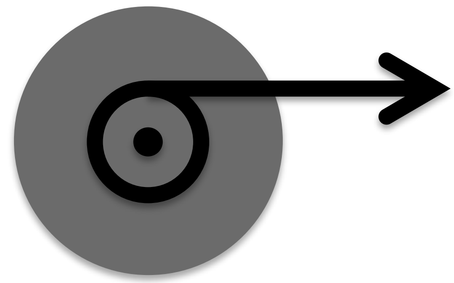
Problem Set #7 due beginning of class, Monday, March 2



#1 You spin up a flywheel by pulling 2 m of string with a tension of 100 N as shown at right. The flywheel is 3 kg flat disk of uniform thickness, is on a frictionless bearing, and has a radius of 30 cm. You have the string wrapped around the hub (or spindle, or pulley) of radius = 10 cm. We will find everything in this problem by starting with energetics!

a) Section 10.3 of your text is about moment of inertia with a nice table showing the moments of inertia for different shapes. Find the moment of inertia of the flat disk flywheel.
b) Find the work I do pulling the string. Where did this work go?
c) Find the final angular velocity, ω. Which lens are we using to solve this problem?
d) Find the total angle, θ the wheel turns through while I am pulling the string.
e) If $\omega_o = 0$, and assuming there is constant angular acceleration, what is the average ω during the time I'm pulling the string, and how long does it take me to pull the string?
f) What is the angular acceleration α, of the wheel while I am pulling the string?
g) Find the torque, τ, that I must apply to accelerate the wheel as I did?

#2 We repeat the above problem using <u>rotational dynamics</u>! Start with the same problem and assume you have so far only calculated moment of inertia and nothing else.

a) Please find the torque, τ provided by the tension of the string pulling on the pulley.
b) Calculate the angular acceleration, α, of the wheel as you are pulling it. What is necessary to have constant angular acceleration while you are pulling the string?
c) We will learn that rotational work is rotational force times rotational distance, or $W = \tau * \theta$. Is the linear work you did pulling the string = the rotational work done on the wheel?
d) Which way, #1, or #2 do you like best?

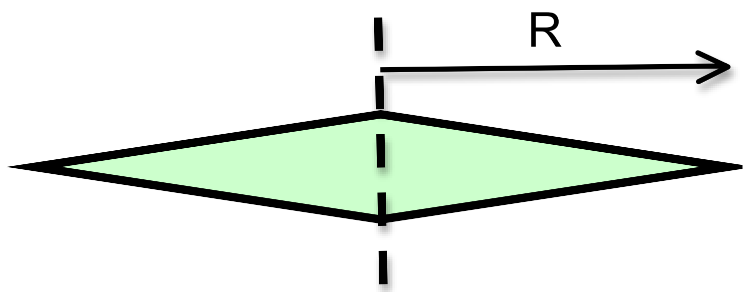
#3 For the problem above, image that we use the same flywheel, but the hub radius is 20 cm; that is the radius of the pulley is doubled. We want to see which other things change and by what factor. Please provide proof. If r_{pulley} => <u>2</u>_ r_o, then:

a) How does this change the total angle θ that the wheel turns while I am pulling the string? θ => __ θ_o
again, please show reasoning for each question.
b) How does the final angular speed change? ω => __ ω_o
c) How does the Torque change? τ => __ τ_o
d) How does the angular acceleration change? α => __ α_o
e) How does this change the time it takes to pull the string? t => __ t_o

#4 For problem #1 and #2 above, imagine that you have the *same pulley*, but instead you attach a flywheel that is twice the radius, made of the same metal, of the same thickness, but has a radius of 60 cm. That is, we double the radius of the flywheel (we have to add more material in the process): $R_{flywheel}$ => <u>2</u>_ R_o,

a) How does this change the mass of the flywheel? $m_{flywheel}$ => __ m_o,
again, please show reasoning for each question.
b) How does the moment of inertia of the wheel change? $I_{flywheel}$ => __ I_o,
c) How does this change the torque that I apply by pulling the string? τ => __ τ_o
d) How does the final angular speed change? ω => __ ω_o
e) How does the angular acceleration change? α => __ α_o
f) How does the total angle θ that the wheel turns while I am pulling the string change? θ => __ θ_o
g) How does this change the time it takes to pull the string? t => __ t_o

#5. I invent a new kind of round discus that spins about a vertical axis (dotted line) as shown at right. The object has a thickness of t_o at the axis (at $r=0$) and it tapers evenly to a sharp edge at $r=R$, or $t = t_o(1-r/R)$. If the mass of the discus is M,



a) Judging from moments of inertia of other objects, please guess as best you can what should be the moment of inertia about the axis in terms of the variables given, and support your estimate with reasons. For starters, you might consider if this moment of inertia is greater or less than a rim of mass M, a disk of mass M, a hollow or solid sphere of mass M.
b) ** (advanced for 141 students). Calculate exactly what the moment of inertia is by integrating over the mass. *Hint: You'll have to do two integrations for this: one to find the volume, and the next to find the moment of inertia. A similar problem was done in the moment of inertia video.*

#6 A child's carousel has a mass of 100 kg and a diameter of 3 meters, and is spinning clockwise as viewed from above at 1.5 revolutions per second. Assume that the mass is uniformly distributed over the circular area. Two kids, 30 kg point masses, each are dropped from rest simultaneously on opposite sides of the carousel, 1 meter from the center.

a) Find the moment of inertia of the carousel and the moment of inertia of the two children.
b) Find the initial angular velocity, ω_o, please include direction using the right hand rule.
c) What happens to the rotation rate of the carousel after the kids are dropped onto the surface? Why is this? Please identify the appropriate physics concept in your answer.
d) Please find the final angular velocity, ω_f.
e) Please find the initial and final kinetic energy of the carousel + children system before and after the stationary kids were dropped onto the carousel's surface. Was kinetic energy conserved? If not where did it go, and how?

#7 You see a 10 kg rock in space moving with constant speed of 10 m/s in a circle of radius 20 meters. I wonder what force is acting on this rock.

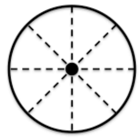
a) Find the angular velocity, ω of the rock.
b) Why do you know the rock is accelerating if it is moving with constant speed?
c) Find the acceleration of the rock, including direction of the acceleration.
d) Calculate the force necessary to accelerate this rock.
e) What kind of force is this? – if you say, "it is centripetal force!" I will be sad. I will be pleased if you say, "I have no idea what force is acting on it, because I can't see anything that the rock is interacting with, so I have to look around at what object must be applying a force of_____(put answer from d) on the rock to make it accelerate at______(put answer from c)."
f) Then you see a string attached to my arm as I spin the rock in a circle. What kind of force is it? Find the tension in the string.
g) Then the string breaks – what happens to the rock? Please Draw a Picture
h) ….instead of me and a string, you see a large sphere in the middle of the rock's circular path. What kind of force might be acting on the rock now? If this force is gravity, what must be the mass of the large sphere in the center? If the mass at the center has the largest possible radius of 20 m, what would be the density of the object? Is there any known substance with this density?
i) ….instead, you notice that the 10 kg rock is actually a small 10 kg toy car driving around in a 20 m circle on a flat parking lot at 10 m/s. Now what force is acting on the car? Please find the coefficient of friction necessary to keep the car moving in this circle.

From Classes:

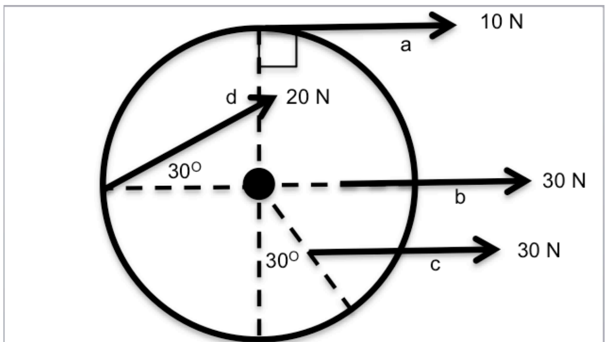
A bicycle wheel has a diameter of one meter and is rotating at:

$$\omega = -\frac{2}{s} + \frac{2t}{s^2}$$

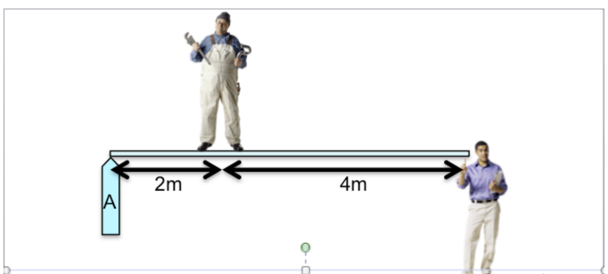
The wheel is on a horizontal axis (0,0) on the (x,y) plane, and positive rotation is considered into the board.



a) At $t=2s$, find the velocity at (0.5 m, 0), include direction
b) At $t=2s$, find the acceleration at (0.5 m, 0), include direction.
c) What is the angular displacement these $2s$?



The radius of the wheel is 4 meters. Please find the torque for each force applied to the wheel. Include direction.



I support a 70 kg Friend on a massless plank
a) What is the lens? How do you start?
b) What is the torque about A from the worker?
c) What is the force on my finger?
d) What is the force that support A is providing?