Experiment 1:
The Room Temperature Filament Resistance of Different Wattage Light Bulbs

Purpose:

Determine the relationship between the wattage of a light bulb and the measured value of the filament resistance.

Materials Needed:

1. Ohmmeter - digital auto-ranging preferred, such as the VWR P/N 26983-175
2. 100 W light bulb
3. Optional - other wattage light bulbs

Procedure:

1. Measure the resistance of the filament of the 100 W (or other) light bulb by connecting one of the probes of the ohmmeter to the bottom contact of the bulb and the other probe to the side of the base of the bulb. This will measure the resistance of the filament, which dominates the resistance being measured.
2. Determine the resistance of the filament using the equation relating the wattage of the bulb to the filament resistance.
3. Discuss why the value of the resistance determined experimentally in step 1 differs from that obtained theoretically in step 2.
4. Optional. Repeat steps 1-3 for other wattage bulbs.
5. Determine the length of the filament from the room temperature resistance of the filament, using the equation:

$$L = \frac{RA}{\rho} .$$

Use the value for the room temperature electrical resistivity of tungsten of $\rho = 5.7 \times 10^{-6}$ ohm-cm. Use a value for the diameter of the filament of 0.0064 cm.

6. Discuss how the calculated length of filament might be contained in the bulb.

Teacher's Guide to Experiment 1

1. The measured value of the resistance of the 100 W bulb filament should be about 9.6 ohms.

2. The equation relating the wattage of the bulb to the filament resistance is:

$$P = \frac{V^2}{R} \quad \text{or} \quad R = \frac{V^2}{P}.$$

Since P = 100 W and V = 120 V, then $R = \frac{(120\ V)^2}{100\ W} = 144$ ohms.

Note that when V stands alone, it represents the voltage. When V appears after a number, it represents the unit of volts.

3. The resistance determined experimentally is the resistance when the filament is at room temperature. At room temperature the bulb is off, no current is flowing through the filament and no power is being dissipated in the filament. The resistance determined theoretically is the resistance when the filament is dissipating 100 W of power, i.e.. it is on and the filament is hot. The resistance of a metal increases as it gets hotter. In this case, the resistance when the filament is hot is 15 (144 ohms/9.6 ohms) times higher than when it is at room temperature.

(Optional: If an ammeter or a shunt resistor and a voltmeter are available, measure the resistance of the filament when the bulb is on by measuring the current I through the filament to determine the resistance using Ohm's Law: R = 120 V/ I)

5. $$L = \frac{RA}{\rho} = \frac{(9.6\ \text{ohms})(\pi)(0.0032\ \text{cm})^2}{5.7 \times 10^{-6}\ \text{ohm-cm}} = 54\ \text{cm}$$

6. The students should realize that the filament length of 54 cm is much longer than the bulb, so that the filament must be folded or coiled in some way. As they will see in the light bulb dissection experiment, the filament consists of a coiled coil of tungsten wire.

Advanced Topic for Answer 5.

The length of the filament can also be estimated in one other way. Equating P in equations 2 and 3, we obtain for the total emitting surface area of the filament:

$$S = \frac{V^2}{\epsilon\sigma R T^4}.$$

Recall that at the operating temperature of about 3000 K, the filament resistance of a 100 W bulb is about 121 ohms. Therefore,

$$S = \frac{(120\text{V})^2}{0.3 \times 5.67 \times 10^{-12}\ \text{W-cm}^{-2}\text{-K}^{-4} \times 121\ \text{ohms} \times (3000\ \text{K})^4}$$

$S = 0.86\ \text{cm}^2$

For a long cylindrical wire, $S = 2\pi rL$ and $r = 0.0032$ cm for a 100 W bulb so

$$L = \frac{S}{2\pi r} = \frac{0.86\ \text{cm}^2}{2\pi \times 0.0032\ \text{cm}}$$

$L = 43$ cm

which is fairly close to the value of 54 cm determined above from the room temperature properties.