



7.7-7.9 Power

Kevin Downey and Ryan Olesen



What is power?

Power is the rate at which work is done.

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

The SI unit for power is the Watt, where one watt equals 1 Joule/second.

Since work = energy transfer, power is also the rate at which energy is expended.

EX: A 60 watt lightbulb expends 60 Joules of energy per second.

7.7 Stair Example Problem

What is the power output for a 60.0-kg woman who runs up a 3.00 m high flight of stairs in 3.50 s, starting from rest but having a final speed of 2.00 m/s? (See **Figure 7.24**.)

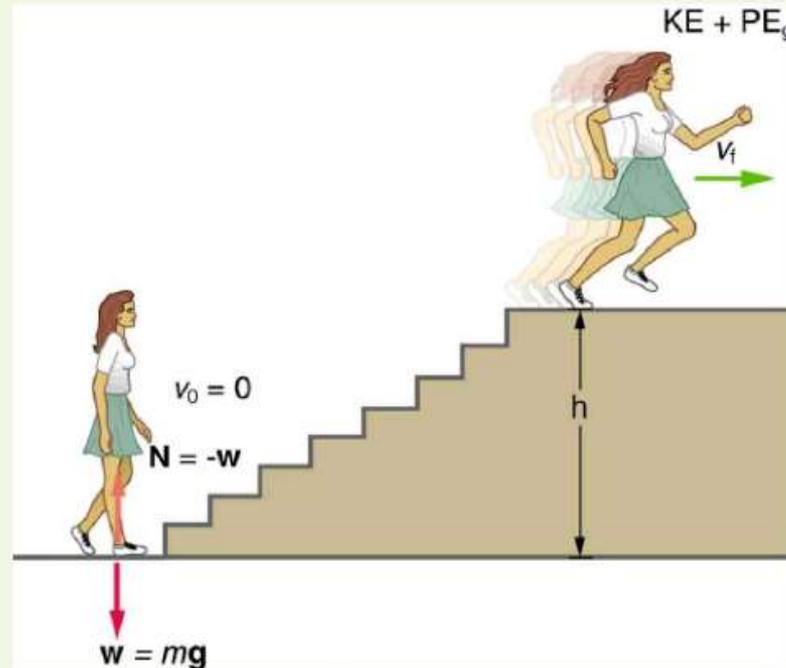


Figure 7.24 When this woman runs upstairs starting from rest, she converts the chemical energy originally from food into kinetic energy and gravitational potential energy. Her power output depends on how fast she does this.

Stair example

$W = KE + PE$, and since both initial values are 0 at bottom of stairs:

$$W = \frac{1}{2} mv^2 + mgh$$

$$P = W/t = (\frac{1}{2} mv^2 + mgh)/t$$

$$\begin{aligned} P &= \frac{0.5(60.0 \text{ kg})(2.00 \text{ m/s})^2 + (60.0 \text{ kg})(9.80 \text{ m/s}^2)(3.00 \text{ m})}{3.50 \text{ s}} \\ &= \frac{120 \text{ J} + 1764 \text{ J}}{3.50 \text{ s}} \\ &= 538 \text{ W.} \end{aligned}$$

Power can also be rewritten as Force x Velocity

This means that powerful objects are both strong and fast

- Bigger force and bigger velocity = more power

$$\text{Power} = \frac{\text{Work}}{\text{Time}} = \frac{\text{Force} \cdot \text{Displacement}}{\text{Time}}$$

$$\text{Power} = \text{Force} \cdot \frac{\text{Displacement}}{\text{Time}}$$

$$\text{Power} = \text{Force} \cdot \text{Velocity}$$

Power Consumption and Energy

$$P=W/t=E/t$$

E is the electricity supplied by the electric company

The energy consumed over a time t is $E=Pt$

Electricity bills use the unit of kW x h

Problem #31

a. $P/P_0 = (5 \times 10^{37} \text{ W}) / 1000 (4 \times 10^{26} \text{ W}) = 1 \times 10^8$

b. 5x increase

c. Supernova is 5 times brighter than our galaxy, so it may be 5 times brighter than a distant galaxy.

31. Suppose a star 1000 times brighter than our Sun (that is, emitting 1000 times the power) suddenly goes supernova. Using data from **Table 7.3**: (a) By what factor does its power output increase? (b) How many times brighter than our entire Milky Way galaxy is the supernova? (c) Based on your answers, discuss whether it should be possible to observe supernovas in distant galaxies. Note that there are on the order of 10^{11} observable galaxies, the average brightness of which is somewhat less than our own galaxy.

Problem #34

34. A large household air conditioner may consume 15.0 kW of power. What is the cost of operating this air conditioner 3.00 h per day for 30.0 d if the cost of electricity is \$0.110 per kW · h ?

$$E = Pt = (15 \text{ kW})(3 \text{ h/d})(30.0 \text{ d})$$

$$= 1350 \text{ kW} \times \text{h}$$

$$\text{Cost} = (1350 \text{ kW} \times \text{h})(\$0.110 \text{ per kW} \times \text{h}) = \mathbf{\$148.5 \text{ for 30 days}}$$

Problem #37

37. A 500-kg dragster accelerates from rest to a final speed of 110 m/s in 400 m (about a quarter of a mile) and encounters an average frictional force of 1200 N. What is its average power output in watts and horsepower if this takes 7.30 s?

Find the force of the engine

$$\text{net}F = Ma$$

$$F - F_f = Ma$$

$$F - 1200 = 500(110/7.3)$$

$$F = 8734 \text{ Newtons}$$

$$W = Fd/t$$

$$W = (8734 \text{ N})(400\text{m})/(7.3\text{s})$$

$$\begin{aligned} W &= 458,849 \text{ Watts} \\ (746 \text{ watts} &= 1 \text{ horsepower}) \\ &= 615 \text{ Horsepower} \end{aligned}$$

Problem #40

40. (a) What is the available energy content, in joules, of a battery that operates a 2.00-W electric clock for 18 months? (b) How long can a battery that can supply $8.00 \times 10^4 \text{ J}$ run a pocket calculator that consumes energy at the rate of $1.00 \times 10^{-3} \text{ W}$?

$$1\text{W}=1\text{J}/\text{sec}$$

a. Energy Output=93,312,000 J for 18 months

b. $80,000 \text{ J} / .001 \text{ J}/\text{sec} = \text{about } 31 \text{ months}$

Problem #46

46. Calculate the power output in watts and horsepower of a shot-putter who takes 1.20 s to accelerate the 7.27-kg shot from rest to 14.0 m/s, while raising it 0.800 m. (Do not include the power produced to accelerate his body.)

$$W = .5(m)(v)^2 + mgh$$

$$= .5(7.27 \text{ kg})(14.0 \text{ m/s})^2 + (7.27 \text{ kg})(9.80 \text{ m/s}^2)(.800 \text{ m}) = 769.5 \text{ J}$$

$$P = W/t = 769.5 \text{ J}/1.20\text{s} = 641 \text{ W}$$

$$1 \text{ hp} = 746 \text{ W} \quad P = 641 \text{ W} \times (1 \text{ hp}/746 \text{ W}) = .860 \text{ hp}$$

Problem #49

49. Using data from **Table 7.5**, calculate the daily energy needs of a person who sleeps for 7.00 h, walks for 2.00 h, attends classes for 4.00 h, cycles for 2.00 h, sits relaxed for 3.00 h, and studies for 6.00 h. (Studying consumes energy at the same rate as sitting in class.)

Activity	Energy Consumption (watts)
Sleeping	83
Sitting at rest	120
Sitting in class	210
Walking	280
Cycling	400

$$E = (7 \text{ h})(83 \text{ w}) + (2 \text{ h})(280 \text{ w}) + (4 \text{ h})(210 \text{ w}) + (2 \text{ h})(400 \text{ w}) + (3 \text{ h})(120 \text{ w}) + (6 \text{ h})(210 \text{ w})$$

Convert hours to seconds

$$E = (25200)(83) + (7200)(280) + (14400)(210) + (7200)(400) + (10800)(120) + (28800)(210) = 17355600 \text{ Joules} = 17,350 \text{ kilojoules} = \text{about } 4100 \text{ calories}$$

Questions

19. Explain, in terms of the definition of power, why energy consumption is sometimes listed in kilowatt-hours rather than joules. What is the relationship between these two energy units?

19) It can't be measured in joules because energy consumption requires a unit of time. Watts is J/s, however most appliances use a lot of energy over a long period of time, so it would make more sense to use kW x h because that is a bigger unit.

22. Do you do work on the outside world when you rub your hands together to warm them? What is the efficiency of this activity?

22) Rubbing your hands together converts work into thermal energy. It only warms about .100 kg of skin.

25. What is the difference between energy conservation and the law of conservation of energy? Give some examples of each.

25) Law of Conservation of Energy: the general law that total energy is constant in any process. Energy conservation is reducing the use of energy (i.e turning down a thermostat).