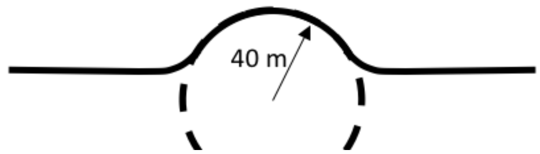
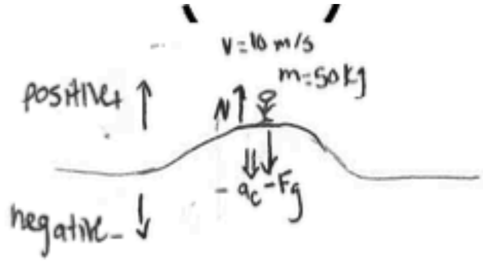
You will be graded on your *communication* of physics understanding.

#1 You know a road with a round hump of radius 40 m as shown. You drive over it at a constant speed of 10 m/s. Your 50-kg body is sitting on a scale. As you go over the very top of the bump, what should the scale be reading? Your process is more important than your answer. We should notice that we are not moving in a straight line, so there is centripetal acceleration… must be caused by forces. So, I know it's dynamics, I write the vector sum of the forces equals mass times acceleration, and I recognize one of the forces is the normal force of the scale. I draw a FBD remembering to identify the direction of acceleration and also pick a positive direction. I'm able to make a vector sum diagram.



Looking at this through a dynamics lens because $\Sigma\vec{F} = m\vec{a}$. We are dealing with the F_g, N, and $a_c = v^2/R$.



$$a_c = \frac{(10\,m/s)^2}{40m} = \frac{100\,m/s}{40m} = 2.5\,m/s^2$$

$$N + -F_g = m(-a_c)$$

$$N = ma_c + F_g$$

The normal force is what will read on the scale.

units!

$$N = 50kg(-2.5\,m/s^2) + 50kg(10\,m/s)$$

$$-125 + 500$$

$$N = 375\,N \quad = 375N/500N = .75\,(50kg) = 37.5\,kg$$

The scale will read <u>37.5 kg</u> because ma_c and F_g are acting in the negative direction and the normal force is acting in the positive direction.

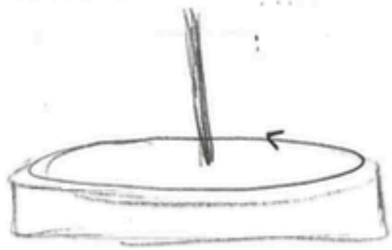
#2 True Story: I know a carousel at a playground. I wish I knew the moment of inertia of it,. While I can measure dimensions, I know nothing about its mass distribution or even what the mass is. How could I measure the moment of inertia? You know what I have in the Physics “toy room”… I have all kinds of force scales, I have masses and wheels and all kinds of other things. I can take a video with my cell phone. Please figure out a way for me to measure the moment of inertia with a complete lens explanation, and set up the correct equations. I can think of several ways…likely the class will find even more ways. I can see using any of three lenses to solve this:

- Rotational Dynamics, because torque causes angular acceleration.
- Angular momentum, because angular momentum is conserved inside of a closed system… or when outside torques = 0.
- Energy lens because I can do work which is converted to rotational energy.

Do we understand what moment of inertia is? It’s kind of how hard it is to get something rotating, or how hard it is to get something to change its rotational velocity, or how much kinetic energy there is in a spinning object. Here’s two ways of the many ways to solve the problem:

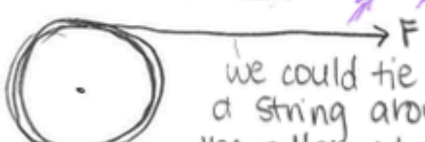
We can use an energy lens to find the moment of inertia if we consider

$W_{rot} \Rightarrow KE_{rot}$



First, to find the rotational work put into the turning carousel, we could use a dynamics lens (both linear & rotational) to discover the torque on the carousel

view from above:



you could also just use $W = F \cdot \Delta x$ work is work.

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we could tie a string around the outer edge of the wheel, put a force on the string, and knowing $\tau = r_{\perp} F$, we can discover the resulting Torque from this force.

we can measure the change in theta from this Torque by observing the # of rotations of the carousel, and with that (because $W_{rot} = \tau \Delta\theta$) we can determine the work put into rotating this carousel from the initial Force.

Lastly, we know that work goes into the carousel and becomes rotational KE of the carousel,

so $W_{rot} = KE_{rot} = \frac{1}{2} I \omega^2$ (we can solve for ω by our $\Delta\theta$ over the time in which that $\Delta\theta$ occured) $\boxed{\text{\& the solve for } I}$

Rotational Dynamics Lens: because you must apply a torque to the carousel in order for it to angularly accelerate

$\tau = I\alpha$

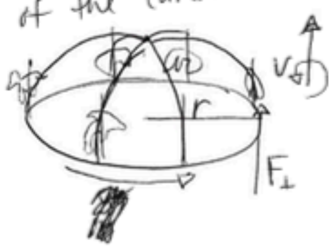
$I = \frac{\tau}{\alpha}$

To set this senario up in class I would grab a spinning plate (the kind Prof. Schwartz stands and spins on) and a phone. I would choose ~~and~~ a set amount of newtons of force (perpendic to apply to the plate and measure the radius to find the torque ($\tau = F_\perp r$).

Ring: $I = mr^2$

this would be an ineffective equation because we dont know m or r of the carousel.

Once I have the Torque, I need to find angular acceleration, which is $\frac{\Delta\omega}{\Delta t}$ for this. I would need to record the torque being applied to determine the change in rotational velocity ($\Delta\omega$) over the time. To do this I would record that initial velocity is zero and calculate how many rotations per second at the ending point, to find the final velocity and set that over the time to find α or angular acceleration. Once I have α and τ, I can solve for I which equals τ/α.



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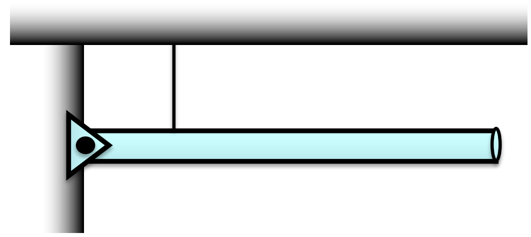
You saw above that you could use a work/energy lens and an angular dynamics lens. Could you also use an angular momentum lens? What if you gave the carousel a good spin and then jumped on the edge while recording its speed on video. How could you use this method to find the moment of inertia?

#3 You see at right a uniform, 10 m long, 200 kg steel "I" beam that is attached to the wall with a rotating hinge. A vertical cable, attached 2 m from the wall prevents the beam from rotating downward on the hinge, holding it in place as shown.



a) Find the tension in the cable

b) Is there any force on the hinge attached to the wall? If not, explain why you know. If so, find the force on the wall (include direction)

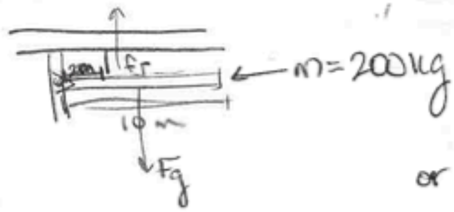
Have we seen problems like this? What lens do we need? Did you label the forces? How many are there? What body are we looking at? Where is the force of gravity working on this?

why you know. If so, find the force on the wall (include direction)

Since Statics, so $\Sigma F = 0$ & $\Sigma T = 0$. In rotational dynamics

a) $\Sigma F = ma$

$0 = F_g - F_A - F_T$

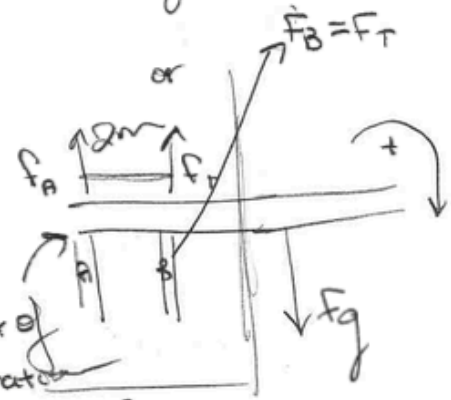


$F_g = (200kg)(10 m/s^2) = 2000N$

so: F_A & $F_T = 2000N$

↳ F_A & $5000N = 2000N$

$F_A = \boxed{-3000N \text{ downward}}$



I know there is a force in the hinge on the wall because without it tension would pull the cable up.

$\Sigma T = F_B r_B - F_C \overset{5m}{r_C}$

$\Sigma T = F_B(2m) - (2000N)(5m)$

$-F_B 2m = (-2000N)(5m)$

$F_B = 5000 N$

$\boxed{F_{Tension} = 5000N \text{ upwards}}$

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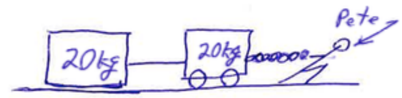
#4 I pull with a force of 100 N on a chain, towing two 20-kg toy railroad cars in a row attached to each other with string. The car in front has low-friction wheels, but the car at the back has no wheels and slides on the rails with a coefficient of friction of 0.1. I pull it for 10 meters.

a) Is the system in equilibrium? How do you know?

b) Please find whatever you can, but ideally, I'd like to know the tension in the string between the two cars.

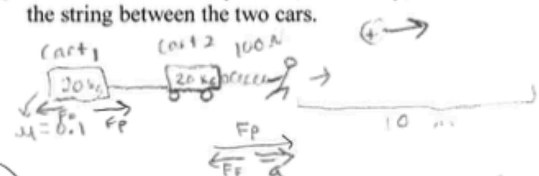


Do we know what equilibrium means? There's two ways to look at it… when all accelerations are zero, including rotational acceleration. This would mean that the vector sum of all the forces in any direction = 0. Because we aren't given any explicit kinematic information about the acceleration, or speed, we might look at forces. Do all forces add to zero in the y direction?... in the x direction? What are these forces? Did we draw a good FBD and label the forces we know?

Did we recognize how to treat this as a system? Is tension a force on the system itself, or is it an internal force… how do we find it then?

In order to find the final speed, it is reasonable to use an energy lens, because my work is changed to kinetic energy and heat. We know heat results from the work of friction. You could also then ask yourself what tension you would need to give the appropriate kinetic energy to either of the cars… however, using a dynamics lens is a little more straight forward. But you have to use both bodies independently, or first recognize that I'm pulling a system of 40 kg.

the string between the two cars.



(A) The system is not in equilibrium bc there is a positive net force and thru the dynamics' lens, forces cause acceleration.

(B) Dynamics lens bc forces cause acceleration. $\Sigma\vec{F} = m\vec{a}$

$F_{N(1)} = mg = 20\,kg(10\,m/s^2) = 200\,N$

$F_F = \mu N$

$F_{F(1)} = 0.1\,(200\,N)$

$F_{F(1)} = 20\,N$

~~$W_{F(1)} = F \cdot \Delta x = 20\,N \cdot 10\,m = 200\,J$~~

$\vec{F}_p = 100\,N$

$\vec{F}_F = -20\,N$

$\Sigma\vec{F}_s = 80\,N$

$\Sigma\vec{F}_s = m_s\vec{a}$

$m_s = 40\,kg$

$80\,N = 40\,kg\,\vec{a}$

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

$\Sigma F_{(1)} = m\vec{a}$

$\Sigma F_{(1)} = 20\,kg \cdot 2\,m/s^2$

$\Sigma F_{(1)} = 40\,N$

$\Sigma F_{(1)} = \vec{F}_T + \vec{F}_F$

$40\,N = F_T - 20\,N$

$F_T = 60\,N$

Total force on system is Pete's force minus F_F.

$100\,N - 20\,N = 80\,N$

so acceleration of system

$\Sigma\vec{F} = m\vec{a}$ $\quad 80\,N = 40\,kg\,\vec{a}$

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

So cart 1 is accelerating at $2\,m/s^2$ so the net force on that cart alone is $\Sigma F_{(1)} = 20\,kg\,(2\,m/s^2)$

$\Sigma F_{(1)} = 40\,N$

But 20 N were lost to friction, so tension in string must be $40\,N + 20\,N = \boxed{60\,N}$

which makes sence b/c

$\Sigma F_{(2)} = 20\,kg\,(2\,m/s^2) = 40\,N$

$60\,N + 40\,N = 100\,N$ which is the force Pete is pulling with

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