Physics 126 Winter 2009
Lecture #5

Current, Resistance, & Ohm’s Law

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Current: Charge in Motion

- Flow in confined channel (like a river)
- Caused by potential differences (voltages)
- Definition: \( I = \frac{\Delta q}{\Delta t} \)
- Unit: Ampere (A)
  \[ 1 \text{ Amp} = 1 \text{ C/s} \]

- 1 A = lots of moving charge!
- Typical house: 200 A
- If flows in a loop: “circuit”
- Direct current (DC): flows one way
- Alternating current (AC): flows back and forth
Conventional Direction of Current

- Truth: particles which carry charge through wires in a circuit are mobile **electrons**
- Ben Franklin: positive charges as the carriers of charge
- The direction of current is by convention the direction in which a positive charge would move
Natural Currents: Lightning and the Northern Lights
Concept Test #1

The label on a car battery proudly claims that the battery will provide “250 amp-hours”. This rating describes the amount of what that can be drawn from the battery?

1) Charge
2) Current
3) Voltage
4) Power
5) Energy

\[ \text{Amp} = \frac{\text{C}}{\text{s}} = \frac{\text{Charge}}{\text{time}} \]

\[ \Rightarrow \text{Amp} \times \text{time} = \text{Charge} \]
Charge Conservation

- Charge conservation: charges cannot be created or destroyed.
- Result: the current which flows into a junction must equal the current that flows out.

\[ i_1 = i_2 + i_3 \]
The Electric Battery

- Used to establish electric current in a conductor
- Transformation of chemical energy stored in the battery to electric energy of the charge carriers
- Two oppositely charged electrodes (terminals)
- Potential difference exists between the terminals
Battery & Current

- When connected together, the potential difference between the battery terminal creates an electric field *inside* the conductor causing charges to move and establishing an electric *current*.

- The current is from regions of high potential to regions of lower potential.
Batteries in Parallel and Series

- A battery pack with four 1.2-volt cells are in series.
- The nominal voltage of the battery string is \( 1.2 \text{ V} \times 4 = 4.8 \text{ V} \)

- With parallel cells, the voltage stays the same = 1.2 V
- Current runtime increases

Resistance

- Life is tough for free electrons
- Resistance:
  - Repulsion from other electrons
  - Vibration of atoms
  - Impurities
- Life is tough for free electrons, especially on hot days
- Energy is dissipated
- Symbol for resistor:

http://regentsprep.org/Regents.physics/phys03/bresist/default.htm
Resistance ($R$) & Resistivity ($\rho$)

- Geometry of conductor matters:
  - Longer $\rightarrow$ more collision $\rightarrow$ more resistance
  - Thicker $\rightarrow$ more cross section area $\rightarrow$ less resistance
  - $\rho = \text{resistivity of material}$
  - Colder $\rightarrow$ less resistance

\[ R = \rho \frac{L}{A} \]

\[ \rho = \rho_0 [1 + \alpha (T - T_0)] \]
Concept Test #2

How does the resistance of a piece of conducting wire change if both its length and diameter are doubled?

1) Remains the same
2) 2 times as much
3) 4 times as much
4) ½ as much
5) ¼ as much

\[ R = \rho \frac{L}{A} \]
Relation among $V$, $I$, $R$

- The resistance of the resistor (light bulb) is $R$
- The voltage across the resistor is $V$
- The current through the resistor is $I$
- "Ohm’s law":

$$V = IR$$

Ohm ($\Omega$)

Assume perfect wire → NO voltage drop!
Ohm’s Law

\[ V = IR \]

**Real Ohm’s Law:**

\[ R = \text{constant for given object} \]

Independent of \( I, V \)
Electric Power

- EPE is transferred to some other form (heat, sound, light, etc.)
- Power:
  \[ P = \frac{\Delta \text{(Energy)}}{\Delta \text{(time)}} = \frac{(\Delta q)V}{\Delta t} = I \]

Fundamental

\[ P = IV = I^2R = \frac{V^2}{R} \]

Resistor

EPE decreases at the light bulb (resistor)
Concept Test #3

What is the resistance of a 100 watt light bulb designed for a 100 volt supply?

1) 50 Ω
2) 100 Ω
3) 150 Ω
4) 200 Ω
5) 250 Ω

\[ P = IV = I^2R = \frac{V^2}{R} \]

\[ R = \frac{V^2}{P} = \frac{(100 \, \text{V})^2}{100 \, \text{W}} = 100 \, \Omega \]
Alternating Current (AC)

- In an ac circuit the direction of current flow through the circuit changes at a particular frequency.
- The frequency used in the United States is 60Hz.
- AC generator symbol:
AC Voltage & Current

- $V$ and $I$ produced by an ac electric generator is sinusoidal

$$V = V_0 \sin(2\pi ft)$$
$$I = I_0 \sin(2\pi ft)$$

Peak values
AC Voltage & Current

Many electrical devices behave the same for a positive and negative voltage, e.g., resistor, light bulb, AC motor.

But some devices behave differently, e.g., Light Emitting Diode (LED).

LEDs can be used to show positive and negative halves of voltage cycle.

**Demo:**

Red LED = Positive
Green LED = Negative
Average Power

\[ \overline{P} = I_{rms} \cdot V_{rms} = I^2_{rms} \cdot R = \frac{V^2_{rms}}{R} \]

\[ I_{rms} = \frac{I_0}{\sqrt{2}} \]

\[ V_{rms} = \frac{V_0}{\sqrt{2}} \]

rms = Root Mean Square