Ch. 12 problems

12.1. (I) Calculate the current through a person and identify the likely effect of touching with one hand a wire carrying 120 V ac (a) if the person is standing on a rubber mat and has a resistance of 200,000 Ω to ground; (b) if the person is standing barefoot on a wet bathroom floor and has a resistance of 5000 Ω to ground.

Ans. a)

$$I = \frac{V}{R} = \frac{120 \text{ V}}{200{,}000\ \Omega} = 6 \times 10^{-4} \text{amps} = .6 \text{ mA}$$

Checking table 12.1, we predict that no sensation of current.

Ans. b)

$$I = \frac{V}{R} = \frac{120 \text{ V}}{5000\ \Omega} = .024 \text{ amps} = 24 \text{ mA}$$

Checking table 12.1, sustained muscular contraction, fatal if continued.

12.2. (I) Suppose a person touches the case of an electrical appliance while taking a bath. The total resistance through the person's hand and body to the metal drainpipe and into the ground is 4,000 Ω. What is the smallest voltage on the case of the appliance that could cause ventricular fibrillation?

Ans. From table 12.1 we know that 100 mA may result in ventricular fibrillation. Solve Ohm's law for voltage and substitute $100 x 10^{-3}$ Amps for the current.

$$I = \frac{V}{R} \text{; Therefore } V = IR$$

$$V = IR = 100x10^{-3} A \bullet 4000\Omega = 400 volts$$

12.3. (I) A man trying to fish a burning slice of bread out of a toaster foolishly uses a metal butter knife and comes into contact with 120-V ac. Luckily, he is wearing rubber-soled shoes and doesn't even feel the current passing through him. (a) What is the minimum resistance of this person to ground? (b) What current would pass through him, and what effect is it likely to have if his hands are wet and he is barefoot with a resistance of only 6000 Ω to ground?

Ans. a) We will use 1 mA for the current, because from table 12.1 we see that it is the threshold of sensation. Use V = 120 volts for the voltage. First we solve Ohm's law for resistance:

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

$$R = \frac{V}{I} = \frac{120 volt}{1x10^{-3} amp} = 1.2x10^{5}\Omega$$

Ans. b) $I = \frac{V}{R} = \frac{120 volt}{6000\Omega} = 0.02 amps$ = 20 mA

The likely effect of a 20 mA current is sustained muscular contraction, fatal if continued-can't breath.

12.4. (I) During experiments to determine the sensitivity of sheep hearts to electric current it is found that a current of 30 μA applied directly to the heart produces ventricular fibrillation. If the resistance of a sheep heart is 500 Ω, what minimum voltage could produce this current?

Ans. First we solve Ohm's law for voltage:

$I = \frac{V}{R}$; Therefore V=IR

V = IR = $30x10^{-6} A \bullet 500\Omega = 0.015 volts = 15 mV$

12.5. (I) A current of 20 μA applied directly to the heart (perhaps by accident during surgery) may cause ventricular fibrillation. If the resistance of a human heart is 300 Ω, what is the smallest voltage that poses a danger when the heart is exposed during surgery?

Ans. $V = IR = 20x10^{-6} \bullet 300\Omega = 6x10^{-3}V = 6.0 mV$

12.6 (I) Example 12.1 mentions that an appliance using 120 V and having a resistance of 100 Ω consumes 144 W of power. (a) Show this. (b) Calculate the current through the person in Example 12.1 if his resistance is 100,000 Ω rather than 10,000 Ω. What is the likely effect of such a current upon him?

Ans. a. We know that we can calculate electrical power by multiplying the current by the Voltage. P=IV

We are given a voltage of 120 V, but not the current, I. We do know that the resistance is 100 Ω. From Ohm's law we know that $I = \frac{V}{R}$. We will substitute for I in the power equation.

$$P = IV = \frac{V}{R} \bullet V = \frac{V^2}{R}$$

$$Power = \frac{V^2}{R} = \frac{(120V)^2}{100\Omega} = 144 watts$$

Ans. b $$I = \frac{V}{R} = \frac{120V}{100{,}000\Omega} = 1.2x10^{-3}A = 1.2 \text{ mA}$$

From table 12.1 we know that this current will result in a slight tingle.

12.7 (II) An electronics technician might work on an appliance while it is plugged in, but she will take care that her resistance to ground is very large. Her body has a resistance of 200,000 Ω, her rubber soled shoes have a resistance of 500,000 Ω, and the rubber mat on which she stands has a resistance of 1,000,000 Ω. What is the maximum harmless voltage she can contact?

Ans. Her total resistance is 200,000 Ω + 500,000 Ω + 1,000,000 Ω. Total resistance is 1.7 x 10^6 Ω. From table 12.1 we know that the maximum harmless current is 5mA, which is 5 x 10^{-3} Amp.

$I = \frac{V}{R}$; Therefore V = IR = $5x10^{-3}A \bullet 1.7x10^6\Omega = 8{,}500 volts$

12.8 (II) Suppose a physician who is well insulated from the ground touches the ungrounded metal case of an appliance that has shorted to its hot wire and thus has a voltage of 120- V ac. With her other hand she simultaneously touches the pacemaker lead of a patient who is grounded. Her resistance is $100{,}000\,\Omega$ and that of the patient is $1000\,\Omega$. Calculate the current through the two people (they are in series), and identify the likely effect on each.

Ans. Because they are in series, the resistances just add normally.
Total resistance is $101{,}000\,\Omega$

$$I = \frac{V}{R} = \frac{120\text{V}}{101{,}000\Omega} = 1.19 \text{ x } 10^{3} \text{ amp} = 1.19 \text{ mA}$$

This will result in just a tingle for the doctor but could be fatal for a micro-shock sensitive patient. 1.19 mA is well above the .20 μA that would cause ventricular fibrillation in the patient.