Power and Energy

Electrical circuits are designed to serve a useful function. When a circuit is equipped with a light bulb, beeper, or motor, the electrical energy supplied by the battery is transformed into other forms in the electrical device. For example, a light bulb transforms electrical energy into heat and light. An electrical device, such as a light bulb, is referred to as a **load**.

Power (P) is the rate at which electrical energy is supplied to a circuit (by the battery) or consumed by the load.

$$power = \frac{energy}{time} \qquad \text{or} \qquad P = \frac{E}{t}$$

Whether we are discussing the energy supplied by the battery, or the energy consumed at the load, power refers to the rate at which energy is being transformed. In a battery, the change is positive (since charges in the battery gain energy), while in a load the change is negative (since the charges in the load lose energy).

The metric unit of power is the watt (W). One watt is equivalent to transforming one joule of energy per second.

When it is observed that a light bulb is rated at 60 watts, this means that the bulb converts 60 joules of electrical energy into heat and light every second. A 120 watt bulb converts twice as much energy per second.

Example 1
A hair dryer uses 180 000 J of energy. A woman uses it for 4 minutes to dry her hair. What power was needed to run the dryer?

Recall that

$$V = \frac{E}{Q} \qquad \text{and} \qquad I = \frac{Q}{t}$$

These can be used to define an alternate method of calculating power.

$$\begin{aligned} P &= \frac{E}{t} \\ &= \frac{VQ}{t} \\ &= \left(\frac{Q}{t}\right)V \\ P &= IV \end{aligned}$$

Thus, the power supplied by a battery or consumed by a load can be determined by multiplying the current and voltage.

$$P = IV$$

Example 2
How much power is needed to run an electric car warmer that requires a current of $5\ A$ and a voltage of $120\ V$?

The kilowatt-hour

Electricity companies who provide energy for homes provide a monthly bill charging those homes for the electrical energy that they used. A typical bill can be very complicated, but somewhere on the bill you will find a charge for the number of kilowatt-hours of electricity that were consumed.

A kilowatt is a unit of power. Specifically, one kilowatt is equal to 1000 watts. An hour is a unit of time. Thus, a kilowatt-hour is a unit of power x time. But if

$$P = \frac{E}{t}$$

then $E = P \cdot t$. In other words, the kilowatt-hour is a unit of energy. To calculate energy consumption in kilowatt-hours, you must complete the following steps as needed:

1. Convert the power from watts to kilowatts (by dividing by 1000).
2. Convert the time to hours.
3. Multiply power by time.

Example 3
A 100 W light bulb is accidentally left on for 7 days while a family is on holidays. Determine the energy consumed by the light bulb in $kW \cdot h$.

Power Worksheet

1. An electric circuit used $120\ V$ to move $2\ C$ of charge. What is the energy required by the circuit?

2. An electric motor uses $120\ V$ at $3.2\ A$.

   a) What power does the motor supply?

   b) How much energy is used by the motor in one hour of use?

3. A $60\ W$ light bulb operates on a $120\ V$ line. How much energy will the bulb use in one hour?

4. A $120\ V$ line supplies $8\ C$ of electricity in $2\ s$ to an appliance.

   a) What is the current supplied by this line?

   b) What power does the appliance use?

5. A television converts $12\ 000\ J$ of electrical energy into light and sound every minute. What is the power of the television?

6. The power of a typical adult's body over the course of a day is $100\ W$. This means that an adult requires $100\ J$ of energy each second.

   a) An apple contains $500\ 000\ J$ of energy. For how many seconds would an apple power a person?

   b) How many joules does a person require each day?

   c) How many apples would a person need to eat to get enough energy for one day?

7. An alkaline AA battery stores approximately $12\ 000\ J$ of energy. A small flashlight uses two AA batteries and will produce light for 2 hours. What is the power of the flashlight bulb?