LAB 4: PASSIVE FORCES - TENSION AND FRICTION(TPL1)

Goals:

- **How to use a Force Probe to measure forces**
- **The characteristics and origin of tension**
- **The characteristics of static and kinetic friction**

Introduction When you pull on one end of a rope attached to a crate, a force is transmitted down the rope to the crate. If you pull hard enough, the crate may begin to slide along the floor. ***Tension*** is the name given to forces transmitted in this way along strings (ropes, wires, etc.). ***Friction*** is the name given to the force that tries to oppose the motion of the crate along the floor.

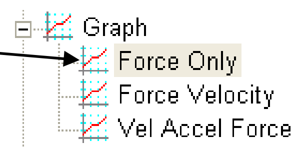
Part 1 What Does a Force Probe Measure?

In this activity you will discover how the force probe responds to pushes and pulls. We will investigate how to calibrate the Force Probe.

1. Connect the Probes. Be sure that the force probe and the motion sensor are connected through USBLink to your laptop. It would be very helpful to look at the online help page for this lab. Clamp the force probe onto the short horizontal pole attached to the table pole (see the picture on the online help page for this lab). This will put the force probe in the orientation we need for the first few sections.

2. Preparing DataStudio. Download the DataStudio experiment file `Lab04_TensionFriction.ds` from the lab schedule webpage, and open it in DataStudio.

3. Preparing the force probe. Press the ZERO button on the probe (this is a "mechanical" tare for the probe), and occasionally we might need to keep track of a zero "offset" in DataStudio.



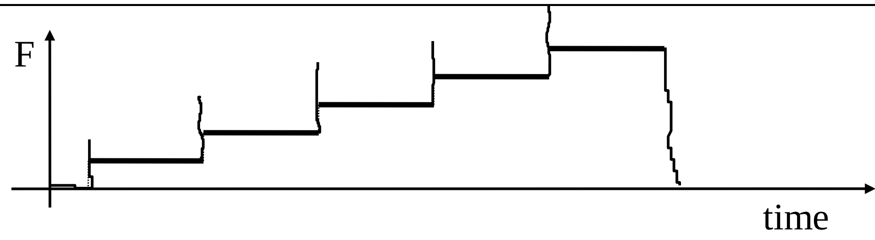
4. Plotting a force-time graph. In DataStudio, select the Force Only graph and start to collect some data. While the program is graphing, push up on the hook gently and then pull down gently (you should see "positive" and "negative" values of the force being graphed). The way the force probe is configured, "positive" means away from the probe (something hanging from it), and "negative" means toward the probe (something pushing back against the usual direction).

Questions [Answer on the Data/Question Sheets.]

a) Did the force probe read zero with nothing hanging from the hook?

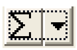
b) Does the force probe record a push as a positive force or as a negative force? What about a pull?

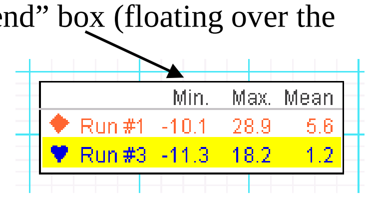
5. Check the calibration by adding masses and graphing. Clamp the force probe to a support with its hook pointing vertically downward. Click on the START button to begin graphing. Add 100 grams to the hook about every 10-15 seconds. Use the box masses – and work out combinations of hook masses so that you can have 100, 200, 300, 400, 500 grams. (Timing does not need to be exact -- we are trying to set up a "plateau" graph to show that the force probe is reading the mass values correctly.) You may need to use the Auto Zoom button in DataStudio to get a better display of your data graph, which should look something like the graph shown below:



Force calibration graph

(The graph may not be "smooth" as the masses are added. There may be spikes, but that is expected. **)**

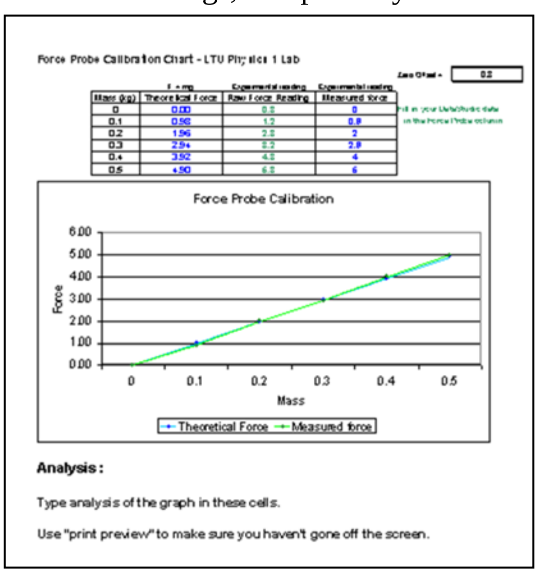
6. <u>Recording data from graph.</u> Click on the run you want to use in the "legend" box (floating over the upper right corner of the data graph) to make that run active (highlighted yellow). Move the mouse to one of the plateaus and click and drag to select a section of the horizontal graph. Make sure under the "summation" button  that the MEAN item is checked – the legend in the graph should show the mean (average) value of your selection. Make sure you avoid the spikes! Also, check to see if there is a non-zero force reading when there was no mass hanging from the probe – if so, record that mean value and enter it on the "zero offset" box on the Data/Question sheet.



7. <u>Recording force values.</u> For each of the "plateaus" we created with the different masses, using the "mean" method above, read the force values during the flat places of the "plateaus". Record your data on the Data/Question Sheet. Use the following equation to calculate the % error of the two columns:

$$\%\ error = \frac{|measured - standard|}{standard} \times 100\%$$

8. <u>Plot graph.</u> On the lab schedule webpage, there is an Excel sheet, **`P1Lab04_Force_Probe_Calibration.XLS`**, load it into Excel. You might want to save it under a new name, as a working copy. Fill in the information from your data table in the appropriate cells in the Excel spreadsheet. (The "standard" force is calculated already, you just need to enter your measured Force Probe readings, and possibly the zero offset value.) There is a sample from Excel:



Take the data from your data page (after class, or if you have time - at the end of class), and graph it with Excel. There is a space below your chart and your graph – you can explain the graph - how does the true weight compare to the force probe reading?

(**Write out these explanations on the spreadsheet itself, so that the chart, graph, and description can all be printed on one page. <u>Print that page and turn it in with the lab</u>**.)

(Sample shown to the left.
The spreadsheet page is pre-set
to fit on one printed page.)

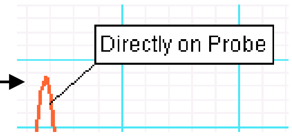
Question [Answer on the Data/Question sheet.]
After graphing the data in the ForceProbeCalibration worksheet - how accurately does your force probe measure force? Are there significant differences between the Force probe reading and the actual force applied?

Part 2 Introduction to Tension Forces

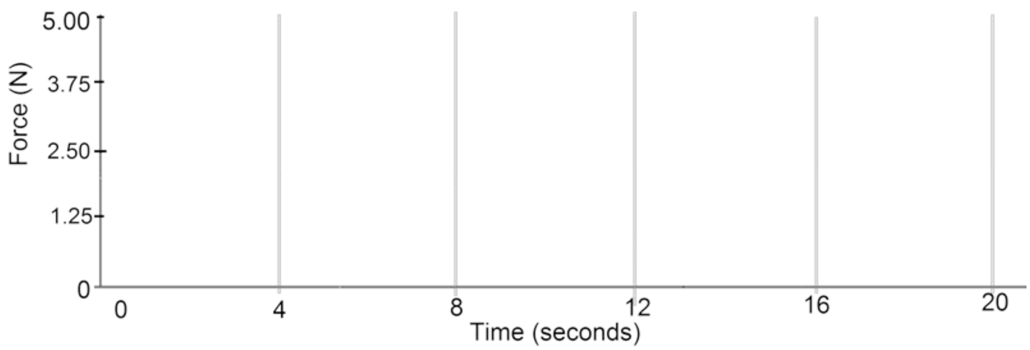
In the next few sections, you will examine tension and its origin by hanging masses from the force probe at the ends of pieces of string and elastic bands. But first, we will get a reading of the mass directly connected to the force probe.

1. Prepare probe and weigh the masses. Click START to start graphing. After about 5 seconds, hang one of the 200-gram masses from the force probe. After 10 seconds, add the second 200-gram mass below the first one (hooked underneath).

2. Save and annotate data. Store this data set, and name it if you wish. There is information about how to annotate the data in the [“store and examine” help page](). For the name, you could put something like “Directly on Probe” (since we will be hanging from string and rubber bands later). Here is an example.



3. Sketch your graph on the axes below. Also, put a “legend” to indicate “Directly on Probe”



Two hanging 200-gram masses

Part 3 Hanging a mass from a piece of String

Predictions If you hung the 200-gram masses from a piece of string attached to the hook, how would the forces measured by the probe compare to those measured with the masses attached directly to the hook?

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Test your prediction using the small piece of string.

1. Prepare probe. Remove all mass from the probe, and hang the piece of string with loops on either end from the force probe. (The string has so little mass – it won’t affect the force reading.)

2. Start graphing. After 5 seconds hang the first 200-gram mass from the end of the string, and add the second 200-gram mass after 10 seconds. Sketch the graph on the above axes, and label it.

Question [Answer on the Data/Question Sheet.]
Compare the forces to the ones with the masses attached directly to the hook. Do the masses still cause the same force readings from the probe? Was there any noticeable effect on the force readings by adding the string?

Move to the Data/Question sheet and answer the questions to Part 3

Part 4 Introduction to Frictional Forces - Forces between surfaces in contact

Introduction If you want to move a crate along the ground, you will need to apply a force to get it started and to keep it moving. This is because there is a force exerted by the ground on the crate, parallel to the surface of the ground. This parallel force between two surfaces in contact with each other, when they are either sliding along each other or when they are being pushed relative to each other (but not moving), is called a *Frictional Force*.

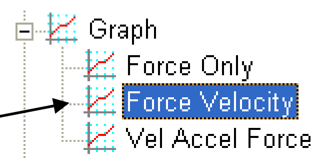
In this activity, you will use the Force Probe to examine the frictional force between a wooden block and the surface of a table or board. You will observe the frictional force both when the *block is at rest* (static friction) and *when it is sliding* (kinetic friction).

1. Prepare the motion detector and force probe. Take down the Force probe from the vertical pole so that you can hold it horizontally and connect it to the string that is tied to the block. Place the detector on tabletop, about 0.5 meters from the legal-sized paper sheet that is taped to the table. Be sure that the block is never closer than 0.5 meter from the motion detector when you are taking data.

Orientation of force probe and motion detector

2. Mass of the block. Measure the mass of your block: ________ kilograms. Now, add enough mass to the block to total roughly 2000 grams.

3. Prepare to graph velocity and force. Save your data from the previous section, and then clear the runs and resave with a new file name to prepare for this section. **Don't** reload the original experiment file, or you will have to calibrate the force probes again! Switch to the Force Velocity graph.



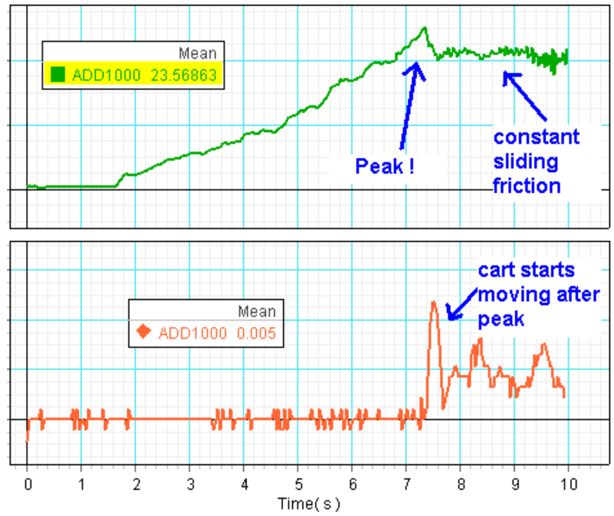
4. Prepare probe. The force probe should be resting on the table horizontally (with the string loose).

5. Prepare block on table. Put the block on the paper sheet with the widest wood face in contact with the paper at 0.5 meters from the motion detector. (The paper will provide a nice rough surface for the block to slide on. We might also use some fine sandpaper – your lab instructor will indicate that if necessary.) Hook the force probe to a piece of string tied to the hook on the front of the block, so that you can pull the block away from the motion detector.

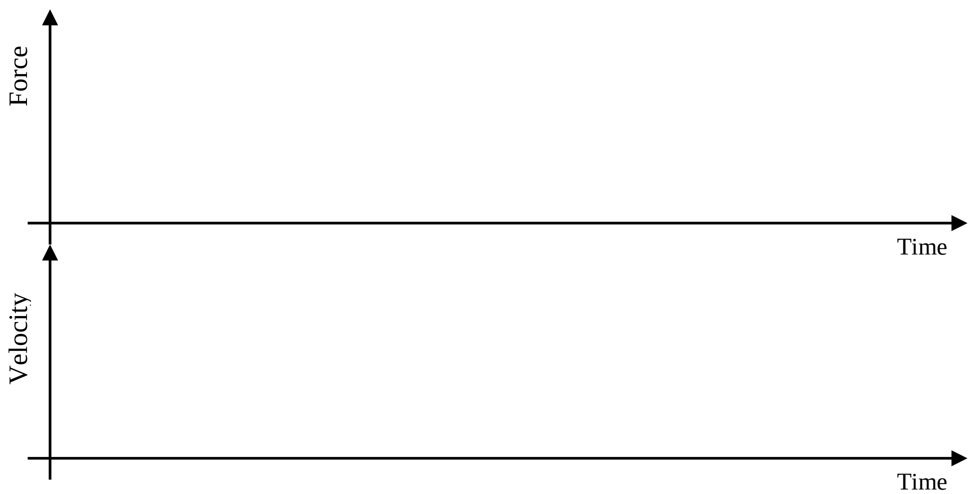
6. Start applying a pulling force to the block. Start graphing with the string loose, then gradually pull very gently on the block with the force probe, and increase the force very slowly.   Be sure that you pull horizontally--not at an angle up or down. When the block begins to move, pull only hard enough to keep it moving with a small velocity - as constant (steady) as possible.

This part of the experiment requires more concentration. We want to be able to record exactly what happens when a block "breaks free" from the surface, and then starts to move. When it is just sitting there, there is a static frictional force that will oppose attempts to move the block. We want to increase, very slowly, our tension force in the string so that the probe can record this increasing static frictional force. [Remember, the static friction opposes any applied force ***up to*** *but not exceeding a maximum.] Then, after the block breaks free, and starts moving, we want to watch the velocity graph to keep it* *moving at a constant velocity. So, it should "stick" just a little before moving, and then should smoothly move along the table.*

Here is an example of what your graph should resemble:



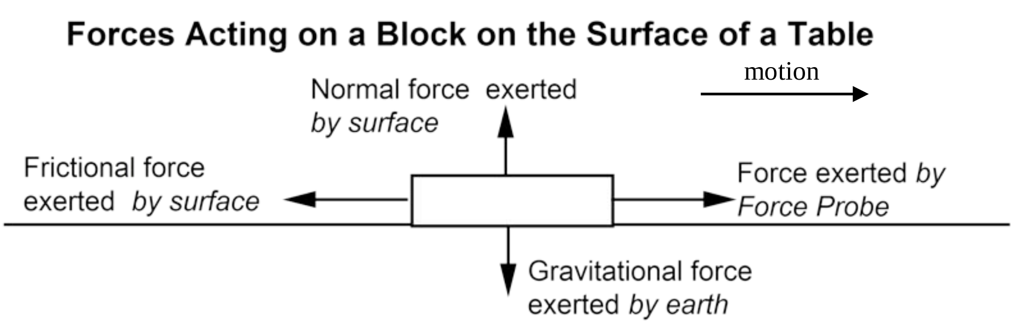
7. <u>Save clean run.</u> If it is a clean run, rename the run – if not, clear the "last data run" (under the Experiment menu) and repeat step 6 until you get a clean run. (You can rename this run 2000gm if you wish.) Sketch your graphs using solid lines on the axes below:



Object being pulled - just prior to motion (static) and then in motion (kinetic)

Move to the Data/Question sheet and answer the questions to Part 4

Comments When the surfaces of two objects are in contact with each other (like a block on a board), the force exerted by one of the objects on the other, parallel to the surfaces is called a *frictional force*. When the objects are at rest relative to each other, the force is known as a *static frictional force*. When one object is sliding on the other, the force is known as a *kinetic frictional force*. See diagram below.



Forces on a block

DATA/QUESTION SHEET FOR LAB 4 - PASSIVE FORCES - TENSION AND FRICTION

Part 1 What Does a Force Probe Measure?

Questions Did the force probe read zero with nothing hanging from the hook?

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Does the force probe record a push as a positive force or as a negative force? What about a pull?

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____

7. Recording force values. For each of the "plateaus" we created with the different masses, using the "mean" method above, read the force values during the flat places of the "plateaus". Record your data below:

"Force Probe reading" = "Raw force reading" - "zero offset"

Hanging Mass (kg)	Actual Force Weight = mg (N)	Raw force Reading (N)	Force Probe Reading (N)	Percent Error
0.0 kg	0.00			
0.1 kg	0.98			
0.2 kg	1.96			
0.3 kg	2.94			
0.4 kg	3.92			
0.5 kg	4.90			

Zero offset = _____ N

Question After graphing the data in the ForceProbeCalibration worksheet - how accurately does your force probe measure force? Are there significant differences between the Force probe reading and the actual force applied?

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Part 3 Hanging a mass from a piece of String

Question Compare the forces to the ones with the masses attached directly to the hook. Do the masses still cause the same force readings from the probe? Was there any noticeable effect on the force readings by adding the string?

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Part 4 Forces between surfaces in contact

Mark an arrow on your sketched force graph at the time when the block just began to move. How do you know when this time is (what evidence do you have)?

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When the block moves at a constant velocity, what force balances the force exerted on the block by the probe?

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Before the block starts moving, as you increase the pull exerted by the force probe on the block, what happens to the magnitude of the frictional force exerted on the block by the table?

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What happens to the frictional force just as the block begins to slide?

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Describe the frictional force as the block slides along at a constant velocity. Does it seem to change very much?

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Questions/Suggestions → Dr. Changgong Zhou czhou@ltu.edu