Q4. (a) Kinetic energy is a scalar \((= \frac{1}{2}mv^2)\), so it has nothing to do with direction. It cannot be negative, because \(v^2 \geq 0\), even if \(v\) is negative.

(b) Potential energy is only defined up to an arbitrary constant; the "zero" can be at any convenient place. So gravitational PE can certainly be negative.

Q6 (a) \(KE = \frac{1}{2}mv^2\), so doubling \(v\) increases \(KE\) by a factor of 4.

(b) \(\Delta W_{net} = \Delta (KE) = \frac{1}{2}m(v^2 - v_0^2)\). So if \(\Delta W_{net} = 0\), then \(v^2 = v_0^2\) so the speed (but not the velocity) must be constant.

P2. \(m = 2.00\) kg \(T = \) pulling force \(W_T = 6.00\) kJ \(\Delta y = ?\)

Constant speed \(\Rightarrow\) No acceleration

\[ \Delta y = \frac{W_T}{mg} = \frac{6.00 \times 10^3 \text{ J}}{(2.00 \text{ kg})(9.80 \text{ m/s}^2)} \]

\[ \Delta y = 30.6 \text{ m} \]
\[ \theta = 30.0^\circ \]
\[ m = 5.00 \text{ kg} \]
\[ \Delta x = 2.50 \text{ m} \]

(a) Work done by gravity \( W_g \):

\[ W_g = F_g \cdot \Delta x = mg \sin \theta \cdot \Delta x = (5.00 \text{ kg})(9.80 \text{ m/s}^2) \sin 30^\circ (2.50 \text{ m}) \]
\[ = 61.3 \text{ J} \]

(b) \( W_f = -f_k \cdot \Delta x \) (force in opposite direction to motion)

Need to use \( f_k = \mu_k n \), where \( n = F_g = mg \sin \theta \)

So \( W_f = -\mu_k mg \cos \theta \cdot \Delta x = -(0.436)(5.00 \text{ kg})(9.80 \text{ m/s}^2) \cos 30^\circ (2.50 \text{ m}) \)
\[ = -46.3 \text{ J} \]

(c) The normal force \( N \) is perpendicular to the motion (its component in the direction of motion is zero),

So \[ W_n = 0 \text{ J} \]
\[ \Delta x = 20.0 \, \text{m} \quad \theta = 20.0^\circ \]

\[ m = 18.0 \, \text{kg} \quad \mu_k = 0.500 \]

Constant Speed: Net force zero — thus \( x \) and \( y \) components are each zero.

Free-body diagram

\[ T \]

\[ f_k = T \cos \theta \quad \text{with} \quad f_k = \mu_k n \]

\[ T \sin \theta = T_y = F_y \]

\[ F_y = n + T \sin \theta \quad \text{with} \quad F_y = mg \]

\( y \) components:

\( x \) components:

\[ (a) \text{ Find } T: \]

\[ \begin{aligned}
mg &= n + T \sin \theta \\
\mu_k n &= T \cos \theta
\end{aligned} \]

Eliminate \( n \):

\[ n = mg - T \sin \theta \]

\[ \mu_k (mg - T \sin \theta) = T \cos \theta \]

Solve for \( T \):

\[ T = \frac{\mu_k mg}{\cos \theta + \mu_k \sin \theta} = \frac{(0.500)(18.0 \, \text{kg})(9.80 \, \text{m/s}^2)}{\cos 20^\circ + 0.500 \sin 20^\circ} \]

\[ T = 79.4 \, \text{N} \]
(b) Work done by tension force, $W_T$:

Component in direction of motion is $T \cos \theta$, so

$$W_T = (T \cos \theta) \Delta x = (79.4 \text{ N}) \cos 20^\circ (20.0 \text{ m})$$

$$= 1.49 \times 10^3 \text{ J}$$

(c) "Mechanical energy lost" = work done by friction

$$W_f = -M_k \Delta x = -M_k (mg - T \sin \theta) \Delta x$$

$$= -[0.500 \text{ (18.0 kg)} (6.80 \text{ m/s}^2) - 79.4 \text{ N} \sin 20^\circ] (20.0 \text{ m})$$

$$= -1.49 \times 10^3 \text{ J}$$

Note that $W_T + W_f = 0$, so no net work on the sledge is done—consistent with constant speed.

P9. \[
\begin{array}{c}
\vec{F}_p \quad \vec{F}_p \\
\vdots \quad \vdots \\
\vec{F}_p \quad \vec{F}_p \\
\end{array}
\]

\[
\begin{array}{c}
V_f = 0 \\
\rightarrow F_p \\
\Delta x \\
\rightarrow +x \\
\end{array}
\]

$m = 2.50 \times 10^3 \text{ kg}$

$W_p = 5000 \text{ J}$

Neglect friction

$\Delta x = 25.0 \text{ m}$

(a) $W_p = \Delta E = \frac{1}{2} m (V_f^2 - V_0^2) = \frac{1}{2} m V_f^2$

$$V_f^2 = 2W_p \quad \rightarrow \quad V_f = \sqrt{\frac{2W_p}{m}} = \left[ \frac{2(5000 \text{ J})}{2.50 \times 10^3 \text{ kg}} \right]$$

$$= 2.00 \text{ m/s}$$

(b) $W_p = F_p \Delta x$ (force in same direction as motion)

$$F_p = \frac{W_p}{\Delta x} = \frac{5000 \text{ J}}{25.0 \text{ m}} = \boxed{200 \text{ N}}$$
If KE₁ = KE₂, then \( \frac{1}{2} m₁v₁² = \frac{1}{2} m₂v₂² \)

Solve for \( v₂ \):

\[
v₂ = \sqrt{\frac{m₁}{m₂}} v₁^2 \quad \Rightarrow \quad v₂ = \sqrt{\frac{m₁}{m₂}} v₁
\]

\[
v₂ = \sqrt{\frac{7.00 \text{ kg}}{2.45 \times 10^{-3} \text{ kg}}} \left( 3.00 \text{ m/s} \right) = 160 \text{ m/s}
\]

\[ \Delta x = 5.00 \text{ m} \]
\[ v₀ = 1.50 \text{ m/s} \]
\[ m = 0.400 \text{ kg} \]
\[ T = 100 \text{ N} \]
\[ \theta = 20.0° \]

Components:

\[
F₃ \leq F₉ \cos \theta \quad \text{(note: is in -y direction)}
\]
\[
F₉ \sin \theta \quad \text{(note: is in -x direction)}
\]

Net force in y direction is zero:

\[ v₁ = F₉ \cos \theta = mg \cos \theta \]
(a) Work done by gravity, \( W_g \):

\[
W_g = -F_g \sin \theta \Delta x = -mg \sin \theta \Delta x
\]

\[
= -(10.0 \text{ kg})(9.80 \text{ m/s}^2) \sin 20^\circ (5.00 \text{ m})
\]

\[
= -168 \text{ J}
\]

(b) Mechanical energy (set due to friction, \( W_f \)):

\[
W_f = -f_k \Delta x = -\left( \frac{m_k mg \cos \theta}{m} \right) \Delta x
\]

\[
= -0.400 (10.0 \text{ kg})(9.80 \text{ m/s}^2) \cos 20^\circ (5.00 \text{ m})
\]

\[
= -184 \text{ J}
\]

(c) Work due to tension force, \( W_T \):

\[
W_T = (100 \text{ N})(5.00 \text{ m}) = 500 \text{ J}
\]

(d) \( \sum W = \Delta KE \Rightarrow W_g + W_f + W_T = \Delta KE \)

\[
\Delta KE = -168 \text{ J} -184 \text{ J} + 500 \text{ J} = 148 \text{ J}
\]

(e) \( \Delta KE = \frac{1}{2} m (v^2 - v_0^2) \Rightarrow v^2 - v_0^2 = \frac{2 \Delta KE}{m} \)

\[
v = \sqrt{v_0^2 + \frac{2 \Delta KE}{m}} = \sqrt{(1.5 \text{ m/s})^2 + \frac{2(148 \text{ J})}{10.0 \text{ kg}}}
\]

\[
= 5.64 \text{ m/s}
\]