ANNOUNCEMENTS

- Homework #7, due Wednesday, October 10

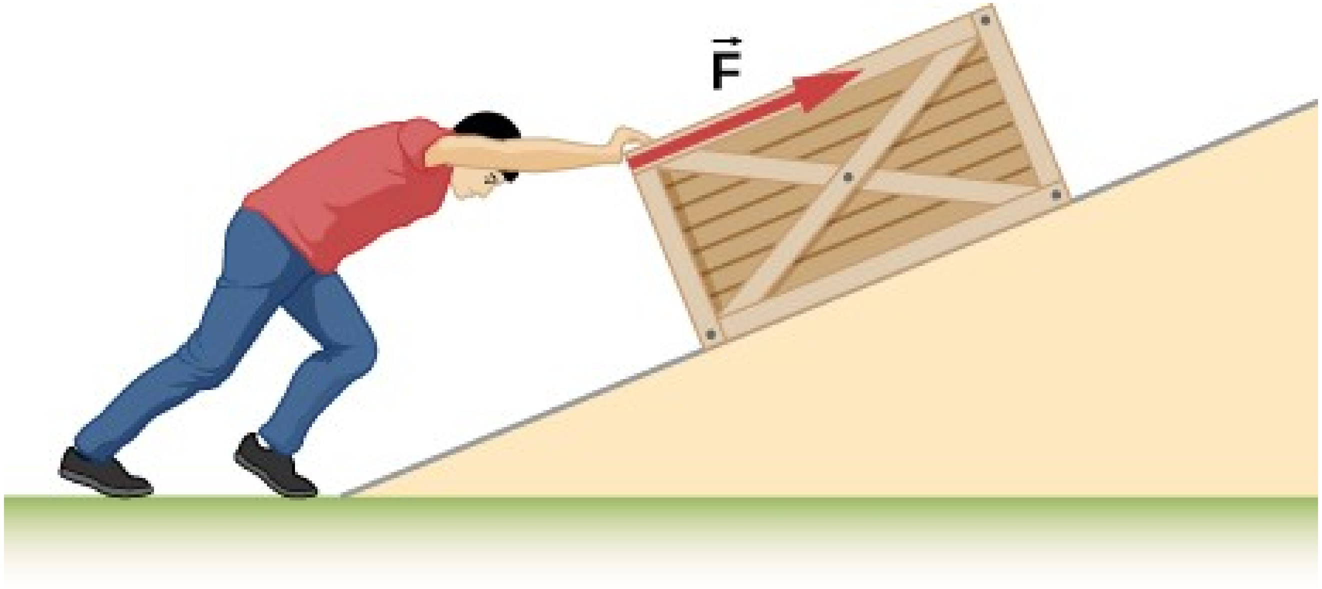
  Conceptual questions: Chapter 7, #4 and #8
  Problems: Chapter 7, #26, #28

- 5-minute quiz on Chapter 7: Friday, October 12

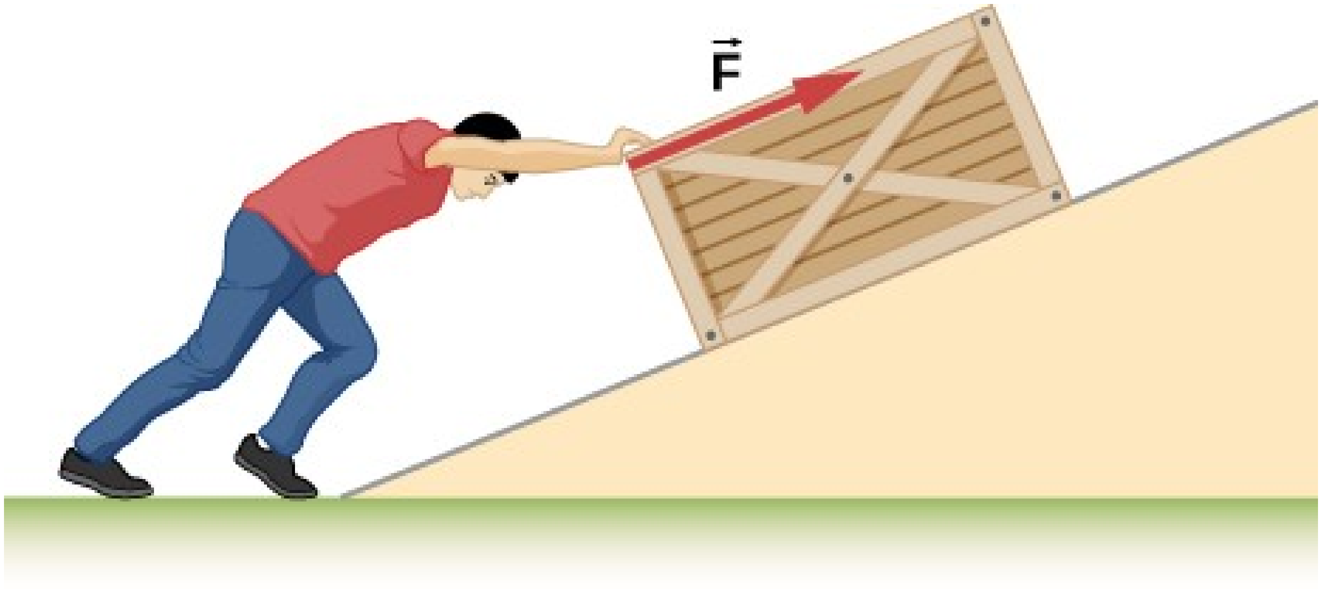
- Read all Chapter 7 by Wednesday.

Work done by a force over an infinitesimal displacement	$dW = \vec{\mathbf{F}} \cdot d\vec{\mathbf{r}} = \left\lvert \vec{\mathbf{F}} \right\rvert \left\lvert d\vec{\mathbf{r}} \right\rvert \cos\theta$
Work done by a force acting along a path from *A* to *B*	$W_{AB} = \int_{\text{path}AB} \vec{\mathbf{F}} \cdot d\vec{\mathbf{r}}$
Work done by a constant force of kinetic friction	$W_{\text{fr}} = -f_k \lvert l_{AB} \rvert$
Work done going from *A* to *B* by Earth's gravity, near its surface	$W_{\text{grav},AB} = -mg\left(y_B - y_A\right)$
Work done going from *A* to *B* by one-dimensional spring force	$W_{\text{spring},AB} = -\left(\frac{1}{2}k\right)\left(x_B^2 - x_A^2\right)$
Kinetic energy of a non-relativistic particle	$K = \frac{1}{2}mv^2 = \frac{p^2}{2m}$
Work-energy theorem	$W_{\text{net}} = K_B - K_A$
Power as rate of doing work	$P = \frac{dW}{dt}$
Power as the dot product of force and velocity	$P = \vec{\mathbf{F}} \cdot \vec{\mathbf{v}}$

Calculate the work done by an 85.0-kg man who pushes a crate 4.00 m up along a ramp that makes an angle of $20.0°$ with the horizontal (see below). He exerts a force of 500 N on the crate parallel to the ramp and moves at a constant speed. Be certain to include the work he does on the crate and on his body to get up the ramp.

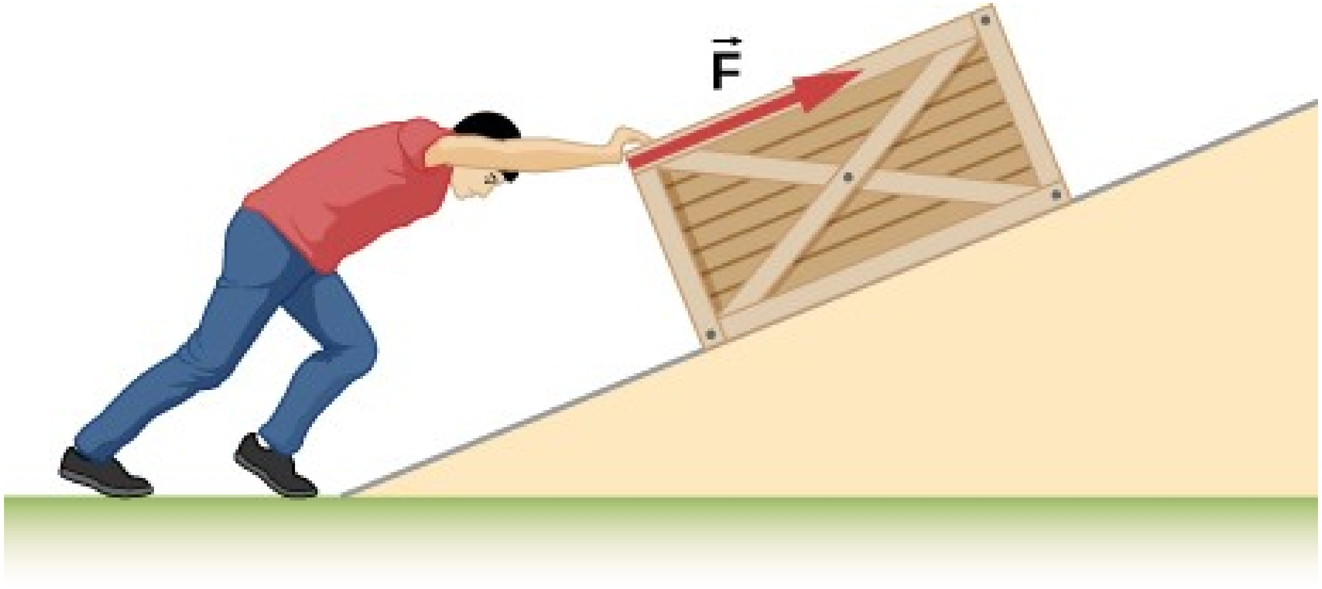


Calculate the work done by an 85.0-kg man who pushes a crate 4.00 m up along a ramp that makes an angle of $20.0°$ with the horizontal (see below). He exerts a force of 500 N on the crate parallel to the ramp and moves at a constant speed. Be certain to include the work he does on the crate and on his body to get up the ramp.



$$W_{crate} = 500 \cdot 4.00 = 2000\ J$$

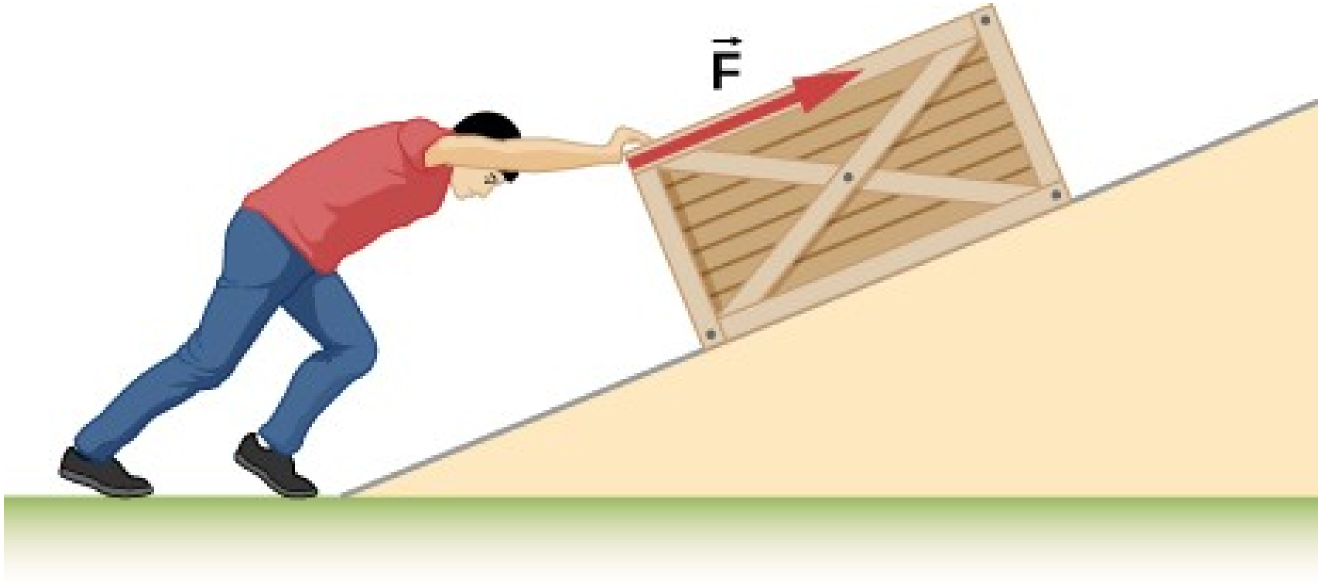
Calculate the work done by an 85.0-kg man who pushes a crate 4.00 m up along a ramp that makes an angle of $20.0°$ with the horizontal (see below). He exerts a force of 500 N on the crate parallel to the ramp and moves at a constant speed. Be certain to include the work he does on the crate and on his body to get up the ramp.



$$W_{crate} = 500 \cdot 4.00 = 2000 \text{ J}$$

$$W_{man} = 85.0 \cdot 9.8 \cdot 4.00 \cdot \sin(20.0°) = 1140 \text{ J}$$

Calculate the work done by an 85.0-kg man who pushes a crate 4.00 m up along a ramp that makes an angle of $20.0°$ with the horizontal (see below). He exerts a force of 500 N on the crate parallel to the ramp and moves at a constant speed. Be certain to include the work he does on the crate and on his body to get up the ramp.

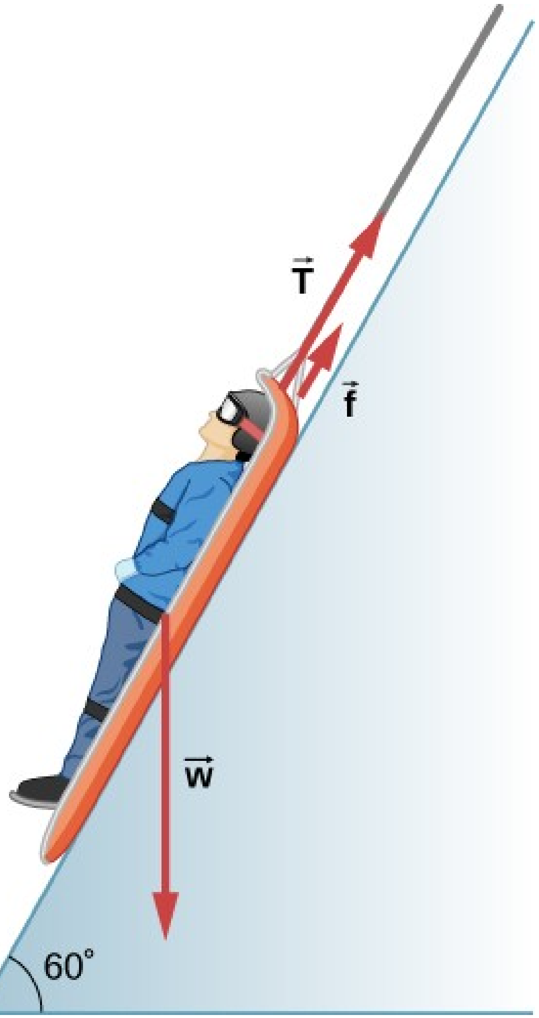


$$W_{crate} = 500 \cdot 4.00 = 2000 \text{ J}$$

$$W_{man} = 85.0 \cdot 9.8 \cdot 4.00 \cdot \sin(20.0º) = 1140 \text{ J}$$

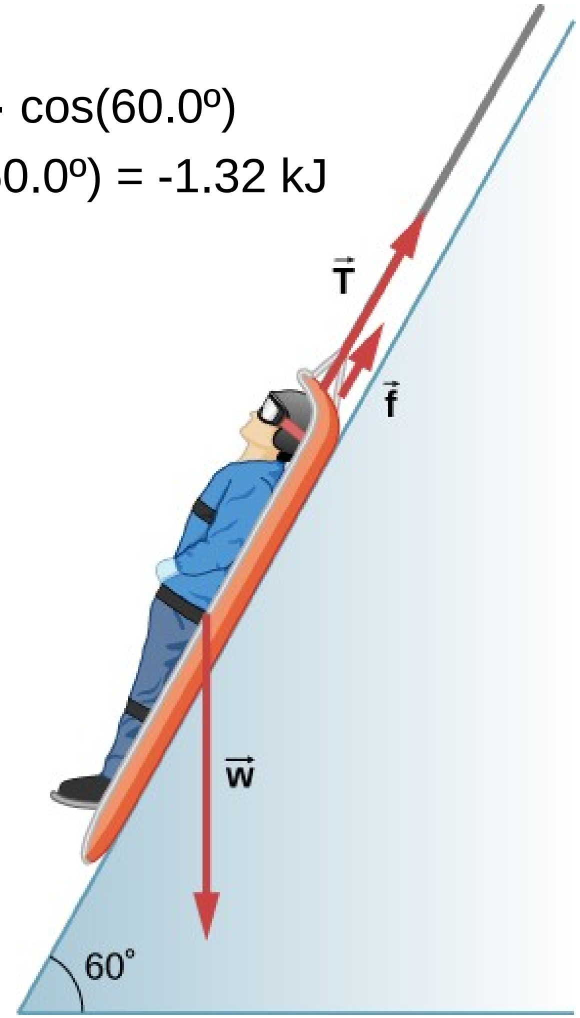
$$W_{Tot} = 3140 \text{ N}$$

Suppose the ski patrol lowers a rescue sled and victim, having a total mass of 90.0 kg, down a 60.0° slope at constant speed, as shown below. The coefficient of friction between the sled and the snow is 0.100. (a) How much work is done by friction as the sled moves 30.0 m along the hill? (b) How much work is done by the rope on the sled in this distance? (c) What is the work done by the gravitational force on the sled? (d) What is the total work done?



Suppose the ski patrol lowers a rescue sled and victim, having a total mass of 90.0 kg, down a 60.0° slope at constant speed, as shown below. The coefficient of friction between the sled and the snow is 0.100. (a) How much work is done by friction as the sled moves 30.0 m along the hill? (b) How much work is done by the rope on the sled in this distance? (c) What is the work done by the gravitational force on the sled? (d) What is the total work done?

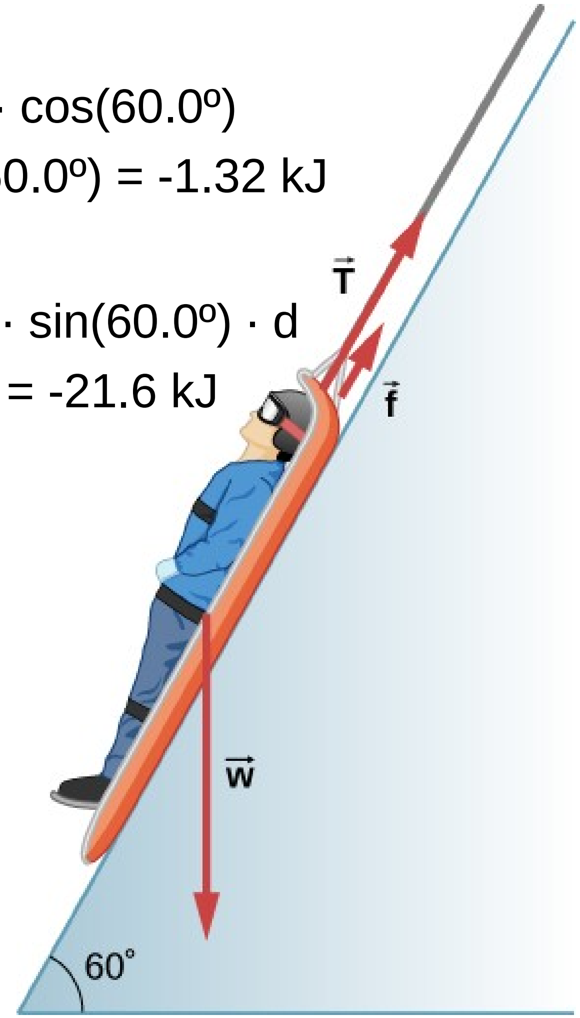
$$W_{friction} = - f_k \cdot d = - \mu_k \cdot N \cdot d = - \mu_k \cdot mg \cdot d \cdot \cos(60.0^\circ)$$
$$= - 0.100 \cdot 90.0 \cdot 9.8 \cdot 30.0 \cdot \cos(60.0^\circ) = -1.32 \text{ kJ}$$



Suppose the ski patrol lowers a rescue sled and victim, having a total mass of 90.0 kg, down a 60.0° slope at constant speed, as shown below. The coefficient of friction between the sled and the snow is 0.100. (a) How much work is done by friction as the sled moves 30.0 m along the hill? (b) How much work is done by the rope on the sled in this distance? (c) What is the work done by the gravitational force on the sled? (d) What is the total work done?

$$W_{friction} = - f_k \cdot d = - \mu_k \cdot N \cdot d = - \mu_k \cdot mg \cdot d \cdot \cos(60.0^o)$$
$$= - 0.100 \cdot 90.0 \cdot 9.8 \cdot 30.0 \cdot \cos(60.0^o) = -1.32 \text{ kJ}$$

$$W_{rope} = - W_{friction} + W_{gravity} = - W_{friction} - mg \cdot \sin(60.0^o) \cdot d$$
$$= 1320 - 90.0 \cdot 9.8 \cdot \sin(60.0^o) \cdot 30 = -21.6 \text{ kJ}$$

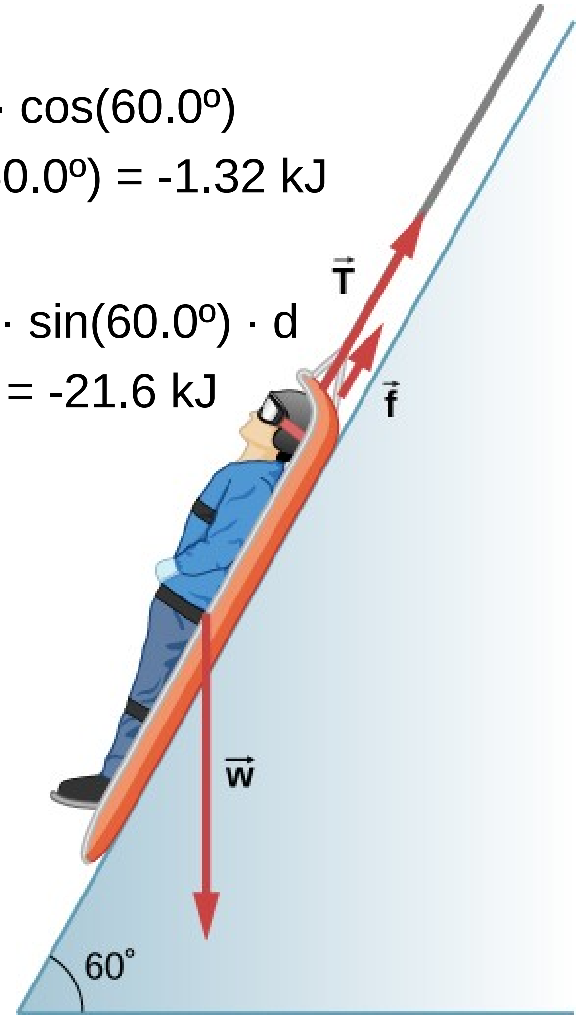


Suppose the ski patrol lowers a rescue sled and victim, having a total mass of 90.0 kg, down a 60.0° slope at constant speed, as shown below. The coefficient of friction between the sled and the snow is 0.100. (a) How much work is done by friction as the sled moves 30.0 m along the hill? (b) How much work is done by the rope on the sled in this distance? (c) What is the work done by the gravitational force on the sled? (d) What is the total work done?

$$W_{friction} = - f_k \cdot d = - \mu_k \cdot N \cdot d = - \mu_k \cdot mg \cdot d \cdot \cos(60.0^o)$$
$$= - 0.100 \cdot 90.0 \cdot 9.8 \cdot 30.0 \cdot \cos(60.0^o) = -1.32 \text{ kJ}$$

$$W_{rope} = - W_{friction} + W_{gravity} = - W_{friction} - mg \cdot \sin(60.0^o) \cdot d$$
$$= 1320 - 90.0 \cdot 9.8 \cdot \sin(60.0^o) \cdot 30 = -21.6 \text{ kJ}$$

$$W_{grav \rightarrow sled} = - W_{gravity} = = 22.9 \text{ kJ}$$



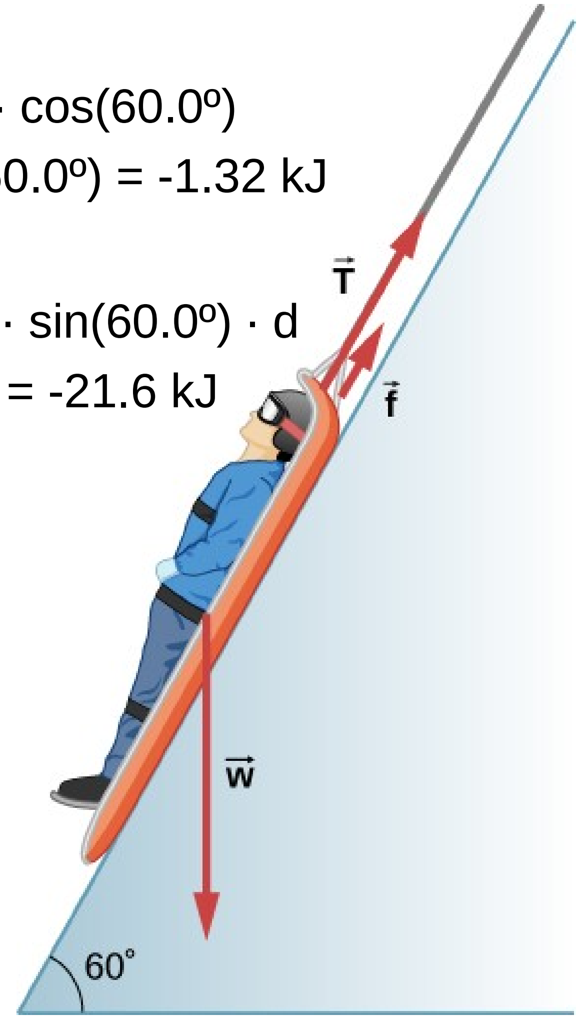
Suppose the ski patrol lowers a rescue sled and victim, having a total mass of 90.0 kg, down a 60.0° slope at constant speed, as shown below. The coefficient of friction between the sled and the snow is 0.100. (a) How much work is done by friction as the sled moves 30.0 m along the hill? (b) How much work is done by the rope on the sled in this distance? (c) What is the work done by the gravitational force on the sled? (d) What is the total work done?

$$W_{friction} = -f_k \cdot d = -\mu_k \cdot N \cdot d = -\mu_k \cdot mg \cdot d \cdot \cos(60.0^\circ)$$
$$= -0.100 \cdot 90.0 \cdot 9.8 \cdot 30.0 \cdot \cos(60.0^\circ) = -1.32 \text{ kJ}$$

$$W_{rope} = -W_{friction} + W_{gravity} = -W_{friction} - mg \cdot \sin(60.0^\circ) \cdot d$$
$$= 1320 - 90.0 \cdot 9.8 \cdot \sin(60.0^\circ) \cdot 30 = -21.6 \text{ kJ}$$

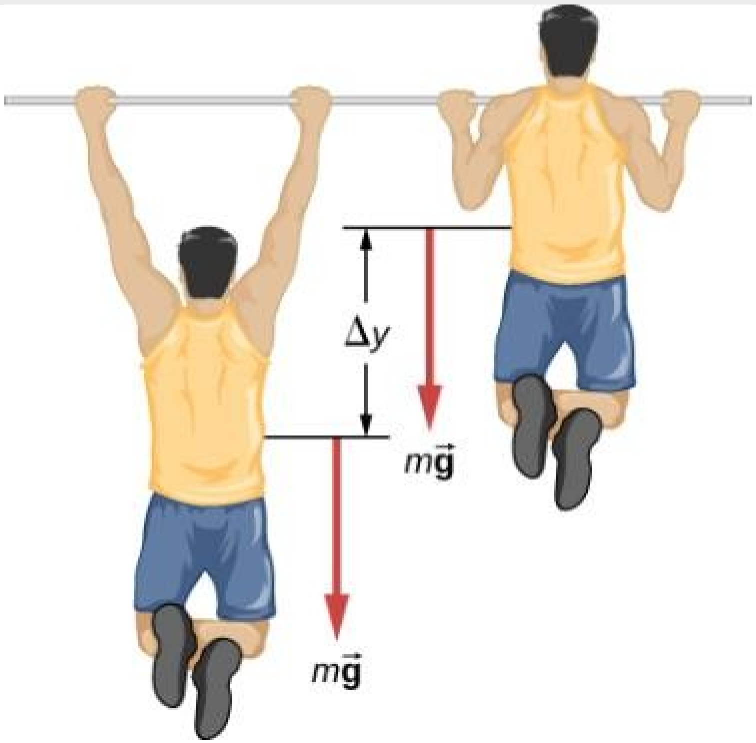
$$W_{grav \rightarrow sled} = -W_{gravity} = \; = 22.9 \text{ kJ}$$

$$W_{Tot} = 0$$



Pull-Up Power

An 80-kg army trainee does 10 pull-ups in 10 s (Figure 7.14). How much average power do the trainee's muscles supply moving his body? (*Hint:* Make reasonable estimates for any quantities needed.)



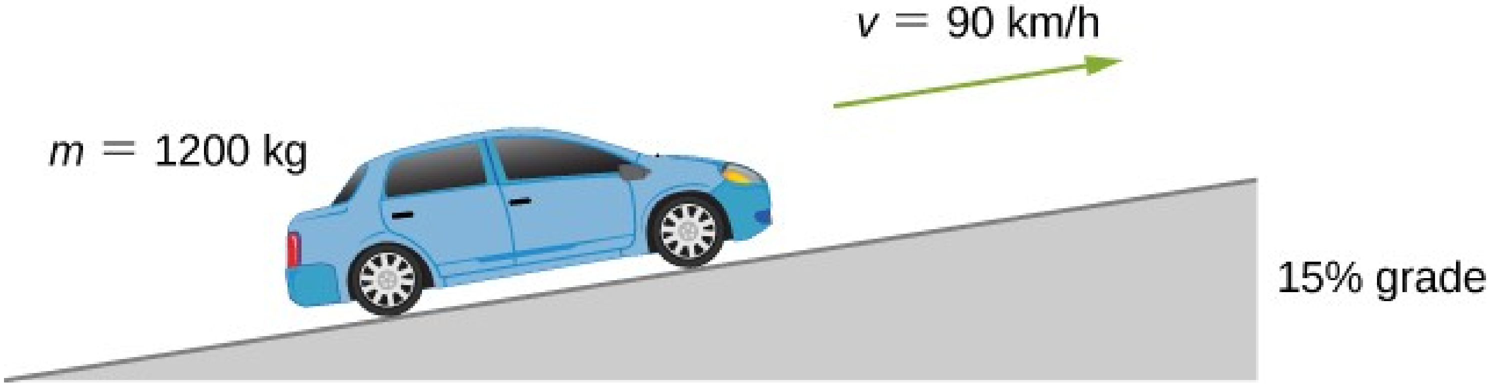
Solution

The result we get, applying our assumptions, is

$$P_{ave} = \frac{10 \times 2(0.9 \times 80\text{ kg})(9.8\text{ m/s}^2)(0.6\text{ m})}{10\text{ s}} = 850\text{ W}.$$

Automotive Power Driving Uphill

How much power must an automobile engine expend to move a 1200-kg car up a 15% grade at 90 km/h (Figure 7.15)? Assume that 25% of this power is dissipated overcoming air resistance and friction.



Strategy

At constant velocity, there is no change in kinetic energy, so the net work done to move the car is zero. Therefore the power supplied by the engine to move the car equals the power expended against gravity and air resistance. By assumption, 75% of the power is supplied against gravity, which equals $m\vec{\mathbf{g}} \cdot \vec{\mathbf{v}} = mgv \sin\theta$, where θ is the angle of the incline. A 15% grade means $\tan\theta = 0.15$. This reasoning allows us to solve for the power required.

Solution

Carrying out the suggested steps, we find

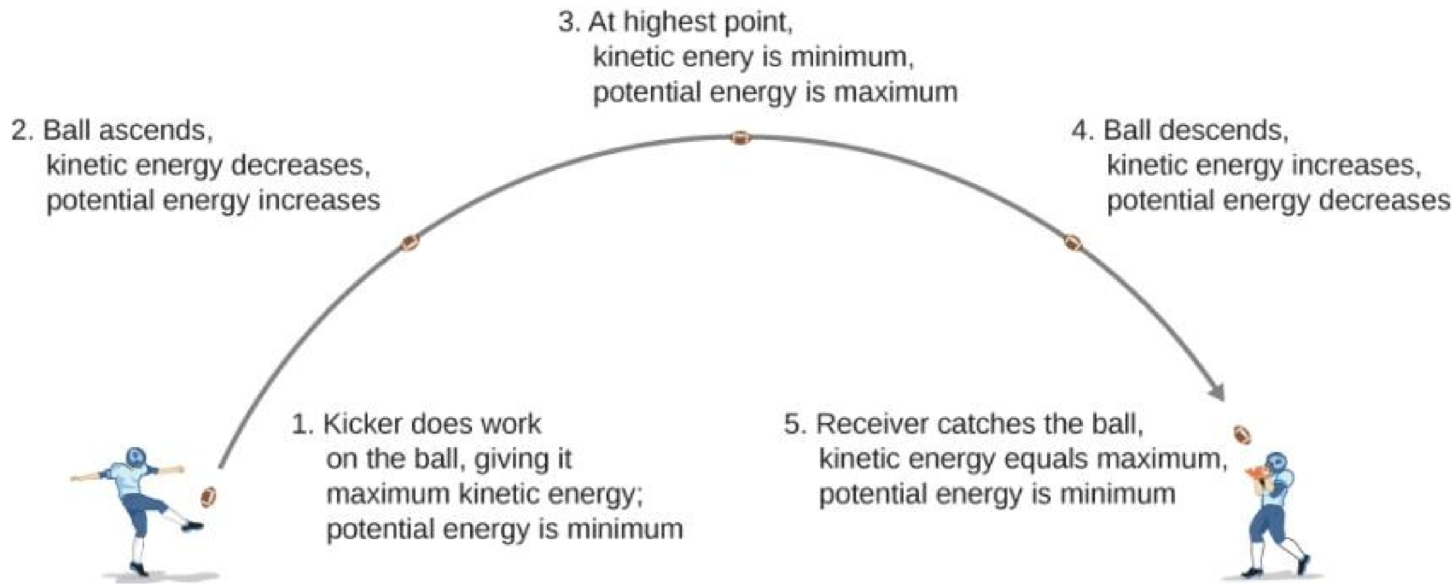
$$0.75\,P = mgv\,\sin(\tan^{-1} 0.15),$$

or

$$P = \frac{(1200\ \times\ 9.8\ \text{N})(90\ \text{m}/3.6\ \text{s})\sin(8.53°)}{0.75} = 58\ \text{kW},$$

or about 78 hp. (You should supply the steps used to convert units.)

POTENTIAL ENERGY



As a football starts its descent toward the wide receiver, gravitational potential energy is converted back into kinetic energy.

$$\Delta U_{AB} = U_B - U_A = -W_{AB}. \quad (8.1)$$

$$\Delta K_{AB} = \Delta U_{AB}.$$

GRAVITATIONAL POTENTIAL ENERGY

In Work, the work done on a body by Earth's uniform gravitational force, near its surface, depended on the mass of the body, the acceleration due to gravity, and the difference in height the body traversed, as given by Equation 7.4. By definition, this work is the negative of the difference in the gravitational potential energy, so that difference is

$$\Delta U_{\text{grav}} = -W_{\text{grav},AB} = mg\left(y_B - y_A\right). \qquad (8.4)$$

You can see from this that the gravitational potential energy function, near Earth's surface, is

$$U(y) = mgy + \text{const.} \qquad (8.5)$$

Spring Potential Energy

A system contains a perfectly elastic spring, with an unstretched length of 20 cm and a spring constant of 4 N/cm. (a) How much elastic potential energy does the spring contribute when its length is 23 cm? (b) How much more potential energy does it contribute if its length increases to 26 cm?

$$\Delta U = -W_{AB} = \frac{1}{2}k(x_B^2 - x_A^2), \tag{8.6}$$

where the object travels from point *A* to point *B*. The potential energy function corresponding to this difference is

$$U(x) = \frac{1}{2}kx^2 + \text{const.} \tag{8.7}$$

$$
\begin{aligned}
K_A + U_A &= K_C + U_C \\
0 &= 0 + mgy_C + \left(\tfrac{1}{2}ky_C\right)^2 \\
y_C &= \frac{-2mg}{k}
\end{aligned}
$$

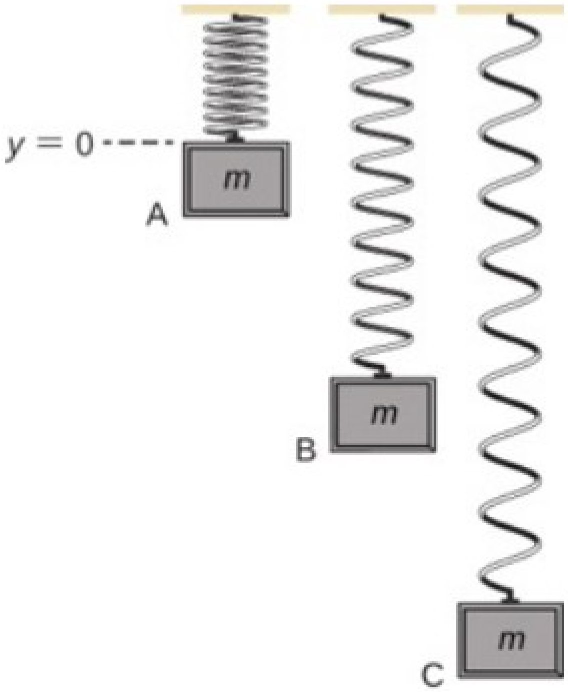
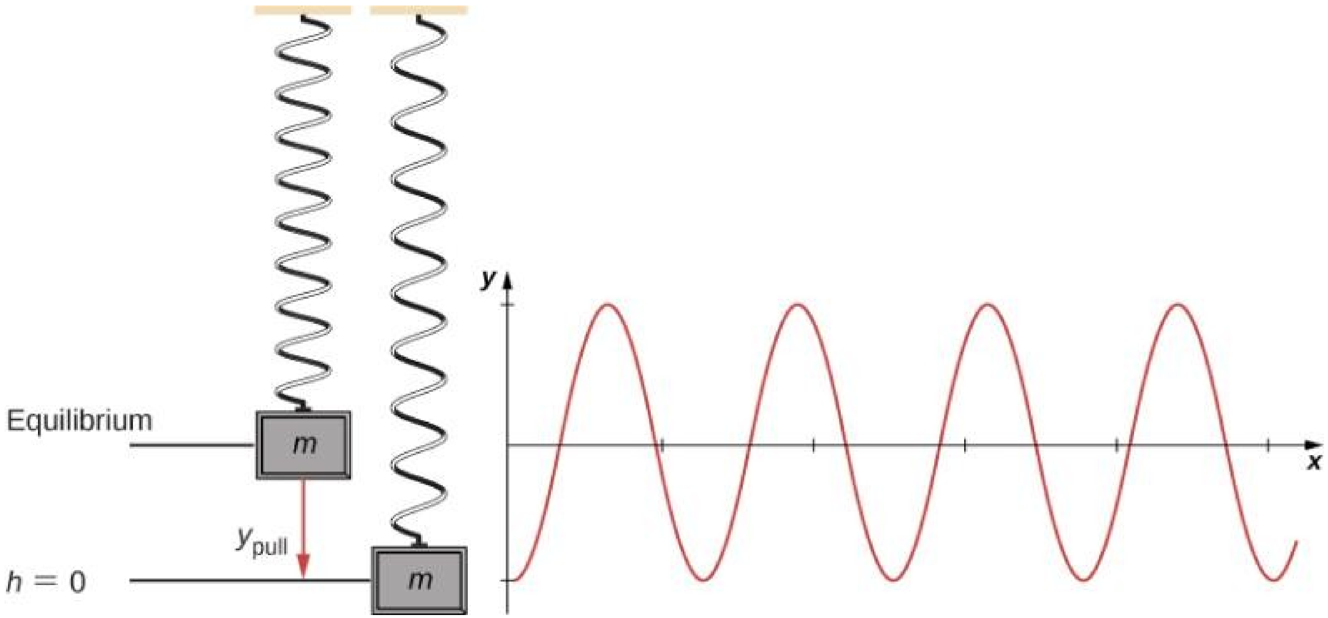


Figure 8.4 A vertical mass-spring system, with the y-axis pointing downward. The mass is initially at an unstretched spring length, point A. Then it is released, expanding past point B to point C, where it comes to a stop.



A vertical mass-spring system, with the *y*-axis pointing upwards. The mass is initially at an equilibrium position and pulled downward to y_{pull}. An oscillation begins, centered at the equilibrium position.