PHYS 1200 Physics of Everyday Experience

Review questions and exercises for Lecture 25 (E&M-3)

1. What gives rise to electrical resistance in a conductor?
2. What is the relation between, current, voltage, and resistance in a circuit?
3. What is the meaning of the electrical power consumed in a circuit and how is it calculated?
4. Why are power strips, devices having multiple electrical outlets, limited by a current rating?
5. What is the difference between series and parallel connections of elements in a circuit, e.g., light bulbs?
6. What is direct current or DC?
7. How can 4, 1.5 V batteries ne connected to provide a voltage of 3.0 V?
8. A simple electric circuit has a 12 V battery connected to a light bulb having a resistance of 100 Ohms. (a) How much current flows through the light bulb, and (b) how much power is consumed by the light bulb?
9. An electrical device uses 5 A when connected to a 100 V power source. What is the resistance of the device?
10. The rear defroster on your car uses a current of 4 A when connected to the 12 V battery. How much electrical power is consumed when the defroster is used to melt the ice?
11. The lithium batteries in a cell phone provide 3.7 V. If the cell phone uses 5 mA (1 mA = 0.001 A), what is its resistance?
12. You have two flashlights that operate on 1.5 V AA batteries. One flashlight uses two batteries in a chain and the second one uses 5 batteries in a chain. Both flashlights have a current of 1.5 A flowing through the circuit. What power is being used by the light bulb in each flashlight?
13. Two light bulbs, one rated at 60 W and the other rated at 120 W, are operated on a 120 V circuit. Which light bulb has the higher resistance?
14. A 1.5 V alkaline D cell battery can provide about 40,000 J of electric energy. If a current of 2 A flows through two of these batteries in a flashlight, how long will the batteries be able to keep the light bulbs on?
15. The two wires of a high-voltage transmission line are providing 600 A to and from a city. The voltage between the two lines is 400,000 V. How much power is the transmission line delivering to the city?

16. When the electric power in problem 15 reaches the city, its voltage is reduced to 120 V before entering the city houses. How much total current is passing through the homes of the city? Assume that there is no loss of electric power in the voltage reduction process.

Answers and Solutions:

1. Electrical resistance in a conductor is caused by the fact that as electrons move through the conductor, they collide with the ions which slows them down and causes them to move in zig-zag paths.

2. V = I R ← Ohm's law.

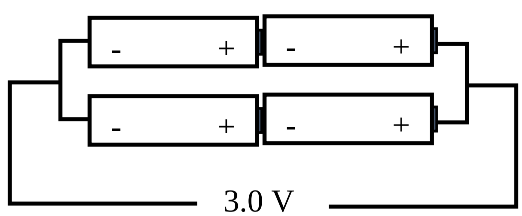
3. As electrons move through a conductor and collide with the ions, heat is produced. The amount of heat energy produced each second is the electrical power dissipation. $P = IV = I^2R$.

4. When multiple appliances are plugged into an outlet, each draws current. The maximum electrical current that the power strip can handle safely is the current rating.

5. Devices connected in series have the same current passing through them. Devices connected in parallel have the same voltage across them.

6. With direct current or DC, the current always flows in one direction. Direct current is produced by batteries.

7. To get 3 V from 4, 1.5 V batteries, they should be connected in this way:



8. (a) I = V/R = 12 V / 100 ohms = 0.12 A. (b) P = IV = 0.12 A x 12 V = 1.44 W.

9. R = V/I = 100 V / 5 A = 20 ohms.

10. P = IV = 4 A x 12 V = 48 W

11. R = V/I = 3.7 V / 0.005 A = 740 ohms

12. With 2, 1.5 V batteries connected in series the total voltage is 3 V, so the power consumed is P = I V = 1.5 A x 3 V = 4.5 W. With 5, 1.5 V batteries connected in series the total voltage is 7.5 V. Then P = IV = 1.5 A x 7.5 V = 11.25 W.

13. $P = I V$, but $I = V/R$ from Ohm's law so $P = (V/R) V = V^2 / R$. Therefore the higher wattage bulb has the lower resistance. We can calculate the resistance directly: $R = V^2/P$, so for the 60 W bulb, $R_{60} = (120)^2 / 60 = 240$ Ohms, and for the 120 W bulb, $R_{120} = (120)^2 / 120 = 120$ Ohms.

14. Power is energy per unit time ($P = E/t$), so energy $E = P t$. A 1.5 V battery with 2 A of current provides $P = IV = 2 \text{ A} \times 1.5 \text{ V} = 3 \text{ W}$ or 3 J/s.
Then $40{,}000 \text{ J} = (3 \text{ J/s}) \times t \rightarrow t = 40{,}000/3 = 13{,}333$ s or dividing by 60 x 60, roughly 3.7 hours.

15. $P = I V = 600 \text{ A} \times 400{,}000 \text{ V} = 6\times10^2 \times 4\times10^5 = 24\times10^7 = 2.4 \times 10^8 \text{ W} = 240\times10^6 \text{ W} = 240 \text{ MW}$.
MW = megawatts = 1 million watts.

16. If there is no power loss in reducing the voltage then the power at the transmission line will be equal to the power consumed by the city homes.

$P_T = P_H = I_H V_H, \rightarrow 2.4 \times 10^8 \text{ W} = I_H \times V_H \rightarrow I_H = (2.4 \times 10^8 \text{ W}) / 120 \text{ V} = 2.0 \times 10^6 \text{ A} = 2 \text{ MA}$.

(The reduction in voltage is done using transformers, which we will discuss later. Transformers are better than 95% efficient.)