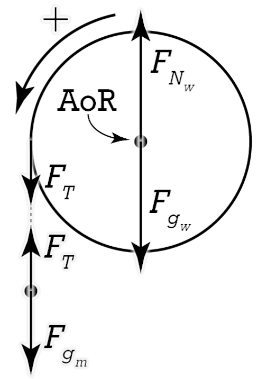
Flipping Physics Lecture Notes:

(2 of 2) Measuring the Rotational Inertia of a Bike Wheel



This is a continuation of “(1 of 2) Measuring the Rotational Inertia of a Bike Wheel.” The following is a very rough summary of what was done in that lecture. Please watch that lecture before embarking on this video’s learning adventure.
https://www.flippingphysics.com/rotational-inertia-bike-wheel-1.html

Knowns: $\alpha = 3.941478\dfrac{rad}{s^2};\ r_{wheel} = 0.332m;\ m_{hanging} = 0.205kg$

$$\sum \tau_{\substack{on\ wheel \\ AoR@axle}} = +\tau_{F_T} = I\alpha \Rightarrow I = \frac{RF_T}{\alpha}$$

$$\sum F_{y_{mass\ hanging}} = F_g - F_T = ma_y \Rightarrow F_T = m\left(g - a_y\right)$$

$$\Rightarrow I = \frac{Rm\left(g - R\alpha\right)}{\alpha} = 0.146800 \approx \boxed{0.147kg \cdot m^2}$$

Does this answer make sense? Recall that, about their center of masses and long cylindrical axes, the rotational inertias of spheres and cylinders were always a fraction times the mass of the object times the radius of the object squared. For example, about their long, cylindrical axes:

$$I_{thin\ hoop} = MR^2\ \&\ I_{solid\ disk} = \frac{1}{2}MR^2$$

I would estimate that this bike tire is roughly halfway between a solid disc and a thin hoop. We could estimate this rotational inertia as

$I_{bike\ wheel} \approx \dfrac{3}{4}MR^2$. Let’s test that:

$$m_{wheel} = 1.96kg;\ R_{wheel} = 0.332m;\ I_{wheel} = XM_{wheel}R_{wheel}^{\ 2} \Rightarrow X = \frac{I_{wheel}}{M_{wheel}R_{wheel}^{\ 2}}$$

$$\Rightarrow X = \frac{0.146800}{\left(1.96\right)\left(0.332\right)^2} = 0.679505 \Rightarrow I_{bike\ wheel} \approx 0.680MR^2 \approx \frac{3}{4}MR^2$$

Notice it would be ***incorrect*** to sum the torques on the whole system at once (wheel and hanging mass):

$$\sum \tau_{\substack{on\ all \\ AoR@axle}} = \cancel{+\vec{\tau}_{F_{T_{wheel}}}}\ \cancel{-\vec{\tau}_{F_{T_{mass\ hanging}}}} + \vec{\tau}_{F_{g_{mass\ hanging}}} = +\vec{\tau}_{F_{g_{mass\ hanging}}} = I\vec{\alpha}$$

This is ***incorrect*** because the hanging mass does not have a rotational inertia about the axis of rotation of the bicycle wheel.

Part B) Determine the force of tension in the string while the wheel is angularly accelerating.

There are two equations we could use to solve for this now:

$$I = \frac{RF_T}{\alpha} \Rightarrow F_T = \frac{I\alpha}{R} = \frac{(0.146800)(3.941478)}{0.332} = 1.742793 \approx \boxed{1.74N}$$

$$F_T = m(g - R\alpha) = (0.205)(9.81 - (0.332)(3.941478)) = 1.742793 \approx 1.74N$$

Notice what happens *before* the wheel is allowed to angularly accelerate, in other words, while the wheel is at rest. Let's sum the forces on the hanging mass.

$$\sum F_y = F_g - F_T = ma_y = m(0) = 0 \Rightarrow F_T = F_g = mg = (0.205)(9.81) = 2.01105 \approx 2.01N$$

The force of tension equals the force of gravity, 2.01N, before the wheel begins to angularly accelerate and then decreases to 1.74 N while the wheel is angularly accelerating.

	Predicted	Measured
at rest	$F_T \approx 2.01N$	$F_T \approx 1.9N$
accelerating	$F_T \approx 1.74N$	$F_T \approx 1.6N$
difference	$\Delta F_T \approx 0.3N$	$\Delta F_T \approx 0.3N$