Introduction to Filament Design Parameters: Background Material for Teachers

Filament diameters and lengths for different wattage light bulbs are shown in the table below. Don't disclose the length of the filament to your students! They will discover it by calculating this number shortly and they will also determine it experimentally. The values in table 1 below were obtained from a GE light bulb brochure.

Table 1: Filament Diameter and Length for Different Wattage Bulbs

Bulb Wattage (W)	Filament Diameter (cm)	Uncoiled filament length (cm)
25	0.0030	56
40	0.0033	38
60	0.0046	53
75	0.0053	55
100	0.0064	58
200	0.0102	72

(For a 60 W bulb, the length of the filament is 53 cm long. The filament, as will be seen later in the dissection experiment, consists of a coiled coil. After the first coiling, the filament length is 8.3 cm and consists of 1100 turns. This coil is then coiled again so that its final length is only 2.0 cm long!)

Let's calculate the resistance of the filament in two different ways from the table above. *Note that the resistance that we are calculating is the resistance of the filament when it is on, i.e. when it is hot.* The electrical resistivity of tungsten at the operating temperature of about 3000 K (2700 C) is about 8.6×10^{-5} ohm-cm or 15 times its room temperature value. Recall that the resistance of metals increases with increasing temperature. This value is to be used in the calculation of the last column below.

Table 2: Filament Resistance When the Bulb is On Calculated in 2 Ways for Different Wattage Bulbs

Bulb Wattage (W)	$R\ (\text{ohms}) = \frac{V^2}{P}$	$R\ (\text{ohms}) = \frac{\rho L}{A}$
25	576	681
40	360	382
60	240	274
75	192	214
100	144	155
200	72	76

To demonstrate in detail how these values were determined, we show the 100 W calculation in detail below.

$$R = \frac{V^2}{P} = \frac{(120\ V)^2}{100\ W} = 144 \text{ ohms.}$$

$$R = \frac{\rho L}{A} = \frac{(8.6 \times 10^{-5} \text{ ohm-cm}) \times (58 \text{ cm})}{\pi (0.0032 \text{ cm})^2} = 155 \text{ ohms.}$$

Note that the values are in relatively good agreement except for the 25 W filament resistance. This suggests that the 25 W filament runs at a somewhat lower temperature than the other bulbs, since then its electrical resistivity would be lower.

The resistance of the filament increases by about a factor of 15 between room temperature and 3000 K. Therefore the room temperature resistance of the filament should be 144 ohms/15 = 9.6 ohms for a 100 W bulb.