Experiment 5

Coefficient of Static Friction

Equipment List: 15 nickels, 1 sheet of printer paper (or similar), approximately a 4 inch wide piece of plain aluminum foil (torn off of the roll), a hardback book, tape, cell phone with Phyphox app installed.

In this experiment you will explore more about forces. You will use the cover of a hardback book as an inclined plane to slide a paper box, holding nickels, down the cover of the book. Depending on the two materials that are sliding against each other, there is so much friction force between the two materials.

When a force is applied to an object, to slide it across a surface, there is an opposing frictional force keeping the object from moving. Well, up to a point. The more force that is applied to the object, the more frictional force will oppose the applied force until the force applied exceeds the maximum amount of frictional force that can occur. Once the applied force exceeds the maximum frictional force then the object will begin to slide across the surface. This maximum amount of frictional force is dependent upon the two materials that make up the object sliding and the surface the object is trying to slide across.

This experiment is focusing on determining the coefficient of static friction. You will determine the maximum amount of force necessary to “break” the static friction to cause the object to just start moving. This maximum amount of force will then be used to determine the coefficient of static friction.

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Normal Force

Component of Weight Force into the Plane

Component of Weight Force down the Plane

Weight Force

Frictional Force

As the angle Ɵ increases (by slowly opening the cover of the book), the component of the weight force down the plane will increase. This is the force applied to the object as discussed above. Once the angle is large enough, causing the applied force (component of the weight force down the plane) to be large enough (maximum value), the paper box holding the nickels will begin to slide. Take note of this angle and record it in the Excel worksheet. You will use your cell phone with the Phyphox app opened and use the “Inclination” feature located in the **Tools** section.

The relationship for the Coefficient of Static Friction is as follows:

The Applied maximum Force (component of weight force down the plane) is determined by knowing the maximum angle achieved, just as the box begins to slide, and the weight of the nickels (weight force).

The Normal Force is equal in magnitude, but opposite in direction to the component of the weight force into the plane. So, the Normal Force can be determined by:

Notice, that in our particular experimental setup, in mathematically determining the coefficient of static friction, the ratio of the maximum Applied Force to the Normal Force results in:

**Making a Folded Paper Box**

You will need a small square sheet of paper, 2-3/4 inches on each side. If you take a sheet of printer paper, 8-1/2 inches by 11 inches, fold it in half…

Save this side

Now, either cut the paper in half along the fold, or carefully tear along the fold to get a half sheet. Fold this half sheet into half again. Cut or tear along this fold. You now have a piece of paper that is 2-3/4 inches wide. To make a square, fold one corner over to meet the other side and mark where the bottom of the triangle meets the paper. Cut, or tear, along the line and you now have a 2-3/4 inch by 2-3/4 inch square to make your paper box. Save the other half sheet of paper to tape to the cover of the hardback book.

a b c d e

a. Fold the paper in half along one axis, unfold, then fold the paper in half along the other axis, and unfold.

b. Flip the paper over and fold the each corner in to the middle.

c. All 4 corners are folded in.

d. Fold one side in to the middle and unfold. Fold the other side in to the middle and unfold.

e. This shows the fold lines.

From this point your lab instructor will help you complete the box.

f g h i

f. Now fold the other side, and its opposite side, in to the middle, and unfold.

g. This is what the folds look like now.

h. Unfold the opposite two sides (does not matter which opposite sides you choose).

i. At this point it is difficult to draw how you will bring up the sides of the box and fold over the ends to complete the box. Your lab instructor will show you in lab.

**Part 1**

**Paper on Paper**

Since the box that will hold the nickels is made of paper you will use this as your first material. Tape a small length of paper onto the cover of the hardback book. Set the paper box onto this sheet of paper, near the top edge of the paper. The box should fit fully onto the sheet of paper, not hanging partially off of the paper. You will use three different sets of masses in the paper box. **Your lab instructor will tell you how much**. For each amount of mass you will do 5 trials of determining the angle at which the box just starts to slide. You must be careful in slowly raising the book cover. If you accidentally shake as you raise the cover the box may begin to move before reaching the maximum angle that you are trying to achieve. Once you are satisfied that you have raised the book cover smoothly and slowly to the point that the box of nickels begins to move record the angle in the Excel worksheet. Repeat for all 5 trials for each of the 3 different masses.

**Part 2**

**Aluminum Foil on Aluminum Foil**

This part is identical to part 1, except that you are adding a piece of aluminum foil to the box, and you are taping a length of aluminum foil to the cover of your hardback book (replacing the paper from part 1).

Cut a piece of aluminum foil that is 2-3/4 inches wide by 3-1/2 inches long. Center the paper box onto the strip of aluminum foil and wrap the two ends up over the sides of the box and press them flat to the inside walls of the paper box. The two sides that have the aluminum foil will be the front and back of the box. Set the box on top of the sheet of aluminum foil (which is attached to your book cover) with the appropriate number of nickels and determine the maximum angle for this aluminum on aluminum combination, recording the angles on the Excel worksheet.

**Part 3**

**Paper on Cell Phone Glass**

This one is to show you how low the coefficient of friction is of your cell phone glass (even if you have a protective film). Remove the aluminum foil from the paper box. Rest your cell phone on a flat surface. Place the paper box and 5 nickels in the box. Very slowly begin to lift the top end of your cell phone. At what angle does the box begin to slide? Record this on your Excel worksheet and determine the coefficient of static friction between paper and your cell phone. No need to do multiple measurements for multiple masses. Just this one will be sufficient.

**Results:**

Compare the coefficients of static friction that you found for paper/paper and aluminum/aluminum with these handbook values.

Paper/paper: This has a range of values listed (0.25 to 0.60) depending on the type of paper. Some websites only give a coefficient of static friction equal to 0.30.

Aluminum/aluminum: If the aluminum is “dry” then the coefficient of static friction is 0.70, but if the aluminum foil is “greasy”, it can have a coefficient of 0.30. If you have uncoated aluminum foil, then it will be considered “dry”. If it is coated with a nonstick surface it will probably be considered “greasy”.

Use the ranges of uncertainty in your comparisons.

**Questions for Discussion:**

1. In this experiment, three different amounts of mass were used. How did changing the mass affect at what angle the box began to move. Explain why it occurred in this way.
2. Describe how the surface texture between the two materials affects how much force is needed to overcome static friction. Use what you observed in this experiment in your answer.
3. The frictional force is related to the normal force of an object. By adding more weight to the paper box the normal force would increase. Why wouldn’t the resulting increase in the frictional force cause the maximum angle at which the box begins to slide to also increase?
4. Of the following, does one require more applied force, or do they require the same amount of applied force to break static friction? Explain your answer.

Applied Force

Applied Force

Pushing

Pulling

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