CH 18-1 – Current

Important Ideas

- An ideal battery maintains a constant potential difference across its terminals regardless of what the battery is connected to. The potential difference across a battery when it is not connected to a circuit is called the battery's *emf*. When a battery is connected to a light bulb, for example, a uniform electric field is created inside each wire in the circuit and the filament (though E in the filament is different than E in the connecting wires). The electric field inside the wire points toward lower potential.
- Current is the rate of flow of charge:

$$I = \frac{\Delta Q}{\Delta t}$$

  Conventional current is the direction of flow of positive charge. If electrons are flowing (as is typical for a conductor), then conventional current is opposite the direction that electrons flow.
- For a wire of cross-sectional area A, the current in the wire is

$$I = neAv$$

  where n is the number of free electrons per unit volume (i.e. electron density) and v is the drift speed of electrons in the wire. The drift speed is related to the electron mobility u (which is a property of the type of metal) and the electric field E that pushes current through the wire. Thus $v = uE$.
- The potential difference across a wire of length L is $\Delta V = EL$.
- The resistivity of the metal is $\rho = \frac{1}{jeu}$. The resistance of the wire is

$$R = \frac{\rho L}{A}$$

- The potential difference across a wire is proportional to the current I through the wire and the resistance of the wire R. This relationship is called Ohm's Law.

$$\Delta V = IR$$

- As current flows through a battery, it gains electric potential energy $|\Delta U| = e|\Delta V|$. As current flows through a resistor (such as a wire), it loses electric potential energy $|\Delta U| = e|\Delta V|$.
- The rate that electric potential energy is gained or lost is called power. Power is energy/time and has a unit of watts. 1 W = 1 J/s. For a device in a circuit,

$$\Delta P = I|\Delta V|$$

  For a resistor,

$$\Delta P = \frac{|\Delta V|^2}{R}$$
$$\Delta P = I^2 R$$

  The brightness of a light bulb is proportional to its power.

Examples

1. If a current of 1 A flows in a wire, how many electrons pass a cross-section of the wire in 1 second?

2. What is the number density of conduction electrons in copper? Copper has a density of 8900 kg/m^3, an atomic mass of 63.5 g/mol, and 1 free electron per atom.

3. What is the drift speed of electrons in a copper wire of diameter 1 mm if the current is 1 A.

4. You connect a 1.5 V battery to a 6 Ω light bulb. What will be the current through the filament of the bulb?

5. How many joules of electrical energy does the bulb use per second?

6. If you double the resistance of the light bulb in the previous question, what happens to the current?

   (a) It changes by factor of 2.
   (b) It changes by factor of 1/2.
   (c) It stays the same.
   (d) It increases by some other factor.
   (e) It decreases by some other factor.

7. A 1.5 V battery is connected to Bulb A and you observe its brightness. You then replace the bulb with Bulb B and observe that it is brighter. Across which bulb is the potential difference the greatest?

   (a) Bulb A.
   (b) Bulb B.
   (c) Neither; it is the same.

8. A 1.5 V battery is connected to Bulb A and you observe its brightness. You then replace the bulb with Bulb B and observe that it is brighter. Through which bulb is the power the greatest?

   (a) Bulb A.

   (b) Bulb B.

   (c) Neither; it is the same.

9. A 1.5 V battery is connected to Bulb A and you observe its brightness. You then replace the bulb with Bulb B and observe that it is brighter. Through which bulb is the current the greatest?

   (a) Bulb A.

   (b) Bulb B.

   (c) Neither; it is the same.

10. A 1.5 V battery is connected to Bulb A and you observe its brightness. You then replace the bulb with Bulb B and observe that it is brighter. Which bulb has a greater resistance?

    (a) Bulb A.

    (b) Bulb B.

    (c) Neither; it is the same.

11. Suppose that Filament #1 has the same length as Filament #2 and they are made of the same material. But Filament #2 has a greater cross-sectional area. Which filament has a greater resistance?

    (a) Filament #1

    (b) Filament #2

    (c) Neither; it is the same.

12. Suppose that Filament #1 has the same length as Filament #2 and they are made of the same material. But Filament #2 has a greater cross-sectional area. Which filament will be brighter in a light bulb that is connected to a battery?

    (a) Filament #1

    (b) Filament #2

    (c) Neither; it is the same.

13. Suppose that Filament A has the same cross-sectional area as Filament B and they are made of the same material. But Filament B has a greater length. Which filament will have a greater resistance?

    (a) Filament A

    (b) Filament B

    (c) Neither; it is the same.

14. Suppose that Filament A has the same area as Filament B and they are made of the same material. But Filament B has a greater length. If in a bulb and connected to a battery, which filament will be brighter?

    (a) Filament A

    (b) Filament B

    (c) Neither; it is the same.