Exam Jam PHY131 – 2nd Half – Dec. 8, 2017

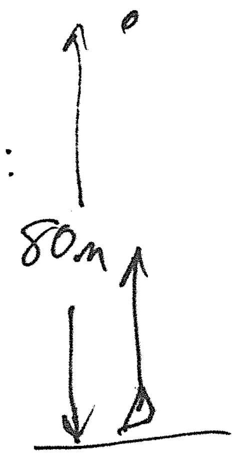
DECEMBER 2015 EXAMINATION – version A
PHY 131H1F
Duration - 2 hours

Problem C

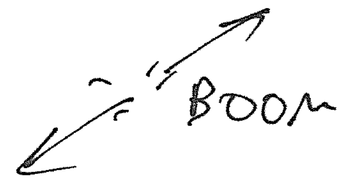
A fireworks rocket is fired vertically upward. At its maximum height of 80.0 m, it explodes and breaks into two pieces. The first piece has mass $m_1 = 1.40$ kg, and the second piece has mass $m_2 = 0.28$ kg. In the explosion, 860 J of chemical energy is converted to kinetic energy of the two fragments.

1. **(4 points)** What is the speed of each fragment just after the explosion?

First:



THEN:



At maximum height, $v = 0$, so just before explosion, it is at rest.

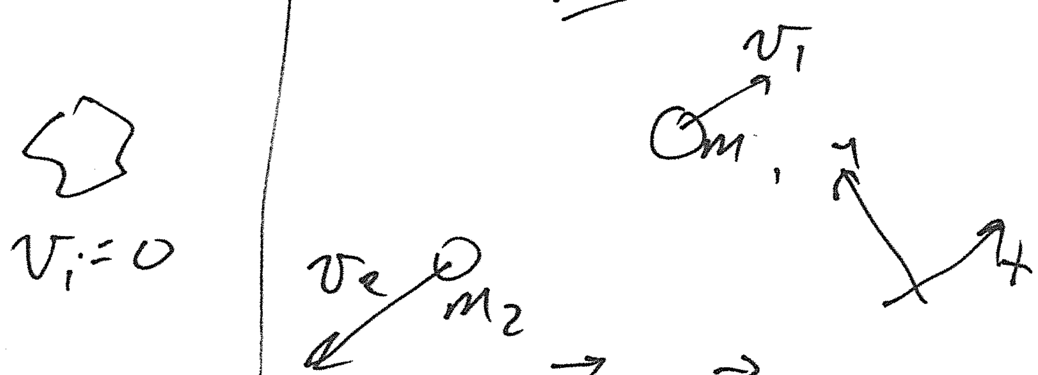
Explosion: Ch. 9 cons. of momentum.

BEFORE:

$v_i = 0$

$\vec{p}_i = 0$

AFTER:



$\vec{p}_f = \vec{p}_i$

Let's Define +x to be the direction m_1 goes, right after explosion

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1. **(4 points)** What is the speed of each fragment just after the explosion?

$(P_f)_x = m_1 v_1 - m_2 v_2 = 0$

$P_{fy} = 0$

$m_1 v_1 = m_2 v_2 \quad (1)$

Need another eq.

Before: $K_i = 0$

After: $K_f = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 = 860$ J $\quad (2)$

2 eqs, 2 unknowns.

$(1) \Rightarrow v_1 = \frac{m_2}{m_1} v_2$

plug into (2):

$\frac{1}{2} m_1 \left(\frac{m_2}{m_1} v_2\right)^2 + \frac{1}{2} m_2 v_2^2 = 860$

Solve for v_2: $\frac{v_2^2}{2}\left(\frac{m_2^2}{m_1} + m_2\right) = 860$

$v_2 = \sqrt{2(860) / \left(\frac{0.28^2}{1.4} + 0.28\right)}$

$\boxed{v_2 = 71.5 \text{ m/s}}$

(1): $v_1 = \frac{0.28}{1.4}(71.5) = \boxed{14.3 \text{ m/s}}$

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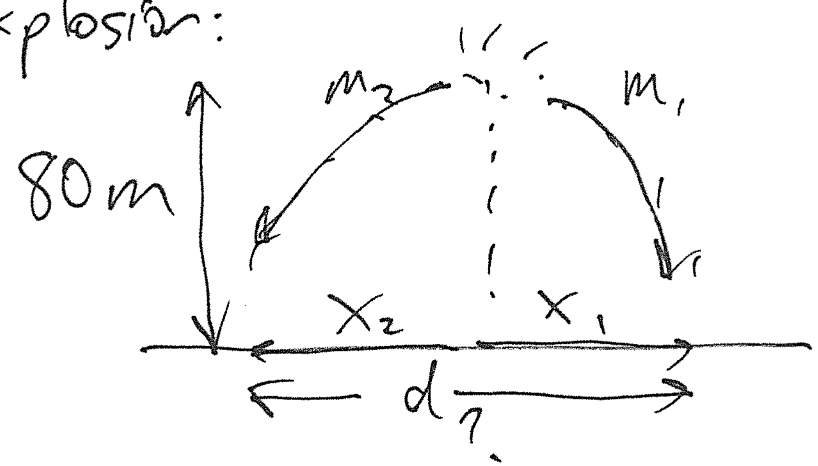
2. **(2 points)** It is observed that the two fragments hit the ground at the same time. What is the distance between the points on the ground where they land? [Assume that the ground is level and that $g = 9.80$ m/s^2 is a constant throughout the motion.]

After explosion:



fall to ground in same time

$y = v_{0y}t + \frac{1}{2}a_y t^2$

$v_{0y} = 0$ for both.

→ They must go sideways.

$v_1 = 14.3$ m/s, to the right

$v_2 = 71.5$ m/s, to the left.

$d = x_1 + x_2$

We need time for fall...

$h = 80\text{ m} = \frac{1}{2}gt^2$

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2. **(2 points)** It is observed that the two fragments hit the ground at the same time. What is the distance between the points on the ground where they land? [Assume that the ground is level and that g = 9.80 m/s^2 is a constant throughout the motion.]

$$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2(80)}{9.8}} = 4.04061 \text{ s}$$

Next: $x_1 = v_1 t \quad (a_x = 0)$

$$= 14.3(4.0)$$

$$= 57.8 \text{ m}$$

$$x_2 = v_2 t = 71.5(4.04) = 289 \text{ m}$$

$$d = x_1 + x_2 = \boxed{347 \text{ m}}$$

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Question 8

Ch.8

Two planets having equal masses are in circular orbit around a star. Planet A has a smaller orbital radius than planet B. Which statement is true? (Note that mechanical energy is defined as kinetic energy plus potential energy.) Same mass

$R_A < R_B$ K , U , $E = K + U$

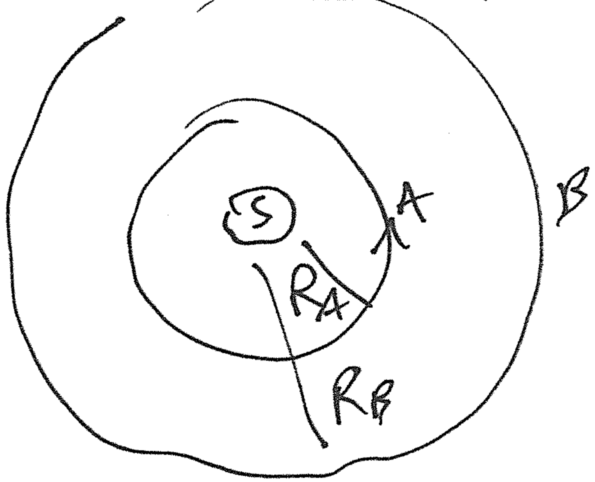
(A) Planet A has less potential energy than planet B, and both planets have the same amount of kinetic energy and mechanical energy.

(B) Planet A has more kinetic energy, less potential energy, and less mechanical energy than planet B.

(C) Planet A has more kinetic energy, more potential energy, and more mechanical energy than planet B.

(D) Planet A has more kinetic energy and less potential energy than planet B, and both planets have the same amount of mechanical energy.

(E) Planet A has more kinetic energy and more potential energy than planet B, and both planets have the same amount of mechanical energy.



Ch.8 Circ. orbit: $v = \sqrt{\frac{GM}{r}}$

$K_A = \frac{1}{2} m v_A^2 = \frac{1}{2} m \frac{GM}{R_A}$

$K_B = \frac{1}{2} m v_B^2 = \frac{1}{2} m \frac{GM}{R_B}$

$R_A < R_B$, $K_A > K_B$

$U_A = -\frac{GMm}{R_A}$, $U_B = -\frac{GMm}{R_B}$

$U_A < U_B$

$K_A + U_A = \frac{1}{2} \frac{GMm}{R_A} - \frac{GMm}{R_A} = -\frac{GMm}{2R_A}$

$E_A < E_B$

5

Exam Jam PHY131 – 2nd Half – Dec. 8, 2017

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Question 9

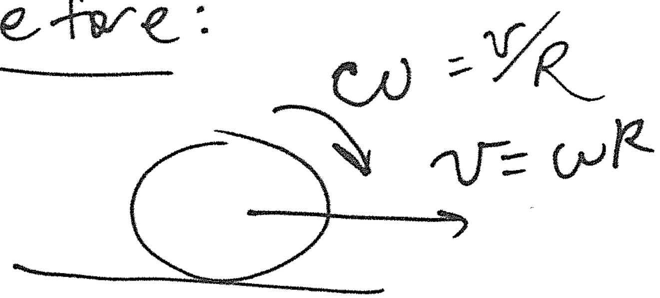
A hoop and a solid disk roll along the ground without slipping. They have the same velocity and the same radius. They both come to the same hill and roll up the hill without slipping. Which makes it further up the hill?

$I = cMR^2$, $c = 1$ for hoop, $c = \frac{1}{2}$ for disk.

(A) The hoop. **(B) The disk.** **(C) They travel the same distance.**
(D) More information is needed to answer this question.

Conservation of Energy.

Before:

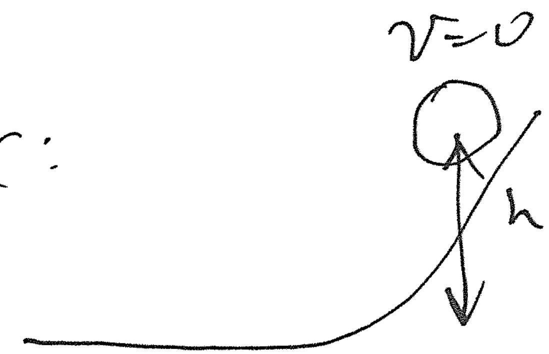


$E_i = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 + \cancel{mgh_i}^{\,0}$

$= \frac{1}{2}mv^2 + \frac{1}{2}(cMR^2)\left(\frac{v}{R}\right)^2$

$E_i = \frac{1}{2}mv^2(1+c)$

After:



$E_f = mgh$

$E_f = E_i$

$\cancel{m}gh = \frac{1}{2}\cancel{m}v^2(1+c)$

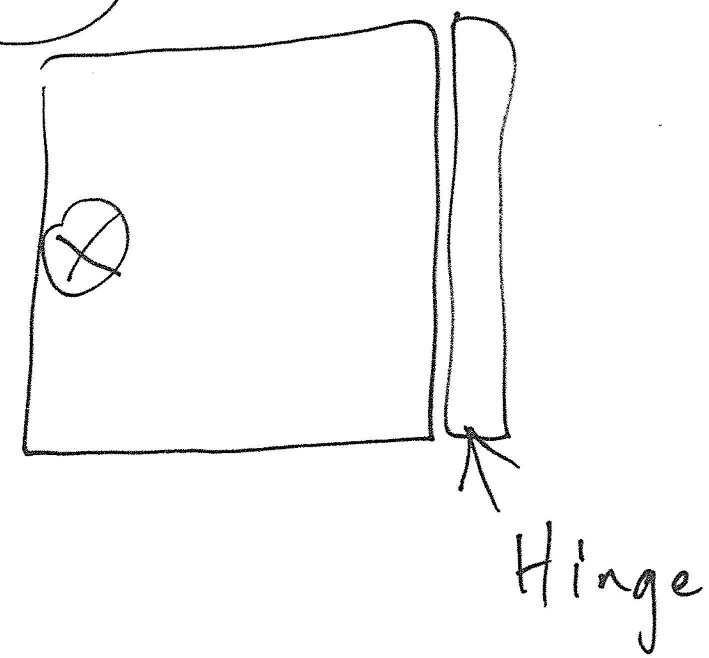
$h = \frac{v^2}{g}(1+c)$

greater c, greater h.

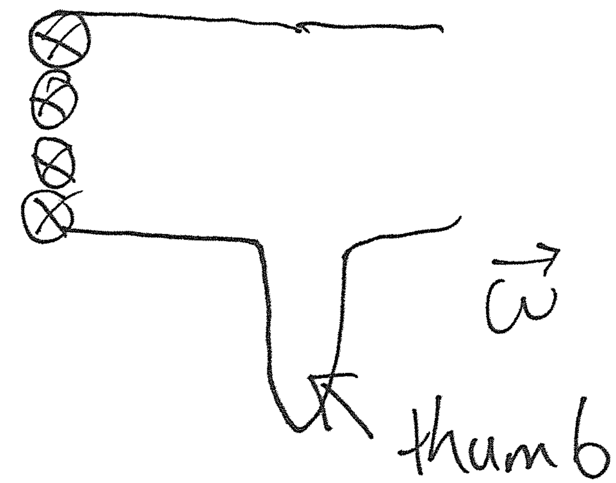
Question 11

As you are leaving a building, the door opens outward. If the hinges on the door are on your right, what is the direction of the angular velocity vector of the door as you open it?

(A) up (B) down (C) to your left (D) to your right (E) forwards



RHR for rotation:



Exam Jam PHY131 – 2nd Half – Dec. 8, 2017

DECEMBER 2016 EXAMINATION – version A
PHY 131H1F
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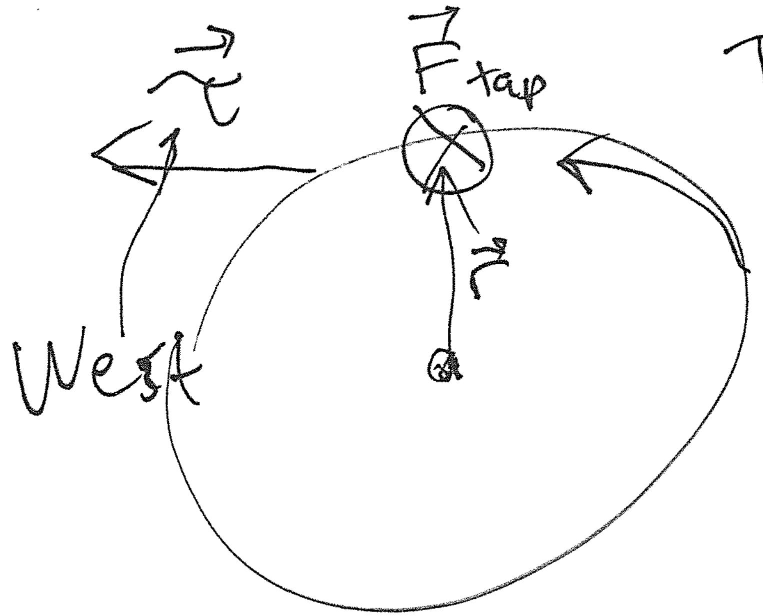
Question 7

A wheel is spinning in a horizontal circle, rotating counter-clockwise when viewed from above. It rotates around its centre of mass, so there is no precession due to gravity. You give the wheel a light tap downward, applied on its north-most side. Assume that the magnitude of the tap is small enough so that the magnitude of the angular velocity does not change. What is the direction of the wheel's angular velocity after your tap?

(A) Down and east. (B) Down and west. (C) Up and east. (D) Up and west.
(E) None of the other answers are correct.



Top view

N
W E
S

Precession

Find $\vec{L}_i$

$\vec{\tau} = \vec{r} \times \vec{F}$

change to $\vec{L}$.

$\vec{L}_i$ ⊙

up + a little west

Exam Jam PHY131 – 2nd Half – Dec. 8, 2017

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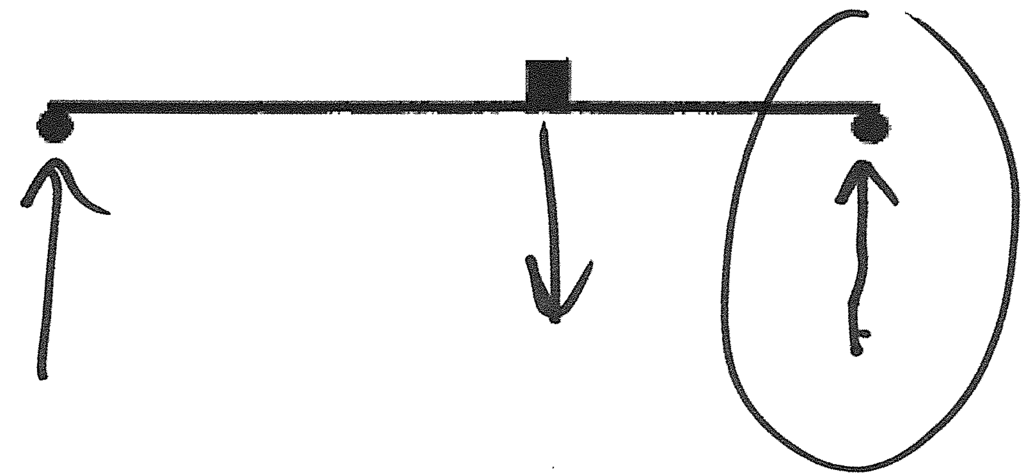
Question 3

I place a heavy block at the 60-cm mark of a ruler which is 1-m long. I hold the ruler up by balancing it on my left finger at the 0-cm mark and my right finger at the 100-cm mark. Which finger exerts a larger force on the ruler?

(A) Left finger.
(B) Right finger.
(C) They exert the same force.
(D) More information is needed to answer this question.



by symmetry

Exam Jam PHY131 – 2nd Half – Dec. 8, 2017

DECEMBER 2016 EXAMINATION – version A
PHY 131H1F
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PROBLEM 2 [10 points] Ch. 12

A ladder (length L and mass M) is leaning to the right. One end rests on the ground, the other end is attached to a rope (length L and negligible mass). The other end of the rope is attached to the ceiling directly above the point where the ladder touches the ground (as shown below). If the height of the ceiling is also L, what is the minimum coefficient of static friction between the ladder and the floor for this to be stable?

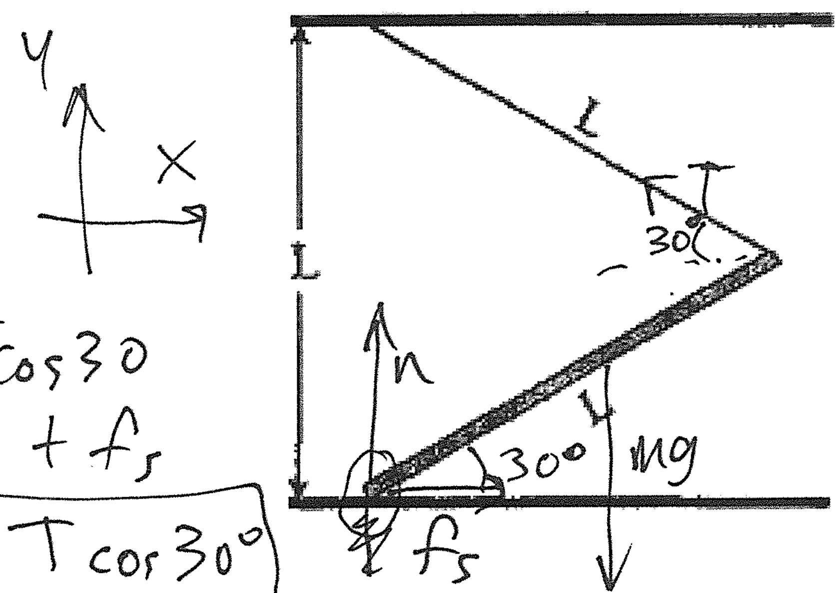
Equilateral triangle: 60° angles all around.

Set $f_s = f_{s,max} = \mu_s n$
solve for μ_s

NO PROBLEM.

① Define x, y, rotation axis

Unknowns: T, n, μ_s, m



$(\Sigma F_{net})_x = -T\cos 30 + f_s$

$\Rightarrow f_s = \boxed{\mu_s n = T\cos 30°}$ (1)

$(\Sigma F_{net})_y = 0 = T\sin 30° + n - mg$

(2) $\boxed{n = mg - T\sin 30°}$

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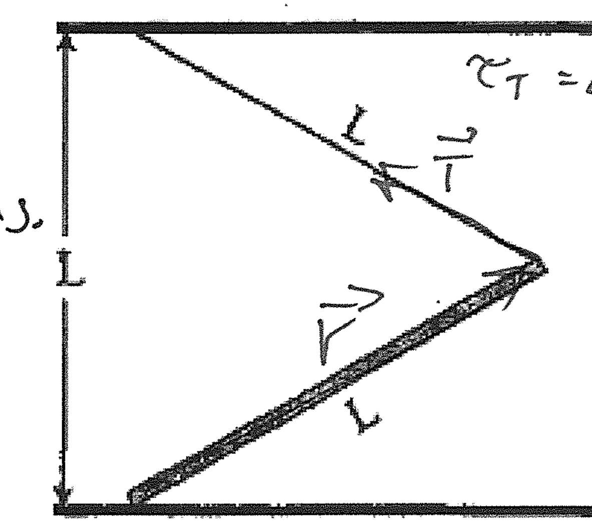
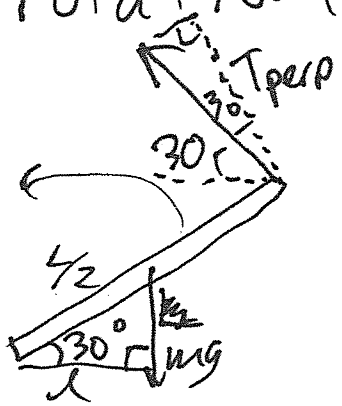


$\tau_T = LT \sin(120)$

Set bottom of ladder = rotation axis.. $\tau_{f_s} = 0$

$\tau_n = 0$



$\tau_T = T_{perp} L$

$\tau_T = +T\cos 30° L$

$\tau_{mg} = -l\,mg = -\frac{L}{2}\cos 30°\, mg$

$\tau_{net} = T\cos 30\, \cancel{L} - \frac{\cancel{L}}{2}\cancel{\cos 30}\, mg = 0$

$T - \frac{mg}{2} = 0$

$\boxed{T = \frac{mg}{2}}$ (3)

3 eqs, 3 unknowns.

Eliminate T, n, (hopefully m)

solve for μ_s

Plug (3) into (2): $n = mg - \frac{mg}{2}\sin 30$

$n = mg\left(1 - \frac{\sin 30}{2}\right)$.

plug into 1:

$\mu_s = \frac{T\cos 30}{n} = \frac{\cancel{Mg}}{2}\frac{\cos 30}{\cancel{Mg}\left(1 - \frac{\sin 30}{2}\right)}$

$\mu_s = \frac{\cos 30}{2\left(1 - \frac{\sin 30}{2}\right)} = \boxed{0.577}$

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PHY 131H1F
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Ch. 13 problem : S.H.M.

PROBLEM 1 [10 points]

A 2.000 ± 0.001kg block is attached to a horizontal spring of spring constant 150 ± 5 N/m. The block is free to oscillate horizontally on a frictionless table, but can only move in the north-south directions. The mass is initially at rest when I give it a quick tap. If my tap imparts 35 ± 3 kg m/s of impulse to the block in the southward direction, what is the position of the mass 3.00 ± 0.01 seconds after the tap relative to its starting position?

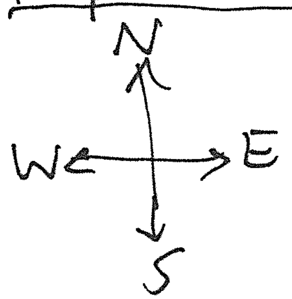
I choose to ignore all of the uncertainties. So..

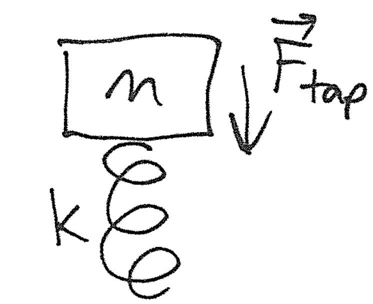
$m = 2$ kg $\quad k = 150$ N/m

Impulse = $J = 35 \ \frac{kg \cdot m}{s}$

$t = 3$ s

Top view:





IDEA : Step 1 : Give an impulse, which gives an initial velocity.
→ The block starts at equilibrium, so, this will be v_{max} for S.H.M.

Step 2 : use S.H.M. equation :

$$x = A\cos(\omega t + \phi)$$

Note: if $x = 0$ at $t = 0$, and v_x is positive at $t = 0$, then

$$\phi = -\pi/2$$

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Step 1

Impulse $J = \Delta p = p_f - \cancel{p_i}$ → 0 at rest.

$\Rightarrow mv = J$, $v_{max} = \frac{J}{m}$

Step 2 $E_{total} = \frac{1}{2}kA^2 = \frac{1}{2}mv_{max}^2$

Solve for A:

$$A = \frac{m}{k}v_{max}^2 = \frac{m}{k}\left(\frac{J}{m}\right)^2$$

$$A = \frac{J^2}{km} = \frac{35^2}{150(2)} = 4.083\,m$$

$$\omega = \sqrt{k/m} = \sqrt{\frac{150}{2}} = 8.66\ \frac{rad}{s}.$$

$$x = A\cos(\omega t + \phi)$$

$$x = 4.083 \cdot \cos\left((8.66 \times 3) - \frac{3.14}{2}\right)$$

NOTE: These are radians
set your calculator to
RAD mode!

$$\boxed{x = 3.06\ m}$$