Resistance
Mobility
Ohm's Law
Circuit Element: Resistor
Resistor as Sensor

Textbook: Ch. 2

**Resistance**

**Relevant Properties**
- Length $L$
- Cross-sectional Area $A$
- Carriers Density $N$
- Unit Vol Mobile Charge Carriers
- Mobility for Charge Carriers $\mu$

**Apply Voltage $V$ Across Material**
What Current $I$ Flows Through in Response?

Assume: Material Uniform
Outside $(V, Wires)$ Ideal

**Definition of Current**
- All Mobile Charge in Block
  - $I = \frac{dQ}{dt}$
  - $\frac{\Delta Q}{\Delta t}$

Choose Any Consistent $\Delta Q, \Delta t$ Make Math Easier
CHARGE IN A MATERIAL: MOBILITY

FREE SPACE

FIELD
\( \varepsilon \rightarrow \)

\( -q_e \)

\( \vec{F} = -q_e \vec{E} \)

FORCE: \( e^- \)

ACCELERATES

MATERIAL

\( \varepsilon \rightarrow \)

"LATTICE" OF ATOMS

ACCELERATED MOTION

"RESET" BY RANDOM COLLISIONS

MOBILITY

DEPENDS ON TEMPERATURE MATERIAL

\( V_d = \mu \varepsilon \)

GO FASTER

PUSH HARDER

AVERAGE MOTION

\( \vec{v}_d \) AVG VELOCITY

\( V \)

\( \text{cm} \)

\( \text{sec} \)
V-I CHARACTERISTIC

\[ \Delta Q = \frac{N A L q_e}{V_{\text{tot}}} \]

\[ \Delta Q = q_e N A L \quad [2] \]

**TIME**

\[ V_d = \frac{L}{\Delta t} \quad \text{MACRO} \quad [3] \]

**MICRO:** \( V_d \) FROM \( E \) FIELD

\[ V_d = \mu E \quad [4] \]

\( E \) FROM APPLIED \( V \)

**UNITS OF** \( [E] = \left[ \frac{V}{m} \right] \)

\[ E = \frac{V}{L} \quad [5] \]


**SOLVE FOR** \( \Delta t \)

\[ V_d = \frac{MV}{L} \]

**MASSAGE**

\[ I = \frac{q_e N A L \mu V}{L^2} \]

\[ I = \left( \frac{q_e N A \mu}{L} \right) V \]

**PROPORTIONAL!**

**OHM'S LAW:** \( V = I R \)

\[ R = \frac{V}{I} \]

\[ R = \frac{L}{2e N A \mu} \]
CIRCUIT ELEMENT: RESISTOR

Ohm's Law

\[ V_R = I_R \times R \]

Voltage drop across resistor

\[ \mathbf{\sigma} = \begin{bmatrix} \frac{V}{A} \end{bmatrix} \]

Resistance

\[ R = \frac{1}{qeN\mu} \cdot \frac{L}{A} \]

Material properties

Resistivity

\[ \rho = \frac{1}{q\mu N} \]  

\{eqn 1.10 in book\} 

\[ \mathbf{\rho} = [\sigma \cdot \text{cm}] \]
RESISTOR AS SENSOR

WHAT HAPPENS TO R IF ...

STRETCH?

\[ L \uparrow \Rightarrow A \downarrow \Rightarrow R^{\uparrow \uparrow} \]

MECHANICAL (GEOMETRY)

\[ R = \frac{1}{\rho \mu N A} \]

STRAIN GAGE

HEAT UP?

\[ T \uparrow \Rightarrow \mu \downarrow \Rightarrow R^{\uparrow} \]

POSITIVE TEMPERATURE COEFFICIENT w/ PTC

SOME MATERIALS

\[ \Rightarrow \downarrow \]

\[ T \uparrow \Rightarrow N^{\uparrow} \Rightarrow R^{\downarrow} \]

FREE CARRIERS

NEGATIVE TEMP COEFF w/ NTC

SHINE LIGHT?

PHOTON ENERGY FREES e\textsuperscript{-} FROM BOND

\[ N^{\uparrow} \Rightarrow R^{\downarrow} \]

PHOTO RESISTOR