Tutorial 7

Current and Resistance

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Lecture Outline

- **Chapter 26/27**, D Halliday, R Resnick, and J Walker, "Fundamentals of Physics" 9th Edition, Wiley (2005).

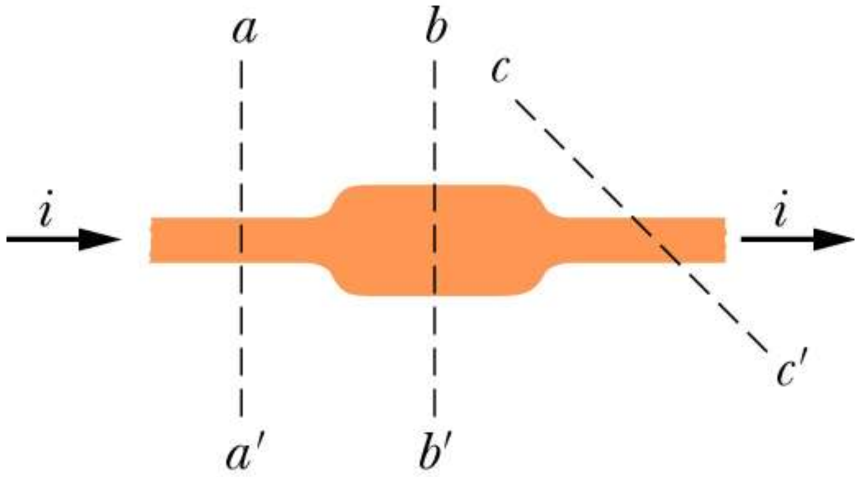
- Current and Resistance
  - Electric current
  - Current density and drift velocity
  - Resistance and resistivity
  - Ohm's law
  - Power in electric circuits

Lecture 07 Review

- Electric current i with unit Ampere, or Coulomb per second is defined as the time rate of flow of electric charges. Physically, it counts how many charges pass through a cross-sectional area over time.
- Since we are only counting the number of charges vs time, how (or the orientation of) the charge passed through the cross-section is not important, thus electric current i is a scalar quantity.

$$i = \frac{dq}{dt}$$

$$q = \int dq = \int_0^t i dt$$



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Lecture 07 Review

- To get a localized view of the current flow, we introduced Current Density $\boldsymbol{J}$, which is defined as the current flow per unit area.
- The value of $\boldsymbol{J}$ depends on both the magnitude and orientation of the unit area, thus it is a vector quantity.

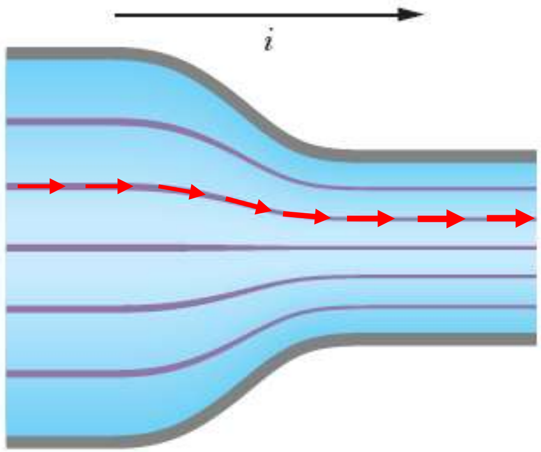

Fig. 26-4 Streamlines representing current density in the flow of charge through a constricted conductor.

$$i = \int \vec{J} \cdot d\vec{A}.$$

$$i = \int J\, dA = J \int dA = JA$$

$$J = \frac{i}{A},$$

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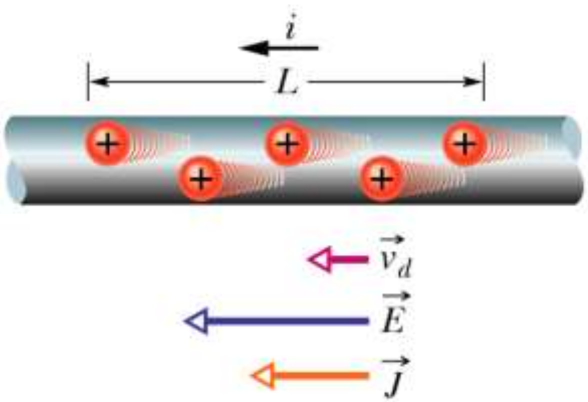
- As the electric charges flow down the wire, their speed depends on a number of factors. Physically, the charges cannot flow down the wire uninterrupted because there are obstacles such as nucleus and other impurities that the charges need to get around.
- A better description of how the charges flow down the wire is ‘the charges drift down the wire’.



$$\Delta q = (nAL)e \qquad \Delta t = \frac{L}{v_d}$$

$$i = \frac{dq}{dt} = \frac{\Delta q}{\Delta t} = \frac{(nAL)e}{L/v_d} = nAev_d$$

$$\boxed{\vec{J} = (ne)\vec{v}_d.}$$

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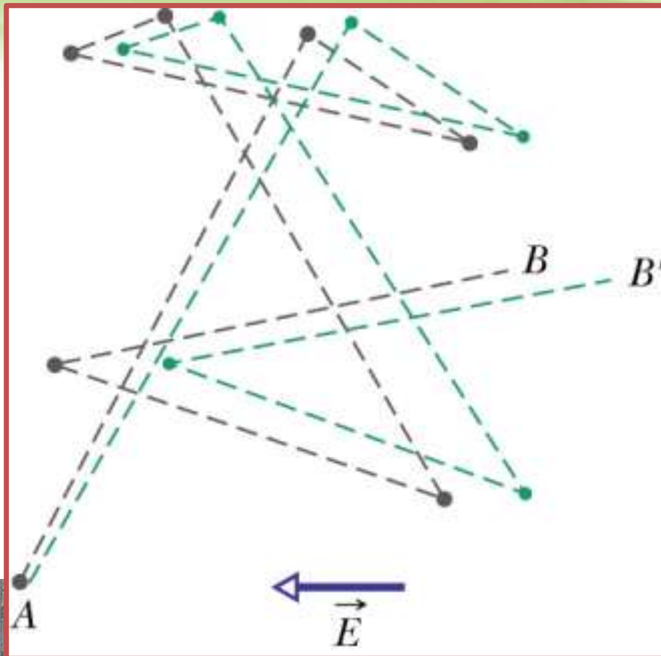
A
B
B'
$\vec{E}$


六福珠寶
LUKFOOK JEWELLERY
SONY
Canon
Nikon
SAMSUNG

Lecture 07 Review

- It is obvious that the drift speed depends on both the material properties (amount of obstacles) and how strong is the current (potential difference).
- To measure the ease of the charges flow in a material, we define Resistance R, having unit Ohm Ω.
- Similar to Capacitance, which is the ratio between voltage and charges in a capacitor, Resistance R is the ratio between the voltage and current in an object $V = R\, i$ (Ohm's Law).

$$R = \frac{V}{i} \qquad \text{(definition of } R\text{).}$$

$$1 \text{ ohm} = 1\ \Omega = 1 \text{ volt per ampere}$$
$$= 1 \text{ V/A.}$$

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Lecture 07 Review

- The localized view of resistance is resistivity ρ which relates the electric field and current density $\boldsymbol{E} = \rho \boldsymbol{J}$.
- Similarly, we introduced conductivity σ which relates E and J where $\sigma = {}^{1}/_{\rho}$ and $\boldsymbol{J} = \sigma \boldsymbol{E}$.

$$\vec{E} = \rho \vec{J}. \quad \Rightarrow \quad \rho = \frac{E}{J}$$

$$\vec{J} = \sigma \vec{E}. \quad \Rightarrow \quad \sigma = \frac{1}{\rho}$$

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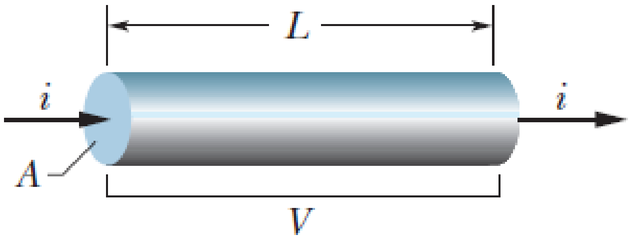
- Note that resistance is a property of an object, such as the resistance of a resistor or a piece of wire, but resistivity is a property of a material, such as resistivity of copper, gold or silicon.



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

- We also noted that resistivity of a material is usually temperature dependent, for most metal there is a linear dependency between temperature and resistivity over a broad range, where the resistivity increases with temperature.

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Halliday/Resnick/Walker
Fundamentals of Physics 8th edition

Classroom Response System Questions

Chapter 26 Current and Resistance

Interactive Lecture Questions

PHY 1202

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26.2.1. In which one of the following situations does a conventional electric current flow due north?

a) Protons in a beam are moving due south.

b) A water molecule is moving due north.

c) Electrons in a beam are moving due south.

d) Electrons in a wire connected to a battery are moving from south to north.

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26.2.2. The battery capacity of a lithium ion battery in a digital music player is 750 mA-h. The manufacturer claims that the player can operate for eight hours if the battery is initially fully charged. Given this information, determine the number of electrons that flow through the player as you listen to your favorite songs for three hours.

a) 6.2×10^{18} electrons

b) 1.0×10^{3} electrons

c) 2.4×10^{9} electrons

d) 6.3×10^{21} electrons

e) 8.1×10^{28} electrons

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26.2.3. When lightning strikes, the current flows from the ground upward to the clouds above. What is the direction of the electric field of the lightning?

a) upward

b) downward

c) perpendicular to the current at each location on the lightning bolt

d) parallel to the ground

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26.3.1. Which one of the following statements concerning the electric field inside a conductor is true if electrons are moving from right to left in a conducting wire?

a) The electric field must be zero in this case.

b) The electric field is directed perpendicular to the direction the electrons are moving.

c) The electric field is directed toward the left.

d) The electric field is directed toward the right.

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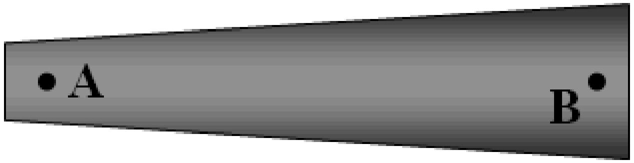
26.4.1. A copper wire is fabricated that has a gradually increasing diameter along its length as shown. If an electric current is moving through the wire, which quantities vary along the length of the wire?



a) current only

b) current and current density only

c) current density and electric field only

d) resistivity and current only

e) current, resistivity, current density, and electric field

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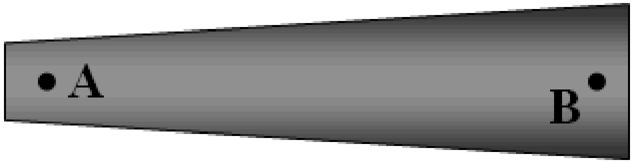

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26.4.4. Wires A and B are identical, except that the length of wire A is one-half that of wire B. If the same potential difference is applied between the two ends of each wire, how does the electric field within wire A compare to that in wire B?

a) The electric field in wire A is one fourth that in wire B.

b) The electric field in wire A is one half that in wire B.

c) The electric field in wire A is the same as that in wire B.

d) The electric field in wire A is twice that in wire B.

e) The electric field in wire A is four times that in wire B.

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26.4.6. When a potential difference is applied to a certain copper wire, a current of 1.5 A passes through the wire. If the wire was removed from the circuit and replaced with a copper wire of twice the cross-sectional area, what current would flow through the new wire? Assume the wires are identical in all other aspects.

a) 0.38 A

b) 0.75 A

c) 1.5 A

d) 3.0 A

e) 6.0 A

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26.4.8. For which combination for the length L and radius r of a wire will the resistance have the smallest value?

a) $L = 0.50$ m and $r = 0.03$ m

b) $L = 0.25$ m and $r = 0.08$ m

c) $L = 0.40$ m and $r = 0.2$ m

d) $L = 0.80$ m and $r = 0.1$ m

e) $L = 0.10$ m and $r = 0.05$ m

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26.5.4. A certain circuit contains a battery and a resistor. An instrument to measure the current in the circuit, an ammeter, is connected in between one of the terminals of the battery and one end of the resistor. The graph shows the current in the circuit as the voltage is increased. Which one of the following statements best describes the resistor in this circuit?

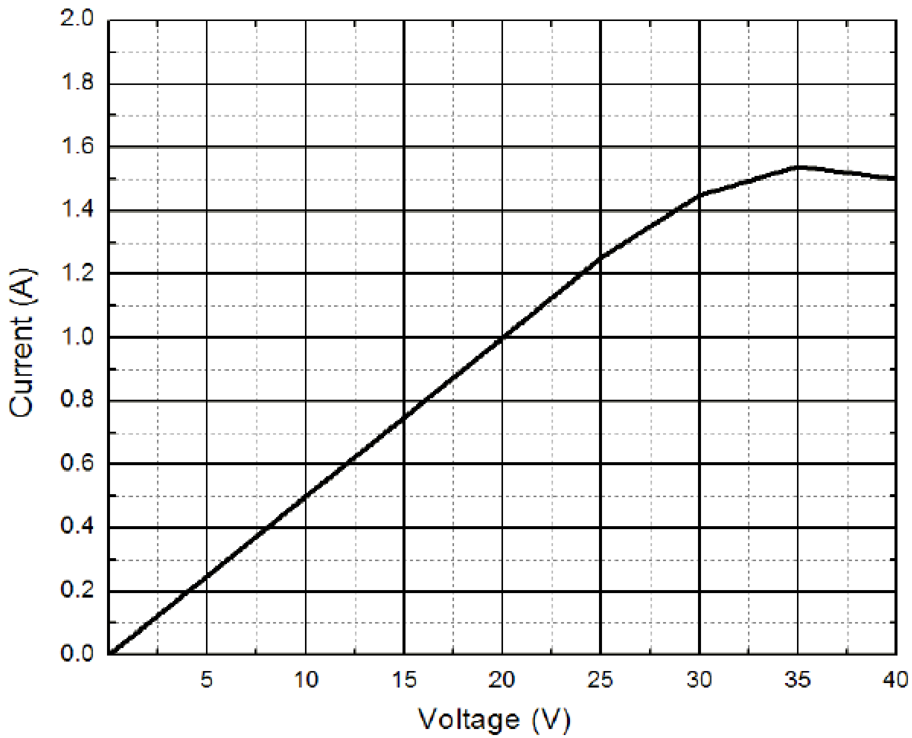
a) The resistor does not obey Ohm's law.

b) The resistor obeys Ohm's law for voltages between zero and twenty-five volts.

c) The resistor obeys Ohm's law for voltages between zero and thirty-five volts.

d) The resistor obeys Ohm's law for voltages between zero and forty volts.

e) The resistor obeys Ohm's law for voltages between thirty and forty volts.



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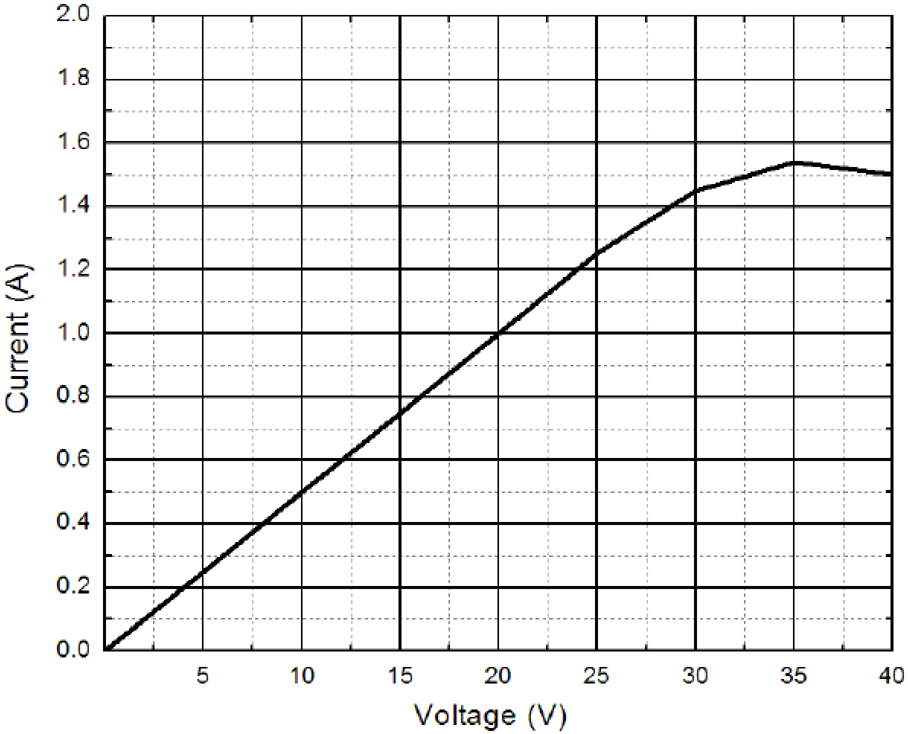

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