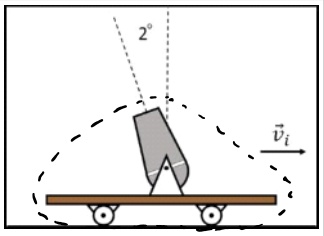
Week 9 Quiz

Monday, November 30, 2020 10:12 AM

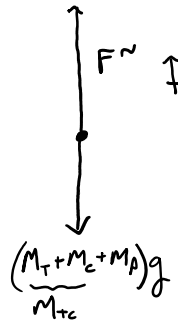
After failing with his weather rockets, Benny decides to try launching a weather probe into the air with a giant cannon. To make matters more interesting for physics students, Benny mounts the cannon onto a train car. The cannon and train car are bolted together and can be treated as one object for this question. The train car + cannon, and weather probe are initially rolling to the right on the level train tracks at a constant, unknown, speed. The train car + cannon together have a mass of 1000 kg, while the weather probe has a mass of 70 kg. The cannon fires the weather probe into the air at an angle of 2 degrees with respect to the vertical. The weather probe's velocity right after it leaves the cannon is 1 km/s directly upwards, with zero horizontal velocity.

(a) Examining the system containing the probe, and train + cannon, is momentum conserved in the horizontal direction? In the vertical direction? Explain your reasoning using words, diagrams, mathematical arguments, etc.

(b) What is the velocity of the train car + cannon system after the launch?



(a) FBD (train + cannon + probe)



[x] $\Sigma F_x = 0$, so $\Delta P_x = \Sigma F_x \Delta t = 0$, momentum conserved in [x]

[y] $\Sigma F_y \neq 0$, $F^{\sim} > F_g$ so probe can accelerate upward

so $\Delta P_y = \Sigma F_y \Delta t \neq 0$, momentum not conserved in [y]

(b) $\Sigma P_{ix} = \Sigma P_{fx} \Rightarrow M_{Tc} V_{i_{Tc_x}} + M_p V_{i_{p_x}} = M_{Tc} V_{f_{Tc_x}} + M_p \cancel{V_{f_{p_x}}}^{0}$

w/ $V_{i_{Tc_x}} = V_{i_{p_x}} \equiv V_i \Rightarrow (M_{Tc} + M_p) \overset{?}{V_i} = M_{Tc} \overset{?}{V_{f_{Tc_x}}}$ (i)

Probe

$\tan\theta = \frac{P_{i_p}}{P_{f_p}} = \frac{V_i}{V_{f_{py}}} \Rightarrow V_i = V_{f_{py}} \tan\theta$ (ii)

Combine (i) + (ii)

$$V_{f_{Tc_x}} = \frac{(M_{Tc} + M_p)}{M_{Tc}} V_{f_{py}} \tan\theta = \boxed{37.4 \text{ m/s}}$$

Rubric

~~ part (a) ~~
1 pt - answer
1.5 pts - reasoning

~~ part (b) ~~
2.5 pts - conservation of momentum equation
2.5 pts - conservation of momentum application
1 pt - impulse analysis attempt
1 pt - impulse analysis application
0.5 pt - answer with units