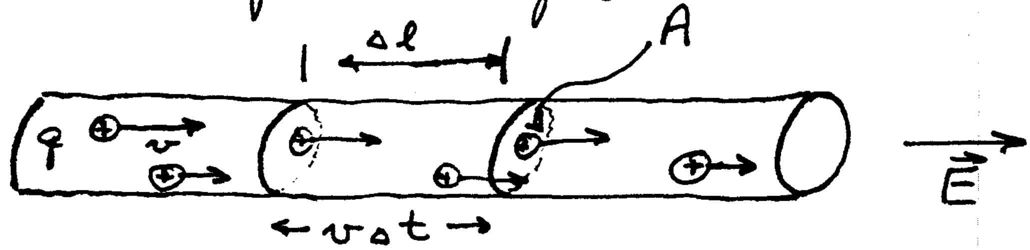
We're faced with a rather confusing picture in E + M. Formalism was developed around ⊕ charge being default (type of charge silk imparts to glass rod.) More recently we've discovered that it is the ⊖ charges which we call "electrons" which are physically moving in a current.

Consider a portion of a



n positive charges per unit volume w/ drift velocity v

in time Δt n charges will travel length Δl where

$$\Delta l = v \Delta t$$

These charges will sweep out a volume ΔV in time Δt

$$\Delta V = A \Delta l = A(v \Delta t)$$

Charge flowing across A will then be

$$\Delta Q = n q \Delta V = nq(A v \Delta t)$$
$$= n q v A \Delta t$$

Current then

$$I = \frac{\Delta Q}{\Delta t} = n q v A$$

For a number of different charge carriers

$$\boxed{I = A \sum n q v}$$

e.g. if have ⊖ chges moving opposite direction

$$I^+ = A n_+ q v$$

$$I^- = A n_- q_- v$$

$$I = 2 A n q v$$

We may define a current density

$$\boxed{J = \frac{I}{A} = \sum n q v}$$

current per unit surface area

Vector current density

$$\boxed{\vec{J} = \sum n q \vec{v}}$$

N.B.

current is a scalar quantity
current density vector

$F = q E$

⊕ charge $\quad \vec{F}$ same direction as $\vec{E}$

$\vec{v}$ and $\vec{E}$ in same direction

$\vec{J}$ and $\vec{E}$ in same direction

⊖ charge $\quad \vec{F}$ opposite $\vec{E}$

$\vec{v}$ and $\vec{E}$ in opposite direction

$\vec{J}$ and E in same direction

$(-q\vec{v})$

$\Longrightarrow$ $\vec{J}$ and $\vec{E}$ always in same direction

10 guage copper wire has $d = 2.95\,mm$ with a current of $20\,A$. What is drift velocity

$$J = \frac{I}{A} = \frac{20\,c\,s^{-1}}{\pi\left(\frac{2.95}{2}\times 10^{-3}\,m\right)^2}$$

$$J = 3\times 10^6\,A/m^2$$

$$J = nqv \Rightarrow$$

$$v = \frac{J}{nq} \qquad n(Cu) \simeq 10^{29}\,m^{-3}$$

$$v = \frac{3\times 10^6\,C\,s^{-1}\,m^{-2}}{10^{29}\,m^{-3}\cdot 1.6\times 10^{-19}\,C}$$

$$v \approx 2\times 10^{-4}\,m\,s^{-1}$$