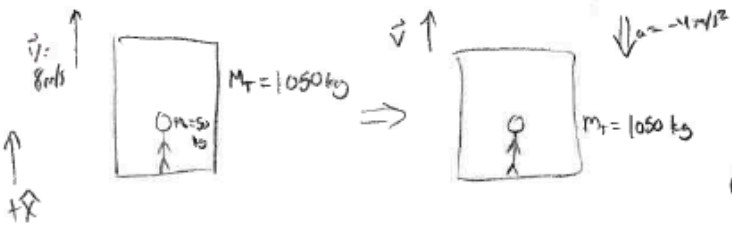
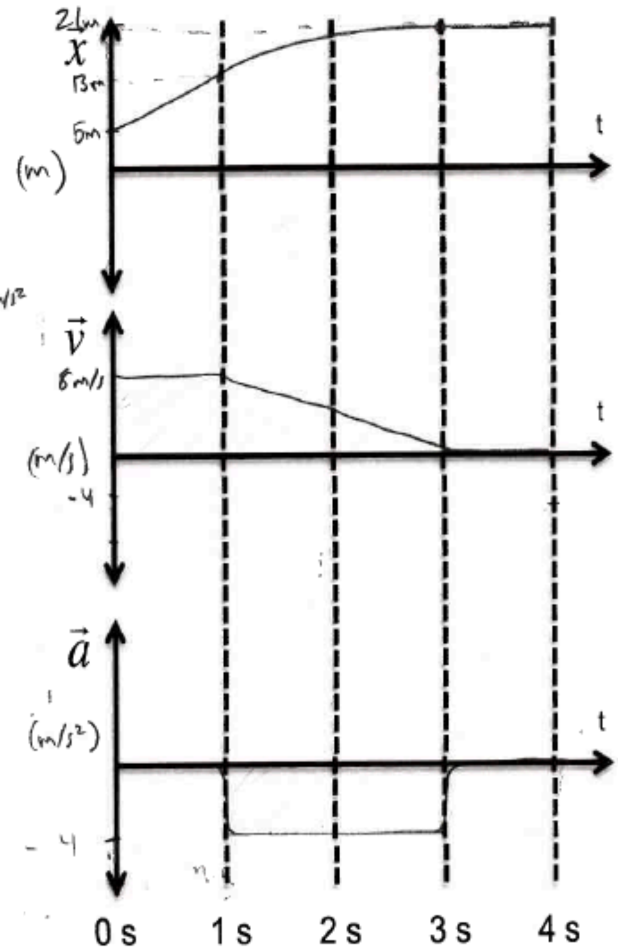
You will be graded on your *<u>communication</u>* of physics understanding.

#1 Your friend has a mass of 50 kg and is standing on a scale inside a 1000 kg elevator. At a height of 5 m (t = 0) she notices that she's moving upwards with constant speed 8 m/s. She continues at this speed for 1 seconds and then comes to rest at a rate of 4 m/s^2. Please make the graphs describing her motion. Label the axes to make the values explicitly clear and show her final height if you can. The horizontal axes do not have to indicate y = 0. *Folks found different ways to get the total distance. Some people integrated velocity – in two different sections. Others found the area under the v-t graph. Some actually integrated numerically… going second by second finding the distance traveled.*

Kinematics, her motion x,v,a is an explicit function of time

$x_0 = 5m$





$x = x_0 + v(t)$

$x = 5m + 8m/s(1s)$

$= 13m$

A

$a = \frac{\Delta v}{\Delta t}$

$\Delta v = a\Delta t$

Area under $v(t) = \Delta x$

$t = 1s \to 3s$

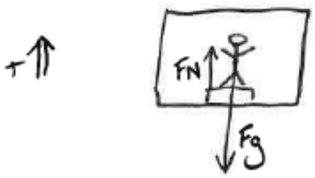
$\frac{(8m/s)(2s)}{2} = 8m + 13m = 21m$

#2 In the problem above what does the scale your friend is standing on read at t = 0.5s, <u>and</u> at t = 2 s. Remember to show your work and thought process completely. Think of convincing someone who is skeptical. *Please reflect on your answer and explain why you think it is correct, or why it might not be correct.*

Dynamics Lens → Forces cause acceleration

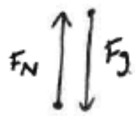
@ t = .5s

$\sum \vec{F} = m\vec{a} \rightarrow 0\ \mathrm{m/s^2}$



$a = 0\ \mathrm{m/s^2}$

*The resultant Force Vector ($\sum F$) in the y direction must be 0 N because there is no acceleration @ t = .5 sec



→ $F_N = F_g \rightarrow (g)(m)$ gravity

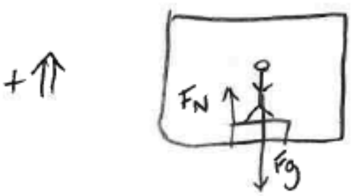
$F_N = (50\,\mathrm{kg})(10\ \mathrm{m/s^2})$

$= \boxed{500N}$

A

@ t = 3sec

$\sum \vec{F} = m\vec{a}$



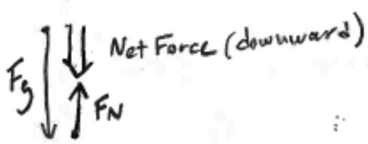
$a = -4\ \mathrm{m/s^2}$

$F_N - F_g = (50\,\mathrm{kg})(-4\ \mathrm{m/s^2})$

$F_N - (10\ \mathrm{m/s^2})(50\,\mathrm{kg}) = -200N$

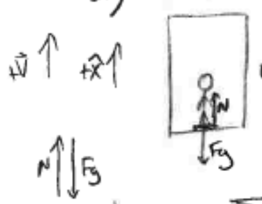
$F_N = 500N - 200N$

$= \boxed{300N}$



$F_g > F_N$

a) @ $t = 0.5s$



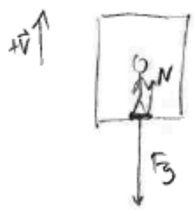
Dynamics, because $F \Rightarrow a$

- at $t = 0.5$ seconds there is constant velocity meaning that $a = \frac{\Delta v}{\Delta t} = 0$. Since $\vec{F} = m\vec{a}$, $F = m(0\,m/s^2) = 0$. There is no acceleration upwards ($a_y = 0$) affecting her weight so $N = F_g$

$\longrightarrow \sum \vec{F} = m\vec{a} = 0$

$N = F_g = ma_g$
$= (50\,kg)(10\,m/s^2) = 500\,N$, this is just the Normal Force as if you were standing w/ 0 acceleration in y direction, yes it makes sense.

b) @ $t = 3s$ Dynamics because $F \Rightarrow a$



$\Downarrow a = -4\,m/s^2$

$\Sigma \vec{F} = m\vec{a}$

Even though her velocity is $0\,m/s$, her Δv with respect to time is still $-4\,m/s^2$ since $a = \frac{\Delta v}{\Delta t}$. After the 3 s, her acceleration is 0 because her $\Delta v = 0$ but up to that 3s mark she still experiences a Δv.

$F_g \Downarrow F_{net}$, $\Uparrow N$

$F_{net} = N + F_g$

$-200\,N = N - 500\,N$
$+500\,N \quad +500\,N$

$N = 300\,N \longleftarrow$ This may not be correct because $t = 3s$ is a weird point when her velocity changes to 0. Before this time, her velocity is changing at $-4\,m/s^2$ but after the $a = 0$ and her weight is normal. Depends on how you view $\frac{\Delta v}{\Delta t}$.

If $a = 0$ then $\Sigma F = ma = 0$

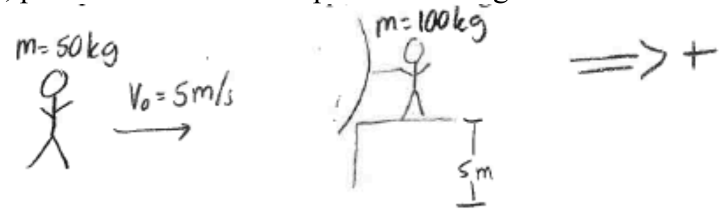
A+

$F_{net} = ma_{net}$
$= (50\,kg)(-4\,m/s^2)$
$= -200\,N$

$F_g = ma_g$
$= (50\,kg)(-10\,m/s^2)$
$= -500\,N$

#3 Jane (50 kg) is glad to see Tarzan (100 kg) and is running toward him at 5 m/s to give him a big hug. He is standing in a tree 5 m above the ground and swings down in the opposite direction to hug her. **Ka-smack!** They hit each other just as Tarzan reaches the ground, and they swing off together.

a) Please *explain* exactly how you would calculate the final speed of these two people holding the vine (and each other).
b) Please also set up the equations.
c) If you are able, please find their final speed indicating direction.



a) I wald first look at this problem through an energy lens, because PE is transformed into KE. I would first find the initial velocity of Tarzan by setting his potential energy equal to his KE, since all his PE energy from standing on top of that tree is turned into KE as he swings down to Jane, friction is negligible in this case. Then I wauld change to a momentum lens, because momentum is conserved during the collision, since there are no outside forces. I wald the momentum lens to find the final velocity of Jane and Tarzan after they collide by using the formula $\Sigma \vec{P}_i = \Sigma \vec{P}_f$.

b) $PE_T = KE_T$

$mgh_T = \frac{1}{2} m v_T^2$

$v_T = \sqrt{2gh}$

$m_J v_J + m_T v_J = (m_J + m_T) v_f$

$$v_f = \frac{m_J v_J + m_J (\sqrt{2gh})}{m_J + m_T}$$

c)

$100kg(10 m/s^2)(5m) = \frac{1}{2}(100kg) v^2$

$\frac{5000J}{50kg} = \frac{50kg\, v^2}{50kg}$

$\sqrt{100 J/kg} = \sqrt{v^2}$

$\sqrt{100 \cancel{kg}\, m^2/s^2 / \cancel{kg}} = \sqrt{v^2}$

$v_T = 10 m/s$

to the left

$(50kg)(5 m/s) + 100kg(-10 m/s) = (50kg + 100kg) v_f$

$250\ kg \cdot m/s - 1000\ kg \cdot m/s = 150kg\ v_f$

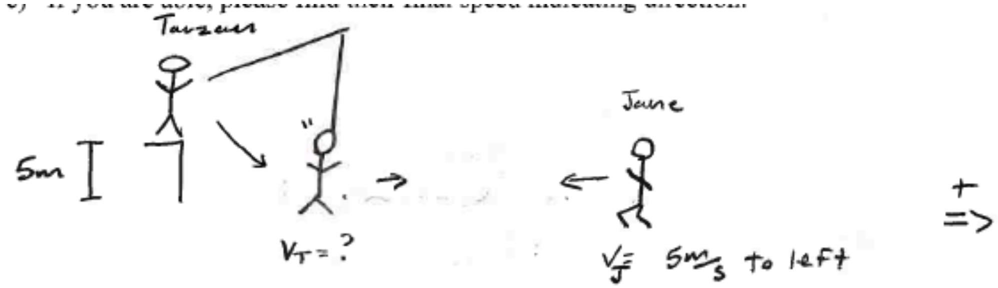
$\frac{-750\ kg \cdot m/s}{150\ kg} = \frac{150kg\ v_f}{150kg}$

$\boxed{V_f = -5\ m/s}$

Jane and Tarzan have a velocity to the left at 5 m/s.

A

c) If you are able, please find their final speed indicating direction.



a) I would use a momentum lens because an inelastic collision occurs and no outside forces act on the system, so momentum is conserved. ($\Sigma \vec{p}_i = \Sigma \vec{p}_f$) From there, I would need to know Tarzan's speed heading into the collision, so I would need to use an Energy Lens because all of Tarzan's Energy is conserved during his drop + changes forms from Gravitational Potential Energy to Kinetic Energy ($E_i = E_f$) ($PE_g \Rightarrow KE$). Knowing Tarzan's initial height + weight + the acceleration of gravity, I can find his velocity heading into the collision, Then I can find their combined velocity because I know $\Sigma \vec{p}_i$.

A

b) Energy Lens (Tarzan's Swing)

$$E_i = E_f$$
$$PE_g = KE$$
$$mgh = \frac{1}{2}mv^2$$
$$(\cancel{100kg})(10 m/s^2)(5m) = \frac{1}{2}(\cancel{100kg})(v)^2$$
$$V_T = 10 m/s$$

Momentum Lens (Inelastic Collision)

$$\Sigma \vec{p}_i = \Sigma \vec{p}_f$$
$$m_T v_T + m_J v_J = m_c v_c$$
$$(100kg)(10 m/s) + (50kg)(-5 m/s) = (150kg)(V_c)$$

c) $\boxed{V_c = 5 m/s \text{ (to the right)}}$

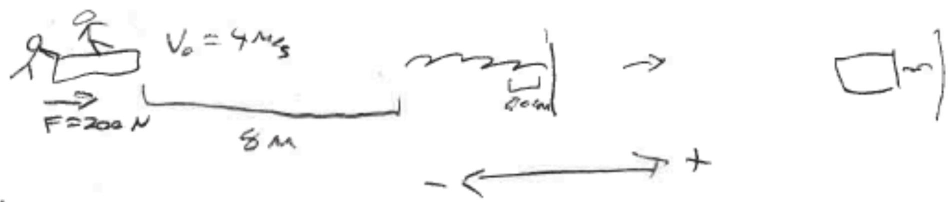
#4 Your friend is on a sled (combined mass: 100 kg) moving at a speed of 4 m/s on flat, smooth snow. To speed him up, you push him forward with a force of 200 N over 8 m. After I'm done pushing my friend, he runs into a spring that compresses 50 cm before bringing him to rest.

a) Please find the spring constant of the spring.

b) _Explain_ where on this ride my friend has his greatest acceleration. Calculate that acceleration if you can.

c) Then you realize that there is a rough spot of snow for the last 4 m that has a coefficient of friction of 0.1. How would this change your approach to calculate the spring constant, and would this consideration result in the spring constant calculated in a) being higher or lower… explain.

Folks found part b) challenging. Some students were able to recognize that the acceleration from the spring was greater than that from my hand… partly because the sled was already moving, sped up over a long distance from my push, but stopped abruptly over a short distance. Very few remembered to use Hook's Law (F = kx) to identify that the maximum force was when the spring was maximally compressed… when the sled comes to a stop…before it turns around and gets shot backwards (which isn't part of the problem). The acceleration is nauseatingly high – close to 10 gravities… It <u>probably</u> wouldn't kill you, but I recommend being careful.



a) Energy Lense

I can use this because energy is conserved and $KE_i + W \Rightarrow PE_s$

So, $\frac{1}{2}Mv_0^2 + F \cdot dx = \frac{1}{2}k(\Delta x)^2$

$$\frac{1}{2}(100\,kg)(4\,m/s)^2 + (200\,N)(8\,m) = \frac{1}{2}k(.5\,m)^2$$

800   600

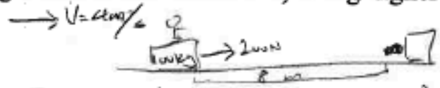
4800 × 4 = 19200

$k = 19200\ N/m$

b) The acceleration ← magnitude is greatest when the sled impacts the spring because it must slow from the maximum velocity to 0 in a very short amount of time.

c) I would change the equation to $KE_i + W_{me} - W_{friction} \Rightarrow PE_s$. This would decrease the amount of total PE_s and therefore the spring constant would also decrease proportionatly

... would this change your approach to calculate the spring constant, and would this consideration result in the spring constant calculated in a) being higher or lower… explain.



a) ENERGY LENS: KE + WORK ⇒ KE ⇒ PE_s

CONSERVED ENERGY BECAUSE ALL KE IS CONVERTED TO PE_s WHEN IT COMES TO REST

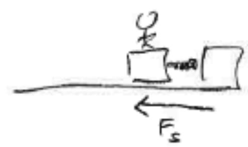
$\frac{1}{2}(100kg)(4m/s)^2 + (200N)(8m) = \frac{1}{2}k(.5m)^2$

$800J + 1600J = \frac{1}{2}k(.5m)^2$

$4800J = k(.5m)^2$ $\boxed{k = 19200\ N/m}$

b) GREATEST ACCELERATION IS WHEN THE SPRING BRINGS THE SLED TO REST. IT STOPS THE SLED WITHIN A VERY SHORT TIME FRAME.

DYNAMICS LENS: FORCES CAUSE ACCELERATION



$F_s = k(\Delta x)$

$F_s = (19200\ N/m)(.5m)$

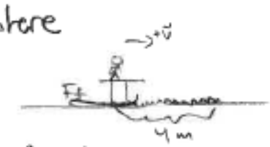
$= 9600\ N$

$F = ma$

$9600N = (100kg)(a)$

$\boxed{a = 96\ m/s^2}$ TO THE LEFT ←

c) This rough spot would affect the energy where



$x_y = 0$

$F_N = F_g$

$E_{k0} \Rightarrow E_{k_i} + W \Rightarrow E_{kf} + \text{heat} \Rightarrow PE_s$

You would lose E_k and friction your PE_s would be smaller since $E_{kf} - \mu mg \cdot \Delta x = PE_s$. Some E_k is lost. This makes your spring constant lower than the original as it would mean that the spring requires the same compression for less energy supplied.