LAB 6 - CONSERVATION OF ENERGY (TPL1)

Goals:
- Record data for a cart going up and then back down a tilted ramp.
- Using a spreadsheet model, investigate kinetic and potential energies related to that motion.

Theory: A cart is rolling on a tilted track. We can measure the Kinetic Energy as $KE = \frac{1}{2}mv^2$ and we can measure the gravitational energy as $PE = mgh = mgx\sin\theta$ (where x is the distance along the incline). The total mechanical energy will be the sum of those two energies, and should be constant (if there is substantial frictional effects, the total energy measured here will not remain constant!). The way we will perform this experiment, we will also experience a Spring Potential Energy – we won't measure it, but we will see its effect!

Preliminary activities

1. Prepare equipment. Connect the motion sensor through a USBLInk and then to the laptop. It would be very helpful to look at the online help page for this lab. Start DataStudio.

2. Load the experiment file. Download the DataStudio file **`Lab06_Energy_Conservation.ds`** from the lab schedule webpage.

Part 1 Up and Down the Ramp – Revisited

A cart starts at the top of the ramp (with gravitational potential energy – measured from the bottom of the ramp) and is released from rest – it will travel down the ramp, trading potential energy for kinetic energy. At the bottom, the cart will have only kinetic energy (just before it hits the bottom). We have simple relationships to convert the distance along the ramp to the gravitational potential energy, and the velocity to the kinetic energy, so we should be able to show that energy is conserved.

1. Energy prediction graphs. Go to the Data/Question sheet and fill out the Energy prediction graphs.

Questions Answer the following question on the Data/Question Sheets.
What should be the connection between the two graphs above – that is, how do they relate to each other, or to any other possible physics concepts?

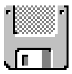
Now you will test your predictions.

2. Preparing track and program. Set up the ramp as shown in the online help page (one end should be tilted up off the table - about 12-15 cm high), and check to make sure the experiment file has the right settings (all of this is covered in the online help page).

3. "Zeroing" the motion detector. We are going to "invert" the data from the motion detector – so it is as though we are measuring from the bottom of the ramp. With the cart resting at the bottom, click START and record a few seconds of data using the POSITION graph in the experiment file. Analyze the data to find the "mean" value of this position, and then input that into the calculation as shown in the online help page.

4. Graphing the cart rolling down the ramp (starting from rest). Start with the cart up near the motion detector (but 0.5 meters away!) – at rest (as shown on the help page). A time scale of 10 sec should be

sufficient. Click START. Release the cart **after** you hear the detector clicking, and keep your hand free of the detector. The cart should be oriented so that the "springy" end is facing down the incline, and can bounce off the end bracket. Let the cart bounce one complete time (thus it hits, bounces back up, goes back down and hits again) – then you can manually stop the cart but let the motion program still record that "lowest" position (to double-check the "zero" we did before). If you have a nice "clean" roll down the incline, that is a good session, otherwise, repeat until you get one. What is a "clean" roll? A nice clean run has clean bounces showing no spikes.



To be safe, SAVE YOUR DATA FROM THIS SECTION (renaming it)

5. Rename that data run. Name it "High Tilt". Then hide it if you want.

6. Second trial. Reset the track with a lower starting height (maybe 6-8 cm from the table at the highest end). Repeat the previous data-taking session, and if you get a good session, then save the file again (for safe keeping). Store the data run, and name it "Low Tilt", but keep DataStudio open, we still need to copy the data to Excel.

Part 2 - Moving the Data from DataStudio to Excel

1. Launch Excel. We will use Excel to analyze the data. We can easily add equations and graphs to the spreadsheet, and it allows us to change numbers and see the result on the graph immediately. To ensure that the data can be structured the right way, there is a "template" already created to help us through the modeling process.

2. Load the energy template. On the lab schedule webpage, there is an Excel sheet, **`T1Lab06_Energy.XLS`**, load it in Excel. You might want to save it under a new name, as a working copy.

3. Description of the template. There are three sheets in the file, "Instructions", "High Tilt", and "Low Tilt". We will copy the data from DataStudio directly onto the High/Low tilt sheets.

4. Copying the data from DataStudio to Excel. Follow the directions on the first page of the Excel file,– copy the "high tilt" data run onto the "high tilt" page of the Excel file. Do the same for the "low tilt" data. Then save the Excel file (under your new filename). Make sure when you paste from DataStudio into the appropriate sheet, you use PASTE SPECIAL and TEXT. Leave DataStudio open – we need to make another calculation, as you'll see in the next section.

Part 3 Modeling the Energy in Excel

1. Worksheet layout. There are three columns of calculations: kinetic energy [**KE**], gravitational energy [**PE**], Total Energy [**Etot**] {the sum of the two previous energies}. There are also two numbers that are used in the calculations … the **Mass,** and the "**gsin(θ)**" term. [The potential energy is measured from the bottom of the track (where we zeroed the cart).].

2. Inputting the constants. The **mass** is easy – determine the mass of the cart and add that number to the appropriate box. The **gsin(θ)** term is a little trickier. But, if we think about the cart rolling down the ramp, we should realize that the acceleration of the cart is also gsin(θ)! So, we go back to the DataStudio program, and for each of the high/low runs, analyze the motion of the cart during the acceleration phase

(when the velocity graph is a straight line). Use the EXAMINE tool (refer to the picture in the online help page), select a region of the Velocity graph where the slope is constant, and click on the LINEAR FIT tool (two buttons to the left of STAT). The annotation box should show the value of the slope. Determine the slopes for both data runs (high and low tilts) and Record them here: (They will be NEGATIVE, but record them as a POSITIVE number, e.g., -0.5 is recorded as 0.5)

gsin(θ) – HIGH = ____________ gsin(θ) – LOW = __________ (both m/s^2)

3. Tweaking the graphs. Once we get those numbers in the EXCEL spreadsheet – the energy graph should look pretty good – the Total Energy should be constant.

Questions Answer the following questions on the Data/Question Sheets. You might want to “resize” the Excel graph, as you answer these.

a) How do your EXCEL graphs compare to the predictions you made? Can you see how these two energy graphs should add up to the total energy?

b) You might notice that the KE graph doesn’t really reach up to the total energy graph at the point before the cart hits ... there is some “smoothing” going on in the ULI motion program – so the velocity graph starts decrease prematurely. But, doesn’t it seem reasonable that the KE graph basically approaches the total Energy graph?

c) You might notice the gravitational potential energy (PE) graph go below zero when the cart reaches the bottom. Why would the PE go below zero at that point?

d) At the bottom of the track, the cart is momentarily at rest ... thus the total energy goes to zero (since we are measuring the KE and the PE from the bottom). But, why does the total energy graph bounce back up again after the cart is at the bottom? (That is, from **where** did the energy come for the cart to move back up the track?)

e) Why doesn’t the energy graph bounce back all the way to the original value – where did the lost energy go?

f) Look at the second “bounce” of the cart at the end (after it comes back partway, and rolls back down again) – does it go as far into negative PE as the first bounce, and if not ... why not?

4. Repeat for the Low tilt. Repeat the above procedures for the LOW page in EXCEL. Don’t forget to change the gsin(θ) value!

Question Answer the following question on the Data/Question Sheets.

g) Are there any significant differences between the HIGH and LOW Excel graphs – and if so, to what do you attribute those differences (for example, do you think friction plays a role differently in the high tilt vs. the low tilt case)?

5. Print the High Tilt graph. Make a printout of the HIGH tilt graph (and the first few rows of the data ... showing the values you chose) and turn it in with the report. [The experiment file should be pre-configured to print a single page – check the instructions in the template about resizing the graphs.]

QUESTION SHEET -- PHYSICS LAB 6 - ENERGY CONSERVATION

Part 1 Up and Down the Ramp – Revisited

1. Energy prediction graphs.

Predictions Sketch your predictions for the "kinetic energy vs. time" and "potential energy vs. time" graphs for the cart starting at the top and rolling down the ramp (and end the graphs just before they hit the bottom of the ramp).

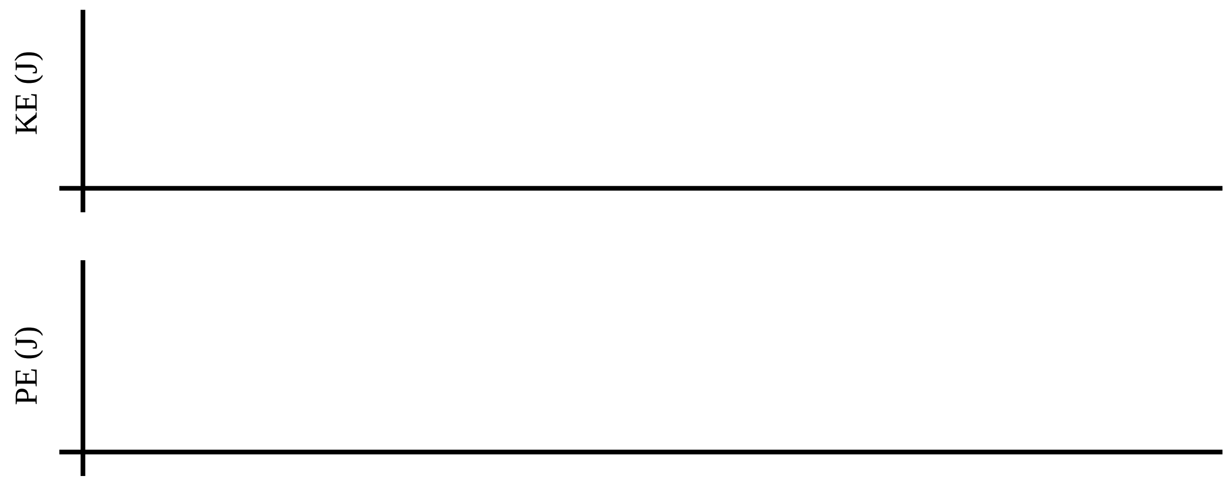


Figure 1 - Prediction Energy graphs for cart motion

Questions What is the connection between the two graphs above – that is, how do they relate to each other, or to any other possible physics concepts?

Part 3 Modeling the Energy in Excel

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f) Look at the second "bounce" of the cart at the end (after it comes back partway, and rolls back down again) – does it go as far into negative PE as the first bounce, and if not ... why not?

g) Are there any significant differences between the HIGH and LOW Excel graphs – and if so, to what do you attribute those differences (for example, do you think friction plays a role differently in the high tilt vs. the low tilt case)?

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