MOMENT OF INERTIA LAB

Background

The first thing you need to know is that this lab is replacing a lab—the rolling objects lab—that has historically had ten page write-ups and was worth 100 points. In other words, it was a major endeavor. This lab will be similar. It will not be as arduous in a spreadsheet sense, but it will test your understanding of Newton's Laws, energy considerations and the definition of *moment of inertia*. We will also expect it to be Word Processed with equations generated using an equation editor (MathType or LaTec or whatever you have available). An example of what the write-up should look like will be presented during lab.

Objective

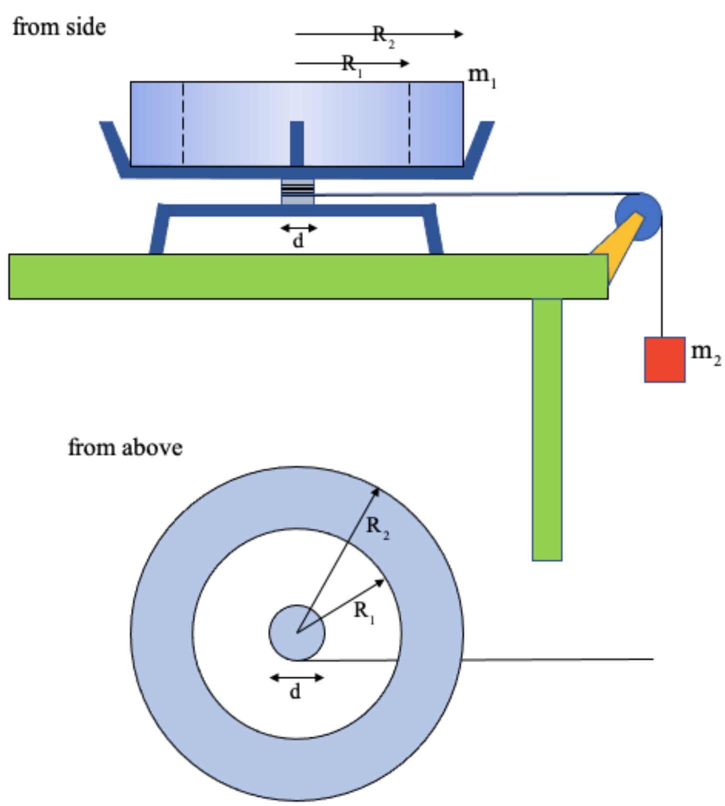
As innocuous as this is going to sound, we want to derive an expression for the *moment of inertia* of a massive cylinder using several approaches. You will additionally need to use the Tracker software to take data from a video and a spreadsheet to evaluate the data.

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 smart pulley (assumed to be massless and frictionless);
- String;
- A meterstick;



Data to be Collected from the video:

- The inside and outside radius of the hoop;
- The mass of the hoop;
- The mass of the hanging mass
- The radius of the platform's hub (this is what the string will be wrapped around);
- Use of the Tracker software (go here for a cheat sheet reminding you 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)

Procedure: This lab has four parts. The middle three will find you deriving expressions for, then using accumulated data to determine the *moment of inertia* of the cylinder. The last section will ask you to make comparisons and commentary about the three techniques.

Part I. Generating data

Look at the video provided. Extract from it as much information as possible. Once done, use the Tracker software on it to generate *velocity vs time* and *position vs time* graphs (this will entail taking the data from the Tracker software and put it into a Google sheets or Excel Spreadsheet program). You will need bits and pieces of information from these graphs throughout the lab.

Part II. Analysis using Newton's Laws

Derive a general algebraic expression for the *moment of inertia* of the hoop using Newton's Second Law. Once you have your expression, use the data collect in Part I to determine a numerical value.

Part III. Analysis using Energy Considerations

Derive a general algebraic expression for the *moment of inertia* of the hoop using energy considerations (and kindly note, the initial velocity should NOT be zero). Once you have your expression, use the data collect in Part I to determine a numerical value.

Part IV. Analysis using the integral definition of moment of inertia

Derive a general algebraic expression for the *moment of inertia* of the hoop using the definition of moment of inertia, or $\int r^2 \, dm$. Once you have your expression, use the data collect in Part I to determine a numerical value.

Part V. Evaluation of results

1.) Labeling well, present the three moment of inertia values you determined above.
2.) How did the two experimentally determined values of I (the one determined using N.S.L. and the one determined using energy considerations) compare (I'd do a numerical comparison)? Comment.
3.) The theoretical value was the value you determined using $\int r^2 \, dm$. How did it compare to the experimental value that was farthest from it? Comment.
4.) There is a very good reason why you would have expected the theoretical value to have been less than the value you actually measured using either of the two experimental approaches. What was it?

Questions

As listed above.

Additional Notes

The report for this lab experience must be presented in word-processed form, and will include:

- **Text**
  Please use a black, serif font, 11-14 point, single or double column.
- **Graphics**
  Graphical images are necessary for free-body diagrams. Please avoid unnecessary shadows. Include labels as appropriate. You can create these directly in Word documents, or you can use a PowerPoint file to create them, then insert them into your Word document as a screen shot.
- **Equations**
  Used for mathematical derivations, calculations.
- **Data Tables**
  These are presented in table or spreadsheet form, with relevant data only.
- **Graphs**
  Each graph should be a minimum half-page per graph, and generated by computer based on spreadsheet analysis, Python program, Desmos software, etc. Please include regression formula for your data on graph.

Your final report will likely run 7-15 pages with cover page, and will be submitted in electronic form (PDF) to Google Classroom.

Report-generating Tools

Students with access to Microsoft's *Office* suite might use that as their foundation for this assignment. A Word document will be used for the report, with drawings produced in PowerPoint and imported in, equations created using Equation Editor, with data tables and graphs created using Excel.

An open-source equivalent is *LibreOffice*, which is available for Windows, Apple, and Linux machines. Apple's *Pages* and *Numbers* packages may be used as well, and Google's *Docs* tools can handle most/all of these requirements. Students have also used LaTeX and InDesign for these reports, although that's overkill for most people.

Make backups of your digital Data

There is a significant risk of running into problems with your data during this assignment. If you don't have a system for keeping backups of your data, now is a good time to figure one out. You might want to consider keeping multiple versions of your documents around as well. Using Google *Docs* can help solve some (but not all!) of these problems.

INSTRUCTOR NOTES:

Why this report? It was originally developed (by Richard White) to:

- help students review important material for this unit
- give students the opportunity to gain some experience in using spreadsheets for analysis, drawing tools for graphics and equation editors for the generation of equations in reports.

Since its inception, there has been positive feedback on the assignment, both from current students who enjoy turning in a more extensive lab report in a more polished form, and from alumni who state that the skills they picked up while completing this assignment served them well in college.

The day that the assignment is due we usually spend 15-20 minutes debriefing the process, and sharing stories of lost data, etc.

Possible rubric for assessing written reports:

ITEM	COMMENTS	POINTS VALUE
Set-Up	Is there a labeled diagram of set-up, etc.	10
Procedure	Is the experimental procedure outlined in sufficient detail?	10
Free-body diagrams	Appropriately drawn	10
Development of equations	F_{net}/Torque analyses; Energy analyses; definition analysis	30
Data tables of results; graphs	a position-time and velocity-time graphs with	20
Sources of Error; Conclusion	Appropriate discussion of sources of error	15
Overall quality of report	Cover page, consistency in formatting, use of colors/gradients, etc.	5