Physics 121 Lab Fall 2009: Extra Credit Project

TA: Kristina Nyland
Due: Friday, December 11, 2009
Points Possible: 50

Overview

You will be investigating the effect of mass distribution on a water bottle's velocity as it rolls down a ramp. To do this, you will compare three different water bottles filled with:

1. Air
2. Water
3. Ice

This experiment sounds simple at first but in order to explain your results you will need to have a good understanding of **moment of inertia**. You will also be building your own equipment and either documenting or presenting your results.

What you will need

The basic idea is to obtain 3 identical water bottles filled with the three different substances listed above and roll them down a ramp. The goal is to determine the velocity of each bottle so that we can answer the question: **which bottle rolls the fastest and *why?***

You will need 3 water bottles, a ramp, a stopwatch, a length measuring device (tape measure or meter stick), a protractor (you may also measure the angle of your ramp with trigonometry if you prefer) and a camera for documenting your set-up. You will also need to obtain the mass of your empty water bottle. You may do this by bringing an empty water bottle to class on December 1st and weigh it there, come up with some reasonable estimate, or find a scale on your own (maybe one at a grocery store?). Remember: no "American" units - SI units only. You'll need to figure out how to convert the volume of the water into an approximation for its mass (the Internet should be useful in figuring this out).

The ramp will involve some mild engineering. I leave it to each individual group to come up with a good apparatus. You will explain how you built your ramp and the pros and cons of your design in your report.

The Rules

- You can work with one other person (no groups bigger than 2 people).
- Each group member must type up their own report. The report must be neatly stapled together or I will not accept it. You may neatly leave space in the written report for hand-written equations if you do not have a good equation editor available with whatever software you use.

- You must document your experiment. This means take pictures of your set-up and include them in the report. You could even make short movie clips of the bottles rolling down the ramp and use some video editing software to measure the times each took to reach the bottom. Taking video is not a requirement, just an option (but if you do make video clips you should give me a copy on a DVD or via email).

Format

The format for this extra credit project is a bit different than that of the standard format for my lab reports. This is because you will be writing the lab itself along with a detailed report. Here is the format you will need to follow for full credit:

- **Introduction** Give some general background on the experiment you are performing. *Explain in words what moment of inertia is and how it affects the motion of a rotating object* (as moment of inertia increases, does the velocity of the rolling object increase or decrease?). Think about what would happen to a bottle filled with a **liquid** as it rolled down a ramp. Would the liquid move at the same angular velocity as the bottle and if not would its angular velocity be smaller or larger than the bottle's? How would the liquid's motion affect the moment of inertia of the bottle?

  Also discuss the basic principles behind objects rolling down ramps. Some specific questions to address are: What is the difference between an object sliding down a ramp and an object rolling down a ramp? How does the angle of the ramp affect the object's velocity? **Support your answers with equations/diagrams** (equations for moment of inertia and total energy in terms of all of your variables, equations for angular momentum, etc. would be good here). I have notes on the equations at the bottom of this list of requirements. It is ok to research these topics to help you answer the questions I have asked and properly introduce your subject material as long as you include references.

- **Hypothesis** What do you think will happen and why? Try to write this part of the report before you do your experiment and support your theory with what you learned from writing your introduction.

- **Equipment** Make a list of all equipment required for your experiment.

- **Apparatus**
  Include a detailed image (from a camera) of your apparatus and label all of the important parts (either by hand or with software). Please also describe how you built your ramp and what considerations you did/did not take into account.

- **Free Body Diagram**
  The forces acting on each water bottle will be basically the same, so just include one generic FBD. Important forces to consider: gravity, friction (make sure I know what TYPE of friction it is - kinetic or static), and the normal force. Also include a velocity vector pointing in the direction the bottle is rolling and label the angle of inclination of the ramp.

- **Procedure**
  I will not be giving you a procedure for this lab. Instead, you will be writing me a step-by-step description of what you did as if you are writing an experiment to be used in a lab manual. Try to make your procedure understandable. Keep in mind aspects of your lab manual which you did not like or found confusing and try to make YOUR lab easier to follow.

- **Data**
  Organize your data in a table(s)! You should perform multiple trials for each experiment. Your (typed) data table(s) should show the result of each trial and then an averaged result for each experiment.

- **Graphs**
  Please include a graph(s) to compare the results of your experiments. Exactly how you do this is entirely up to you. It's your job to come up with something that reflects the results of the experiment.

- **Error Analysis** What errors were present in the lab and what effect(s) did they have on the outcome of your experiments? Were there some error factors that affected one experiment more than another? Remember - "miscalculations" aren't physical errors, so think about other sources of error. Please also include the relative error between the fastest and the slowest bottle.

- **Discussion** What were your results for each experiment? Were they what you expected (and why or why not)? What did you learn from these experiments? Do you think this was a useful experiment?

- **References** This is an extra credit project and you are welcome to research the topic as much as you like. Please cite any references you use in this section. You may use textbooks, Internet resources (Hyperphysics is a good one, for example), etc. Use standard MLA format (but don't worry about including the references in the text).

Notes on Equations to Include in your Introduction:

1. The moment of inertia of each water bottle (think about what type object the bottle approximately resembles based on what's inside (i.e., is it like a hoop? a disc? something in-between?). If you can't get an "exact" equation for the moment of inertia of one of the bottles (hint: the water bottle) give me a general form like this:

$$I_{substance} = \kappa m_{rotated} r^2 \tag{1}$$

$$a < \kappa < b \tag{2}$$

   where κ is some coefficient of the moment of inertia (not to exceed 1 for this experiment!) and $m_{rotated}$ is the mass that rotated *with the bottle* and contributed to the moment of inertia. Think about what values, a and b, that κ lies between.

2. The total energy of the system. Remember, $E_{tot} = K + P$ and $K = K_{translational} + K_{rotational}$. Be careful about the mass you use in different parts of the total energy equation. HINT: for the bottle filled with water does the entire mass of the water contribute to the moment of inertia?