1) Things get kind of crazy in Santa’s workshop this time of year. Santa and the Elves use toy guns (guns that shoot toys) to quickly pass toys around. The guns have been approved by Mrs. Santa and are perfectly safe. One of Santa’s Elves is hanging from a giant lollipop tree, $H = 30$ meters above the workshop floor. The base of the tree is $D = 40$ meters from Santa. Santa is armed with a toy gun. Santa aims and shoots a toy directly at the Elf from his toy gun. The Elf lets go at just the instant that Santa shoots. The muzzle velocity of the gun is 28.57 meters per second. Ignore air friction. The mass of the Elf is 30 kg. Of course, a pile of cotton candy is placed under the Elf to provide a soft landing.

a) What is the speed of the Elf before he hits the cotton candy?

b) What is the time between when the Elf lets go and when he catches the toy?

c) How far above the floor is the Elf when he catches the toy.

d) What is the acceleration of the toy just before the Elf catches it? Give the magnitude and direction.

e) What is the velocity (magnitude and direction) of the toy just before the Elf catches it?
2) A budding young physicist gets a BB-gun for Christmas. Of course, she wants to determine the muzzle velocity of the gun. She sneaks a block of cheese from the kitchen, hangs it from the ceiling by a string $L = 10$ meters long. She fires a BB into the cheese. The cheese, with the BB imbedded in it swings up, making a maximum angle of 53.13 degrees with the vertical. The mass of the BB is $m = 0.5$ g ($5 \times 10^{-4}$ kg) and the mass of the cheese is $M = 4.5$ g ($45 \times 10^{-4}$ kg).

a) How high (maximum height) did the cheese (with the BB embedded in it) rise above its original position?

b) What was the speed of the cheese (with the BB embedded in it) immediately after the BB embedded itself into it?

c) What was the speed of the BB just before it struck the cheese?

d) How much mechanical energy was converted into some other form of energy (heat for example)?

e) How much momentum was lost during the whole process?
3) Consider the accompanying graph representing a particle of mass \( m = 3 \text{kg} \) under the influence of a potential \( U \).

a) What is the force on the particle at \( x = 2 \) meters?

b) What is the force on the particle at \( x = 5 \) meters?

c) What is the acceleration of the particle at \( x = 5 \) meters?

d) If the particle is initially at rest at \( x = 3 \) meters, what is the speed of the particle at \( x = 5 \) meters?

e) If the particle is initially at rest at \( x = 3 \) meters, what is the maximum value of \( x \) it could obtain?
4) Consider an inclined plane with angle $\theta = 36.87$ degrees. The plane is $L = 5$ meters long. A mass $m_s = 7$ kg is placed at the top of the inclined plane. Assume that the plane is frictionless.

a) What is the acceleration of the mass?

b) What is the speed of the mass at the bottom of the incline?

c) Now, if the plane were no longer frictionless, what would the coefficient of friction need to be in order to keep the block from sliding? For simplicity, assume that the coefficient of static friction and the coefficient of kinetic friction are equal in this unusual case.

Go back to the case of no friction, but add a massless pulley of radius $r = 0.3$ meters and a mass $m_h = 4.2$ kg hanging from a rope that passes over the pulley and connects to two masses.

d) What would the acceleration of mass $m_s$ now be? Give magnitude and direction (up or down the incline).

e) Now, if the pulley had mass $m_p = 6$ kg, and a rotational inertia given by $I = \frac{1}{2} m_p r^2$, what would the acceleration of mass $m_s$ now be? Give magnitude and direction (up or down the incline).
5) A mass \( m = 3 \text{ kg} \) on the end of a string rotates in a circle of radius \( r = 0.7 \text{ meters} \). The angular position of the mass is described by the following expression;

\[
\theta = A + Bt \quad \text{where} \quad A = 5 \text{ radians} \quad \text{and} \quad B = 30 \text{ radians per second}.
\]

a) What is the angular position at time \( t = 0 \)?

b) What is the angular speed at time \( t = 5 \text{ seconds} \)?

c) What is the angular acceleration at time \( t = 5 \text{ seconds} \)?

d) What is the \textbf{radial} acceleration at time \( t = 5 \text{ seconds} \)?

e) What is the angular momentum at time \( t = 5 \text{ seconds} \)?

Happy Holidays