Lab: The Motion of Rolling Object AP Physics

Background
Objects that roll without slipping down an inclined plane can be analyzed using Force/Torque concepts, or using Energy (translational and rotational) concepts. In this extended lab, you'll be using both approaches to predict the theoretical motion of a hoop, a disk, and a sphere as they roll down an inclined plane. You'll then collect experimental data to verify or refute your predictions.

Objective
To theoretically predict the motion of a hoop, a disk, and a sphere down an inclined plane, and to verify your predictions by experiment.

Equipment
To be determined and described by you

Procedure
Part I. Theoretical Development

Using first Force/Torque concepts and then Energy (translational and rotational) concepts, develop equations that yield **position**, **velocity**, and **acceleration** as a function of **time** for three different objects rolling down an inclined plane: a hoop, a disk, and a sphere. It won't be surprising to find that at least two other variables—angle of incline θ and acceleration due to gravity **g**—appear in your equations. Perhaps mass m and radius R of the objects will be a factor as well?

Likewise, it shouldn't be surprising to find that the two different approaches yield identical equations. For this reason, in your write-up you'll need to be extremely clear in showing your *development* in both approaches.

Part II. Experimental Confirmation

Perform experiments and collect data that will allow you to verify or refute your theoretical predictions. Again, because each group will be performing experiments of their own design, you'll need to be *extremely clear* in describing your experimental set-up and procedure. Lists of equipment used, data tables of data collected, and photos or diagrams of your set-up should all be part of the laboratory documentation.

Part III. Reporting Results

You will be preparing a word-processed report as your lab write-up (see further details below). Your results should be reported both as data tables and as a series of three graphs—one for each type of object rolled down the incline—with two lines on each: one predicted by your calculations, and one of your experimental results. These graphs should include the functions that are being displayed in the body of the graph itself—your predicted equation and the best-fit model of your collected data—and (obviously) include labels and units on x– and y–axes, as well as a title.

You'll also want to report the percent error between your predicted acceleration and your measured acceleration, which is easily determined from a regression of your data's trend-line.

We expect that our experimental data will vary somewhat from our theoretical predictions. Is there a systematic variance between the two? How much error or uncertainty will be acceptable to you in this lab? Do you have reasonable explanations for any error?

Questions
As listed above.

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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.
- **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 paper form (stapled) and electronic form (PDF).

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.

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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 and drawing tools for graphics.

Since then, 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	3 F_{net}/Torque analyses; 3 Energy analyses	20
Data tables of results; graphs	3 position-time graphs, with both theoretical and experimental lines displayed	20
Sources of Error; Conclusion	Appropriate discussion of sources of error	20
Overall quality of report	Cover page, consistency in formatting, use of colors/gradients, etc.	10