Current I

If no current then in Conductor $E = 0$

But we have current $\Rightarrow \vec{E}$, electrons $\vec{F} = e\vec{E}$

Frictional force opposes motion, reach terminal on

Drift velocity $= V_d$ in direction $\vec{E}$

Flow of charge carriers at a point in Conductor

Current Density Vector $\vec{J}$

Uniform current I across cross section area (A)

$J = I/A \Rightarrow$ Use to compute V_d of charges

# of conduction electrons $=$ (n) per unit volume

(ℓ) = length of wire

Total # of conduction electrons $= nA\ell$ — $\frac{\#}{Vol} \times$ Volume of wire

have charge $\Delta Q = (nA\ell)e$

travel distance of wire length ℓ in a time $\Delta t = \ell / V_d$

(time for all electrons in wire to move out of wire)

$\Rightarrow$ Current $I = \Delta Q / \Delta t$

$$= \frac{nA\ell e}{\ell / V_d} = nAeV_d = I$$

$V_d = I/nAe = J/ne \quad (J = \frac{I}{A})$

Response of object to Potential difference (Voltage) applied = Resistance $= R = V/I$

$I = V/R$: Units $= \frac{\text{Volts}}{\text{amp}}$ = Ohms, $10^3 \Omega = k\Omega$, $10^6 \Omega = M\Omega$

Different materials have different resistivities $= \rho$

Uniform material: Resistivity $\rho = E/J$

Conductivity $= \sigma = 1/\rho$

Uniform cylindrical Conductor, x-sect area A

Length l, Steady Current I

w/ Potential Difference V

$E = V/l \quad J = I/A$

$\rho = E/J = \frac{V/l}{I/A}$

$\frac{V}{l} = \rho \frac{I}{A} \Rightarrow V = \frac{\rho l I}{A}$

$\frac{V}{I} = \frac{\rho l}{A}$, but $R = \frac{V}{I}$

$R = \rho l / A$ Geometry

$R = \frac{\rho l}{A}$ into $V = \frac{\rho l}{A} I$

$V = IR$ Ohm's Law

Resistivity is temperature dependent. If $\rho = \rho_0$ at T_0 then $\rho = \rho_0(1 + \alpha(T - T_0))$ at Temp T, α = mean coefficient of resistivity at temperature T

$R = R_0(1 + \alpha(T - T_0))$ (same α)

A circuit: Battery

$] - V_{ab}$

Charge ΔQ moves thru box thru potential V_{ab} ⇒ decreases potential energy by $V_{ab}\Delta Q$

If in time Δt, $\Delta Q = I\Delta t$ is transferred thru box and V_{ab}

Energy transferred in box $\Delta U = V_{ab}\Delta Q = V_{ab} I \Delta t$

Rate of energy transfer = Power = $P = \frac{\Delta U}{\Delta t} = V_{ab} \cdot I$

Power dissipated in a circuit = VI, use $V = IR$

$P = I^2 R$ or $P = V^2/R$

Units: Volt-Ampere

$1V = \frac{1 \text{ Joule}}{\text{Coul.}}$, $1 \text{ Amp} = \frac{1 \text{ Coul.}}{\text{sec}}$

1 Volt Amp = $\frac{\text{Joules}}{\text{sec}}$ = Watt

Electromotive Force = EMF = provided by Sources such as generators or batteries maintaining Potential Difference btw 2 points Charges enter they get increased Potential Energy EMF = $\mathcal{E} = \frac{\Delta W}{\Delta Q} = \frac{dW}{dQ}$

Units of $\mathcal{E}$ = $\frac{\text{Joules}}{\text{Coulomb}}$ = Volt

Difference btw Potential and EMF:

EMF is potential diff across voltage source when disconnected.

Every Voltage Source has internal resistance (r) as Move charges from low → high Potential

If were no internal resistance ($r = 0$), Connect Resistor across EMF

R $V = \mathcal{E} = IR$

Reality: $r \neq 0 \Rightarrow$ Internal Voltage drop In Source $V_i = Ir$ $\Rightarrow$ Potential difference at Source terminals $V = \mathcal{E} - V_i = \mathcal{E} - Ir$

Resistor "sees" V across it

$V = \mathcal{E} - Ir = IR$

$\Rightarrow I = \frac{\mathcal{E}}{R+r}$ ⇒ Voltage across external resistor R

$V = IR = \frac{\mathcal{E}R}{R+r}$

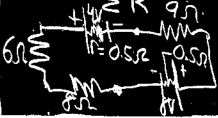
$\frac{R}{R+r}$ = factor by which external voltage from power supply is reduced

Short Circuit: $R = 0$

$V = 0 \Rightarrow I = \mathcal{E}/r$

Several $\mathcal{E}$, R in series, just add them up: ⇒

$I = \Sigma\mathcal{E} / \Sigma R$, example:



$I = \Sigma\mathcal{E} / \Sigma R$

$= \frac{4V + 8V}{0.5\Omega + 6\Omega + 8\Omega + 0.5\Omega + 9\Omega}$

$= 12V / 24\Omega = 0.5A$