11.9. **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:**

![Diagram of piano with forces](image)

**Solve:** For the force $\vec{w}$:

$$W = \vec{F} \cdot \Delta \vec{r} = \vec{w} \cdot \Delta \vec{r} = (w)(\Delta r)\cos 0^\circ = (2500 \text{ N})(5.0 \text{ m})(1) = 12,500 \text{ J}$$

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

$$W = \vec{T}_1 \cdot \Delta \vec{r} = (T_1)(\Delta r)\cos 150^\circ = (1830 \text{ N})(5.0 \text{ N})(-0.8660) = -7920 \text{ J}$$

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

$$W = \vec{T}_2 \cdot \Delta \vec{r} = (T_2)(\Delta r)\cos 135^\circ = (1295 \text{ N})(5.0 \text{ m})(-0.7071) = -4580 \text{ J}$$

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

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

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**11.14. Model:** Use the work-kinetic energy theorem.

**Visualize:** Please refer to Figure Ex11.14.

**Solve:** The work-kinetic energy theorem is

\[
\Delta K = \frac{1}{2} m v_i^2 - \frac{1}{2} m v_f^2 = W = \int_{x_i}^{x_f} F_x \, dx = \text{area under the force curve from } x_i \text{ to } x_f
\]

\[
\Rightarrow \frac{1}{2} m v_i^2 - \frac{1}{2} m v_f^2 = \int_{x=0}^{x=x_f} F_x \, dx = \text{area from 0 to } x
\]

At \( x = 2 \text{ m} \):

\[
\frac{1}{2} (2.0 \text{ kg}) v_i^2 - 16 \text{ J} = \frac{1}{2} (-10 \text{ N})(2 \text{ m}) = -10 \text{ J} \Rightarrow v_i = 2.45 \text{ m/s}
\]

At \( x = 4 \text{ m} \):

\[
\frac{1}{2} (2.0 \text{ kg}) v_i^2 - 16 \text{ J} = 0 \text{ J} \Rightarrow v_i = 4.0 \text{ m/s}
\]
11.41. **Model:** Model the crate as a particle, and use the work-kinetic energy theorem.

**Visualize:**

![Diagram of crate with forces](image)

\[ F_{\text{push}} \]

\[ \Delta x \]

\[ \Delta \theta = 20^\circ \]

\[ h = 2 \text{ m} \]

\[ x_0 = v_{y_0} = 0, \quad x_1 = h/\sin \theta = 5.85 \text{ m} \]

\[ m = 5 \text{ kg}, \quad \mu_k = 0, \quad F_{\text{push}} = 25 \text{ N} \]

**Solve:** (a) The work-kinetic energy theorem is \( \Delta K = \frac{1}{2} m v_1^2 - \frac{1}{2} m v_0^2 = \frac{1}{2} m v_1^2 = W_{\text{total}} \). Three forces act on the box, so \( W_{\text{total}} = W_{\text{grav}} + W_{n} + W_{\text{push}} \). The normal force is perpendicular to the motion, so \( W_{n} = 0 \text{ J} \). The other two forces do the following amount of work:

\[ W_{\text{push}} = F_{\text{push}} \cdot \Delta \theta = F_{\text{push}} \Delta x \cos 20^\circ = 137.4 \text{ J} \]

\[ W_{\text{grav}} = W \cdot \Delta \theta = W \Delta x = (-mg \sin 20^\circ)\Delta x = -98.0 \text{ J} \]

Thus, \( W_{\text{total}} = 39.4 \text{ J} \), leading to a speed at the top of the ramp equal to

\[ v_1 = \sqrt{\frac{2 W_{\text{total}}}{m}} = \sqrt{\frac{2(39.4 \text{ J})}{5 \text{ kg}}} = 3.97 \text{ m/s} \]

(b) The \( x \)-component of Newton’s second law is

\[ a_x = a = \frac{(F_{\text{net}})_x}{m} = \frac{F_{\text{push}} \cos 20^\circ - mg \sin 20^\circ}{m} = \frac{F_{\text{push}} \cos 20^\circ - mg \sin 20^\circ}{m} = 1.347 \text{ m/s}^2 \]

Constant-acceleration kinematics with \( x_1 = h/\sin 20^\circ = 5.85 \text{ m} \) gives the final speed

\[ v_{y_1}^2 = v_{y_0}^2 + 2a(x_1 - x_0) = 2ax_1 \implies v_1 = \sqrt{2ax_1} = \sqrt{2(1.347 \text{ m/s}^2)(5.85 \text{ m})} = 3.97 \text{ m/s} \]
11.48. **Model:** Model the two blocks as particles. The two blocks make our system.

**Visualize:**

![Diagram of two blocks with initial conditions](image)

We place the origin of our coordinate system at the location of the 3.0 kg block.

**Solve:** (a) The conservation of energy equation is \( K_i + U_{i\theta} + \Delta E_{\text{th}} = K_f + U_{f\theta} + W_{\text{ext}} \). Using \( \Delta E_{\text{th}} = 0 \) J and \( W_{\text{ext}} = 0 \) J we get

\[
\frac{1}{2}m_1(v_1)_1^2 + \frac{1}{2}m_2(v_1)_2^2 + m_2g(y_1) = \frac{1}{2}m_1(v_1)_1^2 + m_2g(y_1)
\]

Noting that \((v_1)_1 = (v_1)_2 = v_i\) and \((v_1)_2 = (v_1)_3 = 0 \) m/s, this becomes

\[
v_i = \sqrt{\frac{2m_2g(y_1 - y_i)}{m_2 + m_1}} = \sqrt{\frac{2(2.0 \text{ kg})(9.8 \text{ m/s}^2)(1.50 \text{ m})}{(2.0 \text{ kg} + 3.0 \text{ kg})}} = 3.43 \text{ m/s}
\]

(b) We will use the same energy conservation equation. However, this time \( \Delta E_{\text{th}} = (f_i)(\Delta x) = \mu_s(\eta)(\Delta x) = \mu_s(m_1g)(\Delta x) = (0.15)(3.0 \text{ kg})(9.8 \text{ m/s}^2)(1.50 \text{ m}) = 6.615 \text{ J} \)

The energy conservation equation is now

\[
\frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_i^2 + m_2gy_1 + 6.615 \text{ J} = \frac{1}{2}m_1(v_1)_1^2 + \frac{1}{2}m_2(v_1)_2^2 + m_2g(y_1) + 0 \text{ J}
\]

\[
\frac{1}{2}(m_1 + m_2)v_i^2 + 6.615 \text{ J} = m_2g(y_1 - y_i) \Rightarrow v_i = \sqrt{\frac{2}{m_1 + m_2}}(m_2g(y_1 - y_i) - 6.615 \text{ J}) = \sqrt{\frac{2}{5.0 \text{ kg}}}(2.0 \text{ kg})(9.8 \text{ m/s}^2)(1.50 \text{ m}) - 6.615 \text{ J} = 3.02 \text{ m/s}
\]

**Assess:** A reduced speed when friction is present compared to when there is no friction is reasonable.