Solutions

1. a. $R = \frac{V^2}{P} = \frac{(120\ V)^2}{60\ W} = 240$ ohms

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

   c. $R = \frac{V^2}{P} = \frac{(120\ V)^2}{200\ W} = 72$ ohms

2. a. $I = \frac{V}{R} = \frac{120\ V}{240\ \text{ohms}} = 0.50$ Amps

   b. $I = \frac{V}{R} = \frac{120\ V}{144\ \text{ohms}} = 0.83$ Amps

   c. $I = \frac{V}{R} = \frac{120\ V}{72\ \text{ohms}} = 1.67$ Amps

3. a. $R_{\text{room temp.}} = \frac{240\ \text{ohms}}{15} = 16$ ohms

   b. $R_{\text{room temp.}} = \frac{144\ \text{ohms}}{15} = 9.6$ ohms

   c. $R_{\text{room temp.}} = \frac{72\ \text{ohms}}{15} = 4.8$ ohms

4. a. $L = \frac{RA}{\rho} = \frac{16\ \text{ohms} \times 3.14 \times (.0023\ \text{cm})^2}{5.7 \times 10^{-6}\ \text{ohm-cm}} = 47$ cm

   b. $L = \frac{RA}{\rho} = \frac{9.6\ \text{ohms} \times 3.14 \times (.0032\ \text{cm})^2}{5.7 \times 10^{-6}\ \text{ohm-cm}} = 54$ cm

   c. $L = \frac{RA}{\rho} = \frac{4.8\ \text{ohms} \times 3.14 \times (.0051\ \text{cm})^2}{5.7 \times 10^{-6}\ \text{ohm-cm}} = 69$ cm

5. a. $T^4 = \frac{P}{\epsilon\sigma S}$

$$= \frac{60\ W}{0.3 \times 5.67 \times 10^{-12}\ W\text{-}cm^{-2}\text{-}K^{-4} \times 2 \times 3.14 \times .0023\ cm \times 47\ cm}$$

$T = 2685\ K$

b. $T^4 = \frac{P}{\epsilon\sigma S}$

$$= \frac{100\ W}{0.3 \times 5.67 \times 10^{-12}\ W\text{-}cm^{-2}\text{-}K^{-4} \times 2 \times 3.14 \times .0032\ cm \times 54\ cm}$$

$T = 2713\ K$

c. $T^4 = \frac{P}{\epsilon\sigma S}$

$$= \frac{200\ W}{0.3 \times 5.67 \times 10^{-12}\ W\text{-}cm^{-2}\text{-}K^{-4} \times 2 \times 3.14 \times .0051\ cm \times 69\ cm}$$

$T = 2701\ K$

6. *Solution 1*

For the 25 W bulb, the hot resistance is:

$$R = \frac{V^2}{P} = \frac{(120\ V)^2}{25\ W} = 576 \text{ ohms.}$$

For the 75 W bulb, the hot resistance is:

$$R = \frac{V^2}{P} = \frac{(120\ V)^2}{75\ W} = 192 \text{ ohms.}$$

The hot resistance at the highest setting of the bulb corresponds to the parallel combination of the 25 W and 75 W filaments, so

$$R = \frac{576 \text{ ohms} \times 192 \text{ ohms}}{(576 \text{ ohms} + 192 \text{ ohms})} = 144 \text{ ohms.}$$

Solution 2

The wattage at the highest setting is the sum of the two lower wattages or 100 W.

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

7. It is always better to turn off the lights whenever you leave the room.

The power used by the lamp when it is just turned on is almost 15 times greater than the power used when it is hot, as we learned in experiments 1 and 2.

(Recall that $P=V^2/R$, V is 120 V when the lamp is on and 0 V when the lamp is off, and $R_{hot\ filament} = 15\ R_{cold\ filament}$ so that $P_{cold} = 15P_{hot}$)

The energy used in a given time period t is given by the E = P x t where P is the power. After the lamp is turned on, the time the filament is cold is very short, certainly less than 1 second, because the lamp is instantly bright - it does not slowly build up in brightness. So the power dissipated when the filament is cold (but heating up) during the first second is at most 15 times greater than the power dissipated when the filament is hot for 1 second. Therefore it is more energy efficient to turn off a lamp unless you plan on turning it on again within 15 seconds or so.

An example is shown on the next page. The first light bulb is turned on for 15 sec, then turned off for 45 sec, then turned on again for 10 sec. The second bulb is turned on and kept on for the next 70 sec.

Recall E = P x t and assume that the power dissipated when the bulb is cold (but heating up) is $15P_0$ and that the power dissipated when the bulb is hot is P_0.

The energy used by the first bulb is:
E = 15 P_0 x 1 sec + P_0 x 14 sec + 0 x 45 sec + 15 P_0 x 1 sec + P_0 x 9 sec = 53 P_0 - sec

The energy used by the second bulb is:
E = 15 P_0 x 1 sec + P_0 x 69 sec = 84 P_0 - sec

So the second bulb used less energy than the first bulb.

Time (sec)	Power used by first bulb (units of P_0)	Power used by second bulb (units of P_0)
0	15	15
0.9	15	15
1	15	15
1.1	1	1
2	1	1
14.9	1	1
15	0	1
15	0	1
59.9	0	1
60	15	1
60.9	15	1
61	15	1
61.1	1	1
70	1	1
70	1	1