Generation of Electricity

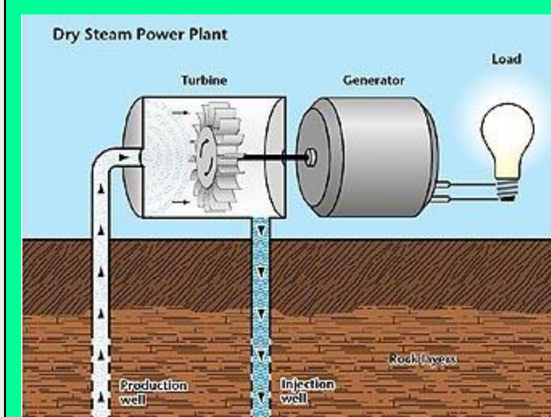
- How is electricity generated?
- Three types of materials
- How does an electric field look?
- Electric energy potential
- Electric potential & current
- Right hand rule
- Electromotive force emf
- Electric motors
- Principle of electric generator
- How is mechanical energy produced?

HOW IS ELECTRICITY GENERATED?

Electricity is generated in several ways:

- **Chemical** energy to electric energy – battery, fuel cell
- **Solar** energy to electric energy – photovoltaic cell
- **Mechanical** energy to electric energy – using an electric generator driven by a turbine or engine

When a **moving magnetic field** cuts a **conductor**, it generates an **emf** or **voltage** in the conductor. The magnetic field can be created by a **permanent magnet** or by an **electromagnet**.



THREE TYPES OF MATERIALS

- Most objects are **electrically neutral** – they have equal amounts of positive and negative charges.

- Materials are divided into 3 categories:

  * **conductors** – metal

  * **semi-conductors** – silicon

  * **insulators** – rubber, wood, plastic

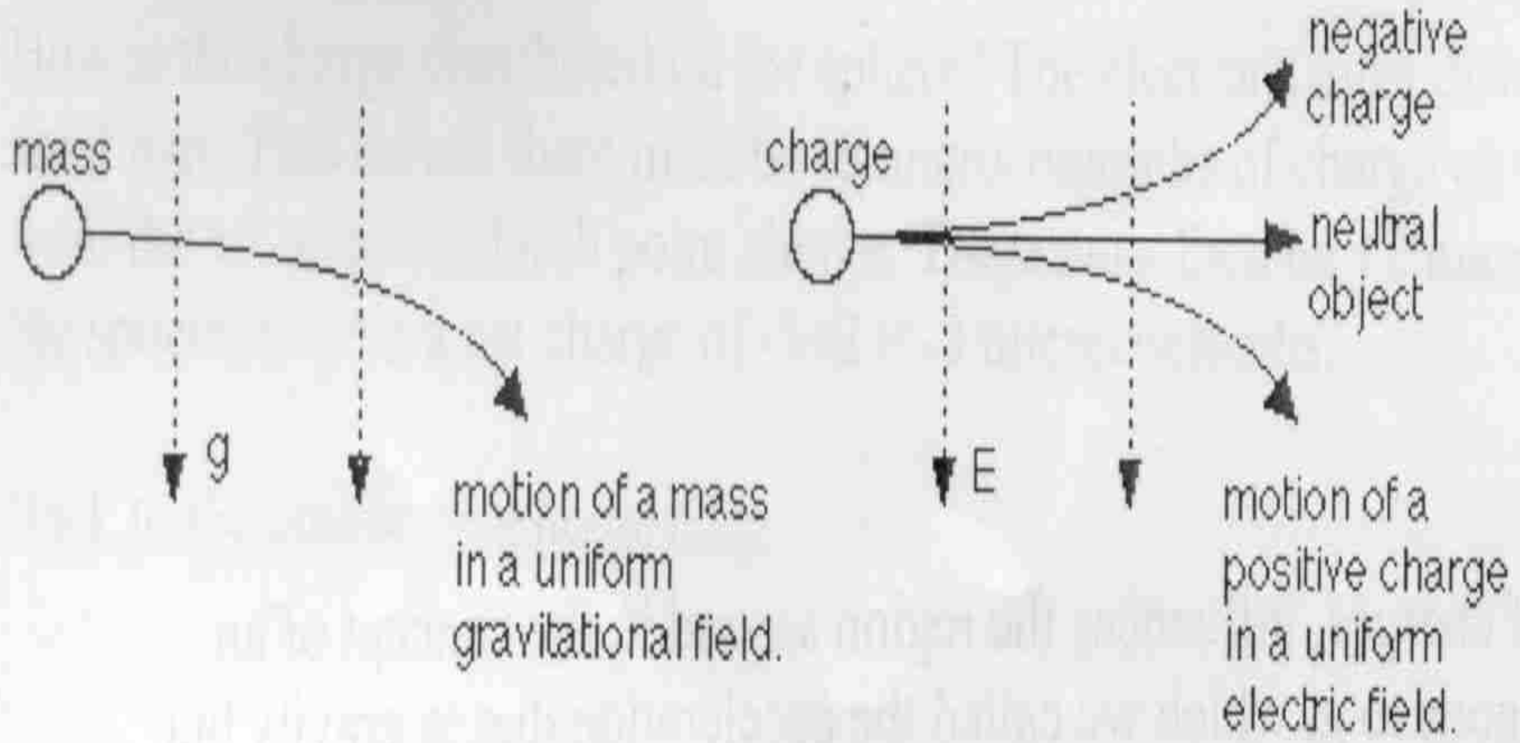
- **Conductors -** the outermost electrons in the atoms are so loosely bound to their atoms and are free to travel around

- **Insulators -** electrons are much more tightly bound to the atoms

- **Semi-conductors -** by adding impurities, the conductivity can be well-controlled

HOW DOES AN ELECTRIC FIELD LOOK?

A uniform electric field is similar to a uniform gravitational field. It affects a charge in the same way as a mass on earth.



ELECTRIC ENERGY AND POTENTIAL

- An object near the earth's surface has **potential energy** because of its gravitational interaction with the earth. Similarly, an **electric potential energy** associated with interacting charges is

$$\mathbf{PE = k\,q\,Q / r}$$

- A charge in a uniform electric field has an electric potential energy similar to gravitational PE:

PE = q E d where **d** is the distance moved **along** the direction of the field

PE = m g h where **h** is the height

- Work done to change the kinetic and potential energy:

$$\mathbf{W = \Delta(KE) + \Delta(PE)} \text{ where } \mathbf{KE = \tfrac{1}{2}\, m\, V^2}$$

ELECTRIC POTENTIAL AND CURRENT

- Electric potential is commonly known as voltage. The **voltage** at a point of distance **r** from charge **Q** is

$$V = k\,Q / r.$$

- Voltage plays the same role for charge that **pressure** does for fluids. If there is a pressure difference between two ends of a pipe filled with fluid, the fluid will flow from the high pressure end towards the lower pressure end.

- **Voltage** is a measure of the potential energy per unit charge:

$$V = PE / q.$$

- **Current** is the flow of charge per unit time; measured in **Amperes** (A) = **Coulombs** (C) per **second** (s).

ELECTRIC ANALOGY

- **Voltage, V** - **Pressure**
- **Current, I [coulombs/sec]** - **Flow [liters/sec]**
- **Resistance, R** - **Pipe wall resistance**

$$V = I\ R$$

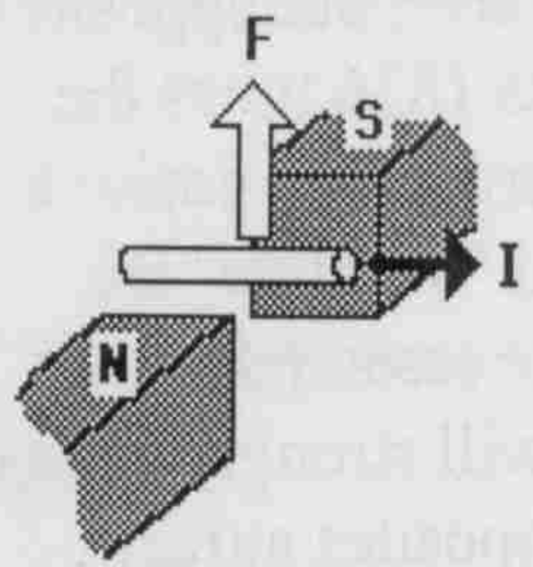
or $$I = V / R$$

- More current will flow if the driving potential is high and the resistance to flow is low.

RIGHT HAND RULE #1

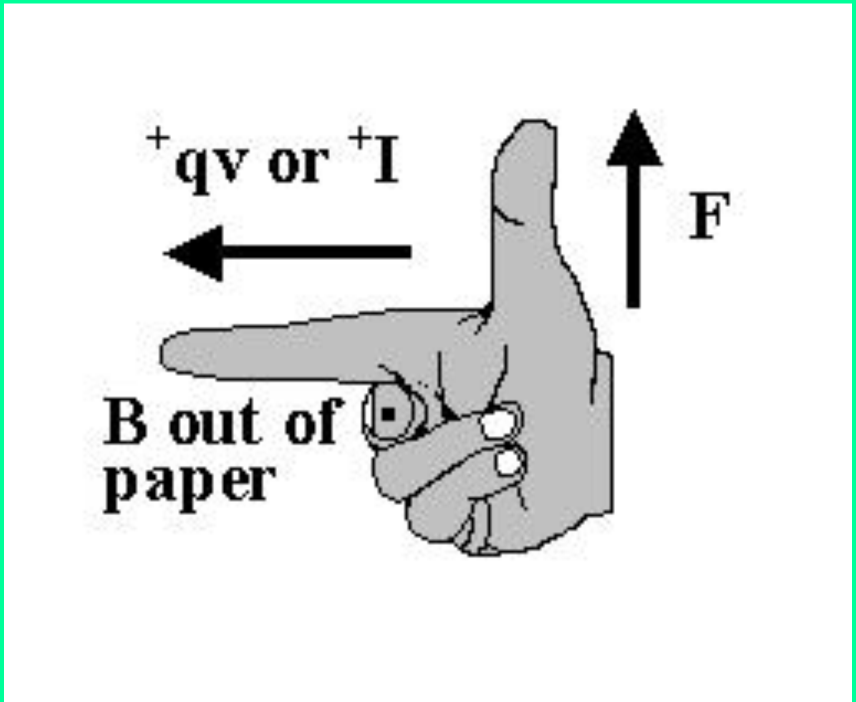
Using your right-hand:

- Point your index finger in the direction of the charge's velocity, **I**
- Point your middle finger in the direction of the magnetic field, **B** (N to S)
- Your thumb now points in the direction of the magnetic force, **F**



Force on current in a magnetic field

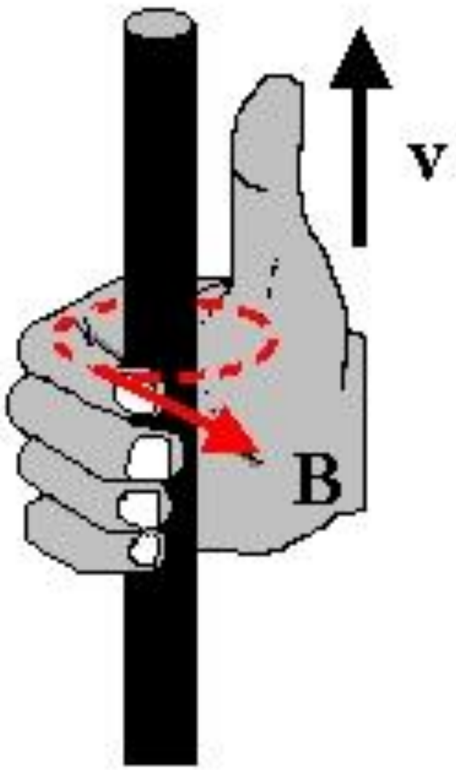
RIGHT HAND RULE #1



- Magnetic field **B** will also exert a force **F** on a charge **q**, but only if the charge is moving as a current **I**.
- **F = q v B sin(θ)**

where θ is the angle between the magnetic field and the velocity of the charge **I**.

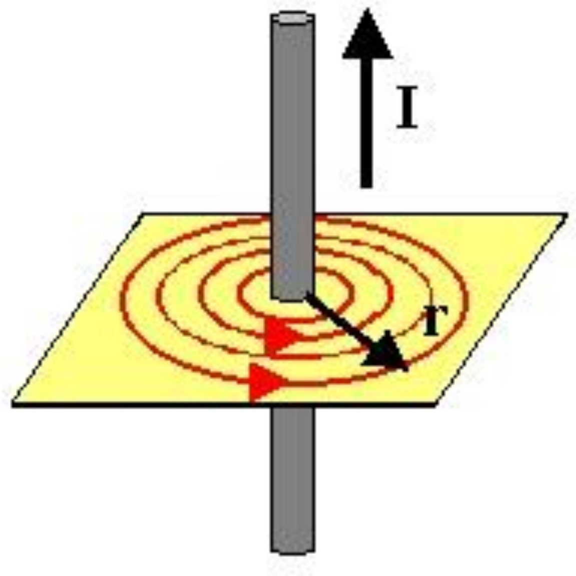
RIGHT HAND RULE #2



Using your right-hand:

- Curl your fingers into a half-circle around the wire, they point in the direction of the magnetic field, B
- Point your thumb in the direction of the conventional current

RIGHT HAND RULE #2



For a long, straight wire, the magnetic field, B is:

$$B = \mu_o I / 2 \pi r \quad T$$

Where

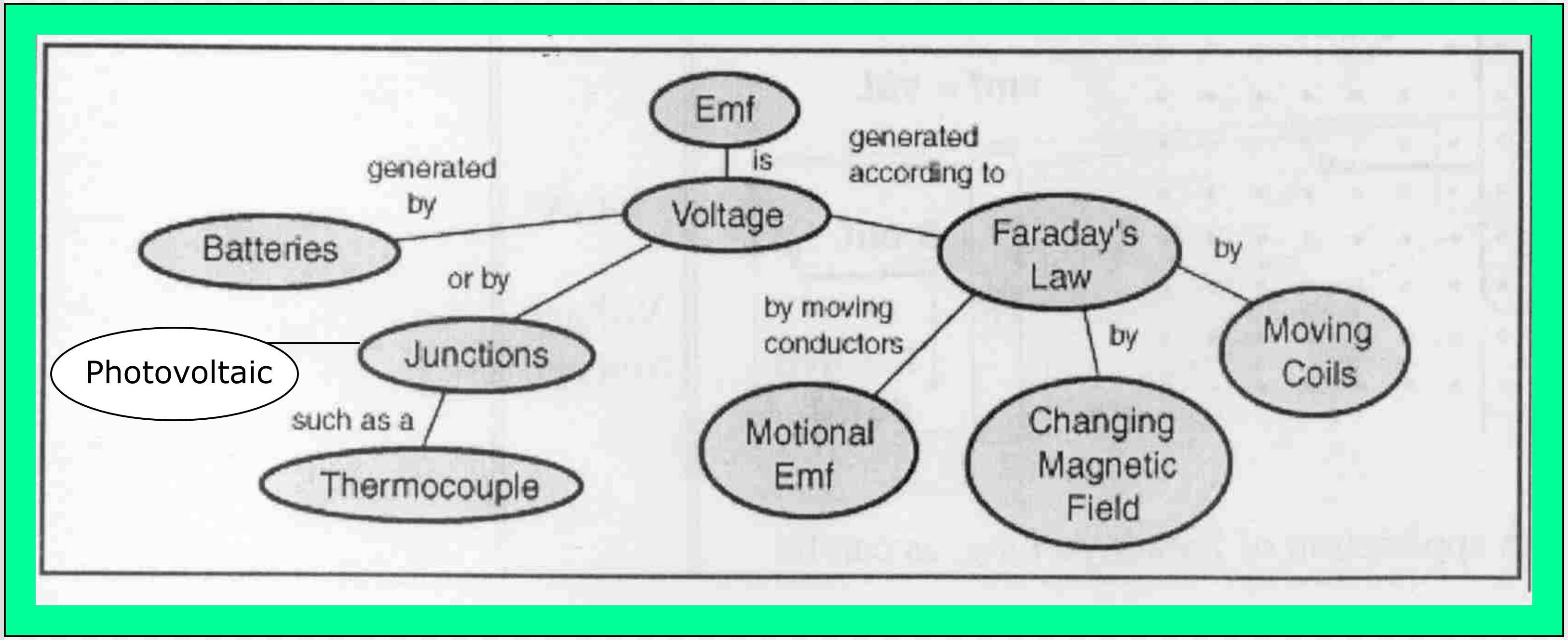
$$\mu_o = 4 \pi 10^{-7} \quad Tm/A$$

r = the radial distance from the wire, m

I = current, A

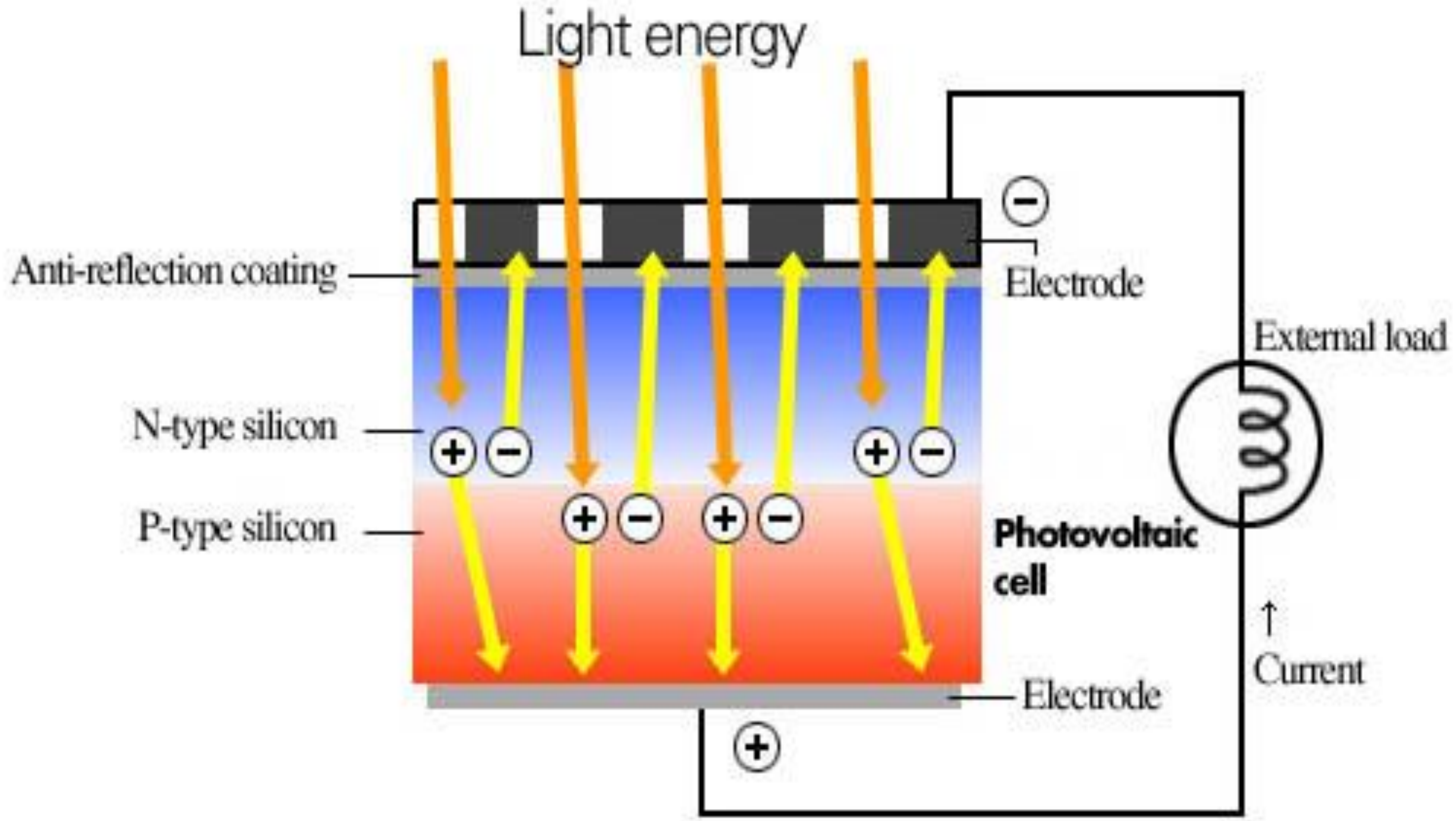
ELECTROMOTIVE FORCE emf

The **emf** is **voltage** generated by batteries, junctions or according to **Faraday's Law** by moving coils, changing magnetic fields or moving conductors. Junctions of dissimilar materials would also generate voltage thru thermocouples and photovoltaics.

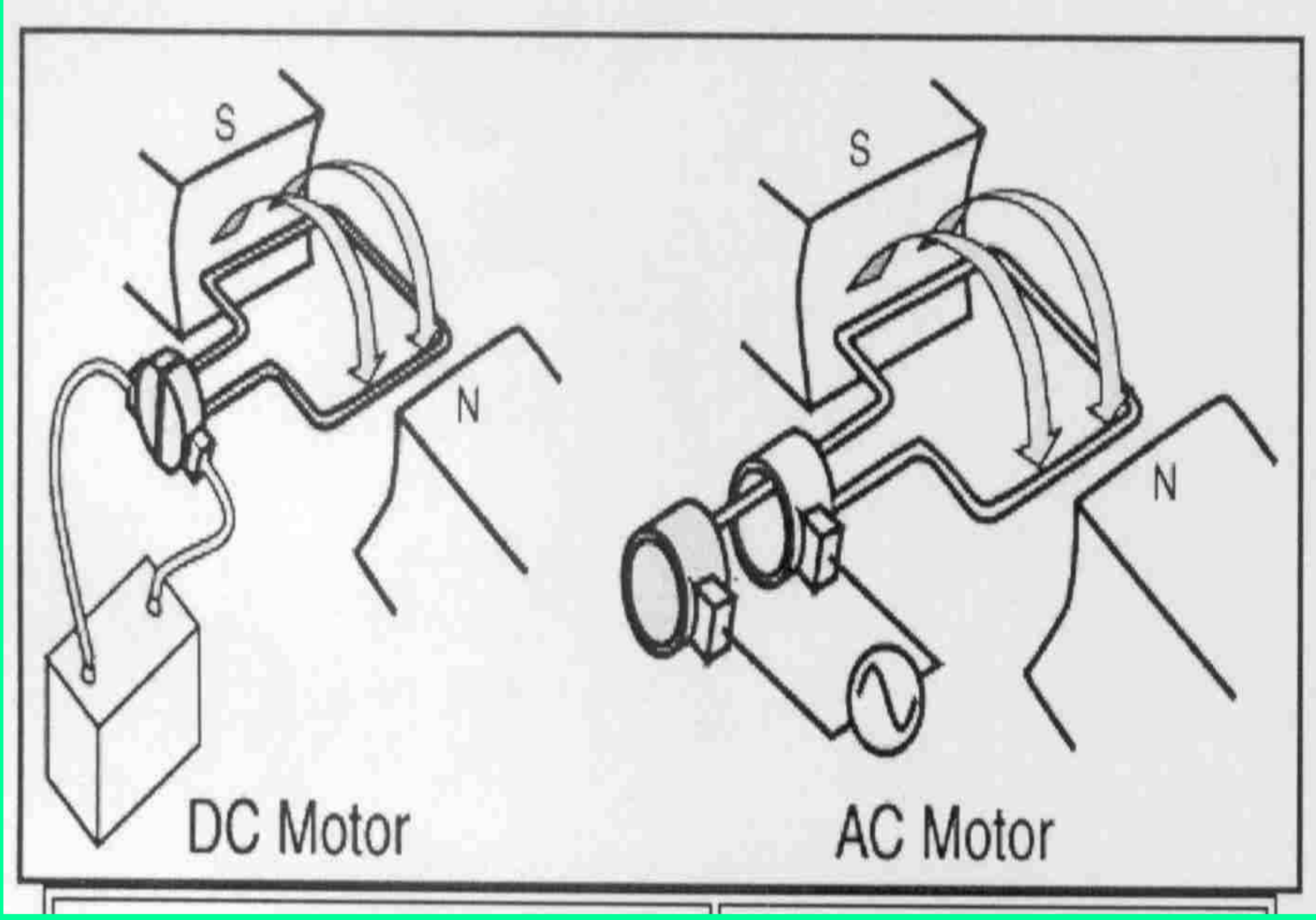


Photovoltaic Principle

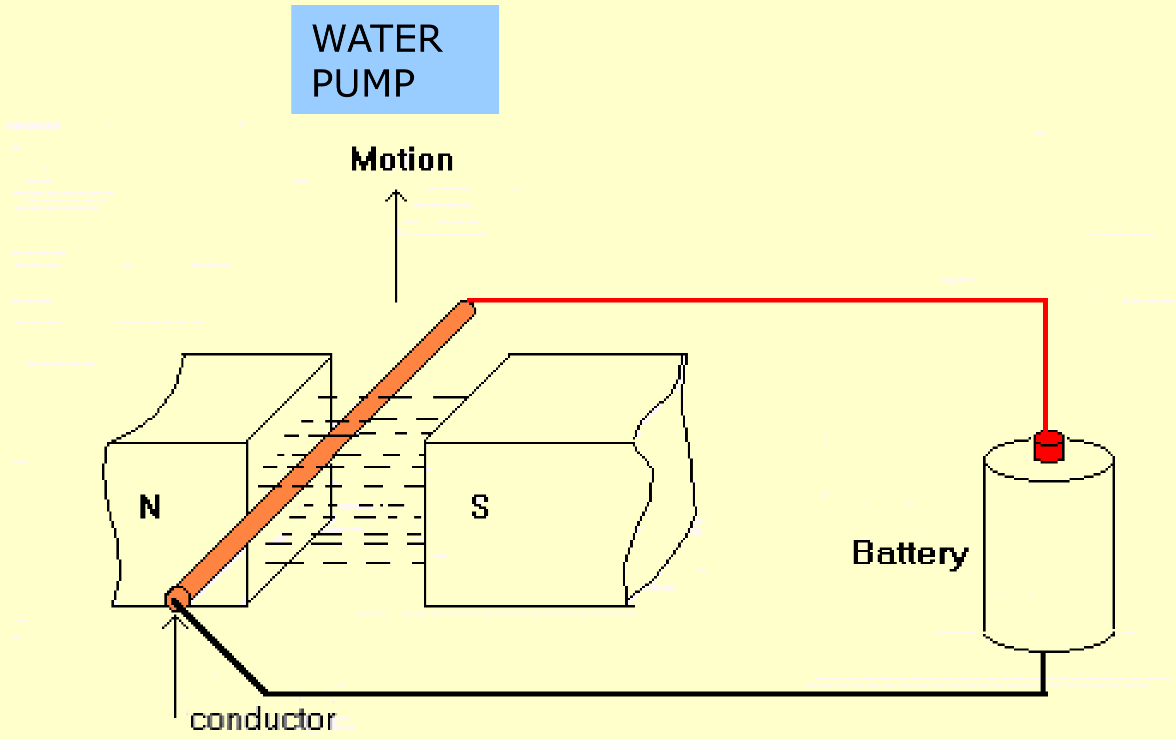
A photovoltaic cell generates electricity when irradiated by sunlight.



ELECTRIC MOTORS

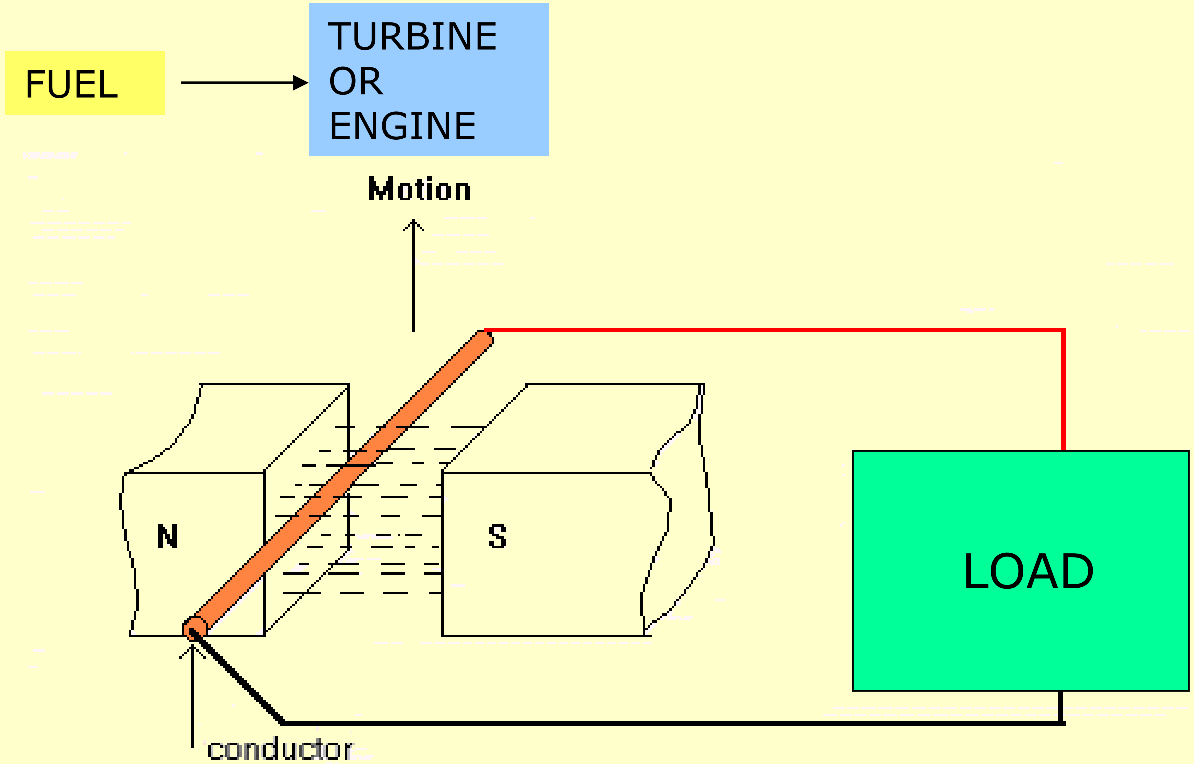


PRINCIPLE OF ELECTRIC MOTOR



Current from battery or electrical supply cuts the magnetic field resulting in a force that drives or rotates the water pump to do work.

PRINCIPLE OF ELECTRIC GENERATOR



The fuel is burned and its energy is captured to drive a turbine or a piston engine which moves a coil against a magnetic field, causing a current to flow and supply power to a load.

HOW IS MECHANICAL ENERGY PRODUCED?

Mechanical energy for rotating either the conductor or the magnetic field is produced by capturing energy from the primary energy source such as:

- Burning the fuel to produce heated gas that drives the piston in a reciprocating engine or rotates the rotor of a gas turbine
- Burning the fuel in a boiler that causes water to boil and expand as steam to drive a turbine
- Harnessing the potential and kinetic energy of water and kinetic energy of wind to rotate a turbine

GENERATION OF ELECTRICITY

- How an Electric Generator Works