

## Power

The world's most powerful tugboats, which are built in Finland, are capable of providing  $8.17 \times 10^6$  W of power. How much work does one of these tugboats do in 12.0 s?

### 1. List the given and unknown values.

*Given:* power,  $P = 8.17 \times 10^6$  W

time,  $t = 12.0$  s

*Unknown:* work,  $W = ?$  J

### 2. Rearrange the power equation to solve for work.

$$\text{power} = \frac{\text{work}}{\text{time}} \quad P = \frac{W}{t}$$

$$P \times t = \frac{W}{t} \times t = W$$

### 3. Substitute power and time values into the equation, and solve.

$$W = (8.17 \times 10^6 \text{ W}) \times (12.0 \text{ s}) = (8.17 \times 10^6 \text{ J/s}) \times (12.0 \text{ s})$$

$$W = 9.80 \times 10^7 \text{ J}$$

## Practice

- One horsepower (1 hp) is the unit of power based on the work that a horse can do in one second. This is defined, in English units, as a force of 550 lb that can move an object 1 ft in 1 s. In SI, 1 hp equals 745.7 W. Suppose you have a horse that has a power output of 750 W. How much work does this horse do in 0.55 s?
- A race car with a 255 hp ( $1.90 \times 10^5$  W) engine is able to accelerate from rest to its top speed in 9.00 s. How much work does the car's engine do in this interval of time?
- The 300-series Shinkansen train of Japan has cars made of the relatively light metal aluminum, so the train can accelerate more easily. Ten of the sixteen cars of this train have their own  $3.00 \times 10^2$  kW motors, one for each of their four axles. What is the work done by one car's four motors in 25 s?
- A ship's diesel engine has a power output of 13.0 MW ( $13.0 \times 10^6$  W). How much work is done by this engine in 15.0 min?

### Sample Problem

Suppose a weightlifter's power output is 178 W during the time he does 3310 J of work on the weights. How long does it take the weightlifter to raise the weights?

**1. List the given and unknown values.**

Given: power,  $P = 178 \text{ W}$

work,  $W = 3310 \text{ J}$

Unknown: time,  $t = ? \text{ s}$

**2. Rearrange the power equation to solve for time.**

$$\text{power} = \frac{\text{work}}{\text{time}} \qquad P = \frac{W}{t}$$

$$P \times \frac{t}{P} = \frac{W}{t} \times \frac{t}{P} = \frac{W}{P}$$

**3. Substitute work and power values into the equation, and solve.**

$$t = \frac{3310 \text{ J}}{178 \text{ W}} = \frac{3310 \text{ J}}{178 \text{ J/s}}$$

$$t = 18.6 \text{ s}$$

## Practice

- In order to sail through the frozen Arctic Ocean, the most powerful icebreaker ever built was constructed in the former Soviet Union. At the heart of the ship's power plant is a nuclear reactor with a power output of  $5.60 \times 10^7 \text{ W}$ . How long will it take for this power plant to do  $5.35 \times 10^{10} \text{ J}$  of work?
- The heaviest loads ever raised were part of the offshore Ekofisk complex in the North Sea. The  $4.0 \times 10^7 \text{ kg}$  complex was raised 6.5 m by over a hundred hydraulic jacks. The work done on the complex during the raising was approximately  $2.6 \times 10^{11} \text{ J}$ . Suppose the power output of all the jacks was  $5.7 \times 10^8 \text{ W}$ . How long did it take the jacks to raise the complex?
- Borax was mined in Death Valley, California, during the nineteenth century. It was transported from the valley by massive wagons, each pulled by a team of 21 mules. Suppose each mule's power output was 746 W (about 1 hp). If in a certain time interval the total work done by the team on the wagon was  $2.35 \times 10^7 \text{ J}$ , how long was that interval of time?
- A runner exerts a force of 334 N against the ground while running a distance of 50.0 m. The runner's power output over this distance is 3.71 kW. How much time does it take the runner to travel 50.0 m?

**Sample Problem**

A certain crane is able to lift  $2.20 \times 10^6$  kg. If the crane is able to raise this mass a distance of 20.0 m by doing  $4.32 \times 10^8$  J of work in 35.0 s, how much power has the crane provided?

**1. List the given and unknown values.**

*Given:* work,  $W = 4.32 \times 10^8$  J  
time,  $t = 35.0$  s

The distance of 20.0 m and the mass of  $2.2 \times 10^6$  kg are not needed to calculate power.

*Unknown:* power,  $P = ?$  W

**2. Write out the equation for power.**

$$\text{power} = \frac{\text{work}}{\text{time}} \quad P = \frac{W}{t}$$

**3. Substitute work and time values into the power equation, and solve.**

$$P = \frac{4.32 \times 10^8 \text{ J}}{35 \text{ s}} = 1.2 \times 10^7 \text{ J/s} = 1.2 \times 10^7 \text{ W}$$

$$P = 12 \text{ MW}$$

**Practice**

- A certain steam turbine is designed to be used as both a power generator and as a pump. When used as a generator, the turbine provides enough power to do  $3 \times 10^{10}$  J of work in 1 min. What is the power output of the turbine?
- The space shuttle, which was first launched on April 12, 1981, is the world's first reusable space vehicle. The shuttle is placed in orbit by three engines that do  $1.4 \times 10^{13}$  J of work in 8.5 min. What is the power output of these engines?

**Mixed Review**

- Lithuania's major nuclear power plant has one of the world's most powerful generators, which has a power output of  $1.45 \times 10^9$  W. How long must this generator run if it is to provide the energy to do  $4.35 \times 10^{11}$  J of work?
- When it is completed in 2002, the International Financial Center in Taipei, Taiwan, will be the tallest building in the world. The International Financial Center will also have the fastest elevators in the world. Two of the 63 elevators will travel from the ground floor to the eighty-ninth floor in just 39 s. Suppose the power output of each elevator motor is 158 kW. How much work will one of these motors do in lifting the elevator to the eighty-ninth floor?