrightarrow \) Pump