7-14
(a) In 1975 the roof of Montreal's Velodrome, with a weight of 360 kN, was lifted by 10 cm so that it could be centered. How much work was done on the roof by the forces making the lift?

(b) In 1960 Mrs. Maxwell Rogers of Tampa, Florida, reportedly raised one end of a car that had fallen onto her son when a jack failed. If her panic lift effectively raised 4000 N (about 1/4 of the car's weight) by 5.0 cm, how much work did her force do on the car?

\[ \text{Work done} = Fd \quad \text{where} \quad F = \text{weight} \quad d = \text{vertical height} \]

\[ \text{Work} = (360 \times 10^3 \text{N})(0.10 \text{m}) \]
\[ \text{Work} = 3.6 \times 10^4 \text{ Joules} \]

\[ \text{Work} = (4000 \text{ N})(0.05 \text{ m}) \]
\[ \text{Work} = 200 \text{ Joules} \]

7-22 A 250 g block is dropped onto a relaxed vertical spring that has a spring constant of \( k = 2.5 \text{ N/cm} \) (Fig. 7-30). The block becomes attached to the spring and compresses the spring 12 cm before momentarily stopping. While the spring is being compressed, what work is done on the block by

(a) the gravitational force on it and
(b) the spring force?

(c) What is the speed of the block just before it hits the spring?

(Assume that friction is negligible.)

(d) If the speed at impact is doubled, what is the maximum compression of the spring?

(Solution on next page)
7-22

The spring compresses total \( d = 0.12 \text{ m} \)

(a) Gravitational force = \( mg \)

Work done by gravity is \( W_g = mgd = (0.25 \text{ kg})(9.8)(0.12) \)

\( W_g = 0.29 \text{ Joules} \)

(+ sign \( \Rightarrow \) work done by it)

(b) With \( k = 2.5 \text{ N/m} \times 10^3 \text{ cm/m} \)

\( k = 250 \text{ N/m} \)

Work done by spring is \( W_s = -\frac{1}{2}kd^2 = -\frac{1}{2}(250 \text{ N/m})(0.12)^2 = -0.9 \text{ Joules} \)

(- sign \( \Rightarrow \) work done on block)

c) If block had speed \( v_0 \) at beginning and is at rest finally \( W_g + W_s = K_f - K_0 = 0 - \frac{1}{2}mv_o^2 \)

\[ 0.29 - 1.80 = -\frac{1}{2}(0.25)v_o^2 \]

\[ v_o = \sqrt{\frac{2(1.50)}{0.25}} = 3.48 \text{ m/s} \]

d) Note \(-\frac{1}{2}mv_o^2 = W_g + W_s\)

\(-\frac{1}{2}mv_o^2 = mgd_1 - \frac{1}{2}kd_1^2\)

\[ d_1^2 = \frac{2mgd_1 - \frac{1}{2}kd_1^2}{k} \]

\[ d_1 = \frac{2mg + \sqrt{(2mg)^2 + 4(mv_o^2)}}{2k} = \frac{mg + \sqrt{(mg)^2 + 4mv_o^2}}{k} \]

The negative root would give a negative value for \( d_1 \), and so clearly is not the one we seek.

So \[ d_1 = \frac{(0.25)(9.8) + \sqrt{(0.25)(9.8)^2 + (0.25)(6.96)^2}}{250} \]

\[ d_1 = \frac{2.45 + \sqrt{6.0 + 3028}}{250} = \]

\[ d_1 = 0.23 \text{ meters} \]
(a) At a certain instant, a particle-like object is acted on by a force
\[ F = (4.0 \text{ N})\hat{i} - (2.0 \text{ N})\hat{j} + (9.0 \text{ N})\hat{k} \]
while having a velocity \( v = -(2.0 \text{ m/s})\hat{i} + (4.0 \text{ m/s})\hat{k} \). What is the instantaneous rate at which the force does work on the object?

(b) At some other time, the velocity consists of only a y component. If the force is unchanged, and the instantaneous power is -12 W, what is the velocity of the object just then?

7-32
The power, or work per unit time, is
\[ P = \frac{dW}{dt} = \frac{d}{dt} (F \cdot \dot{v}) = F \cdot \ddot{v} \quad \text{for constant } F \]
(a) So
\[ P = \left[(4.0 \text{ N})\hat{i} - (2.0 \text{ N})\hat{j} + (9.0 \text{ N})\hat{k}\right] \cdot \left[(-2.0 \text{ m/s})\hat{i} + (4.0 \text{ m/s})\hat{k}\right] \\
= (4.0)(-2.0) + (9.0)(4.0) \\
P = 28 \text{ Watts} \quad \text{(Joules/ sec)} \]
(b) IF \( \vec{F} \) stays the same, and \( \vec{v} = \vec{v}_0 \hat{j} \), with \( P = -12 \text{ Watts} \)
Then
\[ P = F_y \vec{v}_0 \quad \Rightarrow \quad -12 = (-2.0) \vec{v}_0 \]
\[ \vec{v}_0 = \frac{12}{2} = 6 \text{ m/s} \]
7-34 A skier is pulled by a tow rope up a frictionless ski slope that makes an angle of 12° with the horizontal. The rope moves parallel to the slope with a constant speed of 1.0 m/s. The force of the rope does 900 J of work on the skier as the skier moves a distance of 8.0 m up the incline.

(a) If the rope moved with a constant speed of 2.0 m/s, how much work would the force of the rope do on the skier as the skier moved a distance of 8.0 m up the incline? At what rate is the force of the rope doing work on the skier when the rope moves with a speed of

(b) 1.0 m/s and

(c) 2.0 m/s?

(a) In both cases, the rope does work on the skier against gravity. In neither case does the skier's kinetic energy change. Hence, the work done by the rope, \( W_f \), is done against gravity, \( W_g \), i.e., \( W_f = W_g = 900 \text{ Joules} \) (same)

(b) Since speed is constant, and \( F \) is constant, then power is constant.

\[
P = \frac{dW}{dt} = \frac{\Delta W}{\Delta t} = \frac{900 \text{ J}}{8.0 \text{ m}} = \frac{900 \text{ J}}{v} = v \frac{900 \text{ J}}{8.0 \text{ m}}
\]

For (b), with \( v = 1.0 \text{ m/s} \)

\[
P = 1.0 \times 112.5 = 112.5 \text{ Watts}
\]

For (c), with \( v = 2.0 \text{ m/s} \)

\[
P = 2.0 \times 112.5 = 225.0 \text{ Watts}
\]
8-6 In Fig. 8-28, a small block of mass m can slide along the frictionless loop-the-loop. The block is released from rest at point P, at height \( h = 5R \) above the bottom of the loop. How much work does the gravitational force do on the block as the block travels from point P to
(a) point Q and
(b) the top of the loop?

If the gravitational potential energy of the block–Earth system is taken to be zero at the bottom of the loop, what is that potential energy when the block is
(c) at point P,
(d) at point Q, and
(e) at the top of the loop?

(f) If, instead of being released, the block is given some initial speed downward along the track, do the answers to (a) through (e) increase, decrease, or remain the same?

(a) Gravitational force does work
\[ W_{PQ} = mg \cdot d_{PQ} \]
where \( d_{PQ} = \text{vertical distance} \)
\[ d_{PQ} = 5R - R = 4R \]
\[ W_{PQ} = 4mg \cdot R \]

(b) \[ W_{PS} = mg \cdot d_{PS} = mg \cdot (5R - 2R) = 3mg \cdot R \]

(c) \[ U_{PT} = mg \cdot d_{PT} = mg \cdot (5R) = 5mg \cdot R \]

(d) \[ U_{QT} = mg \cdot (R) = mg \cdot R \]

(e) \[ U_{ST} = mg \cdot (2R) = 2mg \cdot R \]

(f) The work and potential energies do not depend on speed of the block. So answers are the same!
8-16 Figure 8-31 shows an 8.00 kg stone at rest on a spring. The spring is compressed 10.0 cm by the stone.

(a) What is the spring constant?
(b) The stone is pushed down an additional 30.0 cm and released. What is the elastic potential energy of the compressed spring just before that release?
(c) What is the change in the gravitational potential energy of the stone–Earth system when the stone moves from the release point to its maximum height?
(d) What is that maximum height, measured from the release point?

\[ k = \frac{mgd}{d} = \frac{(8.0 \text{ kg})(9.8 \text{ m/s}^2)}{0.10 \text{ m}} = 784 \text{ N/m} \]

\[ U_i = \frac{1}{2}ky^2 = \frac{1}{2}(784)(0.40)^2 = 62.7 \text{ Joules} \]

As the stone rises after it is released, the spring pushes upward on the stone until it reaches \( y = 0 \). At this point, the spring exerts no force on the stone. The stone, at \( y = 0 \), has an upward velocity but is no longer in contact with the spring. The stone continues to rise upward. When it reaches its maximum height, \( h \), above its release point, there is no kinetic energy \( \Rightarrow \) so the elastic potential energy, \( U_i \), has been converted to gravitational potential energy.

\[ U_i = mg \cdot h \]

\[ h = \frac{U_i}{mg} = \frac{62.7 \text{ Joules}}{(8.0 \text{ kg})(9.8 \text{ m/s}^2)} = 0.80 \text{ m} \]

or 80 cm