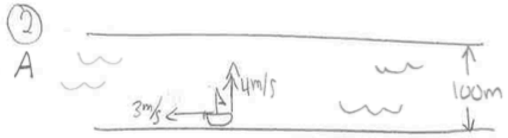
PS#7 Due in Class Tuesday, May 29. Please pay good attention to describe the lens you are using and explain your method.

1. 7.0 Exercise 1, Aiming a boat across a river

(2)

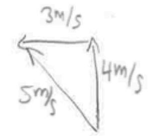


Kinematics in 2D :

why?

directions?

our vectors:

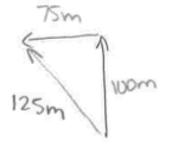


person on a bridge above will see the boat traveling 5m/s north west.

$V_y = \frac{\Delta y}{t}$ $\qquad$ $V_x = \frac{\Delta x}{t}$

$4\,m/s = \frac{100m}{t}$ $\qquad$ $3\,m/s = \frac{\Delta x}{25s}$

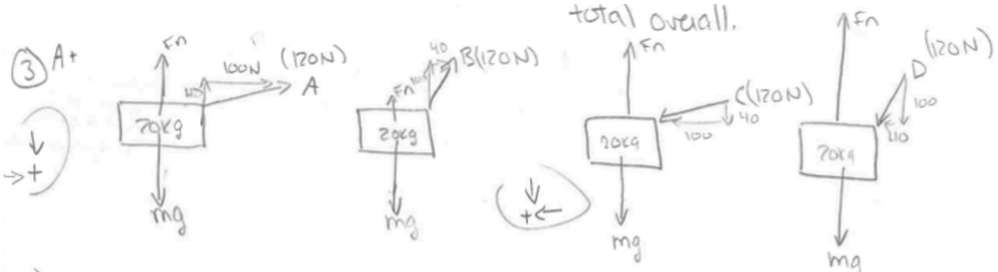
$t = 25s$ $\qquad$ $75m = \Delta x$ (West)



→ 100m North, 75m West, 125m total overall.

2. 7.0 Exercise 2, pulling my daughter in a sled
   My daughter is sledding (total mass = 20 kg), I apply a force of 120 N to her sled. I have four different options (pushing and pulling at two different angles) and I try all of them.
   Make sure to pick a lens and do a good FBD indicating directions.
   a) For each scenario, estimate both the acceleration of the sled and the normal force between the sled and the frictionless snow.

(3) A+



a) Dynamics Lens → dealing with force and accelerations.

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

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

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

A

$100N = 20kg\, a_x$

$\boxed{a_x = 5\,m/s^2}$

$\Sigma F_y = 0$

$mg - F_n - 40N = 0$

$200N - 40N = F_n$

$\boxed{F_n = 160N}$

B

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

$40N = 20kg\, a_x$

$\boxed{a_x = 2\,m/s}$

$\Sigma \vec{F}_y = 0$

$mg - F_n - 100N = 0$

$200N - 100N = F_n$

$\boxed{F_n = 100N}$

C

$\Sigma \vec{F}_x = m a_x$

$100N = 20kg\, a_x$

$\boxed{a_x = 5\,m/s^2}$

$\Sigma \vec{F}_y = 0$

$mg + 40N - F_n = 0$

$200N + 40N = \boxed{F_n \quad 240N}$

D

$\Sigma \vec{F}_x = m a_x$

$40N = 20kg\, a_x$

$\boxed{2\,m/s^2 = a_x}$

$\Sigma \vec{F}_y = 0$

$mg + 100N - F_n = 0$

$200N + 100N = \boxed{F_n = 300N}$

b) A & C have highest and same. B & D are least and same

   b) Now, please rank the different force scenarios in order of least acceleration to greatest acceleration. If some accelerations are the same, please indicate that.

c) Now, let's say the coefficient of friction of the snow is *actually* 0.2. How does this change things? Please rank again the different force scenarios from lowest to greatest acceleration.

c) If the coefficient of kinetic friction is 0.2, then

$F_{fr} = (0.2)(F_n)$

A

$F_{fr} = (0.2)(160N) = 32N$

$\Sigma F_{\vec{x}} = m\vec{a}_x$

$100N - 32N = 20kg\, a_x$

$68N = 20kg\, a_x$ $\boxed{a_x = 3.4 m/s^2}$

B

$F_{fr} = (0.2)(100N) = 20N$

$\Sigma F_{\vec{x}} = m\vec{a}$

$40N - 20N = (20kg)\, a_x$

$20N = 20kg\, a_x$ $\boxed{a_x = 1 m/s^2}$

C

$F_{fr} = (0.2)(240N) = 48N$

$\Sigma F_{\vec{x}} = m\vec{a}_x$

$100N - 48N = (20kg)\, \vec{a}_x$

$52N = (20kg)\, a_x$ $\boxed{a_x = 2.6 m/s^2}$

D

$F_{fr} = (0.2)(300N) = 60N$

$\Sigma F_{\vec{x}} = m\vec{a}_x$

$40N - 60N = (20kg)\, a_x$

$-20N = (20kg)\, a_x$ $\boxed{a_x = -1 m/s^2}$

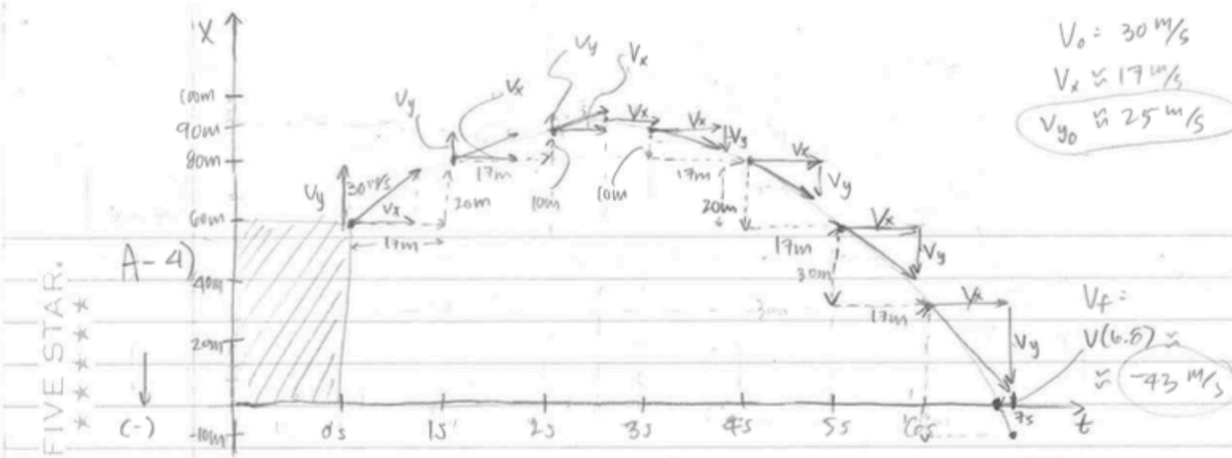
Friction is resistive so it can't accelerate the object backwards.

d) Have you ever pushed a lawn mower (or watched someone do it)? You start with scenario d, pushing along the handle. When you run into some thick grass the "coefficient of friction" might be high enough to stop you cold. What scenario can you change to, and why does this work?

d) You can change to scenario C because you are applying less downward force and therefor there is a smaller Normal force and thus a smaller Friction too which increases the $\Sigma F_{\vec{x}}$.

Yes, that idea is the first thing you will do… lower the handle to reduce the downward component of the pushing force…. but my guess is you have never mowed a thick lawn in Buffalo N.Y. when it's been raining a lot. Scenario "C" is not enough. Eventually, you would turn the lawn mower around and pull it in scenario "A".

3. 7.0 Exercise 4, Throwing a rock upwards The most important first step after making the picture is to determine which direction is the axis. Acceleration is downward, so the horizontal acceleration is zero. Thus, we need to decompose the initial velocity vector into horizontal and vertical components.



$g = -10$ m/s² I use a kinematics lens because I see $x(t)$, $v(t)$, and $a(t)$ all as explicit $f(t)$. Because I know F_g is the only force acting on the rock once it leaves my hand, I know that it's only acceleration is $g = -10$ m/s².

$V_f = V_0 + gt$	$V_{avg} = (V_i + V_f)\frac{1}{2}$	$\Delta x = (V_{avg})(t)$
1 s : $V_y = 25$ m/s $+ (-10$ m/s²$)(1$ s$) = 15$ m/s	$\frac{1}{2}(25$ m/s $+ 15$ m/s$) = 20$ m/s	$(20$ m/s$)(1$ s$) = 20$ m
2 s : $V_y = 25$ m/s $+ (-10$ m/s²$)(2$ s$) = 5$ m/s	$\frac{1}{2}(15$ m/s $+ 5$ m/s$) = 10$ m/s	$(10$ m/s$)(1$ s$) = 10$ m
2.5 s : $V_y = 25$ m/s $+ (-10$ m/s²$)(2.5$ s$) = 0$ m/s	$\frac{1}{2}(5$ m/s $+ 0$ m/s$) = 2.5$ m/s	$(2.5$ m/s$)(1$ s$) = 2.5$ m
3 s : $V_y = 25$ m/s $+ (-10$ m/s²$)(3$ s$) = -5$ m/s	$\frac{1}{2}(0$ m/s $- 5$ m/s$) = -2.5$ m/s	$(-2.5$ m/s$)(1$ s$) = -2.5$ m
4 s : $V_y = 25$ m/s $+ (-10$ m/s²$)(4$ s$) = -15$ m/s	$\frac{1}{2}(-5$ m/s $- 15$ m/s$) = -10$ m/s	$(-10$ m/s$)(1$ s$) = -10$ m
5 s : $V_y = 25$ m/s $+ (-10$ m/s²$)(5$ s$) = -25$ m/s	$\frac{1}{2}(-15$ m/s $- 25$ m/s$) = -20$ m/s	$(-20$ m/s$)(1$ s$) = -20$ m
6 s : $V_y = 25$ m/s $+ (-10$ m/s²$)(6$ s$) = -35$ m/s	$\frac{1}{2}(-25$ m/s $- 35$ m/s$) = -30$ m/s	$(-30$ m/s$)(1$ s$) = -30$ m
7 s : $V_y = 25$ m/s $+ (-10$ m/s²$)(7$ s$) = -45$ m/s	$\frac{1}{2}(-25$ m/s $- 45$ m/s$) = -40$ m/s	$(-40$ m/s$)(1$ s$) = -40$ m

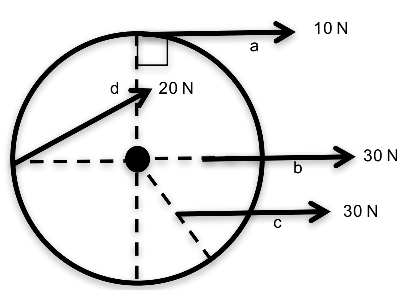
4. 7.1 Exercise 1 pulling child in sled with energy considerations.

We will use an energy lens because the work I do will be transferred to kinetic and thermal energy. We recognize that work is the parallel component of the force times the distance. It looks as though the 40 N tension on the rope provides a little less than 30 N forward and a little more than 30 N upward, Let's say 28 N forward, and 32 N upward. Thus, the 10 kg sled is in equilibrium in the vertical direction with 100 N of gravitational force downward, 32 N of vertical tension upward, and 68 N of normal force (upward). The work done is ~ 280 J

a) Without friction, this would yield 280 J of E_K, corresponding to a final speed of 7.5 m/s.

b) The force of friction with a coefficient of friction of 0.15 is about 10 N, yielding 100 Joules of heat (work of friction), leaving only ~180 J of E_K corresponding to a final speed of 6.0 m/s.

5. Exercise #2 in section 7.1: Torque Wheel.

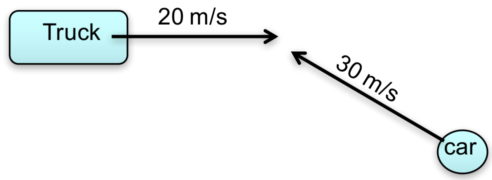


Most of the "mistakes" for this were estimating or just getting the numbers wrong. For starters, a diameter of 1 m means a *radius* of 0.5 m. Then we can see that d) probably has a perpendicular force of only 10 N and c) has a perpendicular force of about 25 N.

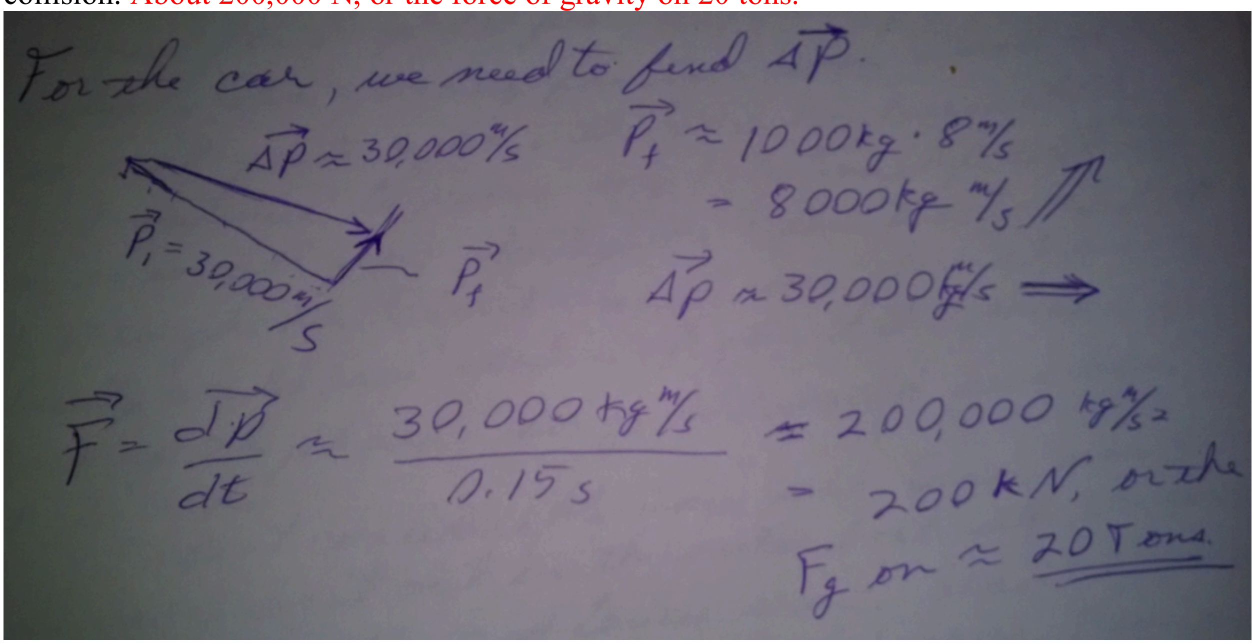
a) $\vec{\tau} = 5\ Nm\otimes$
b) $\vec{\tau} = 0$
c) $\vec{\tau} = 6.5\ Nm\odot$
d) $\vec{\tau} = 5\ Nm\otimes$

6. Exercise #4 in section 7.1: Collision on ice

On a very slippery road, a 1000 kg car and a 2000 kg truck have a collision and stick to each other as shown at right



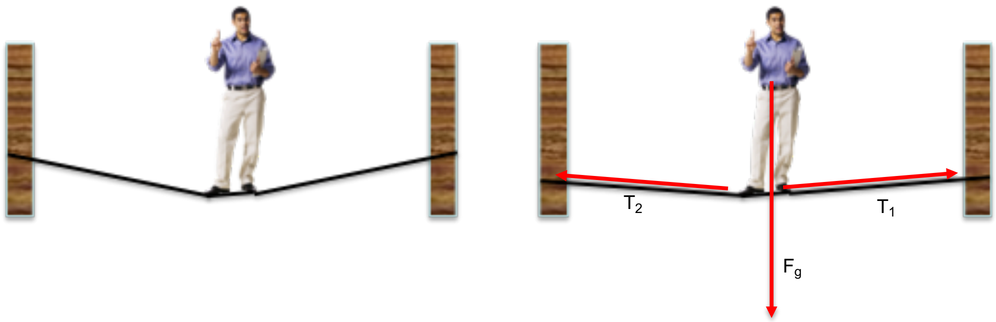
- Could the wreckage have gone off in this direction? How do you know? We are going to conserve momentum here because there are negligible outside forces. Neither of the vehicles have a velocity component in the negative y direction, so this could not be the correct direction.
- Estimate the general direction that the wreckage went after collision. Because we need to conserve momentum, we need to turn this diagram from velocity to momentum. The truck has momentum of 40,000 kg m/s, and the car has 30,000 kg m/s. and ***NO***, this doesn't mean the total momentum is 70,000 kg m/s. If we draw this picture correctly and add the momenta correctly, we should end up with a total momentum of about 25,000 kg m/s in about this direction: Corresponding to a final velocity of about 8 m/s in the same direction.
- Find the impulse that the car received during the collision. Making a good momentum diagram, we can see the change in momentum of the car is about 30,000 kg m/s
- If the collision lasted 1/15 of a second, estimate the average force on the car during the collision. About 200,000 N, or the force of gravity on 20 tons.

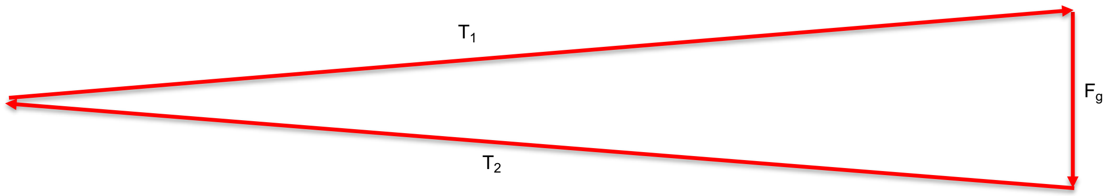


7.

a) In which drawing is the line tighter? Please prove how you know this with a good force drawing and discussion. Lens? Using a dynamics lens… statics. If the vertical acceleration = 0, then the sum of the vertical forces = zero. So, the force of gravity = the vertical components of the tension. Thus, the strings that are more horizontal must have a greater tension. Please see how I have drawn the sum of the forces diagram below for the scenario at right. Notice that the tension is 5 to 6 times as great as the force of gravity. So for the figure at right, the tension is about 4000 N.

b) Using your force drawing, please estimate the tension on the slack line at left.


T_2
T_1
F_g


T_1
F_g
T_2