Preview of Period 14:
Electrical Safety and Transmission

14.1 Fuses and Circuit Breakers

How do fuses and circuit breakers prevent fires?

14.2 Preventing Electric Shock

What safety devices prevent electric shock?

14.3 Transmitting Electricity with Transformers

How can we efficiently and safely transmit electricity from generating plants to consumers?

14.4 Transformers

How do transformers trade voltage and current in a circuit?

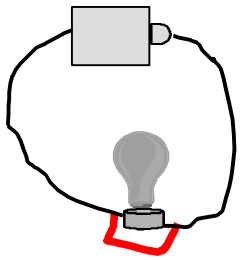
Joule Heating

Joule heating occurs when a resistor is heated as current flows through it.

$$P_{joule} = I^2 R$$

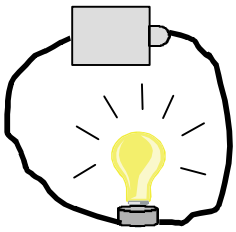
P_{joule} = power (in watts)
I = current (in amps)
R = resistance (in ohms)

- The larger the current, the greater the joule heating. If the current is large enough, joule heating can start a fire.
- A large current occurs when the resistance of the circuit is decreased.
- The circuit resistance decreases as more appliances are connected in parallel.
- A short circuit lowers the circuit resistance by providing a low resistance path for current



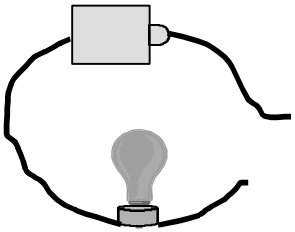
Open, Closed, and Short Circuits

Closed Circuit



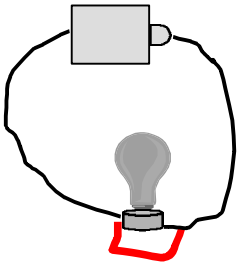
With a closed circuit the bulb lights.

Open Circuit



With an open circuit the bulb does not light.

Short Circuit



With a short circuit bulb does not light because the current follows a path with less resistance that bypasses the bulb.

Devices to Prevent Electrical Fires:

Fuses and Circuit Breakers

- **Fuses:** If a dangerously large current flows through a circuit, the fuse melts and opens the circuit.

- **Circuit Breakers:** A circuit breaker switches opens the circuit if the circuit resistance is lowered and a dangerously large current flows.

Avoiding Electrical Accidents

Preventing Electrical Fires

- Don't lay electric cords under carpeting. Keep cords away from water and heat.
- Disconnect appliances by pulling on the plug, not on the cord. Replace worn cords.
- Never break off the third safety prong on a plug. Use an adapter.
- If a switch or an outlet becomes warm, replace it immediately
- If an appliance catches on fire, unplug it immediately, if possible.
- Never put water on an electrical fire.

Act. 14.2: Devices to Prevent Shocks

Polarized Plugs

- Polarized plugs have one wide blade and one narrow blade.
- The blades fit into an electrical outlet in only one way, so current can flow in only one direction through the circuit.
- Polarized plugs allow appliances to be designed to reduce the risk of shock by the placement of the “hot” connection.

3 Prong Plugs

- The third safety prong is connected to ground.
- If a short circuit inside an appliance allows current to reach the appliance case, the safety ground prong may drain enough current to ground to create a current surge that trips the circuit breaker or blows the fuse.

Act. 14.2: Devices to Prevent Shocks

Double Insulated Cases

- If a short circuit occurs inside an appliance, insulating material in the appliance case prevents shock by separating the case from the current.

Ground Fault Circuit Interrupter

- Ground fault interrupters (GFCI) detect current leaking from the circuit.
- GFCI prevent electric shock by breaking the circuit in the event of a current leak.

Avoiding Electrical Accidents

Preventing Electrical Shocks

- Keep appliances away from water. If an appliance falls into water, unplug it before reaching for it – even if the appliance is turned off. Don't use a wet appliance.
- Don't touch an appliance with a metal object.
- Unplug lamps before changing a bulb and appliances before working on them.
- If someone is being shocked, call 911 for help.

  1) Turn off the power at the circuit breaker or fuse box if you can do so safely.

  2) Use great caution if you try to move a live wire from a person. Do so only using a non-conducting object such as glass, plastic, or DRY wood.

  3) Make sure you are standing on a dry surface.

Effects of Electric Shock on the Human Body

Amount of Current	Effect on the Human Body
0.001 amp	Barely detectable
0.005 amp	Painful
0.01 amp	Paralyzes some muscles making it hard to let go of conductor.
0.02 amp	Paralyzes breathing muscles. Can be fatal if sustained.
0.1 amp	Can cause ventricular fibrillation in the heart, which usually continues after the current stops. Death is likely.

Act. 14.3 Transmitting Electricity

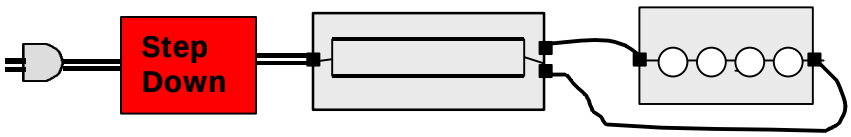
- Large amounts of electricity cannot be easily stored. Therefore, electricity must be generated as it is needed and transmitted to consumers. What is the most efficient way to transmit electricity?

How can we reduce joule heating in transmission wires? Should we use..

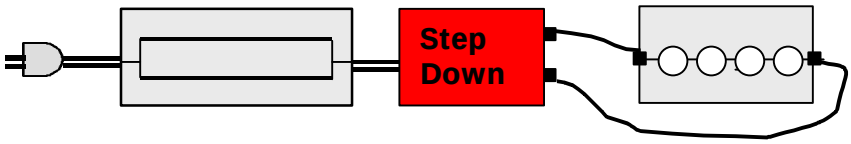
- Higher voltage or lower voltage?
- Very large currents or smaller currents?
- High resistance wires or low resistance wires?

Which circuit will have brighter bulbs?

Circuit #1



Circuit #2



Example of Power Transmission

Suppose we must transmit 1,670,000 amps of current with a voltage drop of no more than 18 volts across the transmission wires. How small must the resistance of the wires be?

Solve $V = I R$, for the resistance R:

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

$$\frac{18 \text{ volts}}{1.67 \times 10^{6} \text{ amps}} = 11 \times 10^{-6} \text{ ohms} = 1.1 \times 10^{-5} \text{ ohms}$$

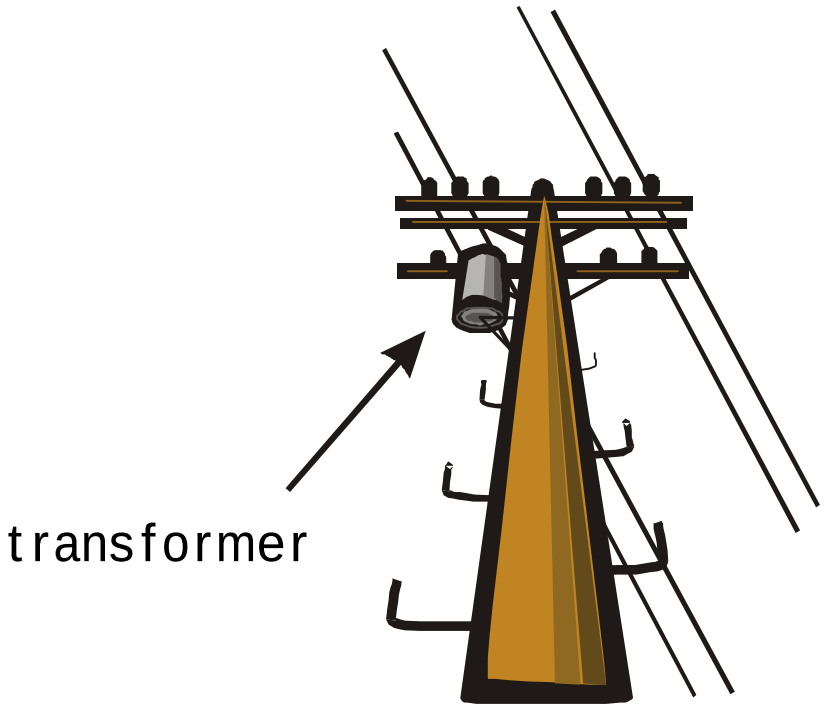
How much power does this small resistance waste as joule heating?

$$P_{joule} = I^{2} R =$$

$$(1.67 \times 10^{6} \text{ amps})^{2} \times 1.1 \times 10^{-5} \text{ ohms} =$$

$$2.8 \times 10^{12} \text{ amps}^{2} \times 1.1 \times 10^{-5} = 31 \times 10^{6} \text{ watts}$$

Act 14.3: Transformers



- **Transformers trade high voltage for low current or low voltage for high current.**
- **A step-up transformer increases the voltage and decreases the current flowing in a circuit.**
- **A step-down transformer decreases the voltage and increases the current.**
- **Transformers work only with alternating (AC) current. They do not work with the direct (DC) current provided by batteries or capacitors**

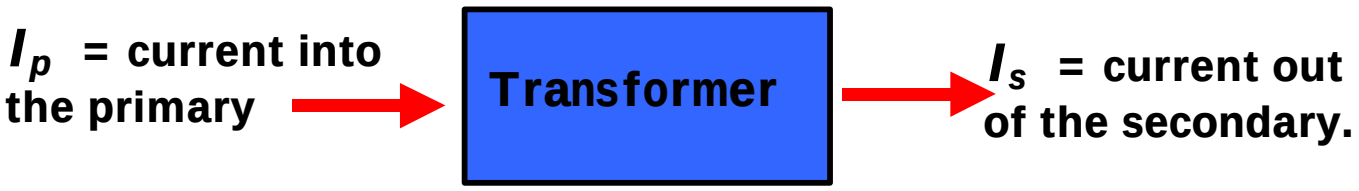
Voltage, Current, and Transformers

- Transformers trade high voltage for low current or low voltage for high current,
- The total power remains constant (except for small heating losses)

Power (into the primary) = Power (out of the secondary)

Since $P = I V$,

$$I_p V_p = I_s V_s$$



V_p = 50,000 volts
I_p = 300 amps

V_s = 120 volts
I_s = 125,000 amps

- Is this a step up or step down transformer?
- How much power goes into and comes out of it?

Period 14 Summary

14.1: **Circuit breakers and fuses prevent fires by opening the circuit when the current becomes dangerously large.**

A larger current and more resistance result in greater joule heating: $P = I^2 R$

14.2: **Ground wires, polarized and 3-prong plugs, and double insulated appliance cases prevent electric shock by preventing current flow through your body.**

Ground fault circuit interrupters open the circuit if current leaks from the circuit.

14.3: **The severity of an electric shock depends on the amount of current, the length of time it flows, and the portion of the body it flows through.**

More current flows through wet skin than through dry skin.

Period 14 Summary, Continued

14.4: **Transformers trade current and voltage, while keeping the power nearly constant.**

If the power into the primary transformer coil equals the power out of the secondary coil,

$$I_p V_p = I_s V_s$$

Step-up transformers reduce the current and increase the voltage for efficient long distance transmission of electricity.

Step-down transformers reduce the voltage and increase the current for safer home use of electricity.

Period 14 Review Questions

R.1. If a live 2400 volt power line dropped onto a car in which you were sitting, what should you do? Why? (The best course of action probably depends on whether your car is operable.) What actions should you definitely avoid?

R.2 If you find a person lying on the ground in contact with a live 2400 volt power line, what should you do? Why? What should you NOT do? Why not?

R.3 Explain why each of the following actions is unsafe:

a) Cutting off the grounding plug of a 3-prong plug so that it can be used in a two-prong outlet.

b) Resetting the same circuit breaker several times in one evening.

c) Pouring water on an electrical fire.

d) Touching a ground wire (or other conducting surface) and an electrical appliance at the same time.

R.4 In household wiring, switches, fuses, and circuit breakers should be installed on the hot side, rather than on the ground side of the circuit. Why?

R.5 Why are appliances that require large amounts of power for proper operation, such as electric ranges and clothes dryers, designed to operate from 240 volt lines rather than 120 volt lines?

Safety Device	Hazardous Situation the Device Prevents
Fuse	
Circuit Breaker	
Polarized Plug	
3 Prong Plug	
Double Insulated Cases	
Ground Fault Circuit Interrupter	