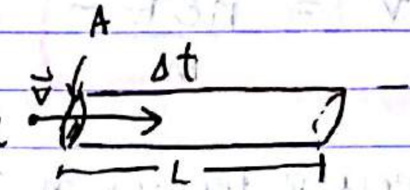
10/22/15

Current & Ohm's law

Review

$I = \frac{dq}{dt}$ $\quad \vec{E}$ $\qquad \vec{F} = q\vec{E}$



total chg = $n e$ Volume = $neAL$ = $neAv\Delta t$ ← drift velocity (because random motion)

$\frac{q}{\Delta t} = I = neAv$ — we don't want area as an constraint. So we define J, current density

$$J = \frac{I}{A} = nev$$

convention

q>0 → $\vec{J}$; q<0 → , ← $\vec{J}$ — $\vec{J}$ defined by q>0. so, $\vec{J} = -nev$

$\vec{v}_{drift} = \frac{J}{ne}$

Ex. Copper (Cu):
$n(Cu) = 8.49e28\ el/m^3$
$J = 5.1e5\ A/m^3$
$v_{drift} = 3.8e^{-5}\ cm/s$ ← slow!

V_{drift} is slow, but there are electrons throughout the wire, which is why light switches are fast. It's the ΔE that matters.

$\vec{F} = m\vec{a} = e\vec{E}$, $\vec{a} = \frac{e\vec{E}}{m}$ $\qquad J \propto v$, not a. (lots of collisions)

avg velocity

$\overline{v(t)} = \overline{v_i(0)} + \overline{at} = \overline{v_i(0)} + \overline{\frac{eE}{m}t} = \boxed{\frac{eE}{m}\tau}$ ← time between collision

$v_i(0)$ ↓ time of collision $\quad \overline{v_i(0)} = 0$, because $\vec{v}_i$ has a direction.

$$J = nev = \frac{ne^2E}{m}\tau$$

e^2 because (1) more q → more J
(2) more q → more $q\vec{E}$ ($\vec{F}$)

material-specific terms: n, τ ← good conductor has long τ

Conductivity σ : $\frac{ne^2\tau}{m}$ ⇒ $\vec{J} = \sigma\vec{E}$

↑ current driven by $\vec{E}$.

∴ $I = \sigma A E$

But let's think about current driven by ΔV.

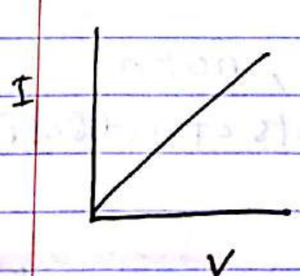
∴ $I = \sigma A \frac{\Delta V}{L}$

Resistance — $R = \frac{L}{\sigma A}$, $I = \frac{\Delta V}{R}$, $\Delta V = IR$ ← Ohm's Law

$[R] = \frac{[\text{Volt}]}{[\text{Ampere}]} = [\text{ohm}] = [\Omega]$

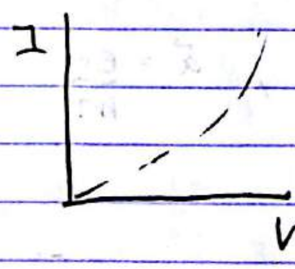
Resistivity — $\rho = \frac{1}{\sigma}$, $R = \frac{\rho L}{A}$

Ohmic materials



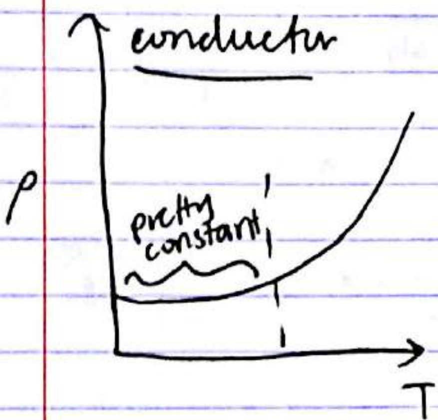
↑ we deal w/ this

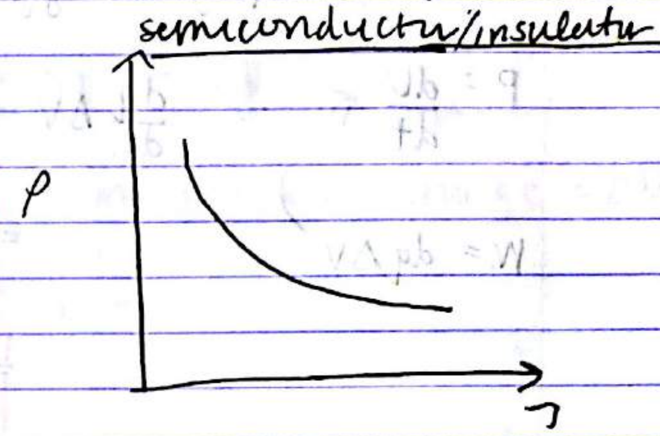
Non-Ohmic materials

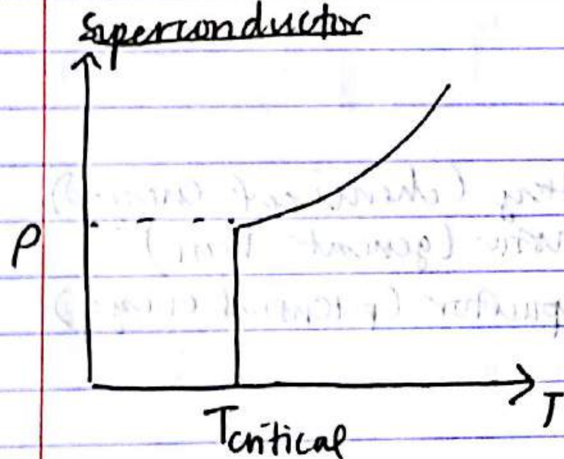


σ, ρ are constant w/ respect to temp. ← approximation

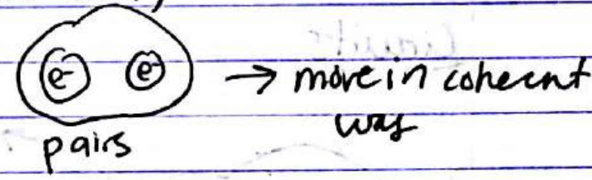
But, collisions w/ atoms → vibration depends on T.





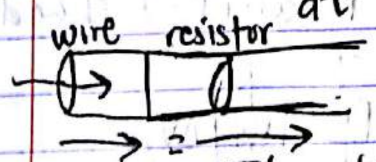


at Tcrit,



(no idea why this happens).

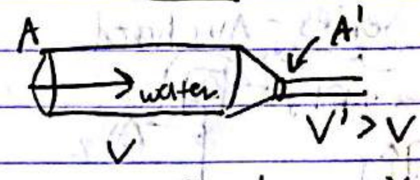
Power: $P = \frac{dU}{dt}$



$J \rightarrow = J'$ (same amt)

$v < v'$

fluid



same amt fluid goes thru A & A'

so, $E_{wire} = \rho_w J_w$ | $\rho_w < \rho_r$

$E_{res} = \rho_R J_R$ | $E_{res} = E_{wire} \cdot \frac{\rho_{res}}{\rho_{wire}}$ ← > 1

so $E_{res} > E_{wire}$.

We know, $W \propto L$

So, $W_{res} > W_{wire}$

- you "pay energy" to go through the resistor

$$P = \frac{dU}{dt} = \frac{dq}{dt}\Delta V = \boxed{\Delta V I}$$

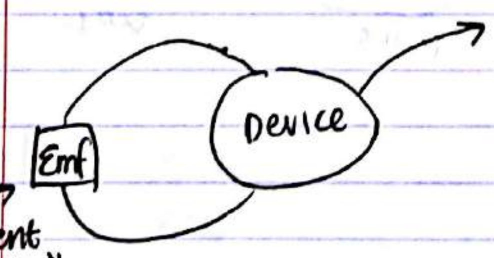
$$dU = dq\,\Delta V$$

$$= \boxed{I^2 R}$$

$$= \boxed{\frac{\Delta V^2}{R}}$$

* Read AC/DC current

Circuits

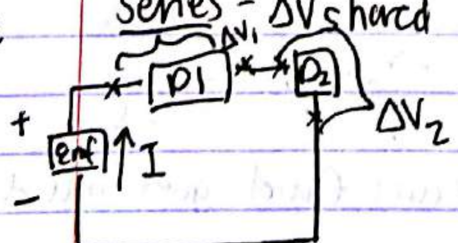


- battery (chemical energy)
- resistor (generates heat)
- capacitor (potential energy)

"the current generator"

- battery
- electric generator
- solar cell
- ⋮

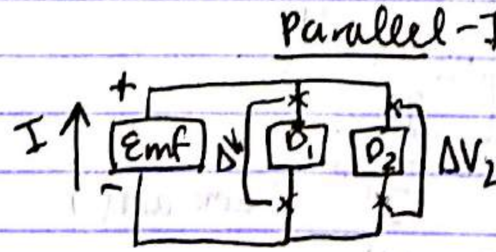
Series - ΔV shared



$$\mathcal{E} = \Delta V_1 + \Delta V_2$$

$$I = I_1 = I_2$$

Parallel - I shared



$$I = I_1 + I_2$$

$$\Delta V = \Delta V_1 = \Delta V_2$$