12.7 Electrical Power and Efficiency

You may have noticed that electrical devices are labelled with a power rating. For example, a compact fluorescent light bulb (CFLs) may be labelled 15 W, while a hair dryer might be labelled 1200 W. What is an electrical power rating, and what does it mean?

MATH TIP

Orders of Magnitude
The prefix kilo means a magnitude of 1000. So a kilowatt (kW) is 1000 watts. Mega means a magnitude of one million. So a megawatt (MW) is 10^6 watts. Giga means a magnitude of one billion. So a gigawatt (GW) is 10^9 watts.

Electrical Power

Power is the rate at which energy is transformed or the rate at which work is done. **Electrical power** is the rate at which electrical energy is produced or consumed in a given time. The unit of measurement for electrical power is the watt (W). One watt is the equivalent of one joule per second (J/s). The higher the power rating value, or "wattage," the more electrical energy a device produces (or uses to operate).

electrical power the rate at which electrical energy is produced or used

Consider a 60 W incandescent light bulb and a 15 W compact fluorescent bulb (CFL). The incandescent bulb uses more electrical energy than the CFL to produce light. However, each produces about the same amount of light. So where does the extra energy used by the incandescent bulb go? It is converted into thermal energy, instead of light.

Measuring Electrical Energy Usage

Electric generating stations have an electrical power rating of megawatts (MW, or millions of watts) or gigawatts (GW, or billions of watts). The joule is a relatively small unit of electrical energy, so we often measure larger amounts of electrical energy in watt·hours (W·h), kilowatt·hours (kW·h), or gigawatt·hours (GW·h). A watt·hour is 3600 times greater than a joule. The **kilowatt·hour** is the SI unit used to measure energy usage. A kilowatt·hour is 1000 times greater than the watt·hour, while a gigawatt·hour is 1 000 000 times greater than a kilowatt·hour. Electricity meters keep track of how much electrical energy is used in homes, schools, and businesses in units of kW·h.

kilowatt·hour (kW·h) the SI unit for measuring electrical energy usage; the use of one kilowatt of power for one hour

We often think of how we can generate more electrical energy rather than think of ways that we can conserve it. An average Canadian family consumes over 16 000 kW·h of electrical energy in one year. That is a staggering amount of energy!

For more information on how to conserve energy,
GO TO NELSON SCIENCE

Efficient Devices

Not all electrical devices use electrical energy efficiently. **Efficiency** is a measure of how much useful energy an electrical device produces compared with the amount of energy that was supplied to the device. For example, an older clothes dryer might use 800 kW·h of electrical energy in one year, while a new model might use 300 kW·h in one year (Figure 1). Both clothes dryers perform the same task, but the newer model is more efficient because it uses less electrical energy than the older model. The difference in energy use is more than 60 %.

efficiency comparison of the energy output of a device with the energy supplied

Figure 1 Newer appliances are more efficient than older models.

Evaluating Efficiency in Devices

Many people use computers. A computer can use up to 600 kW•h of electrical energy in one year if it is left on when not in use. If the computer is put in sleep mode, the amount is reduced to 20 kW•h of electrical energy per year. If you use a computer 1 h for every 4 h that it is on, you would conserve electrical energy by putting your computer into sleep mode when you are not using it or by turning the computer off.

Researching the type of computer that you need may also help save energy. Notebook computers use far less energy than desktop computers. Notebook computers are designed to use energy efficiently, since they often run on rechargeable batteries, which are a limited energy source. Newer LCD screens use less electrical energy than conventional computer monitors and televisions.

We use a lot of electrical energy to provide light. Not all light bulbs use electrical energy efficiently. The incandescent light bulb uses electrical energy to heat a wire, called a filament, inside a glass bulb. The heated filament produces bright light but also produces lots of thermal energy. A typical incandescent light bulb converts about 90 % of the electrical energy into thermal energy, whereas only 10 % is converted into light. The incandescent light bulb is actually better at producing thermal energy than light!

A 100 W incandescent light bulb uses about 40 kW•h of electrical energy in 400 h. A comparable compact fluorescent light bulb (CFL), which emits the same amount of light, would be rated at 25 W but would only use 10 kW•h if it were on for the same length of time (Figure 2). The Ontario government plans to ban the incandescent light bulb by 2012.

Figure 2 (a) Compact fluorescent light bulbs are 20 % to 30 % more efficient at producing light than (b) incandescent light bulbs.

Figure 3 Although LED bulbs are still expensive to buy, their very low energy use over their lifetime makes them a reasonable alternative.

Although efficient, CFLs (and regular fluorescent tubes) contain small amounts of mercury. Mercury is toxic and can harm living things. CFLs must be disposed of properly. Some stores that sell CFLs provide a place for consumers to return their used bulbs for proper recycling, which recovers virtually all the mercury. Interestingly, switching to CFLs can actually reduce mercury pollution by reducing the need for electrical energy, a third of which is produced by burning coal (recall that mercury is emitted by burning coal). The burning of coal is a major source of mercury pollution in Canada.

Recently, a new way of producing light has been developed. Light-emitting diodes (LEDs) need less electrical energy to produce light than any other type of light bulb (Figure 3). They last a very long time and produce almost no heat, making them very efficient. LEDs are used in many applications, such as in Christmas tree lights, computers, traffic lights, billboards, and cars—even your home gaming system may use LEDs.

EnerGuide and Energy Star Labels

When buying any electrical device, it is important to consider both the price of the device and the cost of operating the device over time. A less expensive device might be a tempting purchase, but it may use much more electrical energy than a more expensive device. All household appliances are sold with an EnerGuide label (Figure 4) to help consumers make informed choices. This label provides an estimate of how much electrical energy (measured in kilowatt•hours) the appliance will use in one year. Consumers can compare EnerGuide labels to help make energy-wise choices when buying new appliances.

Some energy-efficient appliances are labelled with an Energy Star® symbol as well as an EnerGuide label (Figure 5). The Energy Star® symbol is used to identify products that meet a minimum level of efficiency.

To learn more about EnerGuide and Energy Star,

GO TO NELSON SCIENCE

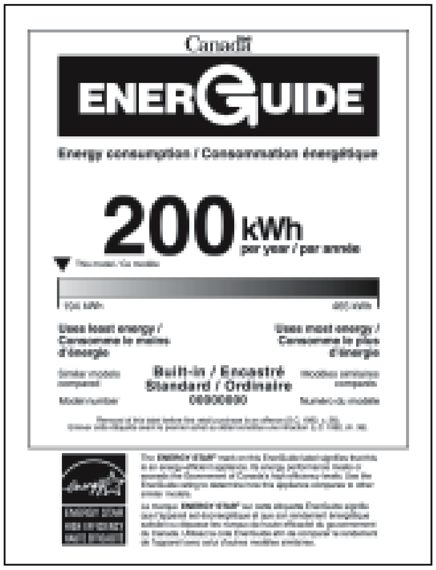

Figure 4 The EnerGuide labelling system by Natural Resources Canada helps consumers make informed choices when buying a new appliance.

Figure 5 The Energy Star® program was created in 1972 by the U.S. Environmental Protection Agency and the U.S. Department of Energy.

Calculating the Efficiency of a Device

The higher the percentage, the more efficient the device is. You can calculate the percent efficiency of a device using the equation:

$$\text{percent efficiency} = \frac{\text{energy out}}{\text{energy in}} \times 100\ \%$$

$$\%\ \text{efficiency} = \frac{E_{out}}{E_{in}} \times 100\ \%$$

Energy out is a measure of how much useful energy the device puts out to do its task. For example, a light bulb might produce 35 J of light energy. *Energy in* is a measure of how much energy the device requires. For example, the same light bulb might require 100 J of electrical energy.

SAMPLE PROBLEM 1 Calculating the Efficiency of a Light Bulb

A light bulb uses 100 J of electrical energy and produces 35 J of light energy. Calculate the percent efficiency of the light bulb.

Given: $E_{out} = 35\ J$
$E_{in} = 100\ J$

Required: percent efficiency (% efficiency)

Analysis: $\%\ \text{efficiency} = \frac{E_{out}}{E_{in}} \times 100\ \%$

$\%\ \text{efficiency} = \frac{35\ J}{100\ J} \times 100\ \%$

Solution: $\%\ \text{efficiency} = 0.35 \times 100\ \%$
$\%\ \text{efficiency} = 35\ \%$

Statement: The efficiency of the light bulb is 35 %.

Practice

A toaster oven uses 1200 J of energy to produce 850 J of thermal energy. Calculate the percent efficiency of the toaster oven.

Timely Use of Electrical Energy

The price of electrical energy changes throughout the day. The most expensive time for electrical energy production is generally weekdays from 9 a.m. to 5 p.m., when the demand for electricity is the greatest. During peak times, fossil fuel plants are run in addition to nuclear and hydro-electric generating stations to supply the extra energy. The cost of electricity during the peak times can be three times more expensive. This means that if you use electrical energy outside of the peak times, such as running a dishwasher at night, you can save money and reduce pollution.

By 2010, all homes and businesses in Ontario will have smart meters (Figure 6). The smart meter is an electrical energy meter connected to your home that measures the amount of electrical energy being used as well as the time at which it is being used.

Efficient appliances and smart meters are two ways to conserve electrical energy. The ultimate power-saving feature is your common sense. When you are not using a device, it makes sense to turn it off, and when you buy a new device, consider all the costs and choose wisely.

Figure 6 Many communities in Ontario have already started implementing smart meters.

Cost of Electricity

In Ontario, the current cost of electricity for homeowners is regulated at 5.6 ¢/kW•h for the first 1000 kW•h during winter and the first 600 kW•h during summer. After 1000 kW•h, the cost increases to 6.5 ¢/kW•h. How much would it cost to use a laptop computer for a year? To figure that out, you would need to know the power rating of the laptop in kilowatts and the length of time that it is operating in hours. You would use this equation:

$$\text{cost to operate} = \text{power used} \times \text{time} \times \text{cost of electricity}$$

SAMPLE PROBLEM 2 Calculating the Cost of Operating a Laptop Computer

A laptop computer uses a 75 W adapter when it is plugged in. Electricity costs 5.6 ¢/kW•h. Calculate how much it would cost to operate the laptop for 1 year for 24 hours per day.

Given: power = 75 W (converted to kW $= 75\ \cancel{\text{W}} \times \frac{1\ \text{kW}}{1000\ \cancel{\text{W}}} = 0.075\ \text{kW}$)

time = 24 hours per day for 365 days = 8760 hours

cost of electricity = 5.6 ¢/kW•h

Required: cost to operate

Analysis: cost to operate = power used × time × cost of electricity

Solution: cost to operate $= 0.075\ \cancel{\text{kW}} \times 8760\ \cancel{\text{h}} \times \frac{5.6\ ¢}{\cancel{\text{kW}} \cdot \cancel{\text{h}}} = 3679\ ¢$

Statement: It would cost 3679 ¢ (or $36.79) to operate a laptop computer for 24 hours per day for 365 days.

Practice

Calculate the cost of operating a 1500 W hair dryer to dry your hair for 6 minutes per day for 3 days. The cost of electricity is 5.6 ¢/kW•h.

From Sample Problem 2, you can see that operating one electrical device for a year is fairly inexpensive. However, we use a lot of technology in our homes. Even when a device is off, it may use a few watts in standby mode, waiting to be used. When you add up all the watts used, they could add up to hundreds of dollars per year.

There are other costs associated with electrical energy. The utility companies that provide the electrical energy also charge you for the distribution and transmission of the electrical energy. This can add a significant amount to your family's electricity bill. In fact, the rate at least doubles when you include these charges.

Not only is there a financial cost to electrical energy, but there is also an environmental cost as well. Remember that many of the ways we generate electrical energy produce some form of pollution. This pollution has a social cost because it can affect people's health and the environment in a negative way.

CITIZEN ACTION

Is Your School Conserving Electrical Energy?

Find a group of people who are interested in reducing the amount of electrical energy used by your school. The group might already exist in the form of an environmental club. Meet with this group or ask to attend an environmental club meeting. Brainstorm ideas about how you could find information on how electrical energy is used in your school. You may wish to develop a survey that could be passed along to students, teachers, administrators, and support staff.

Analyze the information that you collect for common areas where electrical energy seems to be wasted or used inefficiently. Again, brainstorm to suggest ways to reduce electrical energy consumption. Consider replacing inefficient devices with energy-efficient ones. You may also suggest some alternative energy production systems to lower the dependence of your school on the province's electrical grid.

Once you have completed putting together your ideas, prioritize them into categories. These categories may include, but not be limited to, ideas that cost the least, ideas that involve the most energy-use reduction, and ideas that are the most ambitious. Once you have sorted out the ideas, draft a proposal that you could take to your teacher to demonstrate that it could be implemented to help the school conserve energy, save money, and reduce environmental pollution. Present your plan in a report to your teacher.

As an extension to this activity, you could vote on the best proposal as a class. This proposal could be presented to the school's principal. If the principal approves of the plan, the plan could be presented at a teacher's staff meeting and actually be implemented. If successful, it could be a model that can be shared with other schools in your district.

IN SUMMARY

- Electrical power is the rate at which electrical energy produced or used.
- Electrical energy should be conserved and used wisely.
- Purchasing electrical energy–efficient devices saves money and is better for the environment.
- Percent efficiency can be calculated using the equation:

$$\% \text{ efficiency} = \frac{E_{out}}{E_{in}} \times 100\ \%$$

- When purchasing an electrical device, you should also consider the cost of operating it.
- The time of day affects the costs of producing and purchasing the electrical energy that you use.
- The cost of operating an electrical device can be calculated using the equation:

$$\text{cost to operate} = \text{power used} \times \text{time} \times \text{cost of electricity}$$

CHECK YOUR LEARNING

1. Describe an idea that you read about in this section and found to be particularly important. Why do you think this idea is important, and how will you act on it? C
2. Identify three ways that you can conserve electrical energy and produce fewer greenhouse gases. K/U
3. Explain how EnerGuide labels are useful to consumers. K/U
4. When purchasing an electrical device, what are the two financial costs you need to consider? Are there any environmental considerations you would make? Explain your reasoning. A
5. Calculate the efficiency of a compact fluorescent light bulb if it produces 30 J of light energy, while using 95 J of electrical energy. T/I
6. Calculate the cost of operating the following devices. The cost of electricity is 12 ¢/kW•h. T/I
   (a) a 100 W incandescent light bulb for 1000 hours
   (b) a 13 W CFL for 1000 hours
   (c) a 400 W computer for 600 hours
   (d) a refrigerator operating at its peak power of 750 W for one year
7. Calculate the difference between the operating cost of a 60 W incandescent light bulb and a 13 W CFL, each operating for 100 hours. The cost of electricity is 11 ¢/kW•h. T/I