Section 5.5 Power

Physicists use the word power (P) to describe the rate at which energy is transformed, or the rate at which work is done. Your body produces more power when you run up a set of stairs than when you climb up slowly. We may describe power mathematically as follows:

$$P = \frac{\Delta E}{\Delta t} \quad \text{or} \quad P = \frac{W_{net}}{\Delta t}$$

delta Δ = "change in"

Energy, work, and time are scalar quantities, so power is also a scalar quantity (it has no direction associated with it). Since energy and work are measured in joules and time is measured in seconds, power is measured in joules per second (J/s). In the SI system, the unit for power is called the watt (W) in honour of James Watt, a Scottish engineer who invented the first practical steam engine. One watt is equal to 1 J/s.

Sample Problem 1

How much power does a swimmer produce if she transforms 2.4 kJ of chemical energy (in food) into kinetic energy and thermal energy in 12.5 s?

Sample Problem 2

A 64 kg student climbs from the ground floor to the second floor of his school in 5.5 s. The second floor is 3.7 m above the ground floor. What is the student's power?

Practice

1. How long would it take a motor with 0.50 kW of power to do 1200 J of work? T/I
2. A mountain climber with a mass of 55 kg starts from a height of 850 m above sea level at 9 in the morning and reaches a height of 2400 m by noon. What is the climber's average power? T/I
3. A 60.0 kg person accelerates from rest to 12 m/s in 6.0 s. What is the person's power? T/I

Electrical Power

Electrical devices transform electrical energy into other forms of energy. For example, the hot, glowing elements of a toaster transform electrical energy into thermal energy and radiant energy, and an electric guitar transforms electrical energy into sound energy and thermal energy (**Figure 1**).

Like other energy-transforming devices, electrical devices may transform energy quickly or slowly. When they transform energy more quickly, they are more powerful, and when they transform energy more slowly, they are less powerful. The maximum power of an electrical device or appliance is sometimes referred to as the device's power rating. The power rating of an electrical device may be calculated using the equation $P = \frac{\Delta E}{\Delta t}$. Rearranging this equation yields the equation $\Delta E = P\Delta t$, which may be used to calculate the amount of energy transformed by a device.

Sample Problem 1

What is the power of an electric elevator motor if it uses 2.9×10^5 J of electrical energy to lift an elevator car 12 m in 16 s?

Practice

1. The Pickering Nuclear power plant has a power rating of 3100 MW. How much energy can the generating station produce in one day? (Answer in MJ.) T/I [redacted]

Energy Ratings and the Cost of Electricity

Companies that provide electrical energy to consumers use electricity meters to measure the total energy used by your home. The amount of energy used depends on your electical devices and your consumption habits. Energy consumption is measured in kilowatt-hours.

Figure 2 Electricity meters measure the amount of electrical energy used.

Table 1 Power Ratings of Appliances

Appliance	Power rating (W)
laptop computer	20–75
vacuum cleaner	200–700
microwave oven	600–1500
dishwasher	1200–1500
refrigerator	100–500
stove	6000–10 000

kilowatt * hours are units of energy - they are used instead of joules because it keeps the magnitudes of the numbers smaller and more manageable

The use of the kilowatt hour for measuring a change in energy (energy used) becomes apparent when we analyze the equation $\Delta E = P\Delta t$. When power, P, is measured in kilowatts, kW, and the time interval, Δt, is measured in hours, h, the product $P\Delta t$ produces the unit kilowatt hours, kWh. The energy used (transformed) by an electrical appliance, ΔE, is sometimes called the energy consumption rating, or energy rating, of the appliance. Thus, the energy rating is commonly measured in kilowatt hours.

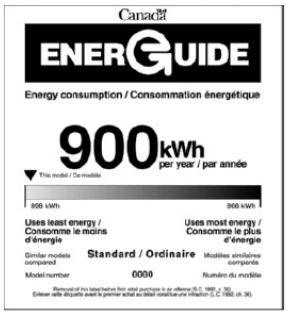

Figure 3 EnerGuide label on a typical household refrigerator

Example: 900 kWh = _____ Joules

$$900kW \cdot h$$
$$= 900\left(\frac{1000J}{s}\right) \cdot 3600s$$
$$= 3,240,000,000J$$
$$= 3,240,000kJ$$
$$= 3,240MJ$$

$$1kWh = 3,600,000J$$

Sample Problem 1 $1kWh = 3,600,000J$

What is the cost of operating a 25 W light bulb 4.0 h a day for 6.0 days if the price of electrical energy is 5¢/kWh?

Case 1

Case 2

Practice

1. Twenty incandescent light bulbs are turned on for 12 h a day for an entire year to light up a store. Each bulb has a power rating of 100.0 W. The average cost of electricity is 6.0¢/kWh. T/I
   (a) Determine the total amount of energy used by all the bulbs in the year.
   (b) Calculate the cost of lighting the store for the year.
   (c) How much money could be saved by using CFLs instead of the incandescent bulbs if each CFL has a power rating of 23 W?

5.5 Questions

1. A 54 kg person climbs a set of stairs at a constant speed from the first floor to the fourth floor in 32 s. The change in height from one floor to the next is 3.4 m. T/I
   (a) Calculate the gravitational potential energy at the top of the climb relative to the first floor.
   (b) Calculate the power of the person for the climb.
   (c) If a lighter person climbed the stairs in the same time, would this person's power be higher or lower? Explain.
2. A 65 kg student climbs 5.0 m up a rope in gym class at a constant speed of 1.4 m/s. T/I
   (a) Determine the time it takes the student to climb up the rope, and then determine the student's power.
   (b) Determine the student's power without finding the time it takes the student to climb up the rope. Explain your reasoning.
3. A student uses a pulley to lift a mass into the air. K/U C
   (a) Assume the mass is lifted at a constant speed. Describe one way you could determine the power of the student when she is lifting the mass.
   (b) Assume the mass started from rest at ground level and accelerated upward with a constant acceleration. What types of energy will the object have while it is being pulled up by the student? How would you determine the student's power in this case?
4. A family of five is planning to install solar panels on the roof of their home to help reduce the cost of electricity and save energy to help the environment. The family plans to install 10 panels, each with a power rating of 600 W. On average, a solar panel can produce electricity for 4.5 h daily. T/I
   (a) How much solar energy will the solar panels transform into electrical energy each day?
   (b) Assume the average cost of electricity is 5.5¢/kWh. How much money will the family save in a year on their electrical energy bill?
   (c) Each person in the family uses electrical energy at an average rate of 2 kWh per day. Will they still need to buy electricity from an electrical energy supplier? Explain your reasoning.
5. Show that 1 kWh = 3.6 MJ. C

Section 5.5 #1,2,5