Physics 4A
Chapter 9 HW Solutions

Chapter 9
Conceptual Questions: 2, 5, 11
Exercises & Problems: 17, 18, 22, 29, 35, 37, 45, 55, 63

CQ 9.2. We have

$$K_A = 8K_B$$
$$\frac{1}{2}m_A v_A^2 = 8\left(\frac{1}{2}m_B v_B^2\right)$$

Since $m_A = \frac{1}{2}m_B$,

$$\frac{1}{2}\left(\frac{1}{2}m_B\right)v_A^2 = 8\left(\frac{1}{2}m_B v_B^2\right)$$
$$\Rightarrow \frac{v_A}{v_B} = 4$$

CQ 9.5. The kinetic energies are equal. Equal forces are applied over equal displacements so that the same work is done on each. Thus, the change in kinetic energy is the same. Because $K_i = 0$, $\Delta K = K_f$. (The plastic will be moving 10 times faster, however.)

CQ 9.11. **(a)** We identify the equilibrium position $s_e = 10$ cm. At $s = 11$ cm, $\Delta s = s - s_e = 11\text{ cm} - 10\text{ cm} = 1\text{ cm}$, and $F_{sp} = F = -k\Delta s = -k(1\text{ cm})$. To get $F_{sp} = 3F$, we must have $3F = -k(\Delta s)'$, which means $(\Delta s)' = 3$ cm. So the spring must have length $10\text{ cm} + 3\text{ cm} = 13\text{ cm}$.
(b) Note that the direction of the force is reversed when the spring is compressed.
To get $F_{sp} = -2F$, we must have $-2F = -k(\Delta s)'$, which means $(\Delta s)' = -2$ cm. So the spring must have length $10\text{ cm} - 2\text{ cm} = 8\text{ cm}$.

9.17. Model: Model the bug as a particle whose increase in speed is due entirely to the wind.
Visualize: We are given $m = 45$ g.
Solve: (a)

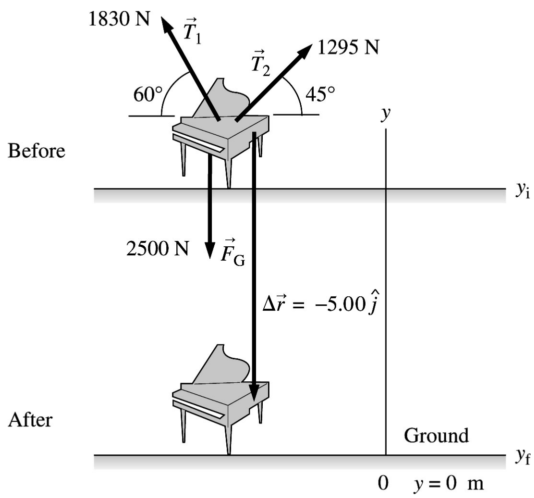
$$\vec{W} = \vec{F}\cdot\Delta\vec{r} = (4.0\hat{i} - 6.0\hat{j})\times 10^{-2}\text{ N}\cdot(2.0\hat{i} - 2.0\hat{j})\text{ m} = (0.080 + 0.12)\text{ J} = 0.20\text{ J}$$

(b) Recall that $v_i = 0$ m/s.

$$W = \Delta K = \tfrac{1}{2}m(v_f^2 - v_i^2) = \tfrac{1}{2}mv_f^2 \Rightarrow v_f = \sqrt{\frac{2W}{m}} = \sqrt{\frac{2(0.20\text{ J})}{0.045\text{ kg}}} = 3.0\text{ m/s}$$

Assess: This seems like a good speed for a bug.

9.18. Model: Model the piano as a particle and use $W = \vec{F}\cdot\Delta\vec{r}$, where W is the work done by the force $\vec{F}$ through the displacement $\Delta\vec{r}$.
Visualize:



Solve: For the force $\vec{F}_G$:

$$W = \vec{F}\cdot\Delta\vec{r} = \vec{F}_G\cdot\Delta\vec{r} = (F_g)\cdot(\Delta r)\cos(0°) = (255 \text{ kg})(9.81 \text{ m/s}^2)(5.00 \text{ m})(1.00) = 1.25\times10^4 \text{ J}$$

For the tension $\vec{T}_1$:

$$W = \vec{T}_1\cdot\Delta\vec{r} = (T_1)(\Delta r)\cos(150°) = (1830 \text{ N})(5.00 \text{ m})(-0.8660) = -7.92\times10^3 \text{ J}$$

For the tension $\vec{T}_2$:

$$W = \vec{T}_2\cdot\Delta\vec{r} = (T_2)(\Delta r)\cos(135°) = (1295 \text{ N})(5.00 \text{ m})(-0.7071) = -4.58\times10^3 \text{ J}$$

Assess: Note that the displacement $\Delta\vec{r}$ in all the above cases is directed downward along $-\hat{j}$.

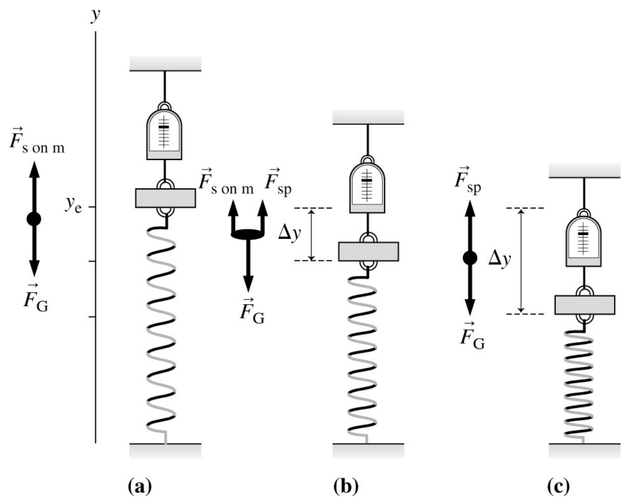
9.22. Model: Use the work–kinetic energy theorem.
Visualize: Please refer to Figure EX9.22.
Solve: The work–kinetic energy theorem is

$$\Delta K = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_i^2 = \int_{0\text{ m}}^{x_f} F_x\,dx = 10x - \tfrac{5}{2}x^2$$

$$v_f = \sqrt{\frac{20x - 5x^2}{2.0 \text{ kg}} + 4.0 \text{ m/s}}$$

$$\text{At } x = 2 \text{ m:} \Rightarrow v_f = 5 \text{ m/s}$$
$$\text{At } x = 4 \text{ m:} \Rightarrow v_f = 4 \text{ m/s}$$

9.29. Model: Assume that the spring is ideal and obeys Hooke's law. We also model the 5.0 kg mass as a particle.
Visualize: We will use the subscript s for the scale and sp for the spring.



Solve: (a) The scale reads the upward force $F_{\text{s on m}}$ that it applies to the mass. Newton's second law gives

$$\Sigma(F_{\text{on m}})_y = F_{\text{s on m}} - F_G = 0 \Rightarrow F_{\text{s on m}} = F_G = mg = (5.0\text{ kg})(9.8\text{ m/s}^2) = 49\text{ N}$$

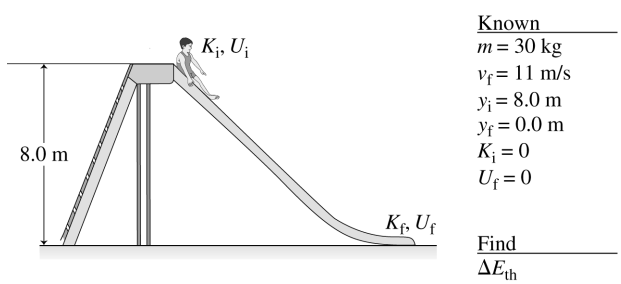
(b) In this case, the force is

$$\Sigma(F_{\text{on m}})_y = F_{\text{s on m}} + F_{\text{sp}} - F_G = 0 \Rightarrow 20\text{ N} + k\Delta y - mg = 0$$
$$\Rightarrow k = (mg - 20\text{ N})/\Delta y = (49\text{ N} - 20\text{ N})/0.02\text{ m} = 1450\text{ N/m}$$

The spring constant for the lower spring is 1.45×10^3 N/m.
(c) In this case, the force is

$$\Sigma(F_{\text{on m}})_y = F_{\text{sp}} - F_G = 0 \Rightarrow k\Delta y - mg = 0$$
$$\Rightarrow \Delta y = mg/k = (49\text{ N})/(1450\text{ N/m}) = 0.0338\text{ m} = 3.4\text{ cm}$$

9.35. Model: Justin is a particle.
Visualize:

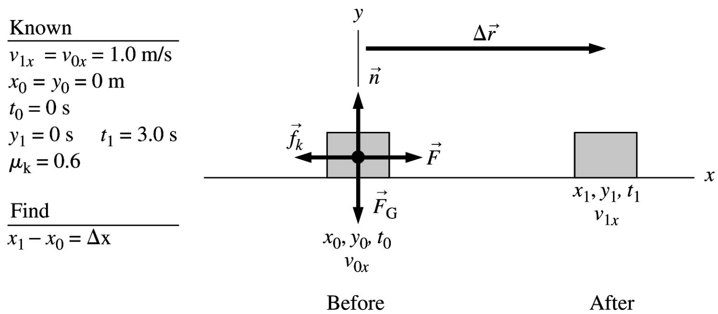


Solve:

$$K_i + U_i + W_{\text{ext}} = K_f + U_f + \Delta E_{\text{th}}$$
$$\Rightarrow \Delta E_{\text{th}} = U_i - K_f = mgy_i - \tfrac{1}{2}mv_f^2 = (30\text{ kg})(9.8\text{ m/s}^2)(8.0\text{ m}) - \tfrac{1}{2}(30\text{ kg})(11\text{ m/s})^2 = 540\text{ J}$$

Assess: This is about 23% of the initial potential energy, which is reasonable.

9.37. Model: Model the steel block as a particle subject to the force of kinetic friction and use energy conservation.
Visualize:



Solve: **(a)** The work done on the block is $W_{net} = \vec{F}_{net} \cdot \Delta\vec{r}$ where $\Delta\vec{r}$ is the displacement. We will find the displacement using kinematic equations and the force using Newton's second law of motion. The displacement in the x-direction is

$$\Delta x = x_1 = x_0 + v_{0x}(t_1 - t_0) + \tfrac{1}{2}a_x(t_1 - t_0)^2 = 0\text{ m} + (1.0\text{ m/s})(3.0\text{ s} - 0\text{ s}) + 0\text{ m} = 3.0\text{ m}$$

Thus $\Delta\vec{r} = 3.0\hat{i}$ m.
The equations for Newton's second law along the x and y components are

$$(F_{net})_y = n - F_G = 0\text{ N} \quad\Rightarrow\quad n = F_G = mg = (10\text{ kg})(9.8\text{ m/s}^2) = 98.0\text{ N}$$

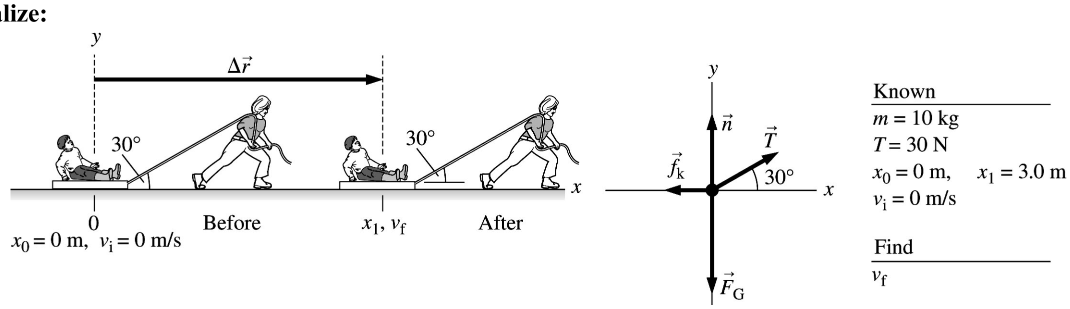
$$(F_{net})_x = \vec{F} - \vec{f}_k = 0\text{ N} \quad\Rightarrow\quad F = f_k = \mu_k n = (0.6)(98.0\text{ N}) = 58.8\text{ N}$$

$$W_{net} = \vec{F}_{net} \cdot \Delta\vec{r} = F\Delta x\cos(0°) = (58.8\text{ N})(3.0\text{ m})(1) = 176\text{ J}$$

(b) The power required to do this much work in 3.0 s is

$$P = \frac{W}{t} = \frac{176\text{ J}}{3.0\text{ s}} = 59\text{ W}$$

9.45. Model: Model Paul and the mat as a particle, assume the mat to be massless, use the model of kinetic friction, and apply the work–kinetic energy theorem.
Visualize:



We define the x-axis along the floor and the y-axis perpendicular to the floor.
Solve: We first need to determine f_k. Newton's second law in the y-direction gives

$$n + T\sin(30°) = F_G = mg \quad\Rightarrow\quad n = mg - T\sin(30°) = (10\text{ kg})(9.8\text{ m/s}^2) - (30\text{ N})\sin(30°) = 83.0\text{ N}.$$

Using n and the model of kinetic friction gives $f_k = \mu_k n = (0.2)(83.0\text{ N}) = 16.60$ N. The net force on Paul and the mat is therefore $F_{net} = T\cos(30°) - f_k = (30\text{ N})\cos(30°) - 16.6\text{ N} = 9.4$ N. Thus,

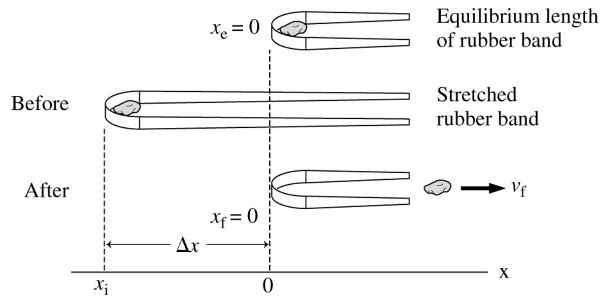
$$W_{net} = F_{net}\Delta r = (9.4\text{ N})(3.0\text{ m}) = 28\text{ J}$$

The other forces $\vec{n}$ and $\vec{F}_G$ make an angle of 90° with $\Delta\vec{r}$ and do zero work. We can now use the work–kinetic energy theorem to find the final velocity as follows:

$$W_{net} = K_f - K_i = K_f - 0\text{ J} = \frac{1}{2}mv_f^2 \quad\Rightarrow\quad v_f = \sqrt{2W_{net}/m} = \sqrt{2(28\text{ J})/(10\text{ kg})} = 2.4\text{ m/s}$$

Assess: A speed of 2.4 m/s or 5.4 mph is reasonable for the present problem.

9.55. Model: Assume that the rubber band behaves similar to a spring. Also, model the rock as a particle.
Visualize:



Solve: From the graph, $|\Delta F_{sp}| = 20$ N for $|\Delta x| = 10$ cm. Thus,

$$k = \frac{|\Delta F_{sp}|}{|\Delta x|} = \frac{20\text{ N}}{0.10\text{ m}} = 200\text{ N/m} = 2.0\times10^2\text{ N/m}$$

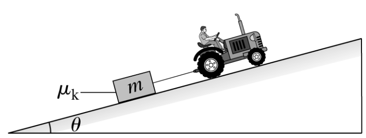
The conservation of energy equation $K_f + U_{sf} = K_i + U_{si}$ for the rock is

$$\frac{1}{2}mv_f^2 + \frac{1}{2}kx_f^2 = \frac{1}{2}mv_i^2 + \frac{1}{2}kx_i^2 \Rightarrow \frac{1}{2}mv_f^2 + \frac{1}{2}k(0\text{ m})^2 = \frac{1}{2}m(0\text{ m/s})^2 + \frac{1}{2}kx_i^2$$

$$v_f = \sqrt{\frac{k}{m}}x_i = \sqrt{\frac{200\text{ N/m}}{0.050\text{ kg}}}(0.30\text{ m}) = 19\text{ m/s}$$

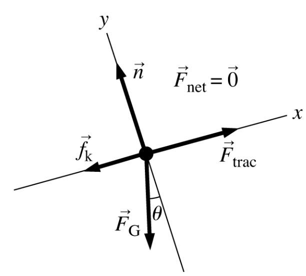
Assess: Note that x_i is Δx, which is the displacement relative to the equilibrium position, and x_f is the equilibrium position of the rubber band, which is equal to zero.

9.63. Model: Model the bale as a particle. Assume the tractor's power output all goes into moving the bale.
Visualize: Use tilted axes.



Known
$m = 150$ kg
$\mu_k = 0.45$
$\theta = 15°$

Find
P



Solve: We need to use Newton's second law in both directions.

$$\Sigma F_y = n - mg\cos\theta = 0 \Rightarrow n = mg\cos\theta$$
$$\Sigma F_x = F_{trac} - mg\sin\theta - f_k = 0 \Rightarrow F_{trac} = mg\sin\theta + \mu_k mg\cos\theta$$

For a constant force and constant velocity

$$P_{trac} = \frac{W_{trac}}{\Delta t} = \frac{\vec{F}_{trac}\cdot\Delta\vec{x}}{\Delta t} = \vec{F}_{trac}\cdot\vec{v} = mg(\sin\theta + \mu_k\cos\theta)v$$
$$= (150\text{ kg})(9.8\text{ m/s}^2)(\sin15° + 0.45\cos15°)(5.0\text{ km/h})\left(\frac{1\text{ h}}{3600\text{ s}}\right) = 1.4\text{ kW}$$

Assess: 1.4 kW seems about right for a tractor.