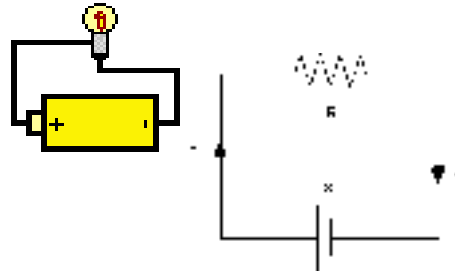


Physics I - Notes Ch. 19-20

Current, Resistance, and Electric Circuits

Electromotive force ($\text{emf} = \mathcal{E} = V$; units are *volts*) – “charge pump”; source that maintains the potential difference (voltage) in a closed circuit; **batteries and generators** (batteries convert chemical potential energy into electrical energy and generators convert mechanical energy into electrical energy)

- The maximum potential difference of a battery is the **emf** of the battery. This potential difference is created by a chemical reaction that transfers electrons from one terminal to another (chemical potential energy in the battery is transformed into electrical potential energy). In a circuit, the battery creates an electric field within and parallel to the wire, directed from the positive toward the negative terminal. The electric field exerts a force on the free electrons causing them to move (**electric current**).



Current (I) – the rate at which charge flows

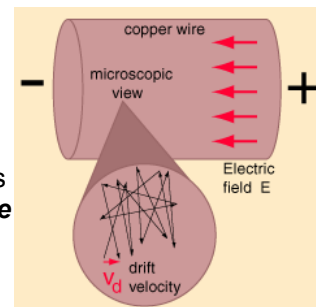
$$I = \Delta q / \Delta t \quad \text{units are } C/s = A \text{ (ampere)}$$

Example problem: How many electrons would pass by if a current of .75A was flowing in the circuit? (HW = Practice 19A pg. 695; #1-5).

- Direct current (dc)** – charge moves around the circuit in the same direction at all times; produced by batteries and dc generators
- Alternating current (ac)** – charge moves first one direction and then the opposite, changing direction from moment to moment; produced by ac generators (power companies)
- Conventional current** – by convention, the direction of the current is the same as the flow of a **positive** charge (in metals, opposite the direction of the flow of electrons); **this is consistent with our earlier use of a positive test charge for defining electric fields and potentials**

- Drift velocity** – net velocity of the charge carrier moving in an electric field

- When you turn on a light switch, the light comes on almost immediately. This is because the electric field reaches electrons throughout the wire at the speed of light in that medium. **But the individual electrons are NOT flowing from one end of the wire to the other at that speed.** In fact, their drift velocity is quite slow (a current of 10.0 A has a drift velocity of about 0.000246 m/s; at this speed it would take an electron 68 minutes to travel 1 m). **This is because the path of individual electrons is zigzag and their speed is much slower than the speed of light.**



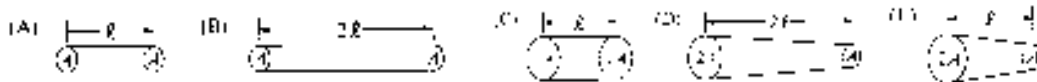
Ohm's law

- When a potential difference, V , is applied across the ends of many metallic conductors, the current is directly proportional to the applied voltage (within a certain range)
 - $V \propto I$; insert a constant and $V = IR$
 - R = proportionality constant = resistance of the conductor
- Ohm's law ($V = IR$):** for many materials (most metals), experiments show that the resistance is constant over a wide range of applied voltages; (ohmic — materials that obey Ohm's law; non-ohmic do not)

Example 1: A 1.5 V battery is connected to a small light bulb with a resistance of 3.5Ω . What is the current in the bulb? (HW = Practice 19B; #1-6)

- Resistance of a material depends on the nature of the material, length, and cross-sectional area.
 - $R = \rho L/A$
 - ρ = proportionality constant known as the **resistivity**; every material has a characteristic resistivity that depends on its electronic structure and temperature (Table 20.1 in your book)
 - In metals, the resistivity increases with increasing temperature**, whereas in semiconductors the reverse is true. **Superconductors** are a class of metals and compounds whose resistance goes to virtually zero below certain temperatures (**critical temperature**).

Example 2: The five resistors shown below have the lengths and cross-sectional areas indicated and are made of material with the same resistivity. Which has the greatest resistance?



- Resistor** – simple circuit element that provides a specified resistance; represented by a zigzag line in circuit diagrams (a straight line represents an ideal conducting wire, or one with negligible resistance). Resistors can be used in circuits to control the amount of current in a conductor.



Electric Power – rate of energy transfer (remember that Power=Work/time, but Work and Energy are interchangeable, so you can think of Power as Energy transferred per unit of time or $P = \text{Energy}/\text{time}$ AND $\text{Energy} = \text{Power} \times \text{Time}$). There are many ways to calculate power:

$$P = IV \quad \text{But since } V=IR, P = I(IR) \text{ or } P = I^2 R \quad \text{And since } I=V/R, P = \frac{V^2}{R}$$

Power units are *Watts* and 1 Watt = 1 Joule per second. Energy could be measured in Watts x seconds, but because we deal with larger amounts of Energy, we convert the Watts to kW and seconds to hours when dealing with our electrical use of energy (like in homes and businesses)...so, we use:

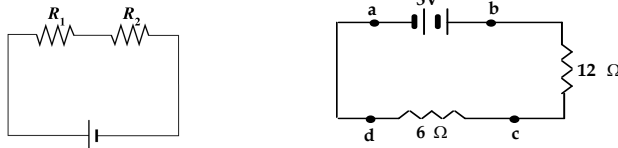
- Kilowatt-hour** – as the unit of energy used by electric companies to calculate consumption. Your electric company doesn't sell electrons, power or "electricity"...It sells ENERGY in kWh.

Example 3: Assuming electrical energy costs \$0.12 per kilowatt-hour, calculate the cost of operating an electric oven 4 hours a day for one year if the oven draws a current of 20.0 A at 120 V. (HW = 19C; #1-4 & 19D; #1-2)

Ch 20 – Schematic diagrams and circuits

- A schematic diagram is a diagram that depicts the construction of an electrical apparatus or circuit using symbols to represent the different circuit elements (emf, resistors, capacitors, wires, switches, ammeters, voltmeters, etc.).
 - An **ammeter** is an instrument used to measure current. **Ammeters must be inserted into a circuit so that the current passes directly through it (in series).** A good ammeter is designed with a sufficiently small equivalent resistance, so the reduction in current is negligible whenever the ammeter is inserted.
 - A **voltmeter** is an instrument used to measure the potential difference (voltage) between two points. **Voltmeters must be inserted in parallel in the circuit.** A good voltmeter is designed with a large resistance so the effects on voltage are negligible when it is inserted into the circuit.

Resistors in series



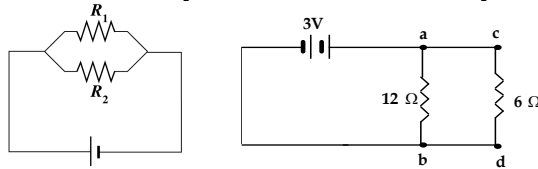
(For more examples of series circuits look in your textbook sample problem 20A)

- Current through all resistors in a series are the same**, because any charge that flows through the first resistor must also flow through the second. $I_t = I_1 = I_2 = \dots I_n$
- The potential difference across the emf is equal to the potential drops across all elements in a series circuit. This type of circuit is often called a “Voltage Splitter”

$$V = V_1 + V_2 \dots V_n$$
- For resistors in series, the **equivalent resistance** is the sum of all the resistors.

$$R_{eq} = R_1 + R_2 \dots R_n$$

Resistors in parallel – Two examples:



(look at sample problem 20 b for more examples of parallel circuits)

- When resistors are in parallel, V across each resistor is the same.**

$$V = V_1 = V_2 \dots V_n$$
- Any current directed into a junction equals the sum of the currents directed out of a junction. This type of circuit is sometimes called a “Current Splitter”.
- For resistors in parallel, equivalent resistance is found as follows:

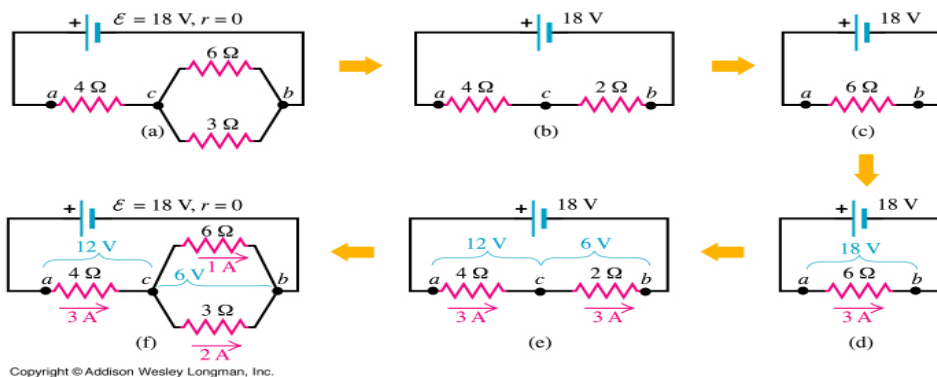
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots \frac{1}{R_n}$$
- Equivalent resistance in Parallel circuits is ALWAYS **less** than smallest resistance in group
- Household circuits are generally connected so appliances, light bulbs, etc. are connected parallel. In this way, each device gets the same V, and each can be operated independently.

Safety devices

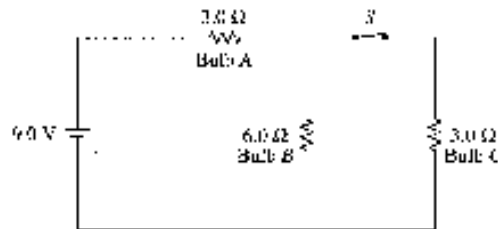
- **Fuses and circuit breakers** are safety devices that prevent circuit overloads that can occur when too many appliances are turned on at the same time (prevents current from overheating wires) or a short circuit occurs.
- **Short circuit** – occurs when a circuit is formed that has a very low resistance; a large current results which may damage appliances or cause a fire
- **Fuse** – a short piece of metal that melts from the heating effect of the current if the current is too large
- **Circuit breaker** – automatic switch that uses a bimetallic strip to open the switch if the current exceeds some set value
- **Ground-fault interrupter** (often found in electrical outlets in bathrooms) – detects small differences in current; opens/breaks the circuit preventing shock if tripped

Combined Series-Parallel Circuits

- Most circuits today use both series and parallel wiring to utilize the advantages of each type. Circuits containing combinations of series and parallel circuits can be understood by analyzing them in steps. When determining the equivalent resistance for a complex circuit, you must simplify the circuit into groups of series and parallel resistors and then find the equivalent resistance for each group until the circuit is reduced to a single resistance. Work your way backwards finding all potential drops and currents across the individual circuits.



Example 4: Light bulbs of fixed resistance $3.0\ \Omega$ and $6.0\ \Omega$, a $9.0\ \text{V}$ battery, and a switch S are connected as shown in the schematic diagram below. The switch S is initially closed.



- Calculate the current in bulb A .
- Which light bulb is brightest? Justify your answer.

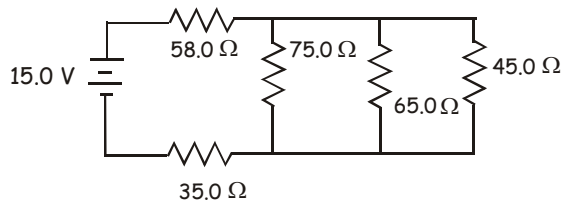
c. Switch **S** is now opened. By checking the appropriate spaces below, indicate whether the brightness of each light bulb increases, decreases, or remains the same. Explain your reasoning for each light bulb.

i. Bulb *A*: The brightness _____ increases _____ decreases _____ remains the same
Explanation:

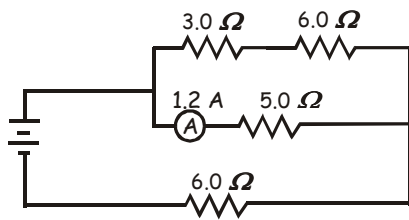
ii. Bulb *B*: The brightness _____ increases _____ decreases _____ remains the same
Explanation:

iii. Bulb *C*: The brightness _____ increases _____ decreases _____ remains the same
Explanation:

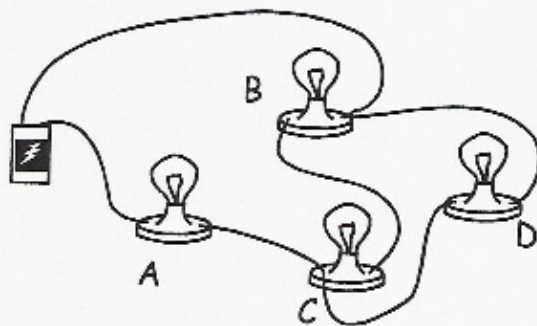
Example 5: Given the circuit below: (a) Find the equivalent resistance for this circuit. (b) Find the current supplied by the battery. (c) Find the current through the $65.0\ \Omega$ resistor.



Example 6: Find the potential difference of the battery in the circuit below.



Example 7: In the circuit shown below, A, B, C, and D are identical light bulbs. Assume the battery maintains a constant potential difference between its terminals and the resistance of each light bulb stays constant.



- Draw a diagram of the circuit using the appropriate symbols.
- List the bulbs in order of brightness, from brightest to least bright. If any two bulbs have the same brightness, state which ones. Justify your answers.
- Describe the change in brightness, if any, of bulb A when bulb D is removed from its socket. Justify your answer.
- Describe the change in brightness, if any, of bulb B when bulb D is removed from its socket. Justify your answer.

Physics Homework:

Ch 19 p. 717-719 #'s 7, 9, 11-15, 18, 21, 25, 28, 30, 32, 34, 36-38, and 40-43.

Ch. 20 p. 754-759 #'s 3, 6, 10, 11-13, 17, 18, 22-24, 35, 36, and 49.