Problem Set #2 due beginning of class, Tuesday Jan 22. Please state the lens you are using and why.

Very important!. Wednesday of Week 2, we will do our first of two projects. We will take kinematic information from videos of an activity. You will provide graphs of your movement as a function of time – position-t, velocity-t, acceleration-t, net force-t, kinetic energy-t, power-t. You will calculate the maximum power you put out. Please plan this activity in a group of 2-4 people. Please read more about the project on the class webpage on our main class website. Please propose an activity/experiment that your group could do. This project (unlike regular homework) constitutes 5% of your final grade. It will be collected on Tuesday, Week 3.

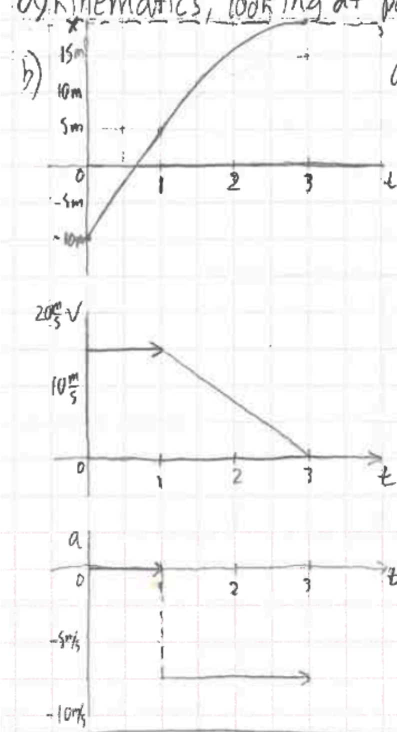
1. My mass is 70 kg, and the mass of my bike is 10 kg. I'm riding my bike at a constant speed of 15 m/s. At 0s, my displacement is $x = -10\ m$. At t = 1s, I apply my breaks and smoothly slow to a stop over a period of two seconds.
   a) What lens do I use to make these graphs?
   b) Please graph my acceleration, velocity, and displacement as a function of time. Label the axes correctly.

   *Then* please also find:

   c) the force exerted by my breaks; *Force of the breaks causes acceleration of the bike and rider*
   d) and the work done by my breaks and *Energy because the work of the breaks turns kinetic energy into thermal energy*
   e) the average power. *Rate of change of energy*
   f) Was energy conserved in this process? How? YES, *energy is always conserved. Kinetic energy was converted to thermal energy. So mechanical energy was "lost" to thermal energy, but the total energy is conserved.*
   g) Was momentum conserved in this process? How? *There is an outside force (the breaks) on the bike, so the bike's momentum isn't conserved. However the force is between the earth and the bike, so the total momentum of the bike-earth system is conserved. That is, the earth gains the momentum that the bike "lost". OR, momentum is transferred from the bike to the earth via the force of friction.*

a) Kinematics, looking at position as a function of time. Mass won't be considered in graph

b)




$a = \frac{\Delta v}{t} = \frac{0\,m/s - 15\,m/s}{2s} = -7.5\,m/s^2$

c) Dynamics: $F = ma$

$M_T = M_P + M_B$

$= 70kg + 10kg$

$M_T = 80kg$

$a = -7.5\,m/s^2$

$F_b = M_T a$

$= 80kg \cdot -7.5\,m/s^2$

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

$= \boxed{-600\,N}$

d) $W = F\Delta X$

$\Delta X$ = Area under $V(t)$ curve from $t = 1s$ to $3s$

$\Delta X = \frac{15\,m/s \cdot 2s}{2} = 15m$

$W = F\Delta X$

$= -600N \cdot 15m$

$= |9000\,Nm|$

(Scalar)

$= \boxed{9000\,Nm}$

$P = W/\Delta t$

$= 9000\,Nm/2s$

$= 4500\,Nm/s$

$= \boxed{4500\,watts}$

e) Kinetic energy was not conserved, for an external force caused a depletion of kinetic energy. However, in general energy was and always is conserved, just not KE, a lot of which was transferred to thermal energy in the brakes

F) lens: momentum

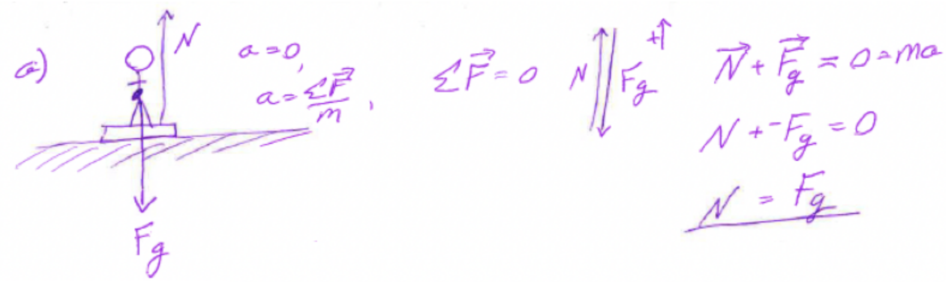
Momentum is not conserved because an external force was present

2. Tracker Assignment,

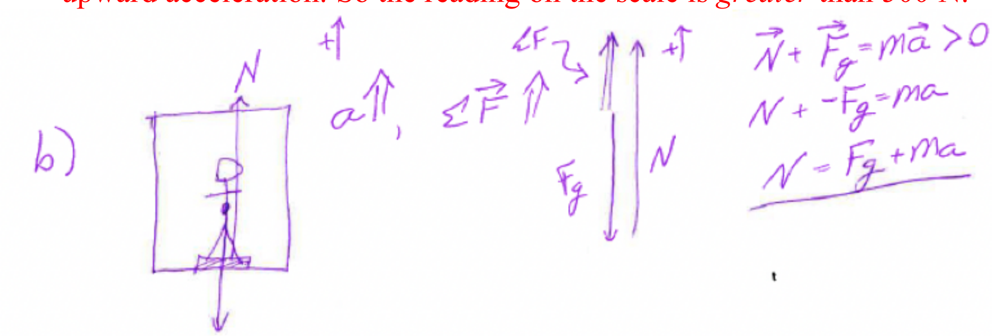
Hopefully, the videos on this project helped.

3. *A true story? You have a mass of 50 kg.* On your trip to Dubai, you visit the tallest building in the world** and select the "extreme" elevator. You bring a bathroom scale and stand on it.

a) You test the scale in the lobby by standing on it. What does it read? Why do you know it reads that? We use a dynamics lens because the forces on you are in *equilibrium*, hence you are not accelerating. I would write $\boxed{\vec{a} = \frac{\sum \vec{F}}{m}}$ and recognize that in equilibrium, acceleration is zero, so the forces must add to zero. Thus, the force of gravity = normal force (of scale) on me = 500 N

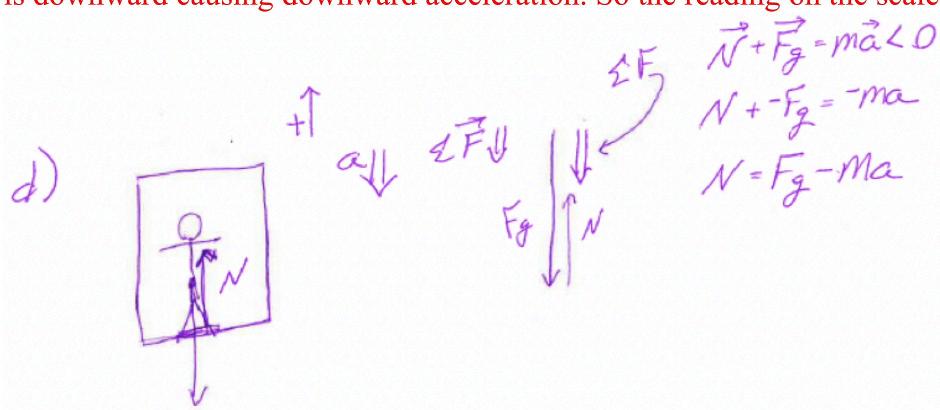



b) When you begin your ascent upward, should the scale read greater, less, or the same as your answer in a) above? You've been in an elevator before. What do ***<u>you feel</u>*** as the elevator begins the ascent? Does this make sense? I feel "heavy", which is the increased normal force pushing harder on me than before. Now, $F_N > F_g$ so the vector sum of the forces is upward causing the upward acceleration. So the reading on the scale is *greater* than 500 N.




c) After a time, you are moving upward at a constant speed. Now, should the scale read greater, less, or the same as your answer in a) above? You've been in an elevator before. What do ***<u>you feel</u>*** when the elevator is moving upward at a constant speed? Does this make sense? I have constant velocity, so I am again in equilibrium… see answer for letter a) and know that the reading on the scale is again 500 N.

d) The elevator slows to a stop at the top floor. As the elevator is slowing, should the scale read greater, less, or the same as your answer in a) above? You've been in an elevator before. What do ***<u>you feel</u>*** when the elevator is slowing to a stop? Does this make sense? I feel "lighter", because the normal force pushing me upward has decreased. Now, $F_N < F_g$ so the vector sum of the forces is downward causing downward acceleration. So the reading on the scale is *less* than 500 N.



e) If the scale you are standing on reads 300 N (or 30 kg) what would your acceleration be (include direction)? Using a dynamics lens, I can see that the vector sum of forces on me is 200 N downward! As my mass is 50 kg, the acceleration would be 4 m/s$^2$ downwards.

e) $N < F_g$ so $a \Downarrow$, this is scenario d above

$\Sigma \vec{F} = \vec{F_g} + \vec{N} = -500N + 300N = -200N \Downarrow$

$a = \frac{\Sigma \vec{F}}{m} = \frac{200N \downarrow}{50kg} = 4\,m/s^2 \Downarrow$

4. From Big Exam #2:

You are pushing a car on flat level ground. The mass is 1000 kg, and you are pushing with a force of 500 N. If the car starts with a speed of 5 m/s and you push it forward 20 m,

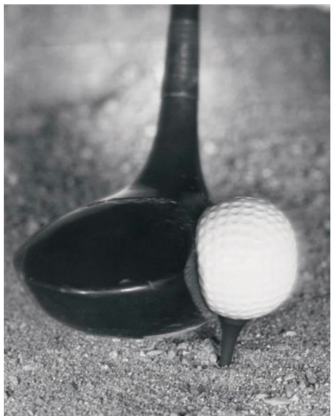
a) What is the final speed of the car?

b) *How about if you push the car in the direction opposite its velocity for 10 meters?*

Please see solutions to BE!#2

5. Denny Shute (https://en.wikipedia.org/wiki/Denny_Shute) was a rather tall professional golfer in the 1930s. "Doc" Edgarton (https://en.wikipedia.org/wiki/Harold_Eugene_Edgerton) was a professor of electrical engineering at MIT who pioneered stroboscopic photography, where an ultra-short flash allowed a process to be illuminated on camera film for such a short time to freeze the process in time. His pictures of a bullet through an apple (http://www.bbc.com/future/story/20140722-the-man-who-froze-the-world) for instance made him famous, and when I was a student there in the early 80's his talks would fill the largest lecture halls with no standing room left. Edgerton photographed Denny Shute hitting a golf ball (http://artsalesindex.artinfo.com/auctions/Harold-Edgerton-5230133/Densmore-Shute-Bends-The-Shaft-1938) in the dark with multiple flashes at a frequency of 100 flashes per second.

a) In this photograph of Denny Shute's drive, how can you perceive speed? What lens do you look at this problem through?



b) Where is the golf club moving the fastest? How can you tell? Which lens do you use?

c) Where is the golf club speeding up and slowing down?

d) How does the speed of the golf ball compare to the speed of the golf club?

e) There was no flash at the moment that the club hits a golf ball. Where is the club when the ball is at the last two positions before leaving the screen?

f) Estimate the speed of the golf ball from this picture. Express it in m/s.

g) Roughly estimate the speed of a golf ball from your experiences. Close your eyes and imagine one being hit, or see a video: https://www.youtube.com/watch?v=8W89QnvY4Rg

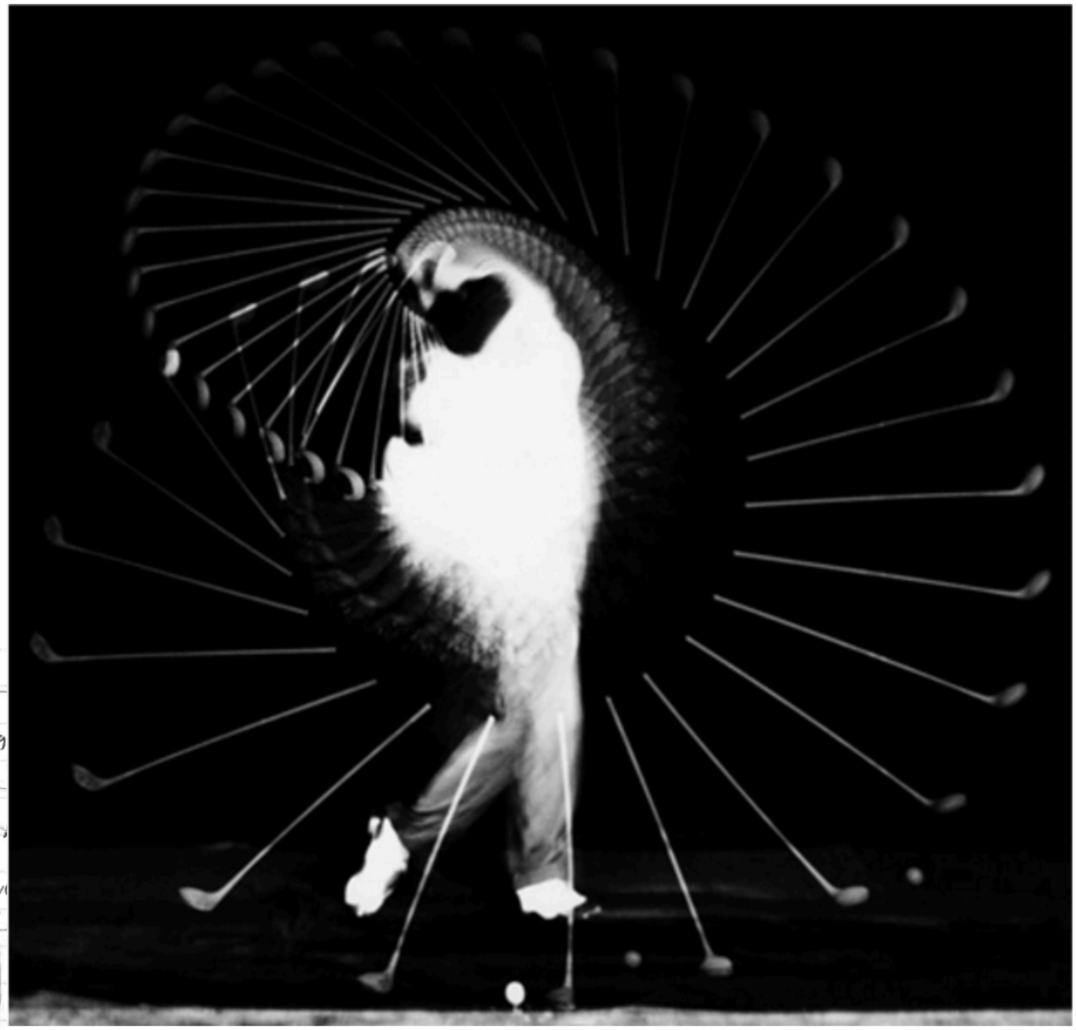
h) When the club hits the ball, the ball speeds up. Should the speed of the club change as well? How do you know? What lens do you use?

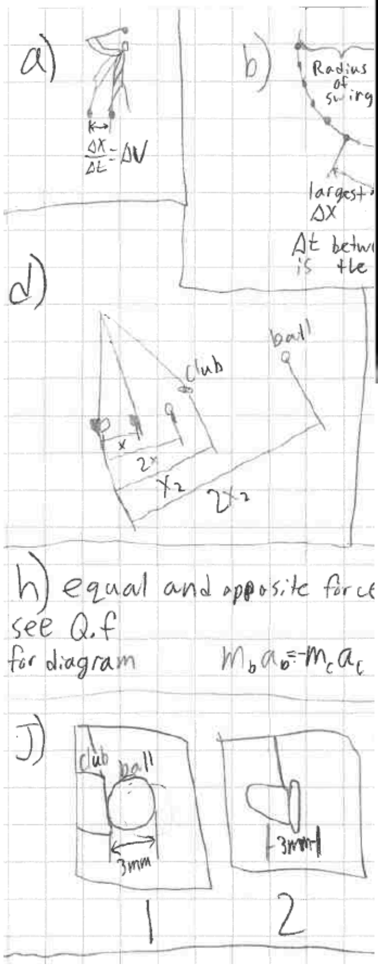
i) From looking at the change in speeds of the ball and club on impact, can you make some statement about their relative masses? Can you estimate the ratio of the mass of the club to the mass of the ball?

j) Please estimate the amount of time that the club is in contact with the ball. You might do this by considering Edgerton's picture, or a careful look at this video at about 30 s: [https://www.youtube.com/watch?v=6TA1s1oNpbk](https://www.youtube.com/watch?v=6TA1s1oNpbk)

k) Please calculate the average force between the ball and club during the collision.

l) Please calculate the average power provided by the club to the ball during the collision





(a) Kinematics lens: One can percieve speed through time (s) and distance (m). The time is given in the frame-rate and distance can be estimated through its relativity to other objects whose dimensions are known.

(b) Kinematics lense: Since speed is measured in distance over time, the point where the golf club is moving the fastest is the frame where the largest distance was traveled.
Answer: Fastest point is the frame before the collision with the ball.

(c) Kinematics lense: The club is speeding up on Denny's down swing, the $\Delta X$ per frame is increasing from the top of his swing, to to the bottom. One can also see the $\Delta X$ per frame decrease during his follow through, the point after colliding w/ ball and beyond.

(d) Kinematics lens: Post-collision, the ball covers about twice as much ground as the club per frame. The ball also increases in speed after the collision where as the club's speed remains relatively constant after immediately after the collision $V = \frac{\Delta x}{\Delta t}$

$V_B \approx 2 V_{club}$

(e) If an imaginary frame were to be shown during the collision, the club and the ball would be at the same position ($X_0$). The next frame, the club is behind the ball ($X_1$), about ½ way between $X_0$ and $X_1$. The next frame, the club is still behind the ball ($X_2$), about half way between $X_0$ and $X_2$. Ball exits frame

(f) Denny's height: 1.78m scale = 1.78m/8cm = .22 m/cm
height in photo: 8cm
$\Delta X$ after two frames: (.22 m/cm)(5.5 cm) = 1.2m $V = \frac{\Delta X}{\Delta t} = \frac{1.2\text{m}}{1/50\text{s}} = \boxed{60\text{m/s}} \approx 130\text{mph}$
$\Delta t$ after two frames: (1s/100 frames)(2 frames) = 1/50 s

(g) looks about like 100mph - 150mph

(h) Dynamics lens: ball exerts an equal and opposite force on the club as the club does to it, thus the club should recieve a negative acceleration, so yes it should see a change in velocity (3rd law of motion). $\vec{p}$ lens... $\Delta V_B >> \Delta V_{club}$
in the photo

*i) If we look closely, it seems the club's decrease in velocity is about ¼ the increase in speed of the ball. Thus the mass of the club should be about 4 times the mass of the ball. If you look this up, is this what you find?*

*j) I'm going to use my momentum lens because force is the rate of change of momentum, but I could use the dynamics lens too because the normal force between the ball and club accelerates the ball (and the club in the opposite direction). Let's say that the club is in contact with the ball for about 1 ball diameter – let's say 2 cm. I show in the video how I find the speed of the golf ball to be about 80 m/s. Thus, the two are in contact is about 1/4000 s, or ~ 2.5 x $10^{-4}$s.*

*k) The mass of a golf ball is about 45g or 0.05 kg. If force is the rate of change of momentum, the momentum the ball gains is about 4 kg m/s. In 1/4000 of a second, this would correspond to a force of about 16,000 N (The force of gravity on a large car, but only for a short time). If you put a golf ball between two steel plates and drove a large car on the top one, would it cause the ball to squish like it does when it's hit with the club? NOTE, the acceleration of the golf ball when it's hit with the club is way way way more than the acceleration of the club head that we calculate in the video to be about 120 gravities ~ 1,200 m/s$^2$. The acceleration of the ball is about 60 m/s * 4000/s ~ 240,000 m/s$^2$ or 24,000 gravities.*

*I use an energy lens because power is the rate of change of energy. The ball gains kinetic energy… we calculate about 160 J in 1/4000 of a second for an average power of about 0.64 MW… MEGA Watts! That's the power put out by a*