Lecture 18

8 Oct 2014

Resistance & Resistivity

- Applying the same potential difference across the terminals of two different materials can result in a different current
- Each material has a different resistivity while a given object has an electrical resistance, which is equal to the voltage difference divided by the current:

$$R = \frac{V}{i}$$

Note that resistance does not have to be constant but can instead vary units for resistance are $\frac{\text{Volts}}{\text{Amp}}$

but it is so important that it gets its own unit, the Ohm

$$1\ \Omega = \frac{1\ V}{1\ A}$$

A conductor for which the goal is to provide a constant resistance is called a <u>resistor</u>

resistance is due to electrons not being free to move in a ~~circuit~~ conductor but instead "colliding" w/ atomic nuclei.

resistance can change due to geometry but resistivity is intrinsic to a material.

resistivity at a given location is defined as

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

E ← magnitude of E-field

J ← magnitude of current density

If the material is uniform, then this will be the same throughout the material & so is intrinsic to the material.

units of ρ are $\frac{E}{J}$ $\frac{V/m}{A/m^2} = \Omega \cdot m$

Copper 1.69×10^{-8}

Iron 9.68×10^{-8}

glass 10^{10}

For uniform materials, we can write a vector equation as

$$\vec{E} = \rho \vec{J}$$

can define conductivity of material as $\sigma = \frac{1}{\rho}$

(reciprocal of resistivity)

Suppose now that we have a uniform wire of copper. Let L be the length & A the cross-sectional area.

Suppose we place a potential difference V across its terminals

QUESTION: What is E-field in terms of V + L?

Remember that $V = -\int \vec{E} \cdot d\vec{s}$

but then choose path along length to get

$$V = EL$$

What is current density?

uniform + derived last time to be

$$J = i/A$$

$$\Rightarrow \quad \rho = \frac{E}{J} = \frac{V/L}{i/A} = R \cdot \frac{A}{L}$$

$$\Rightarrow \quad R = \rho \cdot \frac{L}{A}$$

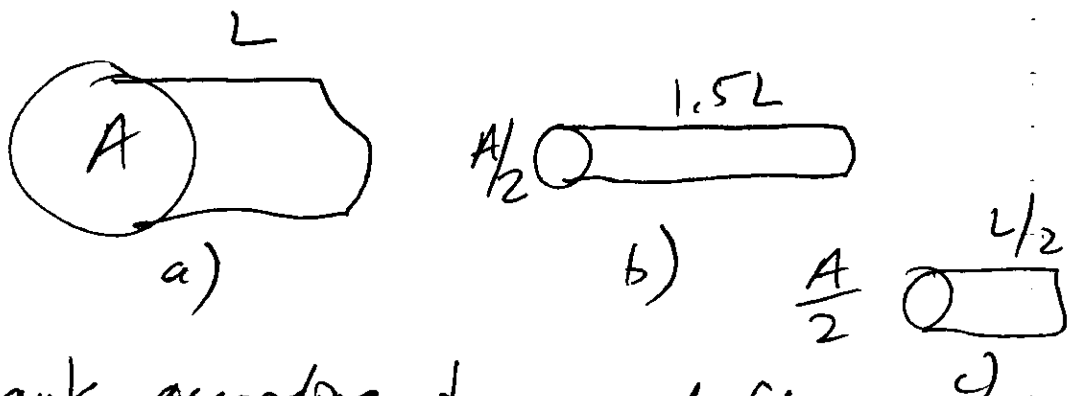
Interpretation:

longer wire has larger resistance between its two terminals.

larger area means less resistance to flow of electrons.

QUESTION:

Given three copper cylinders w/ same potential difference applied across them



Rank according to current flow through them

$V = iR$ + calculate

Resistivity varies w/ temperature

increases w/ higher temperature

@ molecular level, there are more collisions, leading to more resistance.

Can approximate as

$$\rho = \rho_0 + \rho_0 \alpha (T - T_0)$$

where T_0 is a reference temperature like room temperature & ρ_0 is resistivity @ T_0.

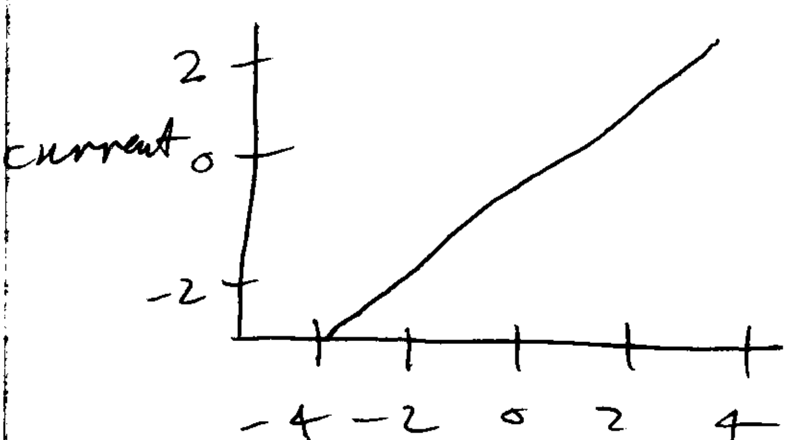
Interestingly, for certain materials, when T is less than critical temperature, resistance drops to zero! (superconductivity)

Ohm's law – correct only in certain situations

if current is always proportional to potential difference, then we say that Ohm's law holds.

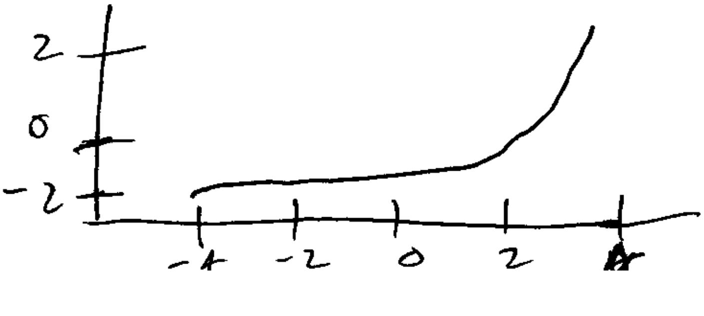
If not, then it does not hold!

For example, if we observe



then Ohm's law holds

If



Ohm's law does not hold (this would be curve for diode)