Section: **Name:** **BU ID:** .

Partner: **Name:** **BU ID:** .

Lab 5: Energy conservation and Work (100 points)

In this experiment you will use a cart, a track, and an ultrasonic motion sensor to investigate what is happening to energy when the cart is moving down the inclined track.

A. You will be analyzing the motion of a cart running down a track.

1. Initially the track is horizontal. There is UMS (ultrasonic motion sensor) attached to one end of the track. Place one bar under the feet of the track to *rise* the end with UMS. *Imagine* a cart placed on the track, close to UMS, and released from rest (so the cart would be moving *away* from UMS). Draw a picture for this situation, show the cart at *two* different locations along the track (the initial which is close to UMS, and the final which is close to the end of the track). Draw the x-axis along the track and chose the positive direction of the x-axis *away* from the motion sensor (i.e. down the track). At one of the locations draw FBD for the cat (show all forces acting on the cart), show cart's velocity and acceleration.

2. Let us use the following notations (***add them to your picture above***):

x_1 – initial position of the cart x_2 – final position of the cart $\Delta x = x_2 - x_1$

h_1 – initial height of the cart above the table h_2 – final height of the cart $\delta h = h_1 - h_2$

θ - angle of the incline of the track l – height of the bar

L – the distance between the feet of the track as measured *along* the track (use the yellow tape attached to it)

3. Use your picture and write an algebraic relationship between δh, Δx, and θ (you should see some kind of a triangle):

4. Use your picture, write a relationship between l, L, and θ

5. This question requires the use of the "trial and error" method. Select one of the equations from above (from part 3 or part 4), *measure* the appropriate variables, use some relationship applied to a right triangle, write below the values for the measured parameters; and calculate:

$\tan\theta =$ $\sin\theta =$ $\cos\theta =$

$\theta =$ (degrees) $\theta =$ (radians)

6. The law of conservation of energy for the cart moving without friction acting on it, can be written as the following ("the master equation"):

$$K_1 + U_1 = K_2 + U_2$$

Explain below the meaning of each term; for each term write its expression: in addition to variables defined in part 2, you can also use *m* (the mass of the cart), and *g* (the magnitude of the free fall acceleration); do NOT use any approximations; you do *not* have to use ALL of the variables; hint: **if stuck - use the Internet** (!):

What is K_1? ____________________________________ $K_1 =$

What is U_1? ____________________________________ $U_1 =$

What is K_2? ____________________________________ $K_2 =$

What is U_2? ____________________________________ $U_2 =$

7. Using your previous equations, solve the law of conservation of energy for the following combination of parameters:

$$\frac{K_2 - K_1}{\delta h} =$$

8. When the cart is moving down the track its height and velocity change. Based on your expression in part 7, state below your opinion (a.k.a. a prediction, a.k.a. a hypothesis) on what will be happening with this ratio, $\frac{K_2 - K_1}{\delta h}$.

9. For the cart moving down the track, ratio $\frac{K_2 - K_1}{\delta h}$

[ ] depends on the initial and final locations of the cart

[ ] does not depend on the initial and final locations of the cart

B. In the following part of the lab you will run an experiment to check your prediction for $\frac{K_2 - K_1}{\delta h}$. The file you need to use to collect data is PY105_lab5.cmbl. To analyze your data you will need to use an Excel file PY105_lab5.xls.

Make sure the track is *leveled* and groves *are clean*.

10. Place the cart about 10 - 15 cm away from UMS, add an extra weight on the cart, make sure there is nothing between the cart and the sensor. Hit [Collect] button, wait for about a second and release the cart. Just before the cart hits the stopper, click [● Stop] button (**ATTENTION**! Y**our partner should catch the cart**).

On the graph for velocity as a function of time you should see a region with a relatively straight line. *If it is not the case, you should repeat the measurements.*

If you see nice and smooth position and velocity graphs, you can use the data. Follow the procedure below.

Measure the mass of the cart and add the mass of the weight: m_{total} = ________________

You have to use the table provided by the LabPro software on the left part of the screen. Choose <u>two</u> locations ("initial" and "final") and corresponded velocities of the cart. When choosing the data for the table below, make sure that the instants 1 (initial) and 2 (final) are separated by at least 3 s (or more for the best result); use the data related to the *actual* motion (i.e. a little bit <u>after</u> the cart has been released and just <u>before</u> it has been caught; i.e. within the *linear* part of the velocity graph). Write in the first raw of the table the data.
Repeat the experiment three more times; fill in the table.

	x_1	v_1	x_2	v_2
1				
2				
3				
4				

11. Open PY105_lab5.exl file, transfer your data into the table, including $\sin\theta$ and the mass of the cart with the weight. Note: The formula in PY105_lab5.exl file automatically calculates ratio $\frac{K_2 - K_1}{\delta h}$ and then it calculates the average error (deviation).

Check the *average error* of your data (the last cell of the table); if it is below 10 - 13 % you are fine; if the error is greatly above 10 % you should repeat your experiment, maybe one of the runs was very" bumpy" (do NOT save your data in the file, if you want to save your data use "save as" but delete your file before leaving the lab).

If the average error is *small*, we can conclude that all $\frac{K_2 - K_1}{\delta h}$ ratios are *equal* to each other (within the margin of an error), or we can say that ratio $\frac{K_2 - K_1}{\delta h}$ is constant.

Note: if the table already has data stored in it, clear the table before entering your data.

12. Based on your data, finish the sentence:
For the cart moving down the track, ratio $\frac{K_2 - K_1}{\delta h}$

[ ] depends on the initial and final locations of the cart

[ ] does not depend on the initial and final locations of the cart

Compare with your prediction in part 8.

13. Now place the cart as far from the motion sensor as possible (close to the bottom of the track), start collecting data and give the cart a push in the direction of the sensor (the cart should stop about 15-20 cm before reaching the sensor, you may want to practice first to make it happens). You need to stop collecting data when the cart is just stopped. Run the experiment four times, fill in the table on the right, again use PY105_lab5.exl file; again assess the average error for the measured ratios $\frac{K_2 - K_1}{\delta h}$.

	x_1	v_1	x_2	v_2
1				
2				
3				
4				

14. Based on your data, finish the sentence:

For the cart moving down the track, ratio $\frac{K_2 - K_1}{\delta h}$

[ ] depends on the initial and final locations of the cart

[ ] does not depend on the initial and final locations of the cart

15. Does your experiment agree with your prediction in part 8? ____________________

16. Would it make any difference if instead of $\frac{K_2 - K_1}{\delta h}$ you were measuring $\frac{K_2 - K_1}{\Delta x}$ (think of the connection between Δx and δh)?

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17. What is ratio $\frac{v_2^2 - v_1^2}{2\Delta x}$ equal to?

[ ] the mass of the cart [ ] the distance traveled by the cart [ ] the acceleration of the cart

We know that when released the cart travels with *a constant acceleration*. Does this fact agree with your predictions and experimental results?

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Equipment.

Lab 5 (12 tables): a cart, a track with a stopper, a metal bar, a motion sensor, a ruler, a meter stick, a friction pad.

Unit layout

L5: 120 minutes

PE5: 80 minutes

<u>Breaks when needed.</u>

Practice Exercise 5: 80 minutes

Section:_______ **Name:____**

A box of unknown mass is sliding with an initial speed 10 m/s across a horizontal *frictionless* floor. Suddenly it encounters a rough section of flooring, which is 2 m long. The coefficient of kinetic friction between the rough section of flooring and the box is 0.2.

For the period when the box was sliding across the rough section of the floor, calculate:

(a) the work done by the force of gravity

(b) the work done by the normal force

(c) the work done by the force of friction

(d) the final speed of the box after sliding across the rough section of flooring.