# Electric Current

- Electric current is the rate at which charges pass through a material ($I = \frac{\text{Coloumb}}{\text{second}} = \text{Amp}$)
- $I = \sum_{i=1}^{N} \frac{q_i}{t}$ or $\frac{dq}{dt}$; note that current is not a vector
- Although it's not "technically" realistic, we say that $I$ is the flow of positive charge
- Current density, on the other hand, is a vector
- We have that current density $\vec{J} = \frac{I}{A}\hat{r}$, where $\hat{r}$ points in the direction of the electric field; also note $I = \int \vec{J} \cdot d\vec{A}$
- Example: current through wire w/ radius R

  (Given $\vec{J} = ar^2$)

  $$I = \int \vec{J} \cdot d\vec{A} = \int_0^R ar^2 \hat{z} \cdot 2\pi r dr \hat{z} = 2\pi a \int_0^R r^3 dr = \frac{1}{2}\pi a R^4$$

# Drift Speed

- Drift speed: the "speed" of a charge through a material

  $v_d = \frac{L}{t}$

  $Q = nVq$ where $n$ is free charge density, $V$ is volume, $q$ is charge on free charges

  $I = \frac{Q}{t} = \frac{nVq}{t} = \frac{nLAq}{t} = nv_d Aq$

  $v_d = \frac{I}{nAq}$

  - Note that $n = \frac{\#\text{ of free charges}}{\text{volume}} = \frac{\#\text{ free charges}}{\text{atom}} \times \frac{\text{atom}}{\text{mass}} \times \frac{\text{mass}}{\text{volume}}$
- Example: Find the drift speed of a 1mm copper wire with a 1 Amp current

  $$n = \frac{1 \text{ free charge}}{1 \text{ atom}} \times \frac{1 \text{ atom}}{(63.54\text{amu})(1.67\times10^{-27}\frac{\text{kg}}{\text{amu}})} \times \frac{8.9\times10^3 \text{kg}}{1\text{m}^3} = 8.44\times10^{28} \frac{\text{charge}}{\text{m}^3}$$

  $$v_d = \frac{I}{nAq} = \frac{1}{(8.44\times10^{28})(\pi\times(0.5\times10^{-3})^2)(1.6\times10^{-19})} = 9.4\times10^{-5} \frac{\text{m}}{\text{s}}$$

# Resistance

- Resistance is the measure of how difficult it is for charges to flow through a wire
- Note that in a wire, $\vec{E}$ is not static; $\vec{E}$ is generated by moving charges and not stationary clumps of charges
- Resistivity, $\rho$, is equal to $\frac{E}{J}$ and has unit $\Omega m$ (ohm × meter)
- Resistance, $\Omega$, is equal to $\rho \frac{L}{A}$
- Ohm's Law: $R = \rho \frac{L}{A} = \frac{E}{J} \times \frac{L}{A} = \frac{V}{I} \rightarrow V = IR$