PHYSICS 534

ANSWERS

EXER 41 **Power**

HESS

Victor Hess was awarded the Nobel prize for physics in 1936 for his discovery of cosmic radiation.

As you know, work is the product of force times the distance through which the force acts (W = Fs). For example, consider a force of 10 N acting through a distance of 10 m. The work done is 100 J. This is true if the work was done in one second, one hour, or one year. That is, the formula for work does not take into account the time it takes to do the work. The concept of power includes the time required to do the work.

Power is the rate of doing work. It tells us how fast work is being done. Power is important in order to establish the "speed" with which a given force acts.

The formula for power is:

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

where P = the power is watts (W)
W = the work in joules (J)
t = the time in seconds (s)

+ **Note**: **Use 10 m/s^2 for the acceleration due to gravity.**

1. Jim slides a box along a floor a distance of 10 m by applying a force of 50 N horizontally in a time of 5 s. Tim also slides a box along a floor a distance of 10 m by applying a horizontal force of 50 N but in a time of 10 s. Determine:

a) How much work did Jim do?

b) How much work did Tim do?

c) Who does more work?

d) What power was developed by Jim?

e) What power was developed by Tim?

f) Who is more efficient?

g) What becomes of the work done by Jim and Tim?

2. Is power a scalar or a vector quantity? **Scalar**

3. In terms of basic units (L, M and T), what are the dimensions of power?

$$P = \frac{W}{t} = \frac{Fs}{t} = \frac{mas}{t} = \frac{kg\frac{m}{s^2}m}{s} = \frac{kg \cdot m^2}{s^3} = \frac{M \cdot L^2}{T^3} = M \cdot L^2 \cdot T^{-3}$$

4. A 20 kg object is pushed 15 m along a horizontal frictionless surface by a horizontal force of 8 N. If the work was done in a time of 12 s, calculate:

a) The work done. [120 J]

$W = Fs = (8\ N)(15\ m) = 120\ J$

b) The power output. [10 W]

$P = W/t = 120\ J/12\ s = 10\ W$

c) What becomes of the work done?

It is lost to overcome friction (in the form of heat and sound energy).

5. It takes a 70 kg man 20 s to walk up to the third floor of a building. If the vertical height he climbs is 12 m, determine:

a) The work done by the man. [8 400 J]

$W = Fs = mgh = (70\ kg)(10\ m/s^2)(12\ m) = 8400\ J$

b) The rate of doing work. [420 W]

$P = W/t = 8400\ J/20\ s = 420\ W$

c) What becomes of the work done?

It is lost to overcome friction (in the form of heat and sound energy).

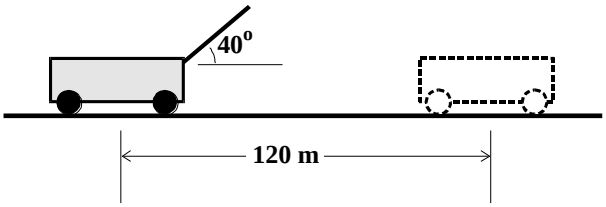
6. What power is required to raise a mass of 40 kg a distance of 5 m in a time of 2 s? [1 000 W]

$P = W/t = Fs/t = mgh/t = (40\ kg)(10\ m/s^2)(5\ m)/2\ s = 1000\ W$

7. A water pump raises 30 liters of water per minute from a depth of 100 meters. What wattage is expended? [5 x 10^2 W]

$P = W/t = Fs/t = mgh/t = (30\ kg)(10\ m/s^2)(100\ m)/60\ s = 5000\ W$

8. Garry pulls a wagon at constant speed along a level street. He exerts a force of 150 N by pulling on the handle of the wagon at an angle of 40^o from the ground. If the time it takes Garry to pull the wagon 120 m is 3 minutes, Determine:



a) The force to overcome friction. [115 N]

$$f = F_H = F_A \text{Cos } 40^o = (150 \text{ N})(\text{Cos } 40^o) = 114.9 \text{ N} = 115 \text{ N}$$

b) The work done. [13 800 J]

$$W = F_A s = (115 \text{ N})(120 \text{ m}) = 13800 \text{ J}$$

c) The power output. [77 W]

$$P = W/t = F_A s/t = (115 \text{ N})(120 \text{ m})/3(60 \text{ s}) = 76.7 \text{ W} = 77 \text{ W}$$

d) What becomes of the work done?

It is lost to overcome friction (in the form of heat and sound energy).

9. If 700 W of power is needed to keep a boat moving through water at a constant speed of 10 m/s, what is the magnitude of the force exerted by the motor of the boat? [70 N]

$$P = \frac{W}{t} = \frac{Fs}{t} = F\frac{s}{t} = Fv \quad \text{Thus} \quad F = \frac{P}{v} = \frac{700 \text{ W}}{10 \text{ m/s}} = 70 \text{ N}$$

10. How much work does a 400 watt fan motor do in 15 minutes? [3.6×10^5 J]

$$P = \frac{W}{t} \quad \text{Thus} \quad W = Pt = (400 \text{ W})(15)(60 \text{ s}) = 360\,000 \text{ J} = 3.6 \times 10^5 \text{ J}$$

11. A 2 000 kg elevator is raised a distance of 18 m in a time of 40 s. Determine:

a) The work done. [3.6 x 10^5 J]

$$W = Fs = mgh = (2000\ \text{kg})(10\ \text{m/s}^2)(18\ \text{m}) = 360\,000\ \text{J} = 3.6\times10^5\ \text{J}$$

b) The power output. [9 x 10^3 W]

$$P = W/t = Fs/t = mgh/t = (2000\ \text{kg})(10\ \text{m/s}^2)(18\ \text{m})/40\ \text{s} = 9000\ \text{W} = 9\times10^3\ \text{W}$$

c) What becomes of the work done?

It goes to the elevator in the form of potential energy (E_P).

12. A 600 N hiker carries a 20 kg nap-sack up a trail. After 30 minutes, he is 300 m higher than his starting point. Calculate the following:

a) The weight of the nap-sack. [2 x 10^2 N]

$$w = mg = (20\ \text{kg})(10\ \text{m/s}^2) = 200\ \text{N} = 2\times10^2\ \text{N}$$

b) The work done on the nap-sack. [6 x 10^4 J]

$$W = mgh = (20\ \text{kg})(10\ \text{m/s}^2)(300\ \text{m}) = 60\,000\ \text{J} = 6\times10^4\ \text{J}$$

c) The work done by the hiker. [2.4 x 10^5 J]

$$W = F_T s = (600\ \text{N} + 200\ \text{N})(300\ \text{m}) = (800\ \text{N})(300\ \text{m}) = 240\,000\ \text{J} = 2.4\times10^5\ \text{J}$$

d) The power output of the hiker. [133.3 W]

$$P = W/t = 240\,000\ \text{J}/(30)(60\ \text{s}) = 133.3\ \text{W}$$

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