

Name: _____

Partner(s): _____

Date: _____

Just Torquing Around

Purpose:

In this lab, you will examine the idea of torque. Additionally, you examine the angular kinematic equations.

Background:

Consider the apparatus shown in Figure 1. If the disk, a turntable, is initially at rest, it will begin to rotate. This rotation is caused by a torque that is created by the tension, T , in the string created by the weight of the hanging mass, m . The force due to tension acts at a radius, r , from the axis of rotation.

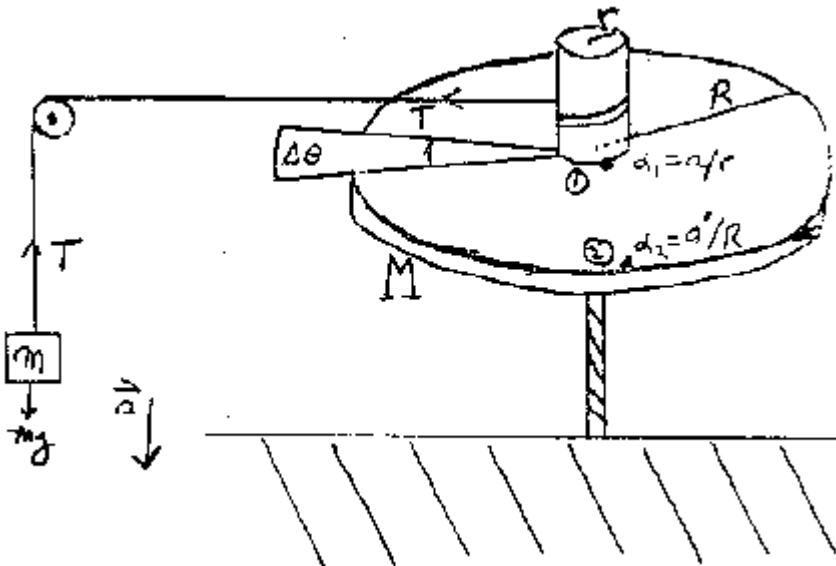


Figure 1

Since the force due to tension acts perpendicular to the axis of rotation, the torque exerted by the force of tension is given by Equation 1, where I is the moment of inertia of the rotating bodies.

$$\tau = I\alpha = rT \quad (1)$$

The tension in the string can be found by applying Newton's second law to the hanging mass.

$$T = mg - ma \quad (2)$$

Plugging this result into Equation 1 yields:

$$I\alpha = mgr - mar \quad (3)$$

By inspection, the linear acceleration of the falling mass in Equation 2, a , is the same as the tangential acceleration of the cylinder where the string is connected. Further, this tangential acceleration is related to the angular acceleration by Equation 4.

$$\alpha = \frac{a}{r} \quad (4)$$

Thus,

$$I\alpha = mgr - m\alpha r^2 \quad (5)$$

From Equation 5, we can now solve for the angular acceleration of the disk in terms of readily measured quantities:

$$\alpha = \frac{mgr}{mr^2 + I} \quad (6)$$

If the apparatus used is such that $mr^2 \ll I$ (and we claim that it is), then, Equation 6 may be further simplified. In the limit where $mr^2 \ll I$, Equation 6 becomes:

$$\alpha = \frac{mgr}{I} \quad (7)$$

As an aside, Equation 7 says that the angular acceleration of the disk is *constant*. As a result, this experiment is the rotational analog of a previous lab, "One-Dimensional Motion". You may wish to refer back to that lab now.

Procedure:

In this experiment, you will measure the angular acceleration, α , of the wooden turntables (a *kinematic* quantity) and compare this measured value with a value calculated from Equation 7 (*i.e.*, based upon *static* quantities).

To obtain an experimental value for α , we *assume* that our system undergoes a uniform acceleration over the duration of the experiment. With this assumption, the motion is described by the angular kinematic equation given in Equation 8.

$$\omega^2 = \omega_0^2 + 2\alpha\theta \quad (8)$$

By measuring the angular velocity of the disk and then measuring it again after one complete revolution, Equation 8 can be written:

$$\alpha = \frac{\omega^2 - \omega_0^2}{4\pi} \quad (9)$$

To experimentally measure the angular velocity, attach a flag of width w , as seen in Figure 1. With the Science Workshop™ software and a photogate using the “Photogate & Solid Object” sensor, you can measure the time that it takes for your flag to pass through the photogate.

The flag that you will attach to the apparatus will pass through the photogate a distance r from the axis of rotation, where the width of the flag is w . Based on this, you can use trigonometry to find the angle, $\Delta\theta$, subtended by the flag as it passes through the photogate. The space below is left for you to do this.

Since the photogate is used to measure the time that it takes the wedge to pass through a photogate, you can calculate the average angular velocity of the disk as it passes through the photogate using $\omega = \Delta\theta / \Delta t$. Based on this, what factors went into your decision for the width of your flag?

Using the average angular velocity of the disk during its passage through the photogate and equation 9, you can compute the angular acceleration, α . At this point, all that remains is a comparison of experimental and theoretical values. For the best results, a series of ω and ω_0 values should be recorded during the descent of the torque producing mass. In this way an average α can be calculated.

Data:

Record the following experimental values below. Recall that m is the mass of the hanging mass, r is the distance from the axis of rotation to the string, $\Delta\theta$ is angle subtended by the paper flag, M_i , R_i and I_i are the mass, radius and moment of inertia of the i^{th} wooden turntable, respectively.

$$m = \underline{\hspace{2cm}} \qquad r = \underline{\hspace{2cm}} \qquad \Delta\theta = \underline{\hspace{2cm}}$$

$$M_1 = \underline{\hspace{2cm}} \qquad R_1 = \underline{\hspace{2cm}} \qquad I_1 = \underline{\hspace{2cm}}$$

$$M_2 = \underline{\hspace{2cm}} \qquad R_2 = \underline{\hspace{2cm}} \qquad I_2 = \underline{\hspace{2cm}}$$

$$I = I_1 + I_2 = \underline{\hspace{2cm}}$$

Record your data below. Recall that α is calculated using Equation 9.

$$\alpha_{\text{average}} = \underline{\hspace{2cm}}$$

$$\alpha_{\text{theory}} = \underline{\hspace{2cm}}$$

$$\% \text{ difference} = \underline{\hspace{2cm}}$$

Initiative:

Possible ideas:

1. List and describe, in detail, all of the torques acting on the disk. Did we neglect any that should have been considered?
2. Determine if we are justified in using *average* angular velocities, when - strictly speaking - our calculation calls for *instantaneous* values. That is, is there anything that could be done to improve the values of ω and ω_0 ? (Hint: see the “initiative page” from the lab on the Work-Energy Theorem).
3. Discuss whether mechanical energy is conserved in this experiment. If not, what fraction is lost? Where is the energy lost?

Conclusions: