PS 250: Lecture 12

Current and Resistivity

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September 25th, 2015

Today's Class

- $\boxed{\text{Current}}$
- Resistivity and Resistance
- Summary

Current

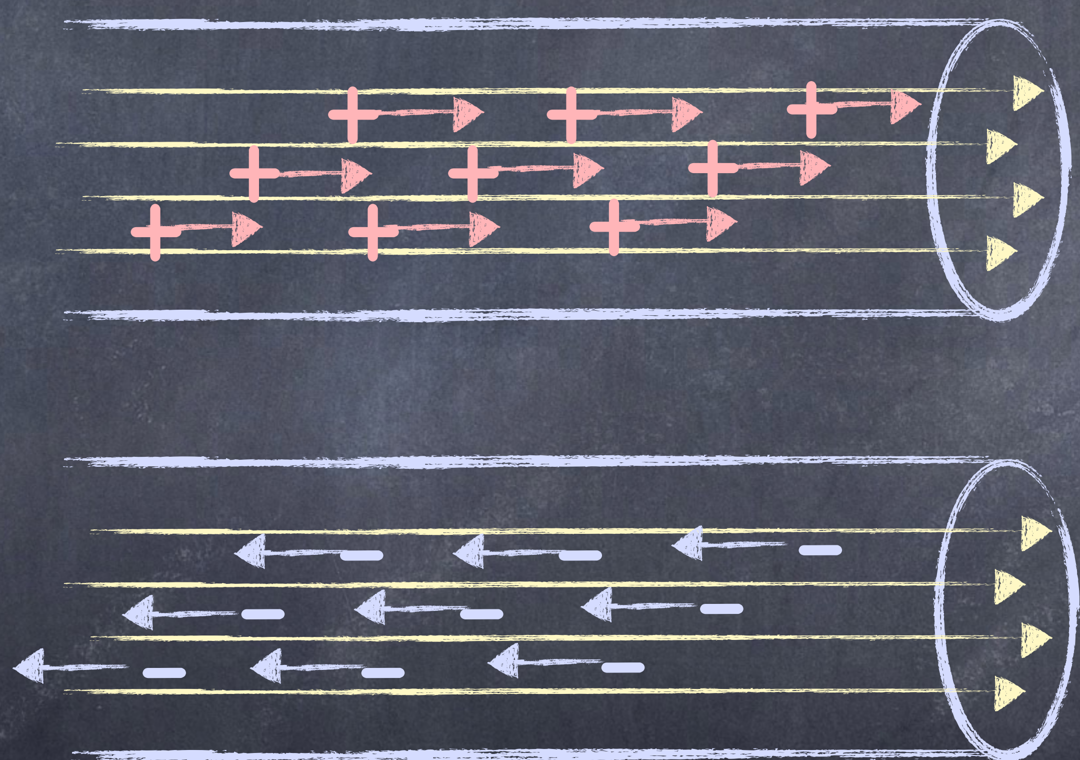
- "Current" describes flow of charges over time, but let's focus on conductors...
- Direction is defined along pathway, from higher potential to lower potential, in the direction of the internal electric field.
- Existence of E-field within conductor is due to resistivity (that we'll discuss later). **Note:** Contrary to static assumption of zero E-field!

Motions of Charge

Charges have drift velocity v_d in the direction of electric field inside the conductor.

Positive Charge Motion

Negative Charge Motion

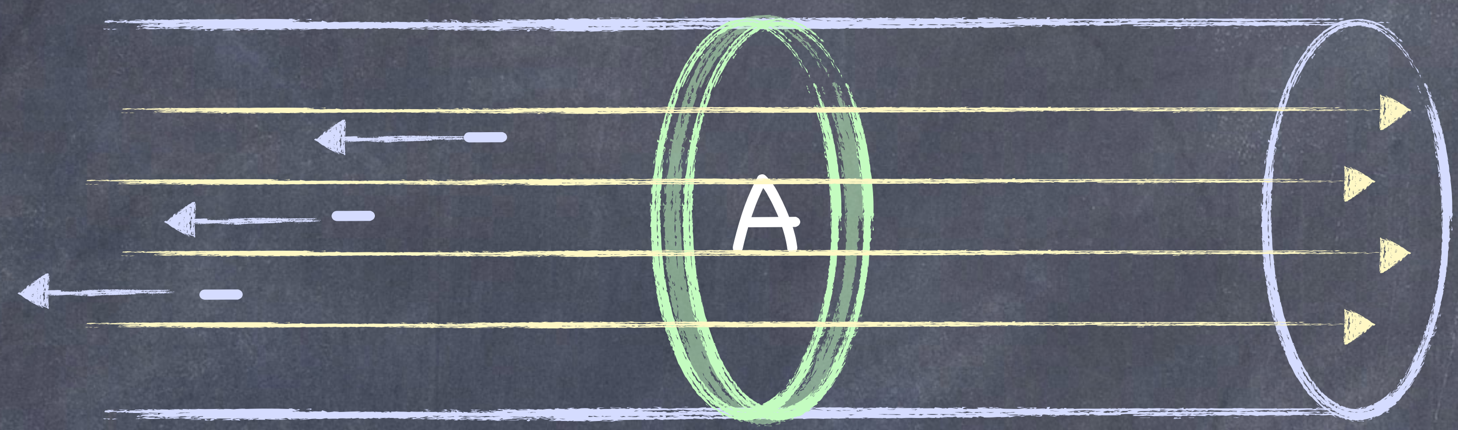


E-Field

E-Field

"Conventional current" assumes flow of positive charge, even though it may involve opposite flow of negative charge.

Current Definitions



Current "I" [Amperes = C/s]

Cross-sectional Area "A" [m^2]

Concentration of charge carriers "n" [m^{-3}]

Drift Velocity of charge carriers "v_d" [m/s]

Charge of individual carriers "q" [C]

Current

Rate of flow of charge "dQ" through area "A" over time "dt":

$$\boxed{I = \frac{dQ}{dt}}$$

Assume number density "n" of particles with charge "q" moving at "v_d":

$$\boxed{I = \frac{dQ}{dt} = nqv_dA}$$

Current and Current Density

Ignore sign of charge, since current is (by definition) directed from higher to lower potentials.

$$\boxed{I = \frac{dQ}{dt} = n|q|v_d A}$$

Current Density:

$$\boxed{J = \frac{I}{A} = n|q|v_d}$$

In Vector Form:

$$\boxed{\vec{J} = nq\vec{v}_d}$$

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Resistivity

- Relates current flow with electric field in conductors. (Note that non-zero electric field implies presence of current, resistivity, and potential diff.)
- It is a linear relationship that applies to "Ohmic" (i.e., linear) conductors.
- Varies with material properties and temperature.
- Large internal electric fields imply large potential differences across the conductor – large losses!
- Superconductors do not exhibit resistivity, and thus do not establish internal E-fields!

Resistivity

$$\boxed{\rho = \frac{E}{J}}$$

Units [Ohms*Meter], where
$[V/m]/[A/m^2]=[V*m/A]=[\Omega*m]$

Conversely, conductivity has units $[\Omega*m]^{-1}$!

In vector form: $$\boxed{\vec{E} = \rho\vec{J}}$$ Applies for "Ohmic conductors"

Resistance

Ohm's Law

$$\boxed{\vec{E} = \rho \vec{J}} \Rightarrow \boxed{V = IR}$$

Resistivity can be related to Resistance:

$$\boxed{R = \frac{\rho L}{A}}$$

Resistivity depends on material properties and temperature, Resistance is also a function of length and cross-sectional area of the conductor!

Summary / Next Class:

- **Mastering Physics** for next Wednesday.
- **Homework** for next Friday.
- **Prepare** to discuss **25.4-25.5**.