AP Physics C - Mechanics

Spring Lab 3 | **"Wait a moment…of inertia…"**

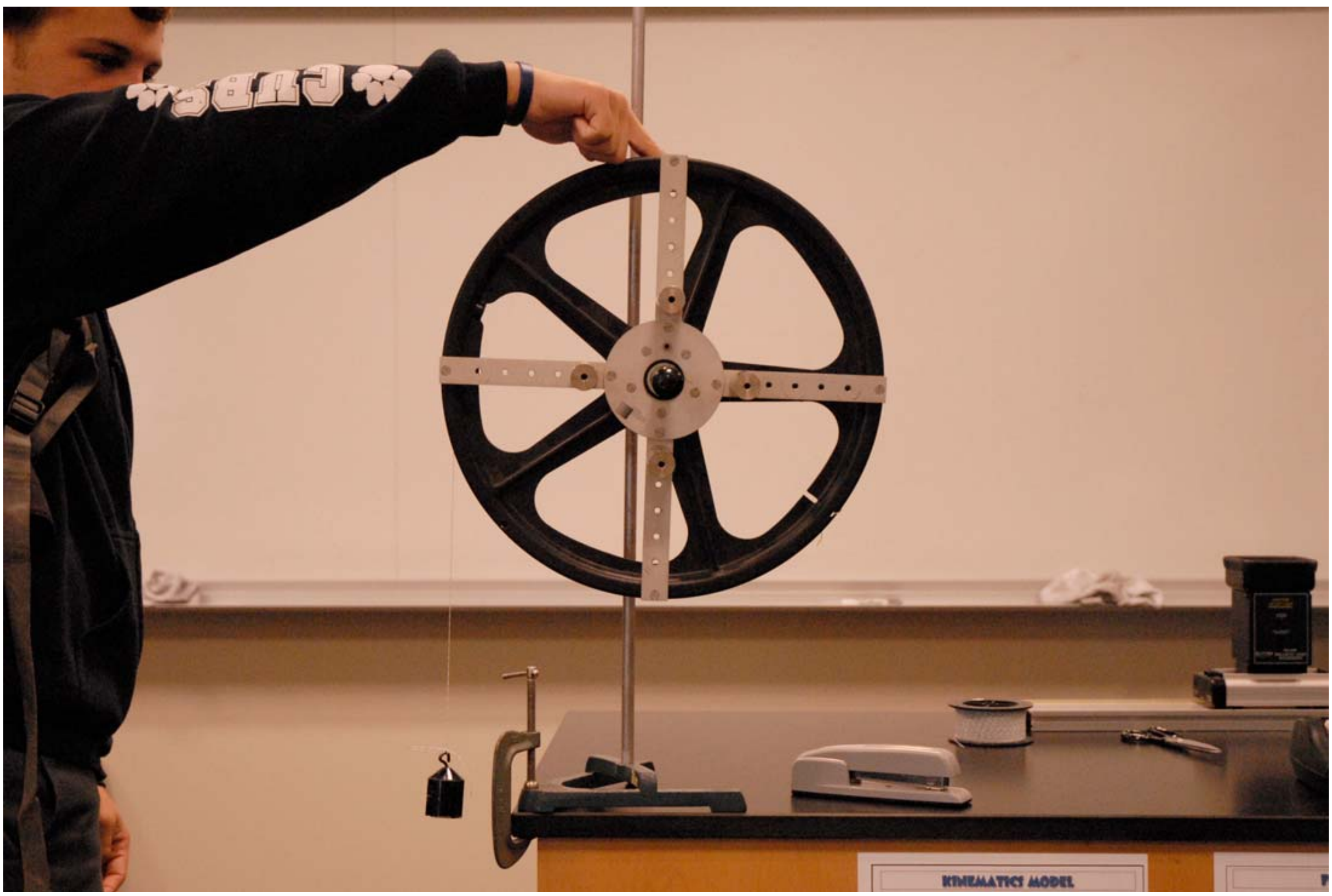
Your Name: ___________________________ Period: _____________________

The Challenge

The challenge for this lab is as follows: Given a rotational inertia for your wheel (placement and/or number of screw-on masses), and a mass on the left hand side of the wheel, calculate the mass needed on the right hand side that will result in a given angular acceleration.

Part A – Torque Revisited

The setup below will be used to analyze torques, rotational kinematics, and moments of inertia acting on the super-rotating wheel of Physics!



Let's start by applying the force model to the wheel…

a. **Draw an FBD for the mass on the left hand side when hanging on a stationary (i.e. non-rotating wheel.) Note the hand that is holding the wheel to keep it stationary. Use m for the hanging mass, M for the mass of the wheel, and F_{hand} for the force on the wheel due to the hand.**

b. **Draw an FBD for the WHEEL.**

c. **Write the ΣF equations for mass m.**

d. Write the ΣF AND $\Sigma \tau$ equations for the wheel while at rest.

e. Derive an equation for the tension in the string holding mass m.

Part B – Torque and motion
This time we'll analyze the wheel while it is accelerating…how will this affect the tension in the string?

For this section assume that the hand is NO longer holding the wheel in place and the mass m is free to fall to the ground.

f. Draw an FBD for m while it is falling.

g. Draw an FBD for the WHEEL while it is being accelerated (angularly) by the falling mass.

h. Write the ΣF equations for the mass m while it is falling.

i. Write the ΣF AND $\Sigma \tau$ equations for the wheel while accelerating.

j. Derive an equation for the tension in the string holding m while it is falling toward the ground in terms of m, g, and a (the linear acceleration of the mass).

k. Derive and <u>equation</u> for I, the moment of inertia of the wheel in terms of m, g, the radius of the wheel r, and the linear acceleration of the wheel.

l. According to your equation in (k) above, what are the units for the moment of inertia I?

PRELAB UNFORTUNATELY ENDS HERE

LAB WORK FORTUNATELY BEGINS HERE

m. **Here we will experimentally determine the moment of inertia "I" (a.k.a rotational inertia) for your wheel or "spider". Perform at least three different trials (with three different masses) to calculate I. Create a data table below to summarize the data that you need to collect in order to calculate I based on your equation in part (k).**

n. **Using your data, calculate the moment of inertia of the wheel for each of your mass distributions.**

p. **Calculate the maximum kinetic energy of the mass m.**

q. **Calculate the maximum "rotational" kinetic energy of the wheel. (Hint: if $K = \frac{1}{2} mv^2$ for object moving linearly, what is your guess for the equation for "rotational kinetic energy"? What are the units for rotational kinetic energy? Perform a dimensional analysis.**

PRELAB 2 BEGINS HERE

PART II – Atwood's Machine

Now that you know the moment of inertia for your wheel configuration, let's build an Atwood's machine. An "Atwood's Machine" is our wheel with TWO hanging masses, one of each side. This setup is used extensively in elevator systems. Below, derive the <u>linear acceleration</u> of the Atwood's Machine in terms of m_1 and m_2, and rotational inertia I (that you found above). Complete in a HW format using correct model. SHOW ALL GORY DETAIL. Hint: You need to draw THREE FBDs…both masses and the wheel.

Part II – Atwood's Machine calculations continued…

PRELAB 2 ENDS HERE

LAB 2 BEGINS HERE

r. **Using your equation for the linear acceleration of the system, perform three trials (with the same masses) to experimentally determine "a". Create a data table below to show the data collected.**

s. **Show the theoretical calculations for "a" and compare to those obtained experimentally. If there is a discrepancy, what factors can account for the differences?**

PRELAB 3 BEGINS HERE

s. In preparation for the Challenge, derive the expression for the linear acceleration of the heavier mass in terms of m_1, m_2, r_1, r_2, and any fundamental constants Complete in a typical HW type format. Use a separate piece of graph paper for this part of the prelab.

Hint 1: Use the Linear/Rotational Force Models

Hint 2: There should be FOUR FBDs, one each for the attached masses m_1 and m_2, and one each for the Wheel and Spider.

III. Lab Debrief (completed individually)

Each of these questions is to be answered with an explanation or justification. Three to four sentences for each question will suffice.

a. Discuss at least TWO concrete things that you learned from this lab.

b. Discuss ONE concrete thing that you still do NOT understand regarding this lab (i.e. torque, rotational inertia, rotational velocity/acceleration, etc.)

c. What was the difficulty level of the experiment? (1-10, 10 most difficult) Why?

d. What was the "fun" level of this experiment? (1-10, 10 most fun). Why?

e. Describe one extension of this lab that would help your understanding of the physics content and increase the fun level of this lab.

f. Create a data table of summarizing the results of your final four trials. The data table should include the mass that was varied, the calculated linear acceleration, and experimental linear acceleration.

g. Create a plot of a_{linear} and $a_{experimental}$ vs. mass (this should be one graph). Be sure to include a chart title, and axis identifiers with units.

h. Explain possible causes of <u>uncontrollable</u> error that could account for the difference between theoretical calculated values and experimentally obtained values. Are there any patterns to the error between your theoretical and experimental values?