Course Title: Applied Physics

Course Code: Phy 121

Credit Hours: 3 (2+1)

Instructor: Engr. S. Sufyan Syed

Textbook:

1) Physics Volume 2, by Halliday, Resnick and Krane, 5_{th}/ 6_{th} Edition.

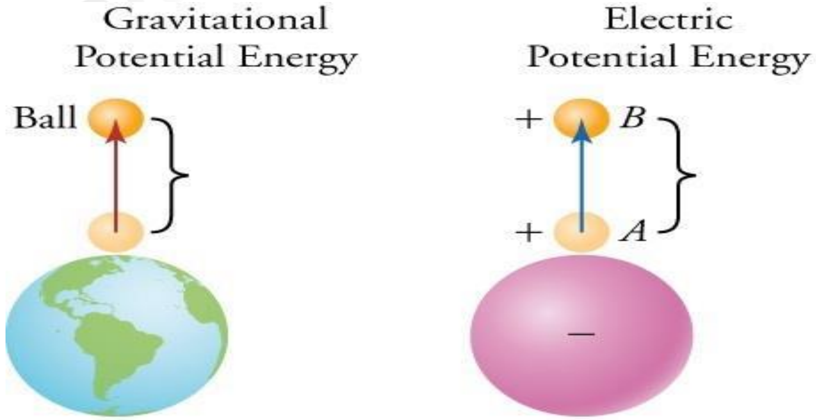
Reference Books:

1) Fundamentals of Physics by Halliday, Resnick and Walker, 5_{th} - 8_{th} Edition.
2) Engineering Electromagnetics by William H Hayt and John A Buck, 6th Ed.

Electric Potential

Potential Energy

Potential energy is the energy held by an object because of its position relative to other objects, stresses within it self, its electric charge, or other factors.



The electric potential *V* at a point *P* in the electric field of a charged object is

$$V = \frac{-W_\infty}{q_0} = \frac{U}{q_0},$$

where W is the work that would be done by the electric force on a positive test charge q_0 were it brought from an infinite distance to *P*, and *U* is the electric potential energy that would then be stored in the test charge. V is a scalar quantity

If a particle with charge *q* is placed at a point where the electric potential of a charged object is *V*, the electric potential energy *U* of the particle will be

$$U = qV.$$

$$(\text{electric potential energy}) = (\text{particle's charge})\left(\frac{\text{electric potential energy}}{\text{unit charge}}\right).$$

The SI unit for potential is the joule J per Coulomb C or it is called the *Volt "V"*

$$1\ \text{V} \equiv 1\ \frac{\text{J}}{\text{C}}$$

1 J of work must be done to move a 1-C charge through a potential difference of 1 V

$$1\ \text{N/C} = \left(1\frac{\text{N}}{\text{C}}\right)\left(\frac{1\ \text{V}}{1\ \text{J/C}}\right)\left(\frac{1\ \text{J}}{1\ \text{N}\cdot\text{m}}\right)$$

$$= 1\ \text{V/m}.$$

Change in Electric Potential. If we move from an initial point i to a second point f in the electric field of a charged object, the electric potential changes by

$$\Delta V = V_f - V_i.$$

If we move a particle with charge *q* from *i* to *f*, then $\Delta U = q\,\Delta V = q(V_f - V_i).$

The change can be positive or negative, depending on the signs of *q* and Δ*V*.

Work by the Field. We can relate the potential energy change ΔU to the work W done by the electric force as the particle moves from i to f by applying the general relation for a conservative force

$$W = -\Delta U \quad \text{(work, conservative force).}$$

Next, we can relate that work to the change in the potential by substituting from

$$W = -\Delta U = -q\,\Delta V = -q(V_f - V_i).$$

Electron Volt

The electron volt which is defined as the energy that electron or proton gains or loses by moving through a potential difference of 1V

$$1 \text{ eV} = 1.60 \times 10^{-19} \text{ C}\cdot\text{V} = 1.60 \times 10^{-19} \text{ J}$$

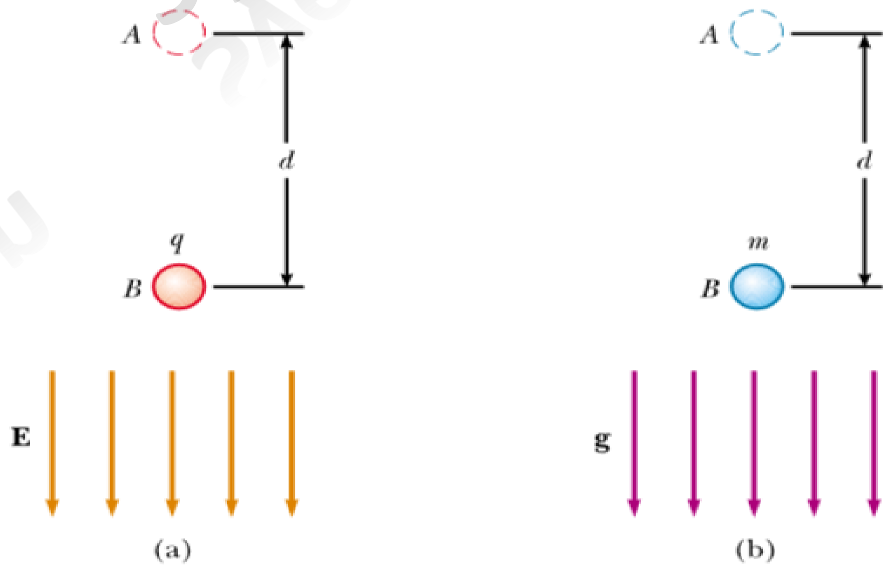
Potential difference in uniform electric field

Potential difference between points A and B separated by distance d, where d is parallel to electric field lines

$$V_B - V_A = \Delta V = -\int_A^B \mathbf{E} \cdot d\mathbf{s} = -\int_A^B E \cos 0^\circ \, ds = -\int_A^B E \, ds$$

Because E is constant, we can remove it from the integral sign; this gives

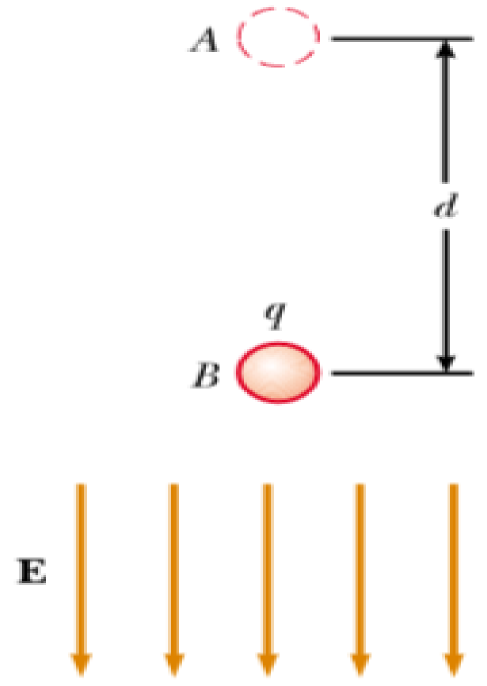
$$\Delta V = -E \int_A^B ds = -Ed$$



The minus sign indicates that B is at lower electric potential $V_B < V_A$.
Electric field lines always point in the direction of decreasing electric potential

Change in potential energy for test charge q_0 moves from A to B

$$\Delta U = q_0\,\Delta V = -q_0 E d$$



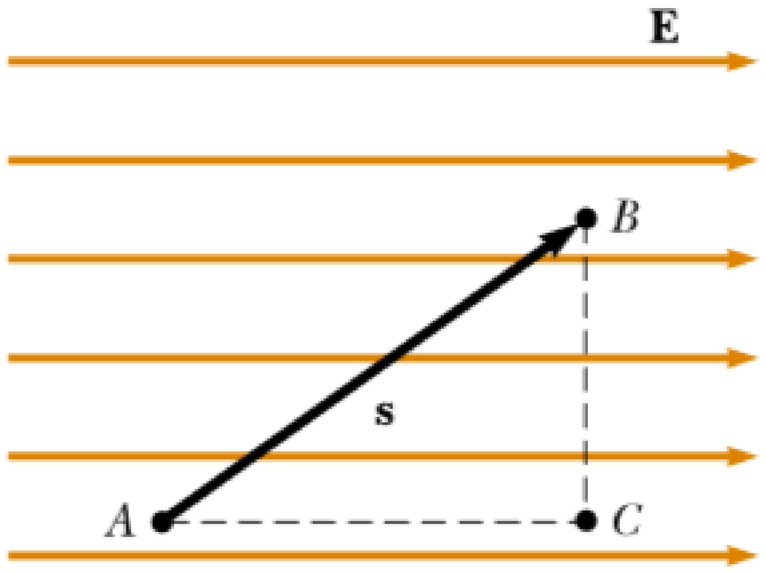
A positive charge loses electric potential energy when it moves in the direction of the electric field.

A negative charge gain eclectic potential energy when it moves in the direction of the electric field

Equipotential Surface

any surface consisting of a continuous distribution of points having the same electric potential.

VB – VA is equal to the potential difference VC - VA

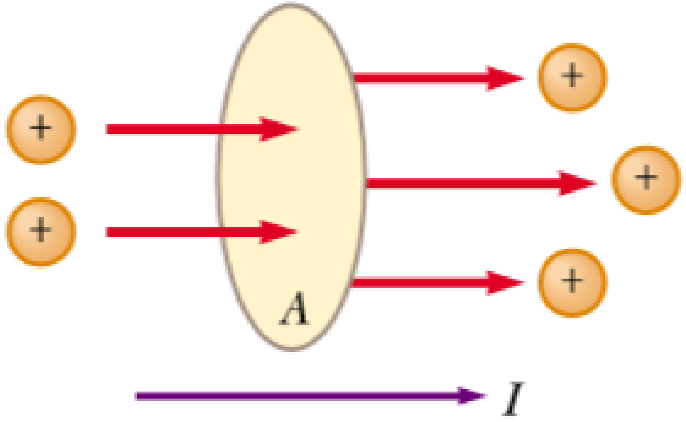


Electric Current

The current is the rate at which charge flows through a surface.

If ΔQ is the amount of charge that passes through this area in a time interval Δt, the average current I_{av} is equal to the charge that passes through A per unit time.

$$I_{av} = \frac{\Delta Q}{\Delta t}$$



Instantaneous Current

If the rate at which charge flows varies in time, then the current varies in time:

we define the instantaneous current I as the differential limit of average current
Instantaneous Current

$$I \equiv \frac{dQ}{dt}$$

Ampere (A)

The SI unit of current is the Ampere (A):

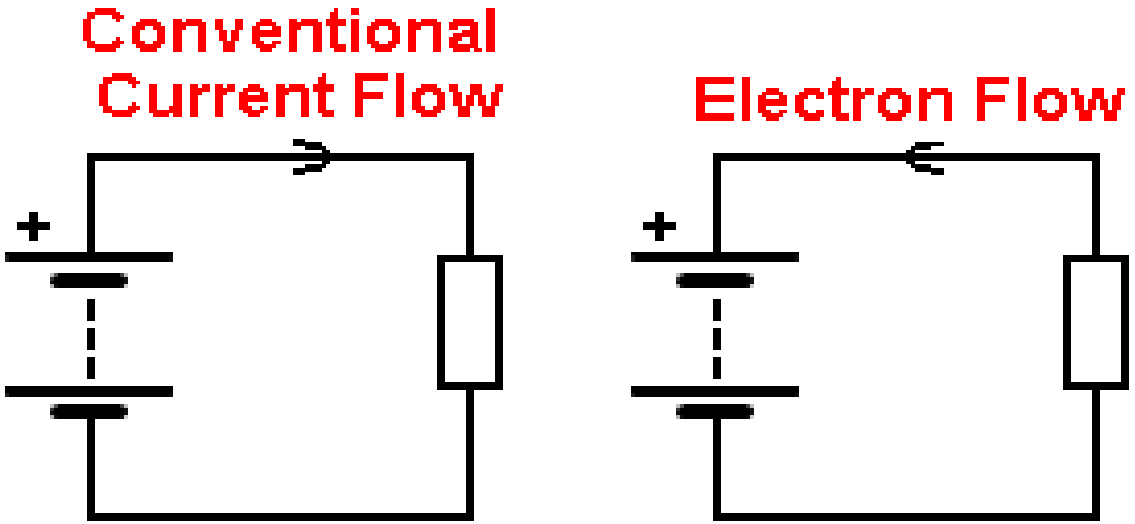
$$1\ \mathrm{A} = \frac{1\ \mathrm{C}}{1\ \mathrm{s}}$$

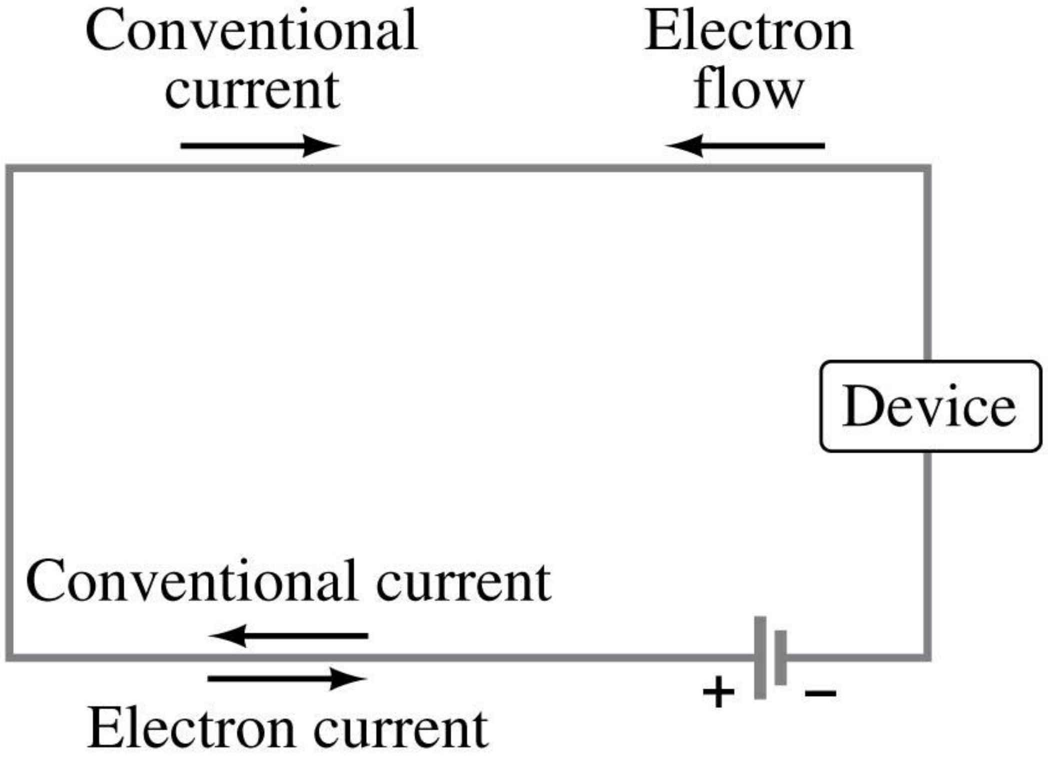
1 **A current is equivalent to 1C of charge passing through the surface area in 1s**.

An ammeter measures the amount of current flowing past a certain point

Direction of the current

It is conventional to assign to the current the same direction as the flow of positive charge.





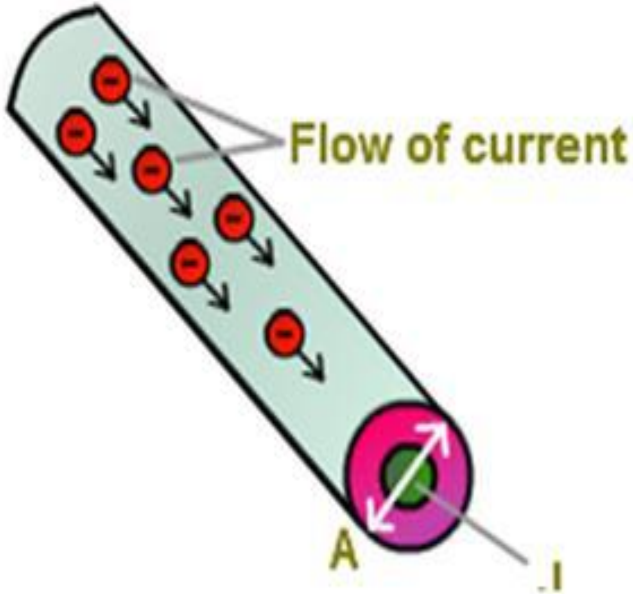
Current Density

Consider a conductor of cross-sectional area A carrying a current *I*. The current density *J* in the conductor is defined as the current per unit area. As the current $I = nqv_dA$, the current density is

$$J \equiv \frac{I}{A} = nqv_d$$

J has SI unit A/m^2. The current density is a vector quantity:

$$\mathbf{J} = nq\mathbf{v}_d$$



J = The flow of current over Cross Section

A current density J and an electric field E are establish in a conductor whenever a potential difference is maintained across the conductor.

If the potential difference is constant then the current is also constant. In some materials, the current density is proportional to the electric field.

$$\mathbf{J} = \sigma \mathbf{E}$$

Where the σ is called the conductivity of conductor.

the ratio of the current density to electric field is a constant σ that is independent of the electric field producing the current

A potential difference $\Delta V = V_b - V_a$ across a uniform cross-sectional area A and length l is

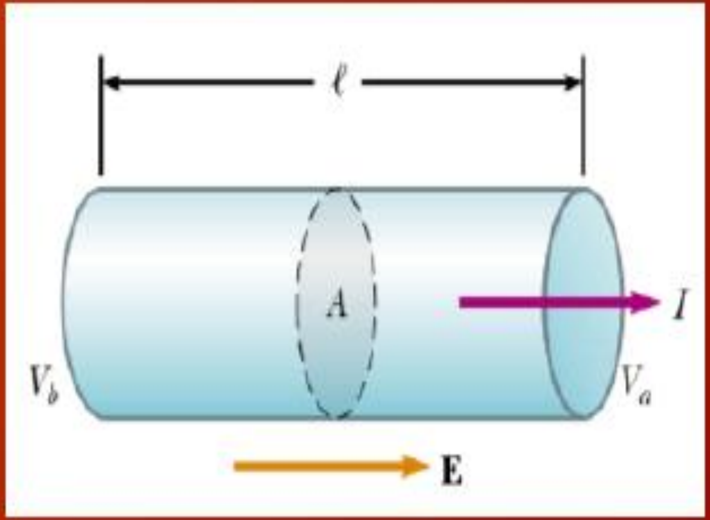
$$\Delta V = E\ell$$

The current density is

$$J = \sigma E = \sigma \frac{\Delta V}{\ell}$$

Because J = I/A, we can write

$$\Delta V = \frac{\ell}{\sigma} J = \left(\frac{\ell}{\sigma A}\right) I$$



$$V_b - V_a = -\int_a^b \mathbf{E} \cdot d\mathbf{s} = E \int_0^\ell dx = E\ell$$

Resistance R

the quantity $\ell / \sigma A$ is called the resistance R of the conductor.

$$R = \frac{\ell}{\sigma A} = \frac{\Delta V}{I}$$

SI unit of R is volts per ampere. One volt per ampere is defined to be 1 ohm (Ω)

$$1\ \Omega = \frac{1\ \text{V}}{1\ \text{A}}$$

Resistivity

The inverse of conductivity is resistivity ρ.

$$\rho \equiv \frac{1}{\sigma}$$

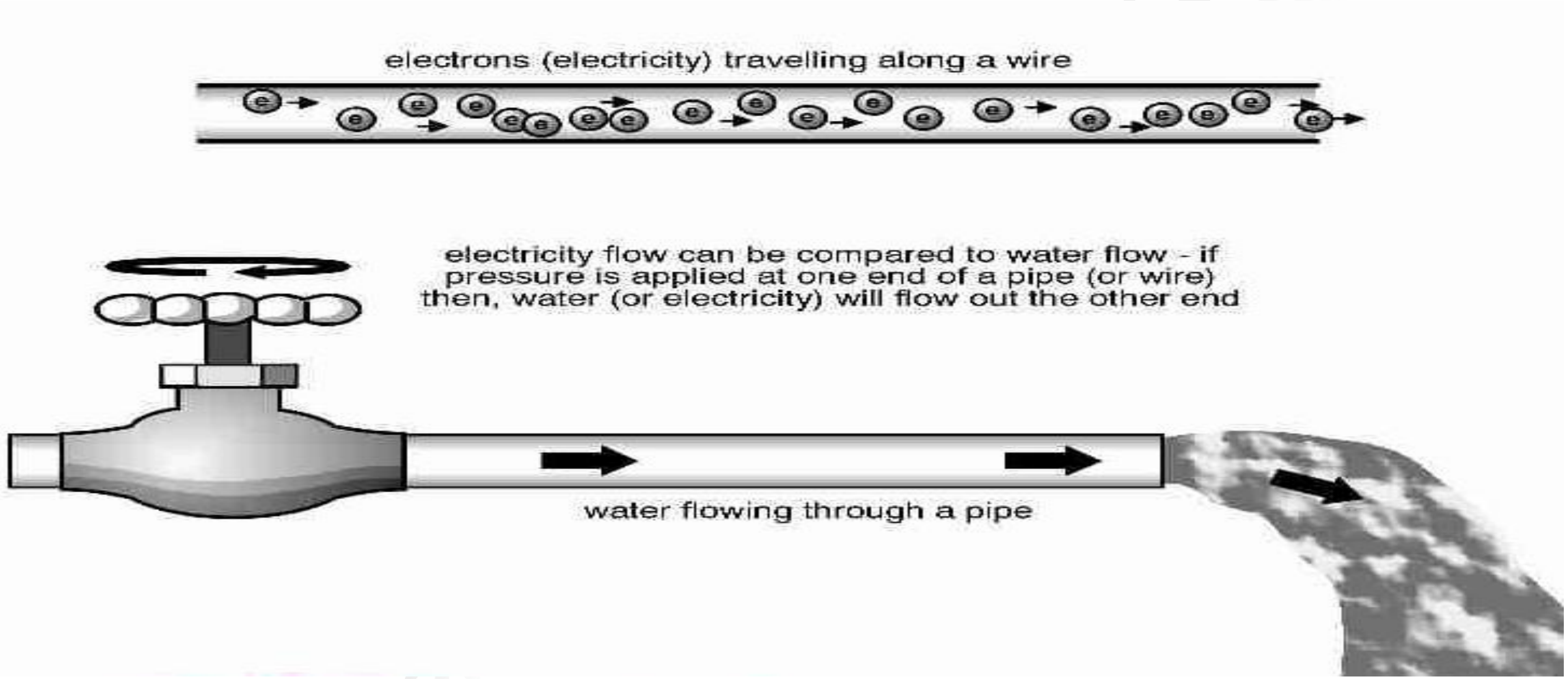
SI unit of ρ is (Ohm-meter)

Resistance of a uniform block of material is

$$R = \rho \frac{\ell}{A}$$

OHMs Law

Current flowing through a wire is like water flowing through a hose.



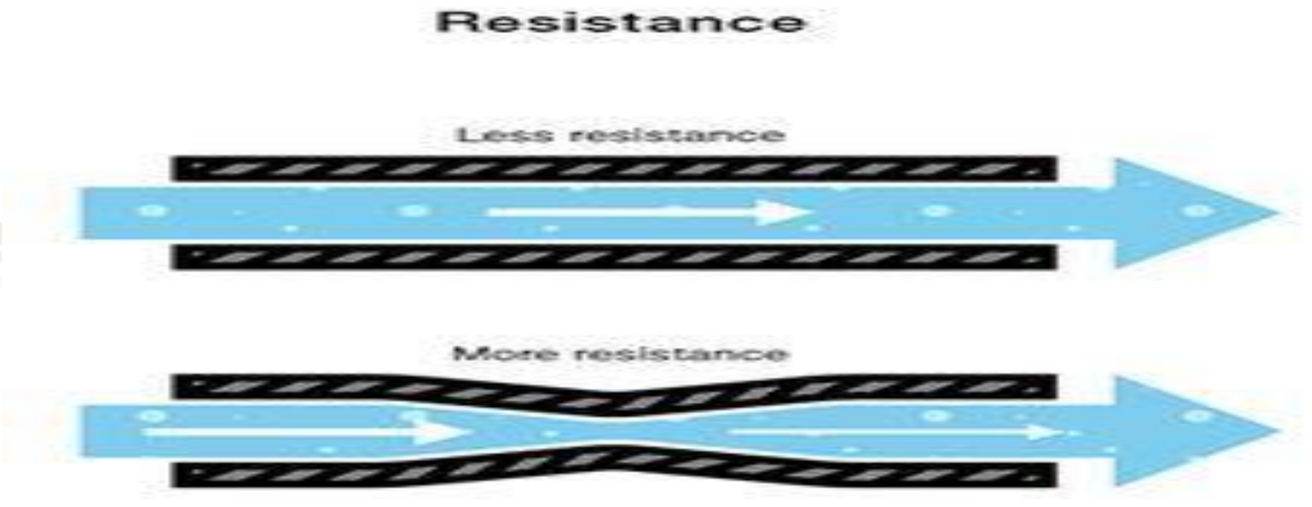
Increasing potential difference or voltage with a higher volt battery increases the current.

$$I \propto V$$

This is like opening the tap wider so more water flows through the hose.

Increasing resistance reduces the current.

This is like stepping on the hose so less water can flow through it.

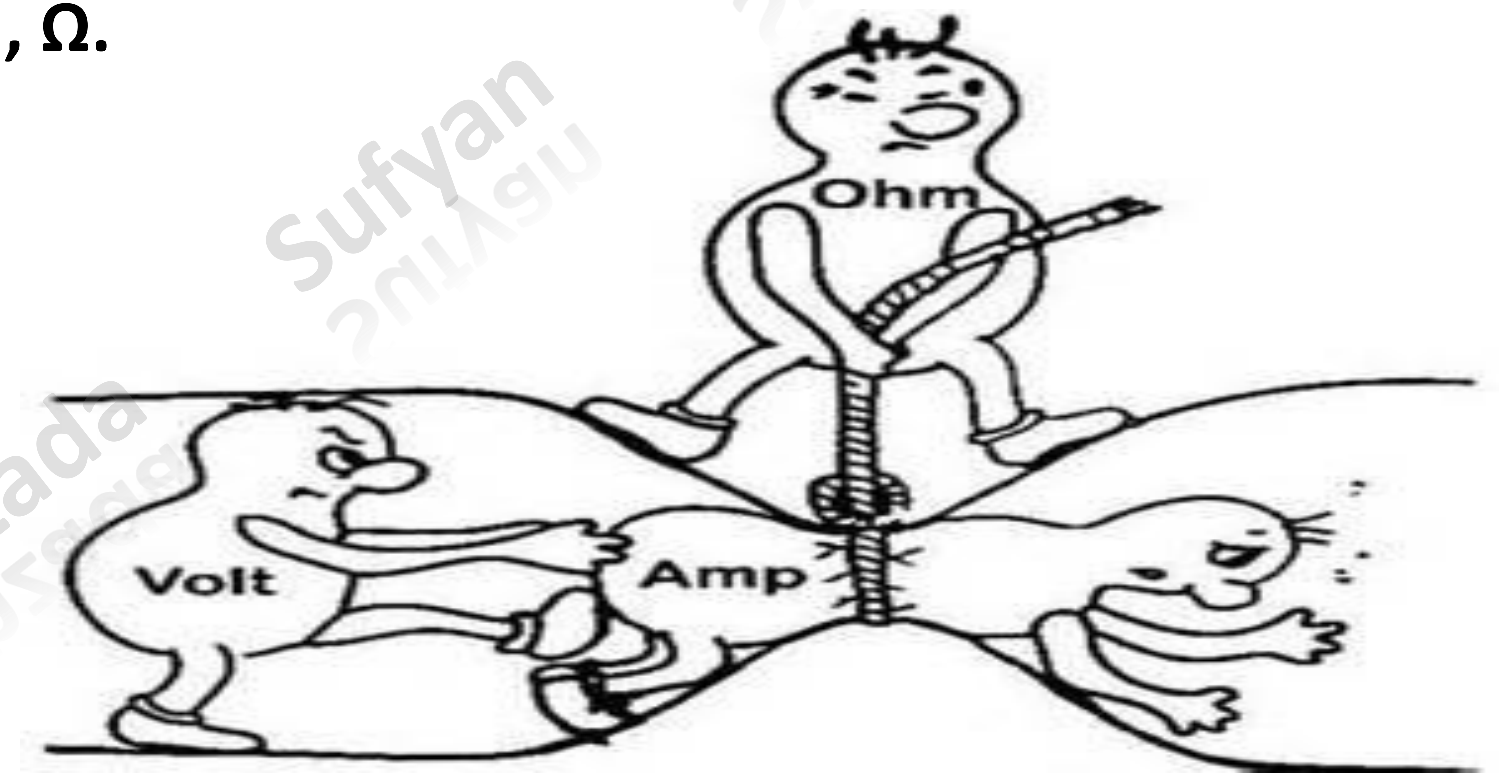


Increasing the resistance, decreases the flow of current and increase in the temperature

The ratio of voltage to current is called the resistance $V = IR.$

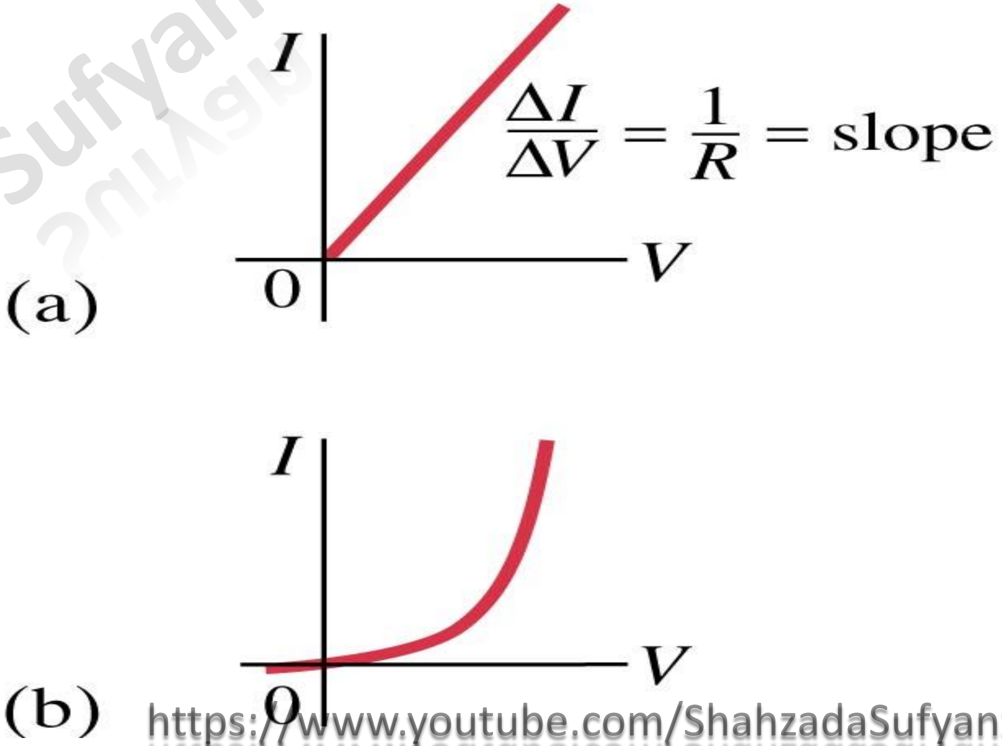
Unit of resistance is ohm, Ω.

$1\ \Omega = 1\ V/A$



In many conductors, the resistance is independent of the voltage, this relationship is called Ohm’s law.

Materials that do not follow Ohm’s law are called non-ohmic and which follows ohm law are called Ohmic materials



Unit of resistance:

the ohm, Ω.

$$1\ \Omega = 1\ \text{V/A}$$

Electric Power

Power is the energy transformed by a device per unit time:

$$P = \frac{\text{energy transformed}}{\text{time}} = \frac{QV}{t}.$$

$$\boxed{P = IV.}$$

Electric Power

The unit of power is the watt, W.

For ohmic devices, we can make the substitutions:

$$P = IV = I(IR) = I^2R$$

$$P = IV = \left(\frac{V}{R}\right)V = \frac{V^2}{R}$$

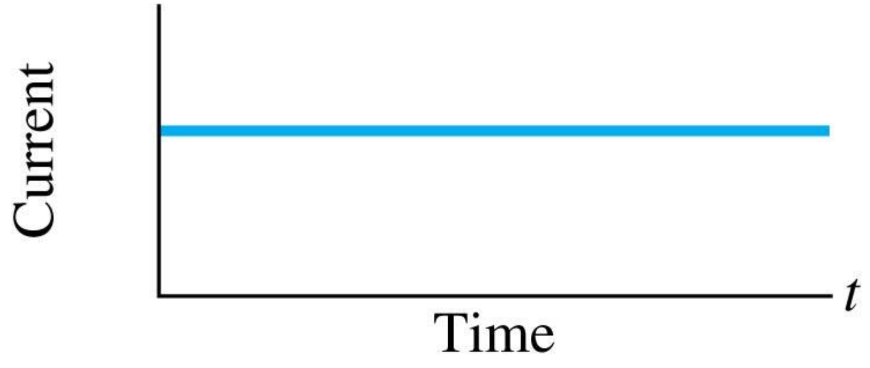
What about your Electricity Bill???

What you pay for on your electric bill is not power, but energy the power consumption multiplied by the time.

We have been measuring energy in joules, but the electric company measures it in kilowatt-hours, kWh.

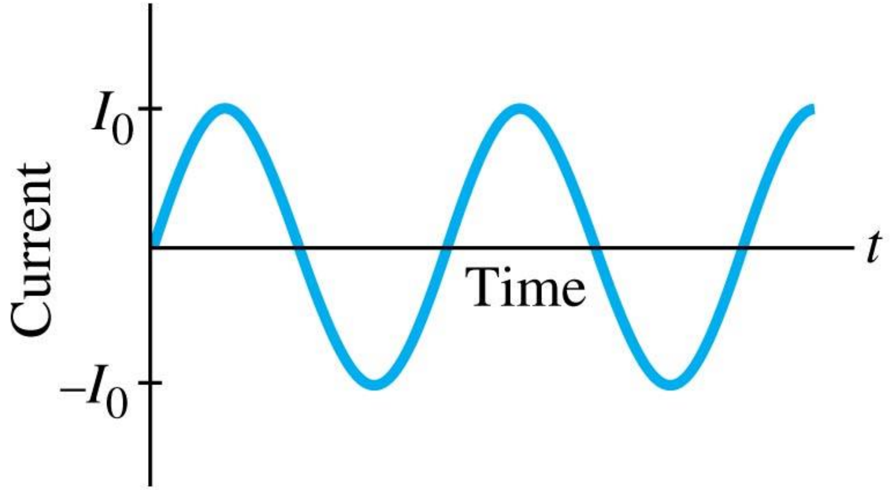
$$\text{One kWh} = (1000\ \text{W})(3600\ \text{s}) = 3.60 \times 10^{6}\ \text{J}$$

Current from a battery flows steadily in one direction (direct current, DC).



(a) dc

Current from a power plant varies sinusoidally (alternating current, AC).



(b) ac