Pre-Lab: Moment of Inertia [5 pts]

Directions: Read this sheet carefully and answer the questions to the best of your ability. It is essential that you understand the theory discussed here before you begin the associated experiment. Use your answers in the Theory section of your formal report.

Two slotted masses are located at opposite ends of a massless horizontal crossbar of length $2R$. The crossbar is fastened to a massless vertical shaft that can rotate free of friction. The radius of the shaft is $r$. A massless string is tied to the shaft and passes over a frictionless pulley. The opposite end of the string is tied to a mass $m$ that is initially at rest a height $h$ above the floor. When the system is released, the shaft accelerates about its axis $A$ at the same rate that the hanging mass falls. The angular acceleration $\alpha$ of the shaft is related to the linear acceleration $a$ of the hanging mass by the formula $a = r\alpha$.

Use your kinematics equations, Newton’s laws, and error propagation formulas to answer the following questions:

1. Show that the total moment of inertia of the shaft-crossbar-slotted masses system about axis $A$ equals $2MR^2$.

2. Show that the net torque acting on the vertical shaft equals $rm(g - a)$, where $a$ is the linear acceleration of the hanging mass.

3. Given the hanging mass starts at rest at height $h$ and reaches the floor in time $t$, derive an expression for the linear acceleration $a$ of the hanging mass.

4. Given the error in mass $\delta M$ and radius $\delta R$, derive an expression for the propagated error in the total moment of inertia formula in Question 1.

5. Show that the relationship between the net torque $\tau$ acting on the shaft and its angular acceleration $\alpha$ is linear; that is, $\tau = (slope)\alpha$. Find the physical quantity represented by the slope.