RESISTANCE AND OHM'S LAW

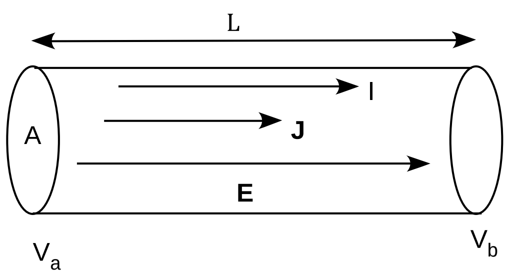
DEF: The current density *J* in a conductor is defined as the current per unit area.

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

Since $\boldsymbol{v_d}$ is a vector, we can define J to also be a vector ***J***.

$\boxed{\mathbf{J} = nq\mathbf{v_d}}$ Current Density

Consider a uniform conductor of length L and cross-sectional area A.



$V_a > V_b$

$\boxed{V = V_a - V_b}$ Potential Difference Across the Conductor

*<u>A current density **J** and Electric-Field **E** are established in a conductor whenever a potential difference is maintained across the conductor.</u>*

What happens to the magnitude of **E** and **J** if we increase V? They both increase! Explain!

Thus, if E increases then J increases and if E decreases then H decreases. Therefore, J is proportional to E!

$\boxed{\mathbf{J} = \sigma\mathbf{E}}$ Ohm's Law

Material that obey Ohm's Law are said to be ohmic. (is independent of E)

Referring to the uniform conductor above:

$$V = E\ell$$

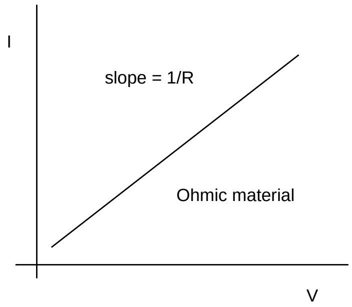
$$V = \frac{J}{\sigma}\ell = I\left(\frac{\ell}{\sigma A}\right)$$

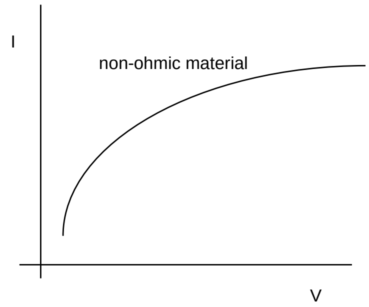
$\boxed{R = \frac{\ell}{\sigma A}}$ Resistance of a Conductor

$\boxed{V = IR}$ "Ohm's Law"

This is equation if often referred to Ohm's Law, but keep in mind that Ohm's Law is $J = \sigma E$.

Material that obey Ohm's Law are called ohmic.





The inverse of the conductivity σ is the resistivity ρ:

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

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

a) Resistance is a measure of the opposition that a material (resistor) presents to the flow of charge.
b) Materials with large values of R are called resistors.

1. For a given ρ and A, the larger   , the larger R and the smaller   , the smaller R.
2. For a given ρ and   , the larger A, the smaller R, and the smaller A, the larger R.
3. For a given A and   , the larger ρ , the larger R, and the smaller ρ the smaller R.

*ρ depends on properties of material

- Materials with large ρ (small σ) are poor conductor but good insulators.
- Materials with small ρ (large σ) are good conductors but poor insulators.

Perfect insulator $\left\{ \begin{matrix} \rho = \infty \\ \sigma = 0 \end{matrix} \right\}$

Perfect conductor $\left\{ \begin{matrix} \rho = 0 \\ \sigma = \infty \end{matrix} \right\}$

Material	**ρ (Ω.m)**
Ag	1.59×10^{-8}
Cu	1.7×10^{-8}
Gold	2.44×10^{-8}
Glass	$10^{10} - 10^{14}$
Rubber	10^{13}
Si	640

The SI unit of Resistance is the Ohm (Ω).

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

(If the potential difference between across a conductor is 1V and the current flowing is 1A, then the resistance of the conductor is 1 Ω.

$$[\rho] = \Omega.m, \quad [\sigma] = 1/\ \Omega.m$$