1. (14 pts) Paul and Patrick push on a 200 lb box with a force as shown in the graph and picture. If the box has a speed of 5.0 ft/s at x=0, what is its speed at x=10 ft?

\[ W = \Delta KE \]
\[ W = F \cdot \Delta x \]
\[ W = F_1 \Delta x_1 \cos \theta + F_2 \Delta x_2 \cos \theta \]
\[ = \left(10^3 \right) \left(5 \text{ ft} \right) \cos 40 + \left(10^3 \right) \left(10^2 \right) \cos 40 \]
\[ = 38.3 + 53.6 \]
\[ = 92 \text{ ft-lb} \]
\[ W = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 \]
\[ v_f = \sqrt{\frac{2W}{m} + v_i^2} \]
\[ v_i = 7.39 \frac{\text{ft}}{\text{s}} \]

2. (14 pts) Dr. Parame is still driving around on his scooter trying to find the EF 151 class to give his departmental overview presentation. The scooter has a 15 hp motor and is only 10% efficient. What is his maximum speed if the max force he experiences is a constant 157 lb?

\[ P_{\text{out}} = F \cdot v \]
\[ n = \frac{P_{\text{out}}}{P_{\text{max}}} \]
\[ n_{\text{max}} = nF \cdot v \]
\[ \eta = \frac{P_{\text{out}}}{P_{\text{in}}} \]
\[ \eta_{\text{max}} = \frac{P_{\text{in}}}{P_{\text{out}}} \]
\[ v = 5.25 \frac{\text{ft}}{\text{s}} \]

or \[ 3.58 \text{ mi/hr} \]

3. (14 pts) A skeptic may say: "Great, but where is the PE?"

\[ KE_1 + PE_1 + W = KE_2 + PE_2 + E_{\text{loss}} \]
\[ W = \frac{1}{2} mv_i^2 + F \cdot d \]
\[ mgh + W = \frac{1}{2} mv_f^2 + (16 \text{ ft}) (1400 \text{ in}) \]
\[ v_2 = 26 \text{ m/s} \]

4. (14 pts) Isaac decides to build a life-size model of the ball-in-tube roller coaster. In his coaster a 100 kg ball starts from rest at the top of Neyland stadium. A pneumatic device provides 10 kJ of energy to get the ball rolling. After several loops and s-curves the ball ends up 42 m lower at the 50 yd line. The total length of the ride is 1400 m. Assume a constant energy loss of 15 J/m. What is the ball's final speed?

\[ 26 \text{ m/s} \]
5. (14 pts) Houston decides a braking device is needed to stop the 100 kg ball from laden's coaster. He estimates the maximum speed of the ball when it exits the coaster will be 54 km/hr and that the ball needs to be brought to a stop in 5.2 seconds. What average force is required of the device?

\[
\frac{1}{2} v_f^2 = \frac{1}{2} v_i^2 + F \cdot \Delta t
\]

\[
F_{avg} = \frac{mv_f - mv_i}{\Delta t}
\]

\[
v_f = 26.11 \text{ m/s}
\]

\[
F_{avg} = \frac{100 \text{ kg} \cdot (0 - 26.11 \text{ m/s})}{5 \text{ sec}} = 522 \text{ N}
\]

6. (14 pts) Abby takes her class to the Down Under to study collisions. They place a 4 lb box at the end of the lane and roll a 3 lb ball into it. The ball sticks in the box and the combination slides to a stop. The energy loss due to friction is 50 ft-lb. What was the original speed of the ball?

\[
\frac{1}{2} (1.4 \text{ lb}) v_f^2 = \frac{1}{2} (1.4 \text{ lb}) (21.12 \text{ ft/s})^2 = 90 \text{ ft-lb}
\]

\[
v_f = 30.5 \text{ ft/s}
\]

7. (16 pts) Following Abby's example, Dean takes his class to the Down Under to play billiards. Two identical balls collide as shown, where \(v_i = 8 \text{ m/s}\) and \(v_f = 5 \text{ m/s}\). The coefficient of restitution is 0.6. What is the velocity of ball 2 after the collision?

Give your answer in \(\vec{v}\) notation.

\[
\vec{v}_2 = \left( (4 \hat{i} - 7.4 \hat{j}) \right) \text{ m/s}
\]

**2D Collision**

\[
\begin{align*}
\vec{v}_{1x} &= \vec{v}_{1y} = 0 \\
\vec{v}_{2x} &= \vec{v}_{2y} = +\hat{j}
\end{align*}
\]

**LOI:**

- **Components**
  - \(v_{1x} = 0\)
  - \(v_{1y} = -8 \text{ m/s}\)
  - \(v_{2x} = +4 \text{ m/s}\)
  - \(v_{2y} = +3 \text{ m/s}\)

- **Components of the ball:**
  - \(v_{1y} = -8 \text{ m/s}\)
  - \(v_{2y} = +3 \text{ m/s}\)

- **Components of the box:**
  - \(v_{1y} = +8 \text{ m/s}\)
  - \(v_{2y} = +3 \text{ m/s}\)

**Elastic Collision**

\[
\begin{align*}
\vec{v}_{1y} - \vec{v}_{2y} &= \vec{v}_{2y} - \vec{v}_{1y} \\
-\hat{j} &= \hat{j}
\end{align*}
\]

**Matrix representation:**

\[
\begin{bmatrix}
1 & -1 & 0 & 0 \\
0 & 0 & 1 & -1 \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
\vec{v}_{1y} \vec{v}_{2y} \\
\vec{v}_{2y} - \vec{v}_{1y} \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
1 & -1 & 0 & 0 \\
0 & 0 & 1 & -1 \\
\end{bmatrix}
\begin{bmatrix}
\vec{v}_{1y} \vec{v}_{2y} \\
\vec{v}_{2y} - \vec{v}_{1y} \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
\vec{v}_{1y} \vec{v}_{2y} \\
\vec{v}_{2y} - \vec{v}_{1y} \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
\vec{v}_{1y} \vec{v}_{2y} \\
\vec{v}_{2y} - \vec{v}_{1y} \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
\vec{v}_{1y} \vec{v}_{2y} \\
\vec{v}_{2y} - \vec{v}_{1y} \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
\vec{v}_{1y} \vec{v}_{2y} \\
\vec{v}_{2y} - \vec{v}_{1y} \\
\end{bmatrix}
\]

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\begin{bmatrix}
\vec{v}_{1y} \vec{v}_{2y} \\
\vec{v}_{2y} - \vec{v}_{1y} \\
\end{bmatrix}
\]

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\begin{bmatrix}
\vec{v}_{1y} \vec{v}_{2y} \\
\vec{v}_{2y} - \vec{v}_{1y} \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
\vec{v}_{1y} \vec{v}_{2y} \\
\vec{v}_{2y} - \vec{v}_{1y} \\
\end{bmatrix}
\]