

# Preview of Period 13: Electrical Resistance and Joule Heating

## 13.1 Electrical Resistance of a Wire

What does the resistance of a wire depend upon?

## 13.2 Resistance and Joule Heating

What effect does resistance have on current flow?

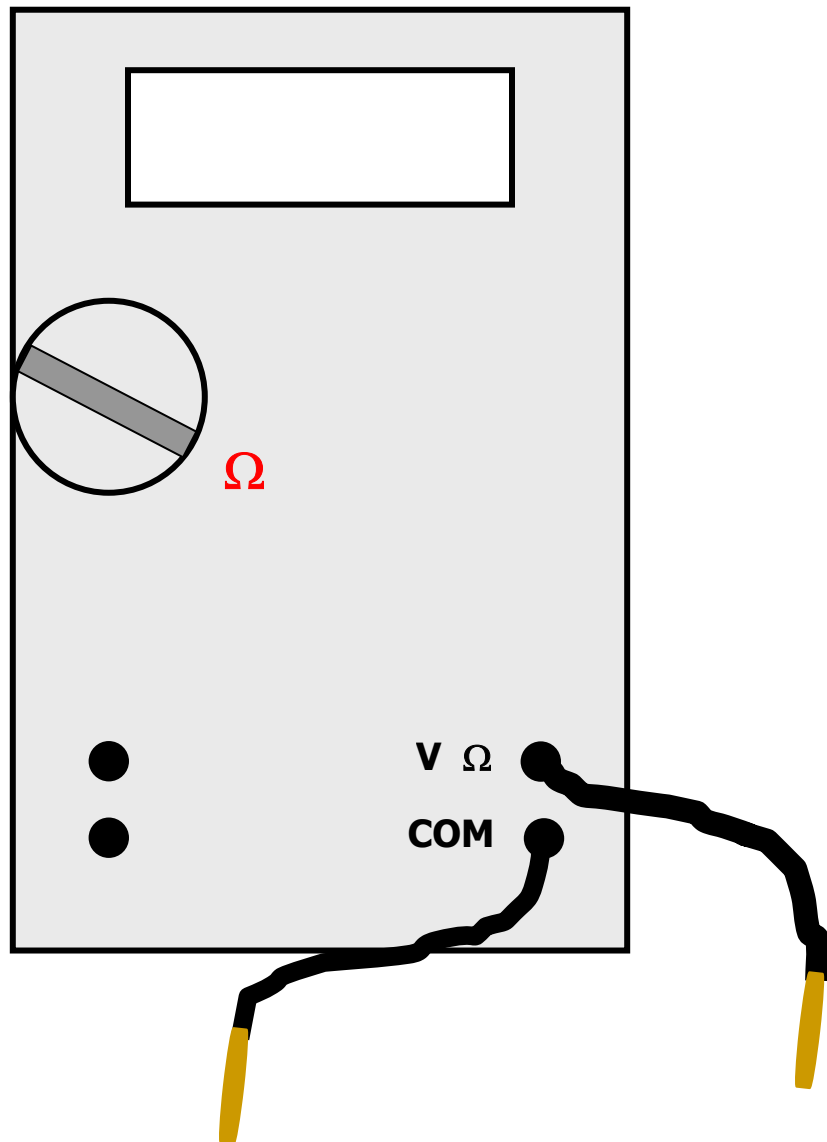
What is joule heating?

## 13.3 Temperature and Resistance

How does the temperature of a wire affect its resistance?

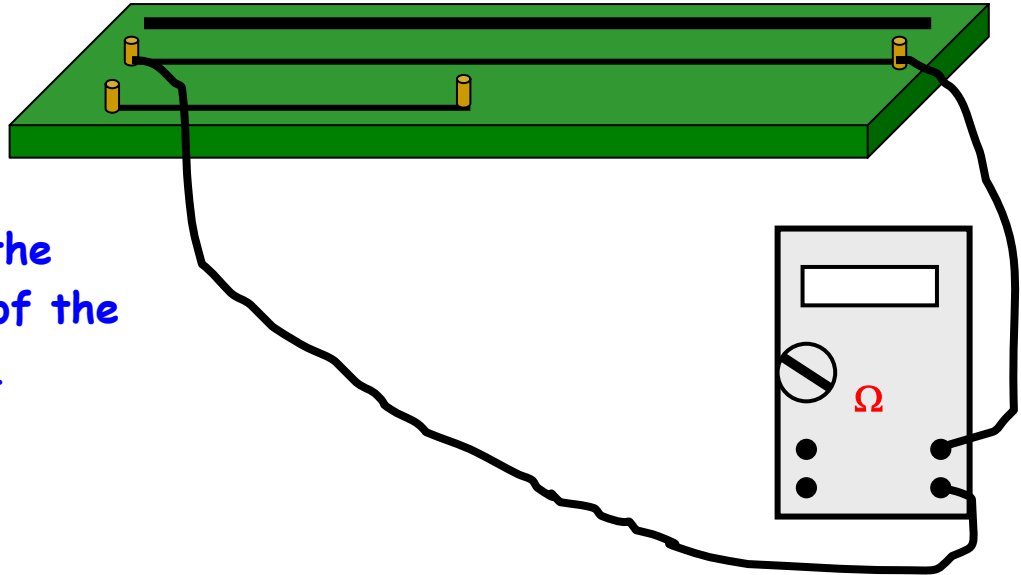
## Measuring Resistance with a Multimeter

1. Turn the dial to the ohm symbol ( $\Omega$ ).
2. Check that the wire leads are attached to the outlets on the **lower right** of the meter.
3. To measure resistance, touch the ends of the leads to each end of the resistor wire.



## Act. 13.1: Measuring Resistance

Measuring the resistance of the 30 cm wire.



1. **Do not connect the battery tray** to the green board with resistance wires.
2. Set the multimeter to "**Ω**" to measure resistance.
3. Touch the ends of the multimeter leads across the **thin** 30 cm wire to measure its resistance. Then move the multimeter leads to the ends of the 15 cm wire to measure its resistance.

## Act.13.1: Resistance of a Wire

Resistance of a wire =  $\frac{\text{Resistivity} \times \text{Length}}{\text{Area}}$

$$R = \frac{\rho L}{A}$$

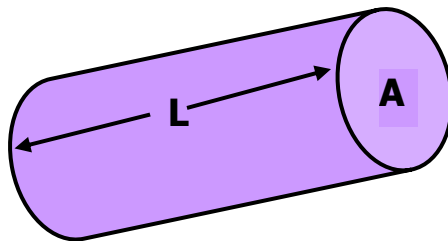
**$R$**  = resistance (in ohms)

**$\rho$**  = resistivity (in ohm meters)

**$L$**  = length of resistor (in meters)

**$A$**  = cross-sectional area (in meters<sup>2</sup>)

A Wire Resistor of Length  $L$  and Cross-Sectional Area  $A$

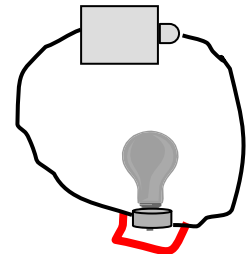


## Joule Heating in Wires

- ◆ Current flowing through wires encounters resistance, and some electrical energy is transformed into thermal energy. This is called **Joule heating**.
- ◆ 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.

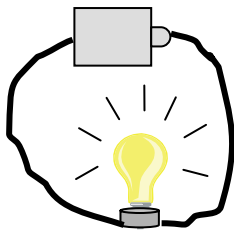
$$I = \frac{V}{R}$$

- ◆ 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



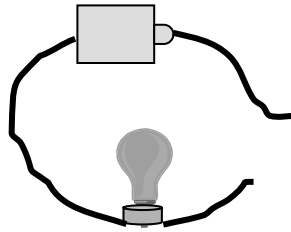
# Open, Closed, and Short Circuits

## Closed Circuit



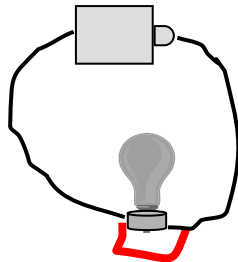
With a closed circuit the bulb lights.

## 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.

## Act.13.2: Resistance and 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)

Since the current  $I$  is squared ( $I \times I = I^2$ ), even a small amount of current can produce substantial joule heating.

$P_{joule} = I^2 R$  is a combination of two familiar equations:  $P = IV$  and  $V = IR$

Substitute  $V = IR$  for the  $V$  in  $P = IV$

$$P = IV = IIR = I^2 R = P_{joule}$$

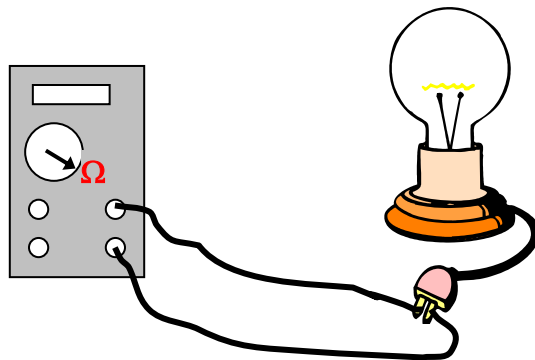
How much power would be wasted by joule heating if  $1.82 \times 10^6$  amps of current flowed through long distance transmission lines with a resistance of 4 ohms?

$$P_{joule} = I^2 R = (1.82 \times 10^6 \text{ amps})^2 \times 4 \Omega = 3.31 \times 10^{12} \text{ amps}^2 \times 4 \Omega = 1 \times 10^{13} \text{ watts}$$

## Act.13.3: Temperature and Resistance

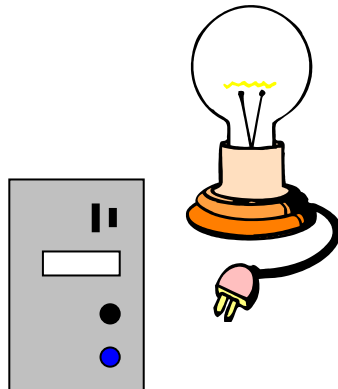
1. Use a multimeter to measure a light bulb's resistance when it is **NOT** operating.

Attach the multimeter leads to the prongs of the lamp's plug. **Caution:** Do **NOT** plug the bulb into an outlet.



2. Use a wattmeter to measure the bulb's voltage and current when it is operating.

Plug the bulb into the outlet attached to the wattmeter cord.

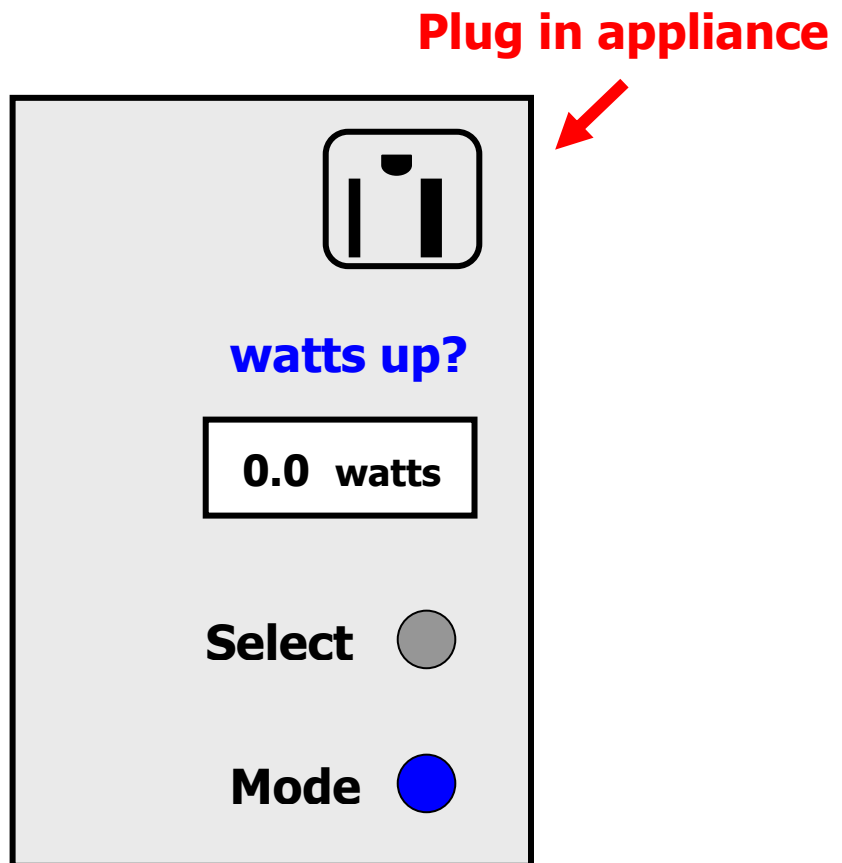


## Voltage and Current with a Wattmeter

Plug the appliance into the outlet in the front of the wattmeter and turn the appliance on. The appliance wattage appears in the display screen.

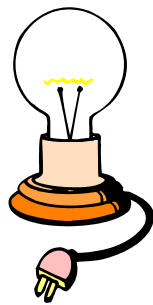
**Voltage:** Press the **MODE** button 4 times until voltage appears in the display screen.

**Current:** Press the **MODE** button once more and amps appear in the display screen.



## Act 13.3: Joule Heating

What happens to the light bulb's resistance while it is operating?



The bulb filament gets very hot.

The connecting wire gets warm from joule heating

- ◆ Most of the power goes to the bulb's filament.
- ◆ Some energy is wasted heating the connecting wires because they have some resistance.
- ◆ The result is a voltage drop along the wire:  $V = IR$  and
- ◆ Joule heating in the wire:  $P_{joule} = I^2 R$

Both of these effects depend on the current,  $I$ , and the resistance,  $R$ , but not on the voltage.

## Period 13 Summary

- 13.1** The amount of resistance of a resistor depends on its length, cross-sectional area, and resistivity.

Resistivity of a wire depends on its temperature and the material from which the wire is made.

$$R = \frac{\rho L}{A}$$

- 13.2** As current flowing through wires, some electrical energy is transformed into thermal energy called **Joule heating**.

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

- 13.3** Much power is wasted heating the wires when large currents are transmitted.

Therefore, electricity is transmitted over long distances at high voltage and supplied to homes at low voltage.

## Period 13 Review Questions

- R.1** Why do appliances that require large amounts of power for proper operation, such as electric ranges and clothes dryers, have thick electrical cords?
- R.2** What factors determine the resistance of a wire? What could you do to reduce the resistance of a wire?
- R.3** What is joule heating? When is joule heating desirable and when is it undesirable?
- R.4** To reduce the amount of energy wasted as joule heating during transmission of electricity, should you use thick wires or thin wires? Why?
- R.5** Why is copper used for household wiring? Why is aluminum no longer used for wiring?