HOOP AND ENERGY LAB

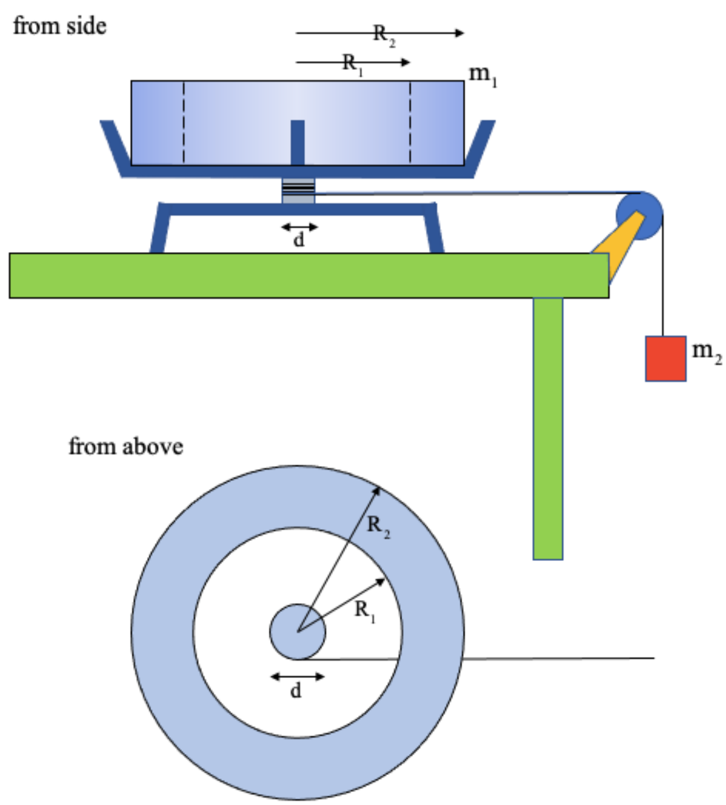
Background: If we are clever, gravitational potential energy can be used to motivate a massive hoop (supported by a rotatable stand) to angularly accelerate. This lab is designed to give you the opportunity to see how energy considerations can be used to evaluate such a system.

A string. wound around the hub of a rotatable support upon which resides a massive hoop, will be threaded over a pulley with its other end attached to a hanging mass, as shown in the sketch. The Tracker software will allow the viewer to extract from a video of the descending hanging mass a *velocity versus time* and a *position versus time* graph for the motion. With that and the moment of inertia for the hoop, we should be able to compare the theoretic velocity of the hanging mass after dropping for some period of time to the actual velocity observed.

Equipment: The video is found at
http://faculty.polytechnic.org/physics/3%20A.P.%20PHYSICS%202009-2010/06.%20rotational%20motion/4. labs/moment%20of%20inertia%20lab.mp4

In it, you will notice:

A platform that can rotate about a central axis;
A massive cylindrical hoop;
A hanging mass;
A “massless and frictionless” smart pulley;
String;
A meterstick;



PLEASE NOTE: At the end of the video, it will say you will need to derive the hoop’s *moment of inertia* using Calculus. You may ignore that statement.

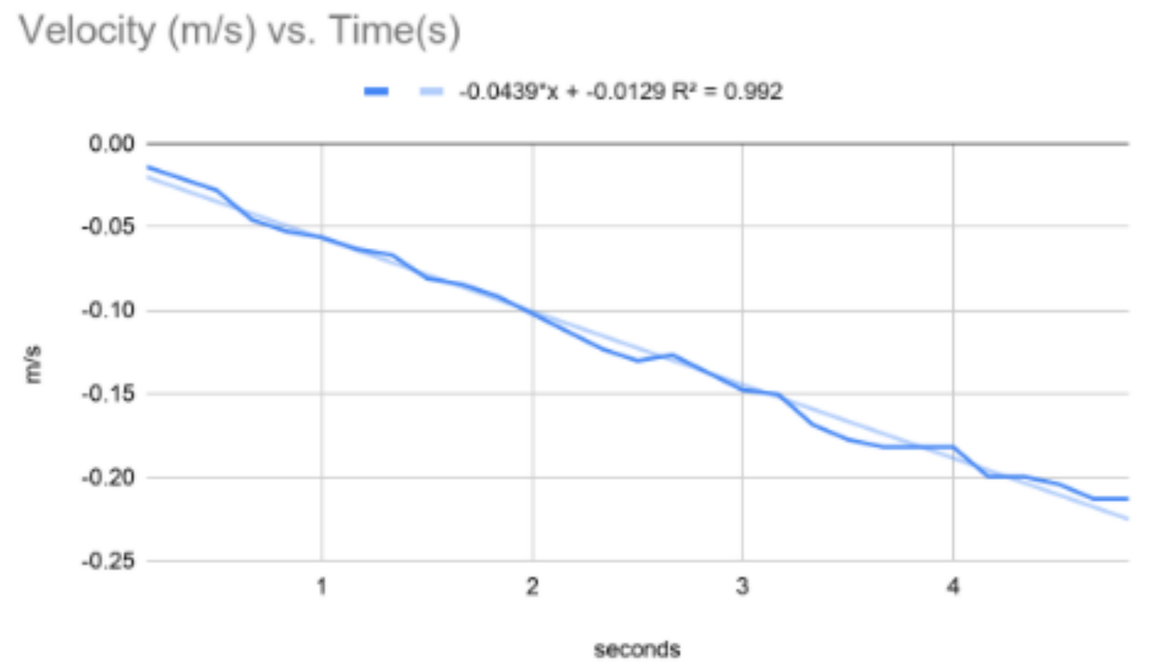
Data to be Collected from the video:

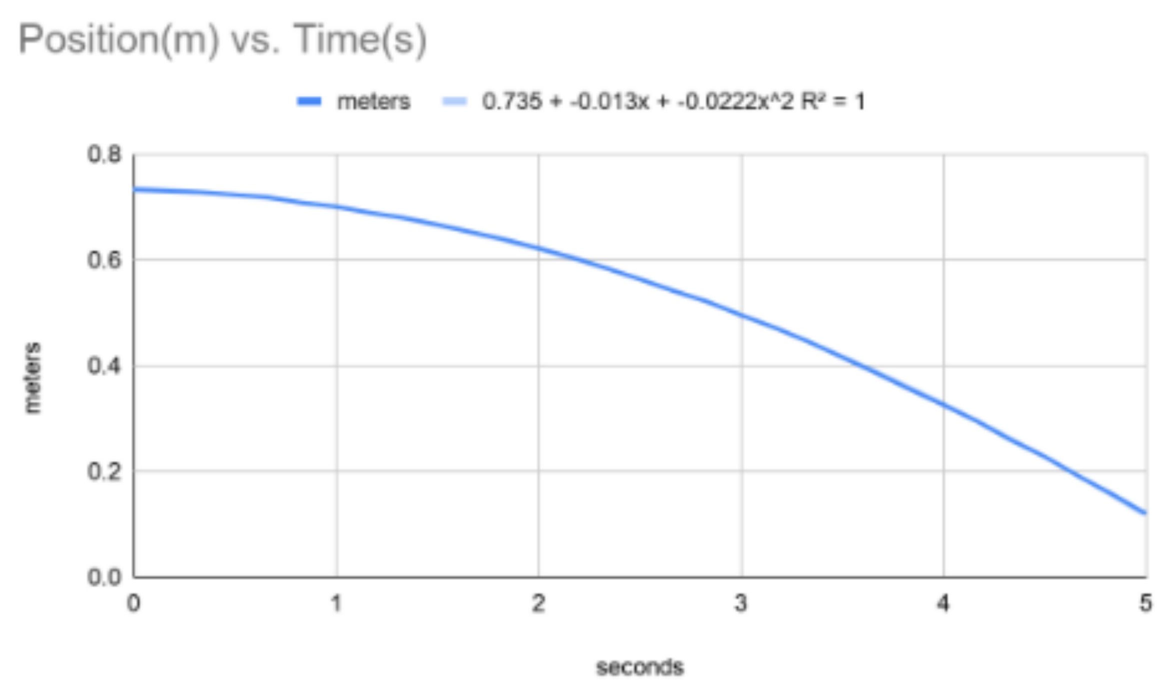
The inside and outside diameter of the hoop, from which you can calculate the inside and outside radius (to make life easier, though you should check the video to be sure I haven’t goofed, the diameters are: inside diameter $d_1 = 22.8\text{ cm}$ and outside diameter $d_2 = 25.35\text{ cm}$).
The mass of the hoop (available from video);
The mass of the hanging mass (available from video);
The radius of the platform’s hub (this is what the string will be wrapped around--available from video);
Use of the Tracker software (view the cheat sheet to remind yourself of how to use the software) and a Google sheet (or Excel spreadsheet) to generate a *velocity vs time* and *position vs time* graph of the hanging mass’s motion as it freefalls (the cheat sheet covers this, also, and remember, it can be found in a document in the TOPICS folder of MyPoly).

Calculations:

Part I. Generating data

1.) Identify and list from the video (appropriately labeled) the mass of the hoop and the mass of the hanging mass.
2.) List the hoop's inside and outside diameter, and from that determine the inside and outside radii.
3.) The Tracker software was used to generate a *velocity vs time* and *position vs time* graph for the run. Those graphs are shown below. You will need bits and pieces of information from these graphs throughout the lab. (As always, you will want to take all your data off the *best fit line* provided on each graph.)





Part II. Analysis using Energy Considerations

4.) We would like to see if the *conservation of energy* really works in a rotating system. Assuming the hanging mess is initially moving with some known speed v_1 (which suggests the hoop is initially rotating with some angular velocity ω_1), start with the generic conservation of energy expression (you know, $\sum KE_1 + \ldots$ etc.) and derive a general algebraic expression for velocity v_2 of the hanging mass after it has dropped a distance "h." You may assume that the *moment of inertia* of the hoop is $\frac{1}{2}M\left(R_1^{\ 2} + R_2^{\ 2}\right)$, where M is the mass of the hoop and the R values are the inside and outside radii, respectively.

Part III. Checking to See If Theory Matches Experiment

5.) Go to the *velocity vs time* graph. Pick a point in time t_1 toward the beginning of the run. Using the *best fit line*, take the velocity associated with that time and call it v_1.

6.) Again using the *velocity vs time* graph, pick a second point in time t_2. Pluck the velocity for that point in time and call it v_2. (Note that you will be comparing this value with the one you will be calculating via the v_2 expression you derived using the energy considerations in Part 4.)

7.) Go to the *position vs time* graph and determine how far the hanging mass traveled between times t_1 and t_2. Call that displacement "h."

8.) In Part 4, you derived an expression for the hanging mass's velocity v_2 after falling a distance "h" using the conservation of energy. That expression for v_2 should have been in terms of the initial velocity v_1, the hanging mass m_h, the hoop's mass M, the hoops inside and outside radii R_1 and R_2 and "h." Use the numerical values for all of those quantities and your conservation of energy relationship to determine the theoretical value for v_2 for this situation.

9.) You now have to values for v_2, one theoretical from the calculation in Part 8 and one from the graph in Part 6. Do a % deviation between the two, assuming the value from the graph is the accurate value (that is, compare the two using that value as the base with $\%\ \text{dev} = \left(\frac{\text{part8} - \text{part6}}{\text{part6}}\right) \text{x}100$)

10.) Comment on your results, and on what they say about the conservation of energy in rotating setting.