AP Physics 1 - Rotational Inertia Lab **Name ______________________**

Objective: To determine examine the rotation and moment of inertia of a rotational apparatus.

Apparatus: String, rotational apparatus, a set of masses, a meter stick, LabQuest, Photogate, laptop, pulley, and/or smart pulley.

Procedure

Part 1:
1. Set up the apparatus, pulley, and photogate as shown in the demonstration model.
2. Set the photogate up in LoggerPro so that it is set on Gate Timing, then set the length to the diameter of the PVC pipe.
3. Hang the first mass on the end of the string, then wind the string around the apparatus until the mass is just below the pulley.
4. Start the recording in LoggerPro, then release the apparatus.
5. Repeat **Procedure 4** to obtain 3 measurements for each of the masses.
6. Change the hanging mass at the end of the string and repeat **Procedures 3, 4 and 5**.
7. Repeat **Procedure 6** until you have obtained data for at least 5 different hanging masses.

Part 2:
8. Take the apparatus apart and measure the mass and length of each piece of PVC pipe in the apparatus, to calculate the theoretical moment of inertia of the apparatus.

Part 3:
9. Go to the back table. Here you will find two identical apparatuses.
10. Wind the string around the apparatuses until the mass is just below the pulley.
11. Release the apparatuses and record any differences you see in their motion.

Theory
When this system is let go, it will accelerate. Since the pulley is very light and virtually frictionless, we will completely ignore it. We can apply the Newton Second Law for the hanging mass and the rotational apparatus. For the hanging mass, draw a FBD for the hanging mass to determine the tension in the string. For the rotational apparatus, use the Newton Second Law for Rotational Motion, $\mathbf{T(r) = \tau = I\,\alpha}$. This is ignoring any friction between the apparatus and the post. The non-slipping condition relates the linear acceleration to the angular acceleration, $\mathbf{a = \alpha\, r}$.

Theoretical estimation of the theoretical moment of inertia
The formulas for the theoretical value for the moment of inertia of the parts of the system are found in our textbook. You can approximate the moment of inertia of the horizontal arm (length L) by either treating it as two rods rotating about their ends [$I_1 = (1/3)m(L/2)^2$] or as one long rod rotating about its center ($I_1 = 1/12mL^2$). The moment of inertia of the vertical PVC pipe can be found using $I_2 = 1/2m(r_o^2 + r_i^2)$. ($r_o$ = outside radius, r_i = inside radius of the pipe). The moment of inertia for the PVC tee can be ignored. The sum of their moments of inertia is I_T. The total moment of inertia is the sum of the individual moments of inertia ($I_T = I_1 + I_2$).

D_0 = 20.67 mm
D_i = 20.07 mm

Data
Now think about what data is the photogate measuring. Describe (*in complete sentences*) 1) the data you will collect (what measurements will you make?) 2) how you will collect the data? (what tools will you use?) and 3) how you will use the data. ***Show any equations you will use to make calculations.*** Record the data in your data table. It is not necessary to copy the entire procedure.

Analyze
1. What is the effect of the net torque on angular acceleration of the apparatus?
2. How is the tangential acceleration at the base of the apparatus different than at the location of the photogate?
3. Sketch an angular displacement vs time and an angular velocity vs time graph for a single trial. Assume the rotation is positive.
4. Plot torque τ versus angular acceleration α on a full sheet of graph paper. Draw a line of best fit through your data. Write the equation for the line of best fit (be sure to include your units).
5. Determine the slope of the line of best fit.
6. What is the significance of the slope of the line of best fit?
7. Determine the theoretical value for the moment of inertia for the apparatus.
8. Compare the two moments of inertia, the experimental value and the theoretical value. Are they matching? Calculate the percentage difference.
9. Discuss a few error sources which could account for any differences in the moment of inertia.
10.Suppose the horizontal pipes on the apparatus were shorter, how would this change the rotational inertia of the apparatus? Explain.
11. Suppose one of the horizontal pipes was shorter than the other. In a single rotation, would the following values at the end of each pipe have the same a) angular displacement? b) tangential speed? c) angular velocity? d) tangential acceleration? e) angular acceleration? Explain your answers.
12. In Part 3 of the procedure, why is the motion of the two apparatuses different even though they are identical in shape.