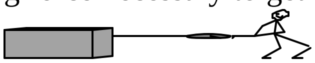
Lab M07: A Study of Sliding Friction **PH305 10/29/03**

Equipment needed per group:

1 large cardboard box with a hook or string attached on one end
several textbooks (identical if possible) with a large loop of cord
1 large force scale
different level surfaces large enough to drag the box across for at least 2 meters

Introduction:

Whenever one object is dragged across the top of another, sliding (kinetic) friction acts on the surface of each object. The size of the sliding frictional force is determined by the characteristics of the two surfaces and the normal force each surface exerts on the other. The sliding frictional force on each surface always acts opposite the direction of relative motion of the surface. In this investigation the bottom of a cardboard box will serve as one surface. The box will slide across various other surfaces which may be different floor coverings or tabletops. You will vary the total weight of the box and provide the horizontal pulling force necessary to get the box sliding and then to slide the box at a constant velocity.



Goals:

- To study how the pulling force necessary to
  a) get the box sliding across a level surface depends upon the weight of the box.
  b) drag the box at a constant rate across a level surface depends upon the weight of the box.

- To study how different surfaces affect the pulling force necessary to drag the box at a constant rate across the surface.

Collecting the Data:

1. Weigh the empty box. Weigh 2 books. Load the box with 2 books. Lay the books flat in the box.

2. Attach the force scale to the box. Horizontally pull on the loaded box just a little, then a little harder, and a little harder, paying attention to the force scale reading. Record the maximum force you can apply before the box just starts to move. Now pull the box at a constant velocity across a level surface while reading the pulling force. Be sure to keep the pulling force completely horizontal and constant or the force reading will be misleading. Try not to jerk on the box as it may tear the cardboard.

3. Record total weight of the loaded box, the maximum force you can apply to the loaded box before it slides and the force to slide the box at constant velocity in your data table. Record three trials.

4. Add 2 more books to the box to change the weight of the box. Repeat steps 2-3.

5. Repeat steps 2-4 until you have 7 data sets spread throughout the range of your force scale. Try to evenly distribute the books in the box for each trial.

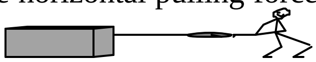
6. Repeat the above steps for a second and a third level surface. Your teacher will tell you what surfaces to use.

Data Analysis:

1. Create a graph with ***sliding friction force*** on the y-axis and ***normal force*** on the x-axis. Use your measurements and the results of your prelab problem to determine the values you should graph.
2. Plot the data for all three surfaces on the same set of axes.
3. Fit the points of each of the three data sets with a straight line—there will be 3 straight lines on the graph.
4. Print out the fitted graph. Be sure the equation of fit to each line is printed on the graph and all labels and an appropriate title are included. This printout must be handed in with your report.

Lab M07: A Study of Sliding Friction-----PRELAB

Name________________________________
block ________

You provide the horizontal pulling force necessary to get the box sliding slide the box at a constant velocity. 

1. Construct the force diagram for the box sliding at a constant velocity across the floor. Remember, no stubby force arrows and all force arrows must be appropriately labeled.

2. Because this is a 2-dimensional situation, you need a net force equation for each of the dimensions…..

a) Write the net force equation for the vertical dimension.

b) Write the net force equation for the horizontal dimension.

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Lab Report

My name ____________________
Block _________

Partner's name ______________
Date ________

<u>Data:</u>

Surface 1:

Average Maximum pulling force with no sliding (N)	Total weight of loaded box (N)	Constant velocity Pulling Force (N)

Surface 2:

Average Maximum pulling force with no sliding (N)	Total weight of loaded box (N)	Constant velocity Pulling Force (N)

Surface 3:

Average Maximum pulling force with no sliding (N)	Total weight of loaded box (N)	Constant velocity Pulling Force (N)

Conclusions and Interpretations:

1. In your own words, without referring to the data, describe what was different about the three surfaces used in this activity.

2. Now look at the graph for each of the surfaces separately. Describe the <u>shape</u> of the graphical relationship between friction force and normal force on the box for each surface.

3. Now compare the three data sets. Describe what is different about the three lines on the graph. How does this relate to your answer for number 1? Be specific.

4. What are the units of the slope for each of the graphs?

5. How was the normal force on the box determined for each trial? How was the kinetic friction force for each trial determined? Explain. Hint—you should use your prelab to answer this.

6. Write the translation table relating the math and the corresponding physics equation for <u>each graph line.</u>

Surface 1 ____________________ Surface 2 ____________________ Surface 3____________________

Math symbol	Physics symbol	Graph fit value	units	Math symbol	Physics symbol	Graph fit value	units	Math symbol	Physics symbol	Graph fit value	units

7. What is the <u>meaning</u> of the slope for each of the graph lines—what physics quantity does it represent?

8. How does the minimum pull force needed to just <u>start</u> the box sliding compare to the force necessary to keep the box sliding at a constant velocity? Why?

9. A) If you were horizontally pushing the weighted box across a floor and then you stopped pushing, describe what happens to the box? Why? How long would it take? Construct the force diagram for the moving box with your pushing force <u>removed</u>.

B) Would your answers to A) depend on what surface the box was sliding across? Why?

10. If your box were on a perfectly frictionless surface, how much pulling force would be required to keep it sliding at a constant speed? Why?

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Teachers Notes

<u>Before doing the lab....</u>

- Get students familiar with the force scales and help them get some feeling for Newtons as a unit of force. Let them pull on the scales with their hands to produce various readings on the scale. Maybe hang one of their textbooks by a string from the force scale to determine the weight of the book in Newtons.

- Try a run through of the experiment yourself to determine:

what range of weight is reasonable for the box and the students. 2-10 books? 1-7 books? Decide by keeping in mind that you don't want the box too heavy for the students to move or so heavy that a hole gets ripped in the box as they try to pull. Modify the write-up to match your needs.

what surfaces in/near your classroom give consistent results. A uniform surface gives more steady force readings. Find at least two (hopefully three) surfaces that differ from one another in roughness. Some ideas...smooth tile, rough cement, wooden table top, table top wiped with furniture polish.

- Decide how the graph will be produced so you can provide the necessary materials. If software expertise is required, prepare the students beforehand if possible.

<u>Equipment hints....</u>

- Xerox boxes are a good size for this activity and are often available in the school setting. Liquor or produce boxes from the market should also work.

- Have some duct tape on hand in case you have to patch up a ripped box.

- Small flat-bottomed metal mass hangers (also called weight hangers) slid through a small hole at the end of the box make great hooks for attaching the force scale. (If you don't find these in the physical science supplies, have a look in the physics supplies.)

- Some people find the metal pull loop on the force scale is painful to the fingers. You can use a short pieces of rope, nylon webbing, or a rag to run through the loop and use as a "handle".

<u>Problems to look for....</u>

- A non-horizontal pulling force will give poor data.

- A non-constant pulling speed will give poor data. Instruct the students to be gentle. To get good results they need pull <u>only hard enough</u> to keep the box moving at a steady rate. They should not be finding out just how fast they can move the box!

<u>Results to hope for....</u>

- The data for each surface should be linear although the points might not line up <u>exactly</u> along a line.

- The roughest surface should yield the steepest graph while the smoothest surface should yield the least steep graph.

<u>Extension activities....</u>

- Try the activity with several ball bearings, wooden dowels, or metal rods between the box and the floor to investigate how rolling friction compares to sliding friction.
- The last question in the write-up could spiral back to or lead into Newton's First Law which deals with inertia.