# 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 3-week 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 $\theta$ 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, 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.

*Part III. Reporting Results*

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 trendline.

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.

**Additional Notes**
In **Excel**, use grid lines around your data to help keep it visually organized. Be sure to set units and appropriate significant figures for columns. You can copy/paste Excel data cells into Word documents.

Use **Excel** to create graphs of data for each of your rolling objects. Your graph should include both a best-fit line for your data, and superimposed on that the predicted function, based on your theoretical analysis. See a follow-up document, the online video tutorial, or the instructor in class for info on how to do this.

Regarding *graphs*: larger is better. For this assignment, graphs should take up *at least* half a page, and preferably a full page.

Most students will choose to use Microsoft's **Word** for their document. In Word, you can use the Drawing toolbar and the grid to help keep objects in your drawings aligned with each other. Use *text boxes* (without borders) liberally in your diagrams to label key components. Feel free to paste digital photos into your document, where appropriate. Use Equation Editor (it comes with Microsoft Office as an optional install) to insert equations and mathematical developments, and blurb extensively so that we can identify important steps in your development.

You may use other applications as well: OpenOffice, LibreOffice, GoogleDocs, Apple's **Numbers** and **Pages**,, LaTeX, etc., all may be used more or less successfully for analyzing your data, making drawings, and writing your report. The instructor will support you in using these alternatives as far as experience allows.

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