Show all work!

\[ W = \int \vec{F} \cdot d\vec{s} \]
\[ K = \frac{1}{2} m v^2 \]
\[ U_{\text{grav}} = mgh \]
\[ P = \frac{W}{\Delta t} \]
\[ p = mv \]
\[ \text{Impulse} = \int \vec{F} \, dt \]
\[ U_{\text{elastic}} = \frac{1}{2} k x^2 \]

1) (5 points) A child's suction cup dart gun uses a spring with a spring constant of 5 N/m. A) If a 0.04 kg dart leaves the gun with a velocity of 2.5 m/s, how much work did the spring do on the dart?

\[ W = \Delta K = K_f - K_i \]
\[ = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 = \frac{1}{2} \times (0.04)(2.5)^2 = 1.25 \, J \]

B) What is the initial compression of the spring?

\[ W_{\text{spring}} = 1.25 \, J = \frac{1}{2} k x^2 \]
\[ x = 0.22 \, m \]

2) (3 points) A 0.2 kg plastic car and a 2.0 kg metal car both roll without friction on a horizontal surface. Starting from rest, equal forces push each car for a time of 1 second. After 1 second, does the plastic car have more momentum than the metal car, the same amount of momentum, or less momentum than the metal car? Explain your answer.

The momenta are the same, since the impulses are the same, the velocities will be different, though.

3) (3 points) Explain the work-energy theorem in your own words.

\[ W_{\text{net}} = \Delta K \]

The sum of the works done on an object by all the applied forces, will cause a change in the kinetic energy of the object.
4) (4 points) A motorcycle has a mass of 250 kg, and the momentum is given by \((4750 \mathbf{i} + 2250 \mathbf{j})\) kgm/s. Determine the kinetic energy of the motorcycle.

\[ v = \sqrt{4750^2 + 2250^2} = 5256 \text{ m/s} \]

\[ K = \frac{1}{2} m v^2 = \frac{1}{2} (250)(5256)^2 = 3.45 \times 10^9 \text{ J} \]

5) (4 points) A pitcher throws a fastball with a horizontal speed of 42 m/s. The batter hits it straight back at the pitcher with a horizontal speed of 33 m/s. If the baseball has a mass of 0.25 kg, how much impulse did the batter give to the baseball?

\[ I = \Delta p = p_f - p_i = m v_f - m v_i = 0.25(-33 + 42) = -19 \text{ kg m/s} \]

6) A block of mass 0.55 kg is given an initial speed of 12 m/s. When released, the block travels 1.2 m across a horizontal surface with a coefficient of kinetic friction equal to 0.56. The block then begins to travel up a frictionless slope that is at a 45° angle.

A) (4 points) What is the speed of the block just before it begins to travel up the slope?

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

\[ f_k \Delta x \cos 80° = \mu_k N \Delta x = 0.56 (0.55)(9.8)(1.2) = 3.62 \text{ J} \]

\[ -3.62 \text{ J} = \Delta K = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 = \frac{1}{2} (0.55)(v_f^2) - \frac{1}{2} (0.55)(12)^2 \]

\[ -3.62 \text{ J} = 275 v_f^2 - 39.6 \]

\[ 35.98 = 275 v_f^2 \]

\[ v_f = 11.4 \text{ m/s} \]

B) (4 points) What is the maximum height the block reaches?

\[ K_i + U_i = K_f + U_f \]

\[ \frac{1}{2} m v^2 + 0 = 0 + m g y \]

\[ \frac{1}{2} (0.55)(11.4)^2 = (0.55)(9.8) y \]

\[ y = 6.18 \text{ m} \]
7) (8 points) During the battle of Gettysburg, the gunfire was so intense that several bullets collided in midair and fused together. Assume a 5.00 gram Union musket ball was moving to the right at a speed of 250 m/s, 22° above the horizontal, and that a 4.75 gram Confederate musket ball was moving to the left at a speed of 280 m/s, 15° above the horizontal. Immediately after they collided and stuck, what was the x- and y-components of the velocity of the fused bullets?

\[
\begin{align*}
\text{Pix} &= \text{Pfx} \quad \text{Pay} = \text{Pfy} \\
\text{x:} &\quad (0.005)(250)\cos 22° - (0.00475)(280)\cos 15° = 0.0975 \text{ m/s} \\
\text{vfx} &= -12.9 \text{ m/s} \quad \text{(to the left)} \\
\text{y:} &\quad (0.005)(250)\sin 22° + (0.00475)(280)\sin 15° = 0.0975 \text{ m/s} \\
\text{vf, y} &= 83.3 \text{ m/s \ upward}
\end{align*}
\]

8) Child A pulls a sled up a hill of height h. Child B pulls another sled, with the same mass of up a hill of height 2h. A) (3 points) Is the potential energy of the first sled greater than, less than, or the same as the potential energy of the second sled? Explain.

The first sled has half the potential energy of the first, since m is the same, and the height is half.

B) (3 points) Is the speed of the first sled greater, less than, or the same as the speed of the second sled?

Uh... this is poorly worded.

If both sleds slide back down, the first sled would be going slower than the second.

9) (4 points) A ball is dropped from a height of 2.0 meters. What happens to the momentum of the ball as it falls? Is momentum conserved? Why or why not?

The ball, by itself, is not a closed system. The earth's gravitational pull will be exerting an outside force on the ball, so momentum conservation does not apply.