1. (6 pts) A person removes a heavy box from a table and places it on the floor. For each of the following, state whether the quantity is positive, negative or zero.

- (2) Work done by gravity on the box
  - POSITIVE
- (2) Work done by the person on the box
  - NEGATIVE
- (2) Net work done on the box
  - ZERO

2. (4 pts) Two possible paths, 1 and 2, are shown for an object that moves from point A to point B under the action of a conservative force \( \vec{F} \). If path 1 is twice the length of path 2, how does the work done by the force on the object along path 1 differ from the work done along path 2? Please justify your answer briefly.

3. (5 pts) Two objects experience a head-on collision. Given only the initial and final velocities of both objects, describe how one could determine whether the collision was elastic or inelastic.

   \[ \text{THE INITIAL VELOCITY OF APPROACH OF THE TWO MASSES SHOULD EQUAL THE FINAL VELOCITY AT WHICH THEY MOVE APART, IF COLLISION IS ELASTIC.} \]

   \[ |\vec{v}_{1i} - \vec{v}_{2i}| = |\vec{v}_{1f} - \vec{v}_{2f}| \]

4. (5 pts) Particle 1 and Particle 2 have the same kinetic energy, but particle 1 is 5.00 times more massive than Particle 2. Calculate the ratio of the magnitudes of their momenta, i.e. calculate \( \frac{|\vec{p}_1|}{|\vec{p}_2|} \).

   \[ K_1 = K_2 \]

   \[ \frac{p_1^2}{2m_1} = \frac{p_2^2}{2m_2} \]

   \[ \frac{p_1^2}{2(5m_2)} = \frac{p_2^2}{2m_2} \]

   \[ \frac{p_1}{p_2} = \sqrt{5} \]
5. (20 pts) Consider the diagram of a roller coaster car below. The roller coaster car starts with an initial speed of 5.00 m/s at position 1, and has a mass of 555 kg. Please answer the following questions:

(a) (8) Assuming negligible friction, what is the speed of the roller coaster car at position 2?

(b) (6) Again assuming negligible friction, if the speed of the roller coaster car at position 3 is 15.0 m/s, what is the height \( h \) of position 3?

(c) (6) Immediately after reaching position 3 a constant frictional braking force of 1800 N is applied to the car. Over what distance does the car come to a stop?

\[
\begin{align*}
\text{a) } & \quad \frac{1}{2} m v_1^2 + m g y_1 = \frac{1}{2} m v_2^2 + m g y_2 \\
& \quad \text{Conservation of Mechanical Energy} \\
& \quad v_2 = \sqrt{v_1^2 + 2 g (y_1 - y_2)} \\
& \quad = \sqrt{(5 \text{ m})^2 + 2 \times 9.81 \text{ m/s}^2 \times (25 \text{ m} - 5.0 \text{ m})} = 20.4 \text{ m/s} \\
\text{b) } & \quad \frac{1}{2} m v_1^2 + m g y_1 = \frac{1}{2} m v_3^2 + m g h \\
& \quad \text{Conservation of M.E.} \\
& \quad h = \frac{1}{g} \left( \frac{1}{2} v_1^2 - \frac{1}{2} v_3^2 + g y_1 \right) = \frac{[0.5 \times (5.00 \text{ m/s})^2 - 0.5 \times (15.0 \text{ m/s})^2 + 9.81 \text{ m/s}^2 \times 25 \text{ m}]}{9.81 \text{ m/s}^2} = 14.8 \text{ m} \\
\text{c) } & \quad W_{\text{net}} = \Delta KE \\
& \quad -F d = -\frac{1}{2} m v_3^2 \\
& \quad d = \frac{m v_3^2}{2 F} = \frac{(655 \text{ kg})(15.0 \text{ m/s})^2}{2 \times (1800 \text{ N})} = 34.7 \text{ m}
\end{align*}
\]
6. (20 pts) A 0.135 kg block with spring constant 20.0 N/m is initially held against a spring that is compressed a distance 0.105 m from its equilibrium position. A second block of mass 0.195 kg is at rest on a frictionless floor. The spring is then released suddenly and the 0.135 kg block slides to the right, detaching from the spring, and then collides with the other block, sticking to it.

(a) (12) Calculate the final velocity of the joined blocks.

(b) (8) Calculate the impulse delivered by the 0.195 kg block on the 0.135 kg block during the collision.

\[
\frac{1}{2} k x^2 = \frac{1}{2} m_1 v_a^2 \quad \text{Cons Mech. Energy, } v_a \text{ is speed of 0.135 kg block before colliding.}
\]

\[
v = \sqrt{\frac{k}{m_1} x} = \sqrt{\frac{20.0 \text{ N/m}}{0.135 \text{ kg}}} (0.105 \text{ m}) = 1.28 \text{ m/s}
\]

After blocks joined (Event B)

\[m_1 v_a - (m_1 + m_2) v_B \quad \text{;} \quad v_B = \left( \frac{m_1}{m_1 + m_2} \right) v_A = \left( \frac{0.135 \text{ kg}}{0.135 \text{ kg} + 0.195 \text{ kg}} \right) (1.28 \text{ m/s}) = 0.524 \text{ m/s, to the right}\]

b) Impulse \[F \Delta t = \Delta \vec{p} \]

\[= m_1 (v_f - v_c) \]

\[= 0.135 \text{ kg } (0.52 \text{ m/s} - 1.28 \text{ m/s}) = -0.103 \text{ kg m/s} \quad \text{(i.e. to the left)} \]
7. (20 pts) A 155 kg crate is pulled from rest up from the bottom of a 27.0 m ramp with a constant force $F_T = 1550$ N acting at an angle of $18^\circ$ below the angle of the ramp as shown. A frictional force of 395 N acts throughout the motion.

(a) (6) Calculate the work done by the force $F_T$ on the crate.

(b) (6) Calculate the work done by the frictional force.

(c) (8) Using the work-kinetic energy theorem, calculate the speed of the crate just as it reaches the top of the incline.

\[ W_{FT} = \int F_T \cdot dq = F_T \cdot d\theta = (1550 \text{ N})(27.0 \text{ m}) \cos 18^\circ = 3.98 \times 10^4 \text{ Joules} \]

\[ W_{FF} = \int F_F \cdot dq = F_F \cdot d\cos \theta = (395 \text{ N})(27.0 \text{ m}) \cos 180^\circ = -1.07 \times 10^4 \text{ Joules} \]

\[ W_{NET} = \Delta K \]

\[ W_{FT} + W_{FF} + W_{\text{gravity}} = \frac{1}{2} m V_f^2 - \frac{1}{2} m V_i^2 
= -mgh \]

\[ V_f = \sqrt{\frac{2}{m} (W_{FT} + W_{FF} - mgh)} \]

\[ V_f = 8.45 \text{ m/s} \]
B. (20 pts) Three kids \(m_1 = 27.0 \text{ kg}, m_2 = 35.0 \text{ kg}, m_3 = 32.0 \text{ kg}\) sit on three corners of a uniform 2.00 meter by 4.00 meter raft as shown. The mass of the raft is 15.0 kg. Calculate the location of the combined center of mass of the raft and kids, relative to the lower left hand corner of the raft. You may treat the kids as point particles.

\[
X_{cm} = \frac{M_1 x_1 + M_2 x_2 + M_3 x_3 + M_R x_R}{M_1 + M_2 + M_3 + M_R}
\]

\[
= \frac{(27 \text{ kg} \cdot 0) + (35 \text{ kg} \cdot 0) + (32 \text{ kg} \cdot 2\text{ m}) + 15 \text{ kg} \cdot (1\text{ m})}{(27 + 35 + 32 + 15) \text{ kg}}
\]

\[
X_{cm} = 0.725 \text{ m}
\]

\[
Y_{cm} = \frac{(27 \text{ kg} \cdot 0) + (35 \text{ kg} \cdot 4\text{ m}) + (32 \text{ kg} \cdot 4\text{ m}) + (15 \text{ kg} \cdot 2.00\text{ m})}{(27 + 35 + 32 + 15) \text{ kg}}
\]

\[
Y_{cm} = 2.734 \text{ m}
\]