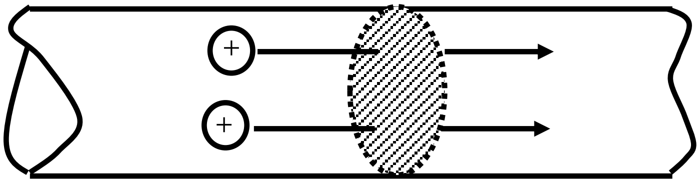
Current & Resistance

I. Current – I

A. **Definition:** Current is defined as the rate at which charge flows through a surface:



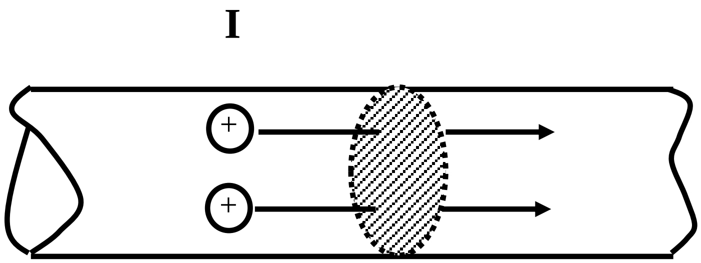
B. **Direction:** The direction of positive current flow is chosen

as the direction that ______________________________

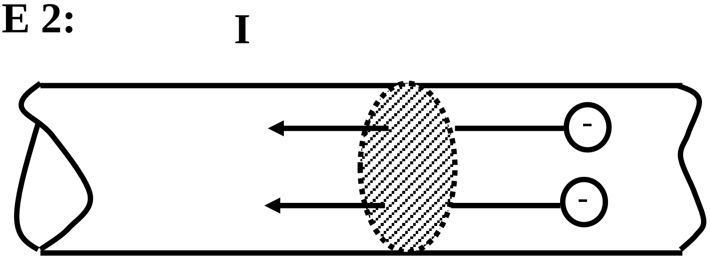
charge flows. (regardless of the true nature of the charge

carrier)

EXAMPLE 1:



EXAMPLE 2:



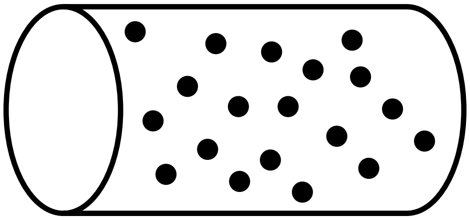
C. Units :

II. Model for Current in a Conductor

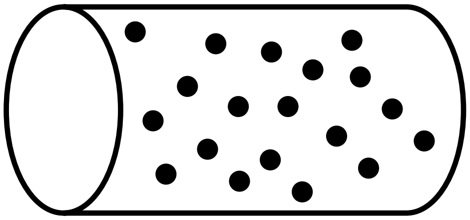
A true description of the microscopic processes of the flow of charge in modern electronics requires an understanding of the atom which requires Quantum Mechanics and Solid State Physics.

For this class we will restrict ourselves to the description of the flow of charge in metal conductors which can be modeled with less complicated classical physics.

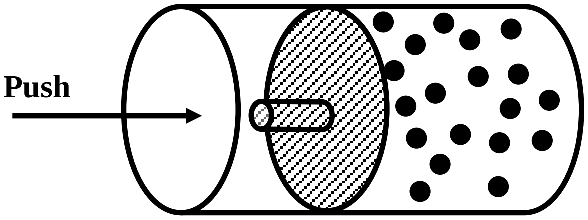
A. The outer electrons in a good conductor (ex. a metal) are very weakly bound to the atom. Thus, we can consider them to be free like atoms in a gas. This removes our need for the more exact and mathematically complex physics of Quantum Mechanics.



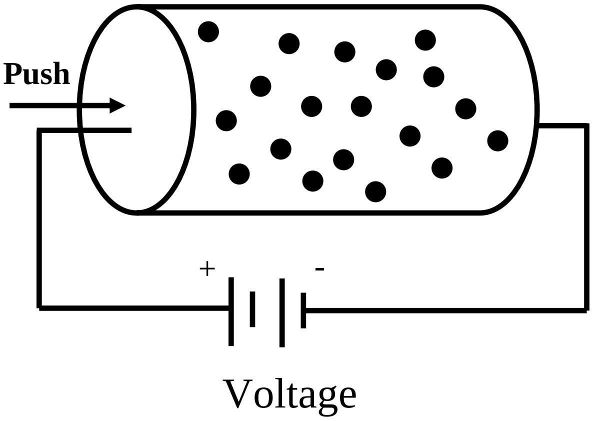
"Random Motion in Ideal Gas"



"Random Motion of Charges in a Conductor"



"Random Motion + Gas Flows to Right"



"Random Motion + Current Flow to Right"

B. Microscopic View

Let $n \equiv$ number of charge carriers per volume

$\vec{v}_d \equiv$ average net velocity of charge carrier (drift velocity)

$q \equiv$ charge on a carrier

$A \equiv$ cross sectional area

Thus, we have

ΔQ = (number of carriers) (charge per carrier)

$\Delta Q =$

but $\Delta x =$

$\Delta Q =$

We define the current density as $J \equiv \frac{I}{A}$.

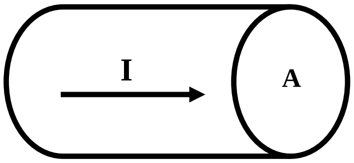
Thus, we have for the current density the result:

$$\boxed{J = n\,q\,V_d}$$

At the microscopic level, current flow in a material can occur in multiple dimensions and may have different drift velocities in each direction. Thus, the current density can be written in full vector form as:

$$\boxed{\vec{J} = n\,q\,\vec{V}_d}$$

EXAMPLE: What is the magnitude of the drift velocity of an electron in aluminum, if 5.00 A of current flow through an aluminum wire of area $4.00\text{x}10^{-6}$ m^2. (You may assume that each aluminum atom provides one electron for current conduction)

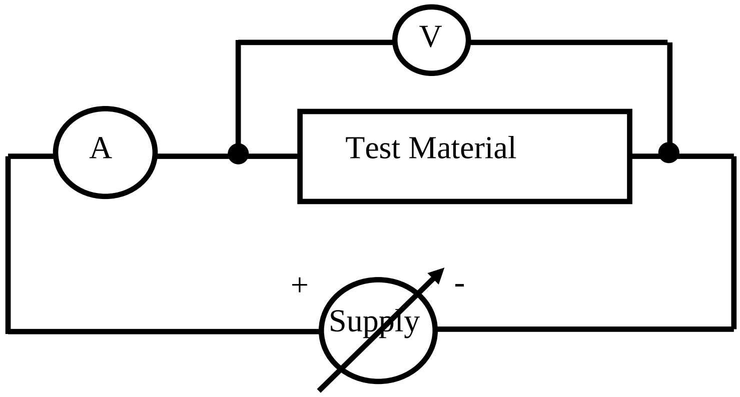


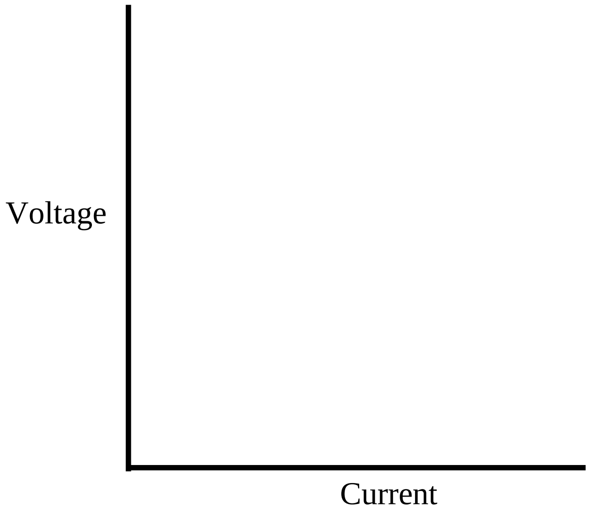
GIVEN: $A = 4.00\text{x}10^{-6}$ m^2, $\rho = 2.70$ g/cm^3, $I = 5.00$ A, and $q = 1.60\text{x}10^{-19}$ C

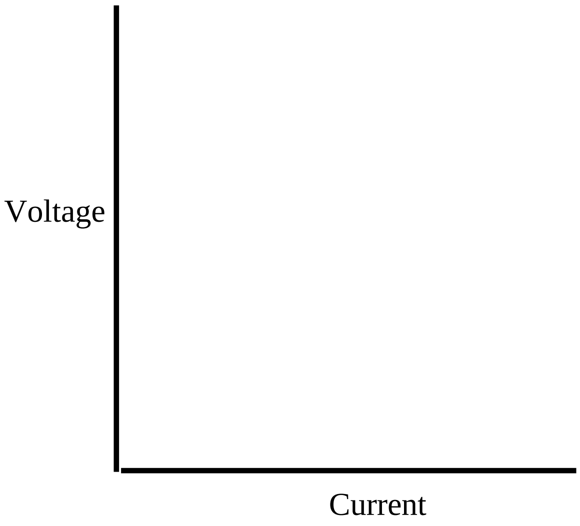
SOLUTION:

III. Ohm’s Law

George Simon Ohm showed that for some materials the current that flows through a material is ________________ ____________________________ to the potential difference across the material. Such materials are called ____________ materials.







“____________ Material”

“ ___ ___ ______ Material”

NOTE: Ohm's Law is not a law!!! Most materials do not have the correct I-V curve.

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IV. Resistance and Resistors

A. Resistance is a measure of a materials __________________

to the flow of charge through the material. It is the

______________________ of our I-V graph.

For an ____________________ material of fixed dimension,

the resistance is constant for a given temperature.

B. The unit of resistance is the __________________. Its

symbol is the _____________.

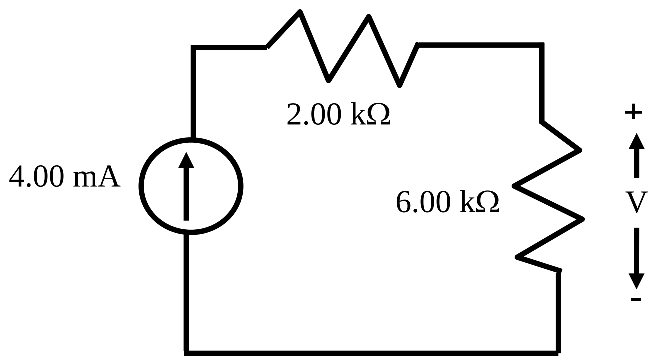
C. Resistor – An electrical element that transfers electrical energy into heat or mechanical energy while obeying Ohm’s Law.

Resistor Symbol:

Ohm’s Law:

EXAMPLE 1: What is the resistance of a material if you measure a voltage drop of 10.0 V when 4.00 mA of current flows through it?

EXAMPLE 2: What is the voltage drop across the 6.00 kΩ resistor in the circuit below?



V. Resistivity and Conductivity

A. The resistance of an element depends not only on the material from which the element was constructed but also upon the:

1) ____

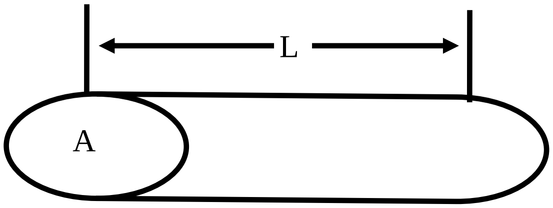
2) ____

B. The resistivity, ρ, is an intrinsic property of material at a given temperature just like density, melting point, etc.

C. The relationship that connects the intrinsic material property of resistivity and a resistor's resistance is:

D. Conductivity, σ, is defined as the inverse of resistivity.

EXAMPLE: You are required to construct a 2.00 Ω resistor using a carbon rod with a cross sectional area of 1.00×10^{-2} cm^2 piece of carbon. How long must your carbon rod be?



GIVEN: $\boldsymbol{\rho = 3.5 \times 10^{-5}\ \Omega \bullet \mathrm{m}}$ “Table in book”

SOLUTION:

VI. Temperature Effects of Resistance and Resistivity

A. As temperature increases, the resistance and resistivity of a

material ____!!

Increasing the temperature of a material causes the bound atoms to vibrate at increased speeds. These atoms scatter the moving charge carriers thereby reducing current flow.

(Consider people trying to travel on a moving sidewalk without hitting sliding doors that are constantly opening and closing. Higher temperature corresponds to faster doors!!)

B. Temperature Model for Resistivitivy

$\rho(t) \cong$

where α is the "temperature coefficient of resistivity"

EXAMPLE: What is the resistivity of silver at 100 C°?

SOLUTION: From tables in the book, we have for silver at 20 C° a resistivity of $1.47x10^{-8}$ Ω • m and a temperature coefficient of resistivity of $3.8x10^{-3}$ $(C°)^{-1}$.

VII. Power in Electric Circuits

A. The power supplied or consumed by any electrical circuit element (resistor, capacitor, battery, inductor, etc.) is given by

B. Special Formula for Resistor

Since resistors obey Ohm’s law, we can rewrite our general formula as

EXAMPLE: What is the power being dissipated by the resistor and stored by the capacitor in the circuit below: