PHYS 103 LAB 6 ENERGY CONSERVATION

INTRODUCTION

In this lab you will investigate whether the *principle* of *energy conservation* applies to a dynamics cart propelled up an incline. You will use a **Motion Sensor** to monitor the cart's progress as it ascends up and descends down the incline. You will tabulate your results using **Microsoft Excel**.

THEORY

The *gravitational potential energy* of an object is given by:

$$GPE = mgh \,, \tag{1}$$

where *GPE* denotes the *gravitational potential energy*, *m* is the *mass* of an object, *h* is its *height*, and where $g = 9.8\text{m/s}^2$ is the *gravitational acceleration* on Earth. There are other types of *potential energy* (e.g. *potential energy* of a compressed or stretched spring) but we will not concern ourselves with them in this lab. The *kinetic energy KE* of an object is given by:

$$KE = \frac{1}{2}mv^2 \,, \tag{2}$$

where *KE* denotes the *kinetic energy*, *m* is the *mass* of an object, and *v* is the *velocity* that the object is moving with. The sum of *potential energy* (or generally *potential energies*) and *kinetic energy* gives us the *mechanical energy* of our object.

$$ME = PE + KE \tag{3}$$

Assuming that there are no *non-conservative forces* such as *friction* or *air resistance* (which dissipate mechanical energy) present in a system, the *mechanical energy* of a system is conserved i.e. it does not change overtime, so

$$ME_{\text{initial}} = ME_{\text{final}} = ME_{\text{any time}}, \tag{4}$$

In this lab you'll propel a dynamics cart up an incline and observe how its *gravitational potential energy*, *kinetic energy*, and *mechanical energy* vary over time as the cart first ascends up and then descends down the incline. You'll try to ascertain if its *mechanical energy* is indeed conserved or do *non-conservative forces* play a role.

PROCEDURE

1. Use the electronic scale to measure the *mass* of the dynamics cart. <u>Record this value.</u>

2. Attach the track to the stand, the end with the cart launcher being at the low end.

3. Attach the **Motion Sensor** to the high end of the track. Make sure that the stand is placed behind the **Motion Sensor.**

4. Adjust the *angle* θ that the track makes with the horizontal to be about 20°. Make sure that the bottom edge of the **angle indicator** is aligned with the bottom edge of the track. The outcome of this experiment is very

sensitive to the accurate measurement of the *angle*, so make also sure that you avoid the error associated with parallax. (Parallax is a difference in the apparent position of an object viewed along two different lines of sight, or from different angles. To get an idea extend your arm in front of you and look what is the position of your hand against some more distant background like the room's wall when you look at it with your left eye closed. Then open your left eye and close your right and look again. Does the position of your hand against the background appear shifted? You've just experienced parallax, because when you use one eye at a time you view your hand from a different angle) Record the value of the *angle* θ and convert this angle to radians. ***Make sure you do not change this angle for the remainder of this experiment.***

5. Open **Data Studio**.

6. From the list of sensors in the **'Experiment Setup'** window select **'Motion Sensor'** and then drag the **'Motion Sensor'** icon over the digital channel 1 on the image of the **Interface Box**. Double–click on the **'Motion Sensor'** icon, select the **'Motion Sensor'** tab and set the trigger rate to 100 Hz.

7. Physically connect the **Motion Sensor** to the **Interface Box** digital channels 1 and 2 of the **Interface Box** as shown in your **'Experiment setup'** window. Check to make sure that the **Motion Sensor** is set to the long-range designation.

8. In **Data Studio** create graphs of *position* versus *time* and *velocity* versus *time.*

9. Place the dynamics cart on the bottom end of the track against the depressed launcher. Make sure that its wheels are in the grooves of the track and that they can move freely.

10. Now do a trial Run. Have your partner press the **'START'** button of the **Data Studio** and immediately launch the cart up the incline with the cart launcher. Have your partner press the **'STOP'** button in **Data Studio** after the cart returns to the bottom of the track**.** Make sure that the **Motion Sensor** tracks the cart all the way along the incline. If it does not then adjust the tilt of the **Motion Sensor** until it does. If after a few tries the data is still spiky, ask your instructor for help**.**

11. Once you get a good Run make graphs of *position* versus *time* and *velocity* versus *time* in a single window in **Data Studio**. In the *position* versus *time* graph select the data that corresponds to the time when the cart is launched up, goes up the incline, and then comes back down with a bit of data before or after. Then click on "Edit" in the top toolbar and choose "Copy". Paste this data onto **Excel:** click on cell A1 and paste. Back in **Data Studio** ***in*** the *velocity* versus *time* graph select the data for about the same time interval. Then click on "Edit" in the top toolbar and choose "Copy". Paste this data onto **Excel:** click on cell C1 and paste.

12. Copy these tables to a worksheet in **Excel**. Select the data for the time interval when the cart is in motion and delete the rest from your **Excel** table.

13. Look at the data in the **Excel** worksheet. To make the times coincidental for both data sets we need the *time* in cell C3 to fall between the *times* in cells A3 and A4. If that is not the case, delete the data (and shift cells up) either from columns A and B (together) or from columns C and D (together) until these *times* do coincide. Select/highlight the data to be deleted with a mouse then right click and select delete from the drop down menu and then choose "shift cells up".

13. In the fifth column (column E) of your table find the *distance d* that the cart travelled up the incline. To do this consider figure 1. As you can see the *position* ***P*** of the cart that **Motion Sensor** measures and the *distance d* that the cart travelled up the incline are related in the following way:

$$\boldsymbol{d} = \boldsymbol{L}\text{-}\boldsymbol{P} \qquad (5)$$

For the initial distance ***L*** from the **Motion Sensor** to the cart (see figure 1 below) use the position value in cell B3. Then subtract from it the value for the position at a given time. So in cell E3 you should enter: =$B$3-B3, which is, of course zero. That's just right: we want to set the initial height and thus the initial distance *d* to zero. In subsequent rows, once the cart ascends the incline, this will give you =$B$3-B_{whatever} which is exactly what we need.

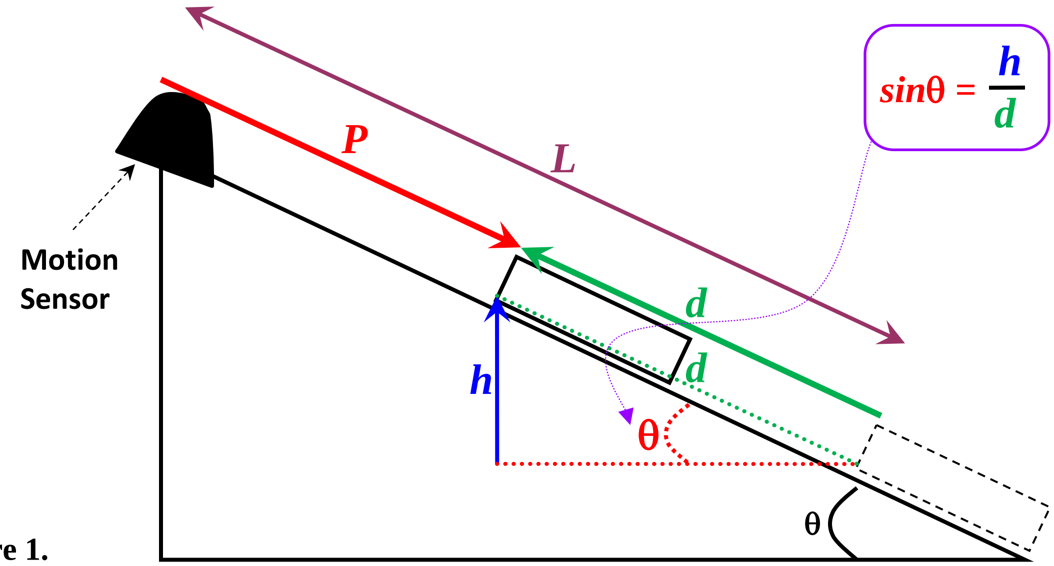

Figure 1.

14. <u>In the sixth column (column F) of your table calculate the *height* of the cart above its initial position using equation (6).</u>

$$\boldsymbol{h} = \boldsymbol{d} \sin \theta \,. \tag{6}$$

15. If your original *height* is not zero, ask your instructor for help in adjusting it (we are only resetting our zero *height* i.e. zero of *gravitational potential energy*, this way).

<u>16. In the seventh column of your table (column G), using equation (1), calculate the *gravitational potential energy* of the cart at each time.</u>

17. <u>In the eighth column of your table (column H), using equation (2), calculate the *kinetic energy* of the cart at each time.</u>

18. <u>In the ninth column of your table (column I) add the *gravitational potential* and *kinetic energies* of the cart to find its *mechanical energy* (see equation (3)).</u>

19. <u>Plot the *gravitational potential*, the *kinetic* and the *mechanical energy* of the cart on one graph in **Excel** as a function of *time*.</u> The easiest way to do this is to copy the entire worksheet to sheet 2, delete the headers (rows 1 and 2 – since you have a copy of the worksheet you can always double check what's where). Then select the entire columns of data (columns A, G, H and I) by placing the cursor on each column header (it changes to a black down arrow - see figure 2 - that allows you to select the entire column with one click) while holding down the "Ctrl" button. Do the cosmetic work on the graph: adjust the scale, label the axis (include units) and create a legend.

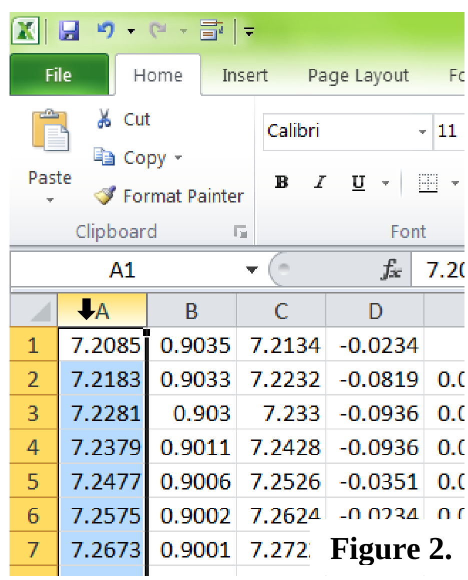

Figure 2.

20. Discuss **your** results:

a) How does the *gravitational potential energy* of the cart change as the cart ascends the incline? Why? Relate it to the motion of the cart.

b) How does the *gravitational potential energy* of the cart change as the cart descends the incline? Why? Relate it to the motion of the cart.

c) How does the *kinetic energy* of the cart change as the cart ascends the incline? Why? Relate it to the motion of the cart.

d) How does the *kinetic energy* of the cart change as the cart descends the incline? Why? Relate it to the motion of the cart.

e) How does the *mechanical energy* of the cart change as the cart ascends and descends the incline? Is it conserved? Discuss your results. Do they meet your expectations? (Note: if your graph of mechanical energy bows up or down check the angle indicator for misalignment with the track and double check your angle reading. It is conceivable that mechanical energy of the cart may be dissipated, but not that it increases spontaneously, so the bow shaped graph cannot be "real". It is, in fact, an artefact of angle mismeasurement and very sensitive to it. Also, please realize that at best we measure the angle ±1°, so we have a freedom to adjust it within this range. In fact, the graph of mechanical energy, or its flatness, gives us a better, more precise, estimate for the angle than the angle indicator can.

f) Based on your results were friction and air resistance negligible factors in this experiment? Explain why or why not.

21. Print Data Studio graphs and the Excel graph: **PRINT THE EXCEL GRAPH ONLY!!!!!!!!. DO NOT PRINT THE SPREADSHEET!!!!!!!!!**

It makes very boring read - I actually prefer the phone book!!!!! ☻

Delete your files from the computer.
Disconnect all equipment, close all applications, and log off your PC.
DO NOT TURN THE COMPUTER OFF.
Make sure you leave the classroom as you found it.

LAB 6 REPORT

Group name:..

Partners' names:.......................................

....

....

INTRODUCTION:

DATA PRESENTATION:

4.

20. a)

b)

c)

d)

e)

f)

REMINDERS: **DO NOT PRINT THE EXCEL TABLE, just the graph.**
Include units.
Make sure to attach all your data and graphs. No data = No credit
Please do not hand in the manual, just the report.

CONCLUSION: