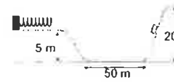
You will be graded on your *COMMUNICATION* of physics understanding No calculator A+

#1 You and your friends are excited to be the first people to be on the new super drop ride. With you and your friends in a car, the total mass is 1000 kg. You drop down a very slippery track as shown at right (in a drawing that is way way too small to be used as a reasonable diagram). You start at the top at rest and compress the spring at the end by 2 meters as you come to a stop.

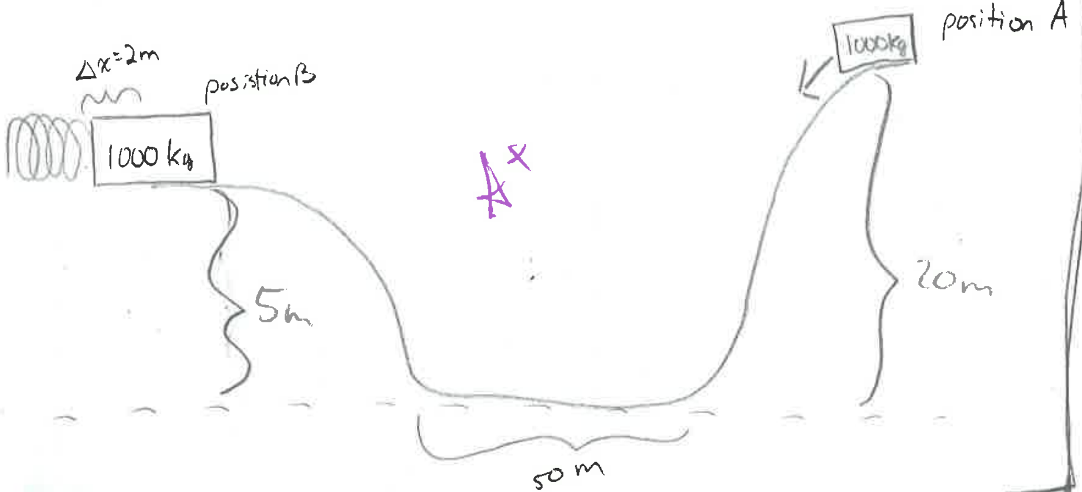


a) Without finding the answer, explain completely how you would go about finding the spring constant from the information given, right up to setting up the formulas.

b) Without finding the answer, explain completely how to find the maximum acceleration as we compress the spring, right up to setting up the formula.

c) Let's say now that there is a coefficient of friction on the level part of the track of $\mu_d = 0.2$. Please describe how this would affect the way you solved (a) above for the spring constant.

d) *Save for the end only if you have extra time*. Can you tell me if the consideration of friction would have a large or small effect on your answer for (a), *supporting your answer.*



c) If there were a frictional force, then I would have needed to calculate how much energy was lost to heat as the cart ran over the level track, and subtract that from the total energy.

$F_{f} = \mu N = \mu mg$

$\Delta E = Fd = (\mu mg)(d)$

$TE_f = mgh_A - (\mu mg)(d)$

Then find k the same way, but using the new TE

a) Using an energy lens, I would first find the potential energy at position A, which is equal to the total energy because the ride starts at rest, meaning it has no kinetic energy. I would then find the gravitational potential energy at position B, knowing that the total energy found at position A must be equal to the sum of the gravitational and spring potential energies at position B because energy is conserved and the ride comes to a stop meaning it ends with no kinetic energy. Once I had found the value of the spring potential energy as the difference between the total energy and the gravitational potential at position B, I would use the spring potential energy equation and the knowledge that the spring was compressed 2m to calculate k.

$PE_A = mgh_A = TE$ $\quad PE_{s_B} + PE_{g_B} = TE = mgh_B + \frac{1}{2}kx^2$ $\quad \frac{1}{2}kx^2 = mgh_A - mgh_B$

$$\boxed{k = \frac{2mg(h_A - h_B)}{x^2}}$$

b) Using the equation for the force of a spring, I could find the maximum force, and then knowing F = ma and m is constant, say the position with the maximum force is the position with the maximum acceleration; then calculate that force and find that acceleration. Use a force lens

$F_{spring} = kx$ $\quad$ F is at max when x is at max $\quad F_{spring} = k \cdot x_{max} = ma$ $\quad a = \frac{k x_{max}}{m}$

You will be graded on your ***COMMUNICATION*** of physics understanding [redacted]

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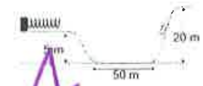

A

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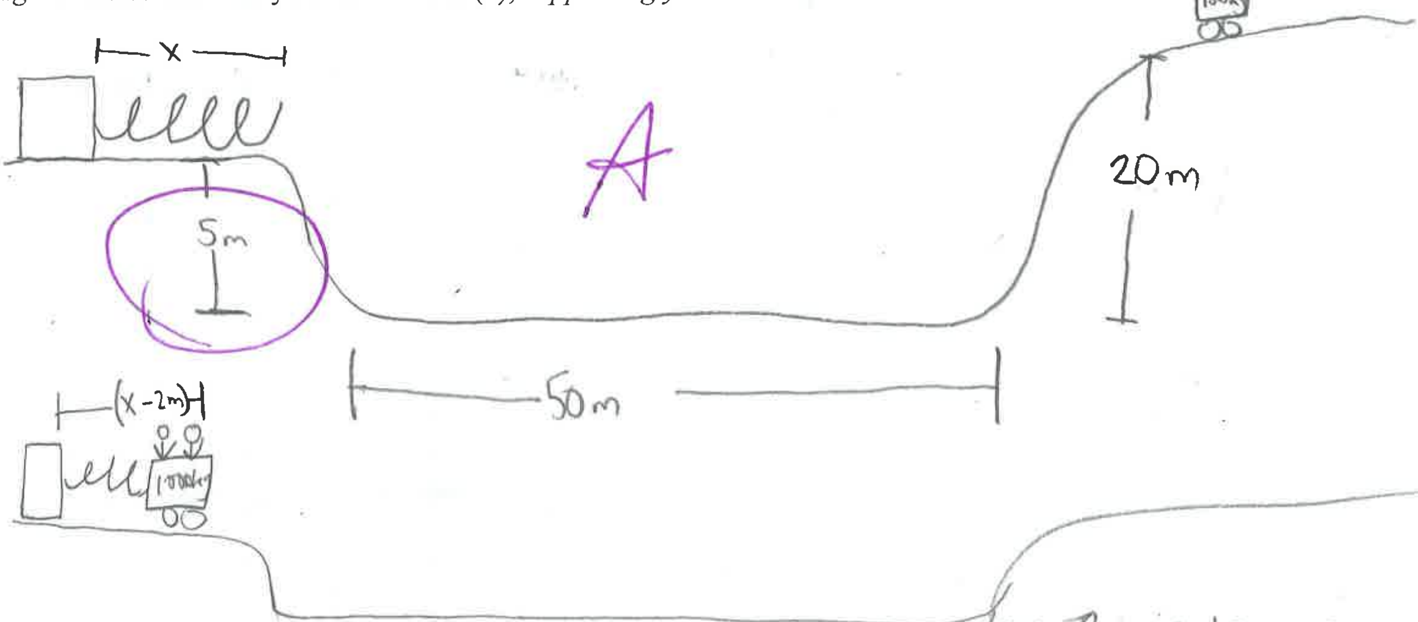


a.) You can find the compression of the spring using an energy lens. This is because you can see that throughout the problem, there are several transfers in energy that do not have much loss. So, you see that $E_g = E_k$ and $E_k = E_s$, so you can use those transitions to determine the coefficient of the spring.

$E_g = E_k = E_s + E_{g_f} \Rightarrow E_g = E_s + E_g \Rightarrow mgh_{(h_f)} = \frac{1}{2}k(\Delta x)^2 + mgh_f \Rightarrow (1000\,kg)(10\,m/s^2)(20m) = \frac{1}{2}k(2m)^2 + (1000\,kg)(10\,m/s^2)(5)$

b.) Using a dynamics lens, we see that the problem asks to find the maximum acceleration of the car as we compress the spring, and we know that $F_s = -k\Delta x$, and $F = ma$, so the maximum acceleration is at the maximum compression point of the spring.

So, $F_s = -k\Delta x = ma \Rightarrow -k\Delta x = ma \Rightarrow -k(2m) = (1000\,kg)(a)$

c.) Using a dynamics and energy lens, you see that the force of friction that is on the cart throughout the level part of the track gives the cart an acceleration in the negative direction, so the force of friction causes the cart to lose some of its kinetic energy as heat, or thermal energy, making the energy used to compress the spring less, and thus, reducing the value of k, since $E_s = \frac{1}{2}k(\Delta x)^2$, so you would have to subtract the energy lost to friction from the final kinetic energy.

) The consideration of friction would have a large effect on my answer because, looking at this through an energy lens, $E_{g_0} = E_k + \underset{\substack{\uparrow \\ \text{Energy lost to friction}}}{E_f} = E_s + E_{g_f}$

$E_g = mgh = (1000\,kg)(10\,m/s^2)(20) = 200{,}000\,J$

$F_f = \mu_d(N) = \mu_d \overset{F_n = mg}{(mg)} = 0.2(1000)(10) = \frac{10{,}000}{5} = 2000\,N$

$E_f = W_f = F_f(\Delta x) = 2{,}000\,N(50\,m) = 100{,}000\,J$

$\Rightarrow E_g = E_k + E_f$

$200{,}000\,J = E_k + 100{,}000\,J$

$\underline{E_k = 100{,}000\,J}$

So, with the consideration of friction, the amount of energy that is lost to friction is 100,000 J or 50% of the total energy in the problem, so therefore, friction has a very large effect on our answer for (a), specifically, making k much smaller.

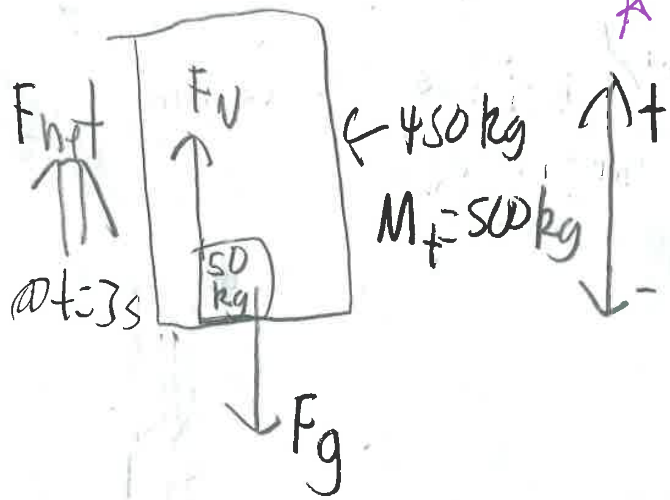
~~so~~ even more, when you consider that you still have to subtract the ~~Δ~~ Energy ⇒ $E_{g_{final}} = mg(\underline{5m})$

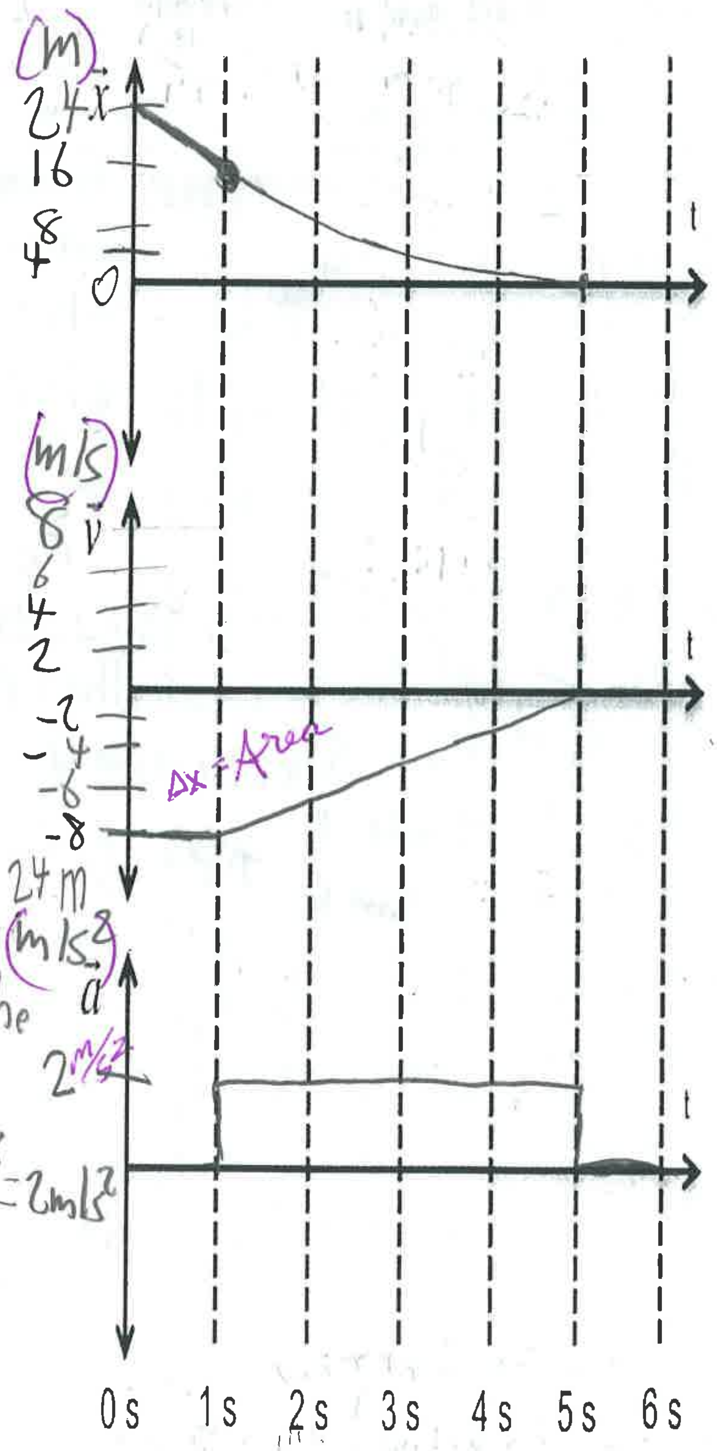
#2 The mass of your friend is 50 kg and she is in a 450 kg elevator for a total mass of 500 kg. She is moving downward and her speed is decreasing as she stops on the ground floor. The table at right indicates the speed as a function of time.

a) Please make the graphs describing her motion. Make sure they have the right shape, and if you have time, please fill in the correct numbers.

Time (s)	Speed (m/s)
0	8
1	8
2	6
3	4
4	2
5	0
6	0

A++





This is really a kinematics problem because we are calculating acceleration and position from velocity.

$$\int_0^6 v\,dt = 8\,m/s(1s) + \tfrac{1}{2}(8\,m/s - 0\,m/s)4s = 24\,m$$

From integrating velocity, I know she lost 24 m total.

$$a = \frac{\Delta v}{\Delta t} = \frac{0\,m/s - (-8\,m/s)}{4s} = \frac{8\,m/s}{4s} = 2\,m/s^2$$

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

#2 The mass of your friend is 50 kg and she is in a 450 kg elevator for a total mass of 500 kg. She is moving downward and her speed is decreasing as she stops on the ground floor. The table at right indicates the speed as a function of time.

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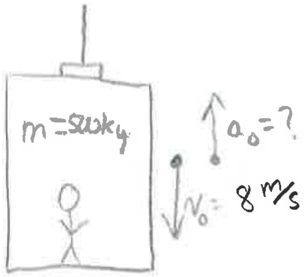


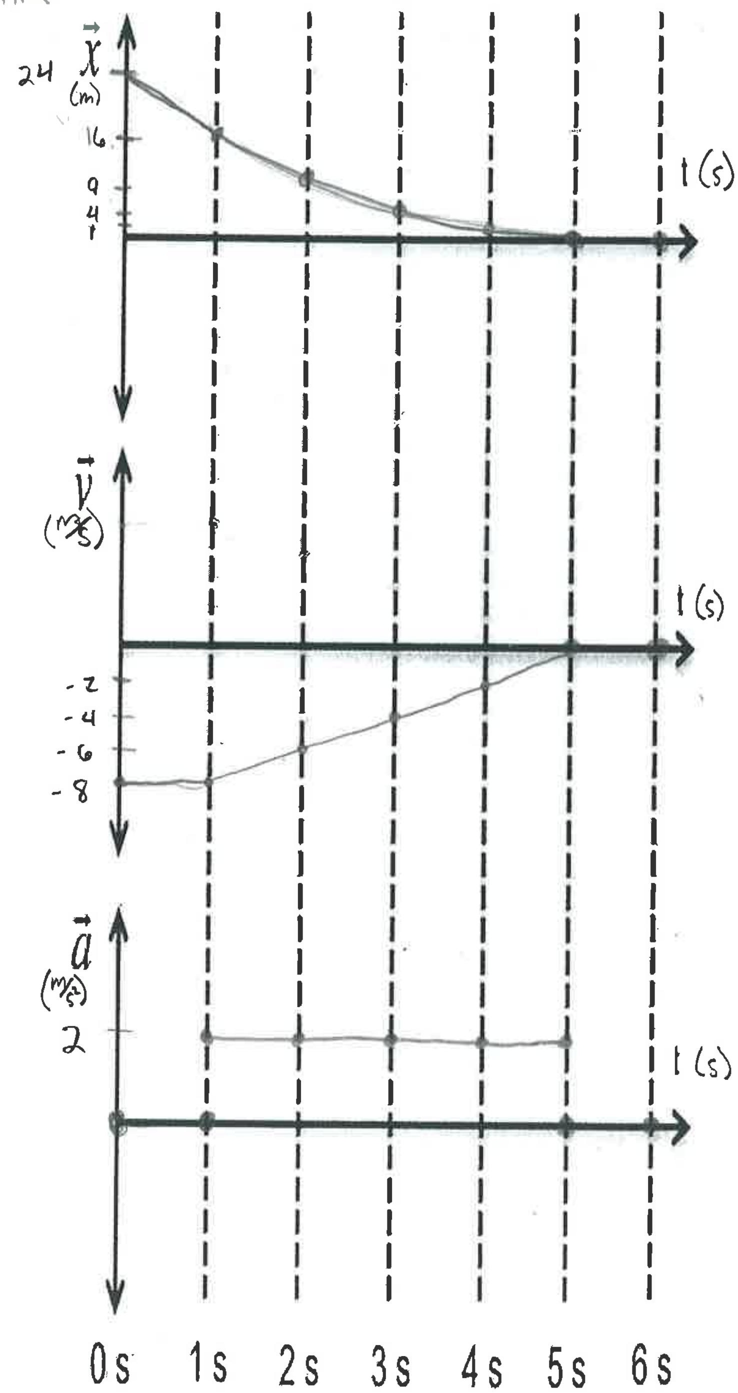
Use a kinematics lens, because this is acceleration, velocity, displacement, and time

find Δx as the are under the graph of velocity

plot velocity graph from table

A

find a as the slope of the velocity graph



#3 Imagine your friend is 50 kg and is standing on a scale in the previous page.

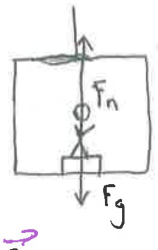
a) What does the scale under her read at t = ½ s?

b) What does the scale under her read at t = 3 s?

Using a dynamics lens, you can see that this is a dynamics problem, because we are dealing with forces and acceleration.

a) $t = \frac{1}{2}s$

$+\vec{x} = \uparrow$



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

(stick figure) $= 50kg$

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

$F_n - F_g = ma$

$F_n - mg = ma$

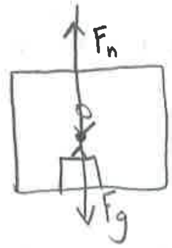
$F_n = (50kg)(0\ m/s^2) + (50kg)(10\ m/s^2)$

$F_n = 500\ \frac{kgm}{s^2} = 500\ N$

The scale under the friend reads 500 N because the system is in equilibrium, so the normal force equals the force of gravity.

b.) $t = 3s$

(stick figure) $= 50kg$



$\vec{a} = 2\ m/s^2 \uparrow +$

$\sum F = ma$

$F_n - F_g = ma$

$F_n - mg = ma$

$F_n = ma + mg$

$F_n = (50kg)(2\ m/s^2) + (50\ kg)(10\ m/s^2)$

$F_n = 100\ \frac{kgm}{s^2} + 500\ \frac{kgm}{s^2}$

$F_n = 600\ \frac{kgm}{s^2} = 600\ N$

The scale under the friend reads 600 N, because they are accelerating upwards, so the normal force is greater than gravity.

A++

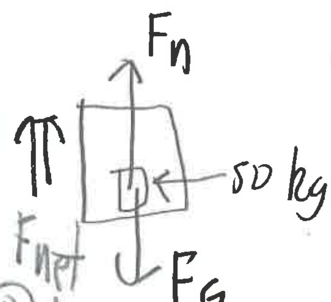
#3 Imagine your friend is 50 kg and is standing on a scale in the previous page.

a) What does the scale under her read at t = ½ s?

b) What does the scale under her read at t = 3 s?

This is a dynamics problem because there are forces acting on an object and we are finding net force. I will use the dynamics lens.

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



A+

@ t = 3s

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

a) $F_n - F_G = m\vec{a}$ $a = 0$ @ $t = \frac{1}{2}s$

$F_n - F_G = m(0) = 0$

$F_n = F_G$

$F_n = 50\,kg(10\,m/s^2)$ The scale will read 50 kg at $t = \frac{1}{2}s$

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

$F_n - F_G = m\vec{a}$

$F_n - F_G = m(2\,m/s^2)$ The scale will read 60 kg at $t = 3s$

$F_n = F_G + m(2\,m/s^2)$

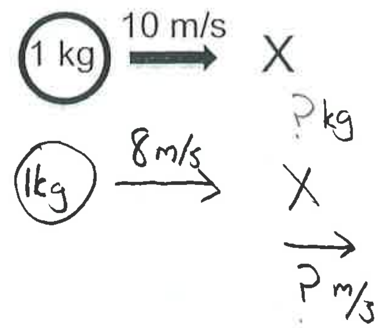
$F_n = m(10\,m/s^2) + m(2\,m/s^2)$

$F_n = 50\,kg(12\,m/s^2) = 600\,kg \cdot m/s^2$

$600\,kg \cdot m/s^2 \,/\, 10\,m/s^2 = 60\,kg$

#4 A 1.0 kg ball moving at 10 m/s *to the right,* has a totally *elastic* collision with *stationary* "Ball X" of unknown mass, and *continues on to the right* at 8 m/s. We want to find the mass of Ball X, and its final velocity. Is it a good idea to draw a picture?

E_k conserved



a. Without doing any math, can you tell me if the mass of Ball "X" is more or less than 1 kg? That is: fill in the space with <, >, or = : m_X < 1 kg

please give a reason

This is because the momentum of the 1.0 kg ball was not affected largely, and the 1.0 kg ball still moved to the right ~~after~~ after the collision.

b. What must be the momentum of Ball X after the collision?

Using a momentum lens, you see that momentum must be conserved in the collision,

so $P_{1.0_0} = P_{1.0_f} + P_{x_f}$

$+ \Rightarrow$

$m_{1.0} V_{1.0_0} = m_{1.0} V_{1.0_f} + m_x + v_x$

A+

$(1.0\text{ kg})(+10\text{ m/s}) = (1.0\text{ kg})(+8\text{ m/s}) + P_x$

$10\ \frac{kgm}{s} = 8\ \frac{kgm}{s} + P_x \Rightarrow \boxed{P_x = 2\ \frac{kgm}{s}}$

c. What must be the kinetic energy of Ball X after the collision?

Since the collision is elastic, you can use an energy lens because you know that kinetic energy is conserved in the collision.

$E_{k_0} = E_{k_f} + E_{kx}$

$\frac{1}{2}(1\text{ kg})(10\text{ m/s})^2 = \frac{1}{2}(1\text{ kg})(8\text{ m/s})^2 + E_{kx}$

$50\ \frac{kgm^2}{s^2} = 32\ \frac{kgm^2}{s^2} + E_{kx} \Rightarrow \boxed{E_{kx} = 18\ \frac{kgm^2}{s^2} = 18\text{ J}}$

d. Find the mass of ball X and the final velocity of ball X.

$(m_x)(V_x) = 2\ \frac{kgm}{s}$

$\frac{1}{2}(m_x)(V_x)^2 = 18\ \frac{kgm^2}{s^2}$

$\frac{\frac{1}{2}\cancel{m_x}(\cancel{V_x})^2}{\cancel{m_x}\cancel{V_x}} = \frac{18\ \frac{kgm^2}{s^2}}{2\ \frac{kgm}{s}}$

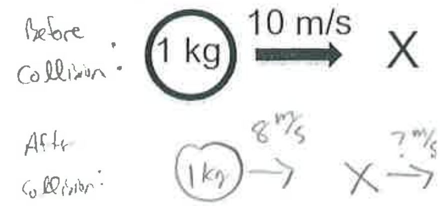
$\frac{1}{2} V_x = 9\text{ m/s}$

$\boxed{V_x = 18\text{ m/s}}$

$(m_x)(18\ \frac{m}{s}) = 2\ \frac{kgm}{s}$

$\boxed{m_x = \frac{1}{9}\text{ kg}}$

#4 A 1.0 kg ball moving at 10 m/s *to the right,* has a totally *elastic* collision with *stationary* "Ball X" of unkno mass, and *continues on to the right* at 8 m/s. We want to find the mass of Ball X, and its final velocity. Is it a good idea to draw a picture? Yes.



a. Without doing any math, can you tell me if the mass of Ball "X" is more or less than 1 kg? That is: fill in the space with <, >, or = : m_X < 1 kg
please give a reason

Both kinetic energy and momentum must be conserved, so if the ball is still going to the right with minimal loss in velocity, ball X must have a smaller mass.

momentum and energy lenses

b. What must be the momentum of Ball X after the collision?

The initial momentum of 10 kg m/s must be conserved. The final momentum of the first ball is only 8 kg m/s to the right, so ball X must have a momentum of $\boxed{2\ \text{kg}\,\frac{m}{s}\ \text{to the right.}}$ to the right

A

momentum lens

c. What must be the kinetic energy of Ball X after the collision?

The initial KE, $\frac{1}{2}mv^2 = \frac{1}{2}(1kg)(10\frac{m}{s})^2 = 50J$, must be conserved. The final KE of the first ball is only $\frac{1}{2}mv^2 = \frac{1}{2}(1kg)(8\frac{m}{s})^2 = 32J$, so ball X must have a KE of $\boxed{18\ J.}$

because it's an elastic collision.

energy lens

d. Find the mass of ball X and the final velocity of ball X.

Using the relationship between kinetic energy and momentum,

$$KE = \frac{p^2}{2m} = \frac{(2\ kg\frac{m}{s})^2}{2m_x} = 18J \qquad \frac{4\ kg^2\frac{m^2}{s^2}}{18\ kg\frac{m^2}{s^2}} = 2m_x \qquad m_x = \frac{2}{18}kg = \boxed{\frac{1}{9}kg}$$

Now use the calculated mass to find the final velocity, using momentum.

$$p = 2\ kg\frac{m}{s} = m_x v = \left(\frac{1}{9}kg\right)v \qquad \boxed{v = 18\frac{m}{s}}$$

Name _______________

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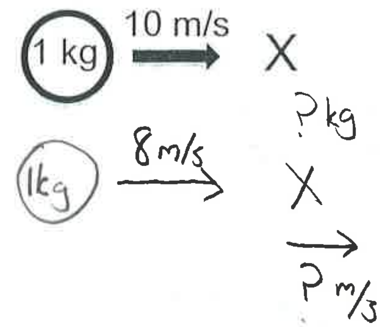

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This is because the momentum of the 1.0 kg ball was not affected largely, and the 1.0 kg ball still moved to the right after the collision.

b. What must be the momentum of Ball X after the collision?

Using a momentum lens, you see that momentum must be conserved in the collision,

so $P_{1.0_0} = P_{1.0_f} + P_{x_f}$ $\quad + \Rightarrow$

$m_{1.0} V_{1.0_0} = m_{1.0} V_{1.0_f} + m_x + V_x$

A+

$(1.0\ kg)(+10\ m/s) = (1.0\ kg)(+8\ m/s) + P_x$

$10\ kgm/s = 8\ kgm/s + P_x \Rightarrow \boxed{P_x = 2\ \frac{kgm}{s}}$

c. What must be the kinetic energy of Ball X after the collision?

Since the collision is elastic, you can use an energy lens because you know that kinetic energy is conserved in the collision.

$E_{k_0} = E_{k_f} + E_{kx}$

$\frac{1}{2}(1\ kg)(10\ m/s)^2 = \frac{1}{2}(1\ kg)(8\ m/s)^2 + E_{kx}$

$50\ \frac{kgm^2}{s^2} = 32\ \frac{kgm^2}{s^2} + E_{kx} \Rightarrow \boxed{E_{kx} = 18\ \frac{kgm^2}{s^2} = 18J}$

d. Find the mass of ball X and the final velocity of ball X.

$(m_x)(V_x) = 2\ \frac{kgm}{s}$

$\frac{1}{2}(m_x)(V_x)^2 = 18\ \frac{kgm^2}{s^2}$

$\dfrac{\frac{1}{2}\cancel{m_x}(\cancel{V_x})^2}{\cancel{m_x}\ \cancel{V_x}} = \dfrac{18\ \frac{kgm^2}{s^2}}{2\ \frac{kgm}{s}}$

$\frac{1}{2} V_x = 9\ m/s$

$\boxed{V_x = 18\ m/s}$

$(m_x)(18\ \frac{m}{s}) = 2\ \frac{kgm}{s}$

$\boxed{m_x = \frac{1}{9}\ kg}$

Name [redacted]