

**PY 105**

**Lab 2: Introduction into Kinematic**

**Section:** \_\_\_\_\_ **Name:** \_\_\_\_\_ **BU ID:** \_\_\_\_\_.

**Partner:** \_\_\_\_\_ **Name:** \_\_\_\_\_ **BU ID:** \_\_\_\_\_.

**Part I**

**Part Ia: Average speed and velocity. For the full credit you need to: a) provide a clear explanation of your strategy; b) run the experiment; c) obtain reasonable data; d) conduct correct calculations of the average speed and average velocity).**

Use a measuring tape and a stopwatch (or your smartphone) to measure distance and time, and use collected data for calculating the average speed and average velocity of a student (one of you) walking (or running) two staircases up (or down; you choose the actual motion).

You and your partner should develop an experiment to measure *average speed* and *average velocity* and do it together. Before taking measurements, describe what you plan on doing and check your plan with a TF.

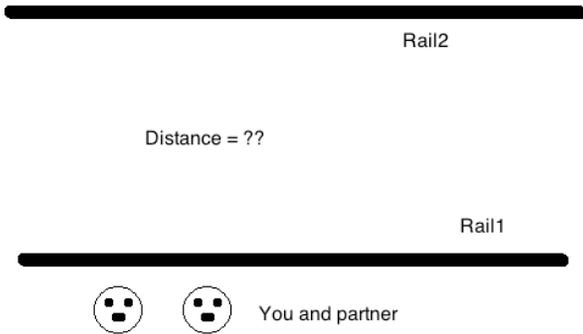
Use the space below to show your work; provide the exact definition for each quantity you will measure, provide appropriate data and calculations.

**Part Ib.**

Develop and execute a strategy to measure the distance between two rails in the hallway divided by the open space (please, do *not* drop anything in it!). You can use some masking tape to indicate important locations, a laser pointer, a protractor, and a measuring tape. **Note:** both of you – you and your partner - must stay *on the same side* of the hallway; after finishing your work, however, you can take a measuring tape and check your result by a direct measurement. Use the units provided by the measuring tape.



1. Describe clearly your strategy in a space below; show the diagram of your experiment. Before taking measurements check your plan with a TF.



2. Execute your experiment, provide the appropriate data and calculations, and present the result.

## Part II: 1-D motion.

### APPARATUS

- o Computer and interface
- o Cart with (magnetic) bumpers
- o Bars to tilt the track
- o 2.2-meter track with a stopper
- o Ultrasonic Motion sensor (UMS)

In this part you will be using the Logger Pro program. Locate PY105\_lab2.cml file and double-click on the file to start it (usually in a folder PY105), if asked click on Connect. In Logger Pro you should see a position versus time graph, a velocity versus time graph, and a table showing time  $t$ , position  $x$ , and, velocity  $v$  readings (you can resize the windows). To erase any previous data click on Data and then on Clear All. An ultrasonic motion sensor (UMS) is attached to one end of the track to measure instantaneous positions of the cart (to stop continuous clicking click on Experiment and uncheck “live readings” in the fall down menu).



You will be analyzing the motion of a cart traveling up or down of an inclined track. Tilt the track with the means of one bar; place a cart on the track (keep it about 15 - 20 cm away from the sensor; make sure when released the cart is moving *away* from the sensor and hits the stopper by its bumper, you may want to catch the cart just before it hits the stopper). If needed you can change the timing of the experiment: click on Experiment, Data collection and change the Duration, click on Done.

You may find it useful to set a zero point for the position of a cart. Place the cart on the track, make sure the cart is stationary, and nothing is between the cart and the motion sensor. Then, from the Experiment menu, select Zero, and choose “Zero Distance” (or click on the Zero button, or use the combination Ctrl-0). The motion sensor will click as it reads the cart’s position.

**Experiment 1. One bar is used to tilt the track, the cart is released from rest and moving down the track and *away* from UMS (make sure that the positive x-direction is down the track).**

To start your measurements hit  button, wait for about 1 s (you should start hearing fast clicks the sensor is making when taking the data), and release the cart. When the cart almost hits the stopper, hit  to stop collecting the data (and try to catch the cart to prevent it from falling off the track).

On the screen of your computer you should see two graphs: a position versus time graph and a velocity versus time graph. Click on each graph and use the Ctrl-J combination to autoscale the graph for a better visibility. If the graphs are too noisy you should repeat the run (you may need to clean up the grooves in the track).

Select two time instances  $t_1$  and  $t_2$  (one should be close to  $t = 0$  and another one close to the time when you stopped collecting data),

Use your graphs/table and write down the data:

$$t_1 = \quad \quad \quad x_1 = \quad \quad \quad v_1 =$$

$$t_2 = \quad \quad \quad x_2 = \quad \quad \quad v_2 =$$

Velocity  $v_1$  above is ... (finish the sentence, choose one correct answer)

[ ] spontaneous      [ ] instantaneous      [ ] average      [ ] mean      [ ] immeasurable

Explain your choice.

Draw a picture, show the x-axis *for the tilted track*, indicate the initial and final positions of the cart, clearly show by an appropriate vector initial and final velocity, displacement, average velocity, average acceleration.

State below your expectation for each quantity you will be calculating using your measurements.

I expect		(choose one)
displacement		<input type="checkbox"/> < 0 <input type="checkbox"/> = 0 <input type="checkbox"/> > 0
average velocity	to be	<input type="checkbox"/> < 0 <input type="checkbox"/> = 0 <input type="checkbox"/> > 0
average speed		<input type="checkbox"/> < 0 <input type="checkbox"/> = 0 <input type="checkbox"/> > 0
average acceleration		<input type="checkbox"/> < 0 <input type="checkbox"/> = 0 <input type="checkbox"/> > 0

Use your data and calculate distance, displacement, average velocity, average speed, average acceleration of the cart for interval  $t = (t_1, t_2)$ ; show your work, clearly state *the name* of every equation you used.

Click on the position graph. Select a region of the graph by clicking-and-dragging with the mouse (try to make as wide selection as possible, but exclude noise by avoiding the very first and very last instants) and then click Curve Fit button, . Select Quadratic fit from the list and click . Click  to return to the main graph. You will see a box with equation  $At^2 + Bt + C$ . Using the table on the next page, write down the value of coefficient  $A$ .

Click on the velocity graph, select the same region of the graph (make sure it starts and ends at almost *the same* instants as your selection for the position graph), and click Regression button, . Now you will see a box with equation  $mt + b$ . Write down the value for coefficient  $m$ .

$A$	$m$	$C$

Repeat experiment 1 one more time (in order to have good data, you may need to repeat the experiment more times, but need to use the data from only two best runs, with the smoothest graphs).

State below the meaning of each coefficient in motion equation  $At^2 + Bt + C$ .

State below the meaning of each coefficient in velocity equation  $mt + b$ .

According to your description above, for your experiment, what should be the *exact values* of coefficients  $B$  and  $b$ ? Explain.

$B =$                        $b =$

**Transfer your values for  $A$ ,  $B$ ,  $C$ ,  $m$ , and  $b$  into the table on page 7.**

**Experiments 2, 3.**

Using the technique you have learned doing experiment 1, you have to explore *two more* different cases (see below), taking *two* measurements for each case (to obtain good data you may need to make more runs but use two with the smoothest graphs). For each set of graphs, first click on the position graph. Select a region of the graph by clicking-and-dragging with the mouse (try to make as wide selection as possible, but exclude noise by avoiding the very first and very last instants) and then click Curve Fit button, . Select Quadratic fit from the list and click . Click  to return to the main graph. You will see a box with equation  $At^2 + Bt + C$ . You need to write down the values for coefficients  $A$ ,  $B$ , and  $C$  (*for coefficient  $B$  write the exact value it should have because the cart has been released from rest*); to keep all your data organized use the table provided on page 7.

Click on the velocity graph, select the same region of the graph (make sure it starts and ends at almost *the same* instants as your selection for the position graph), and click Regression button, . Now you will see a box with equation  $mt + b$ . You will need to write down the values for coefficients  $m$  and  $b$  (*for coefficient  $b$  write the exact value it should have because the cart has been released from rest*).

For each experiment, draw a picture (i.e. “a photograph”, “a snapshot”) of you experiment; add/show the x-axis, the initial position, the final position, the initial velocity, the final velocity, and the acceleration of the cart.

**Experiment 2.** Add another bar to change the angle of the track, add a friction pad to the cart (i.e. a small paper sticker), place a weight on the cart (about 200 g). For each run release the cart from rest. Draw below a picture for experiment 2.

State below your expectation for each quantity you will be calculating using your measurements.

I expect		(choose one)
displacement		<input type="checkbox"/> $< 0$ <input type="checkbox"/> $= 0$ <input type="checkbox"/> $> 0$
average velocity	to be	<input type="checkbox"/> $< 0$ <input type="checkbox"/> $= 0$ <input type="checkbox"/> $> 0$
average speed		<input type="checkbox"/> $< 0$ <input type="checkbox"/> $= 0$ <input type="checkbox"/> $> 0$
average acceleration		<input type="checkbox"/> $< 0$ <input type="checkbox"/> $= 0$ <input type="checkbox"/> $> 0$

Run the experiment twice, take the data and write the results in the table on page 7. Were your expectations correct? Comment.

**Experiment 3.** In the two last experiments the cart should be placed at the bottom of the track and needs to have its initial velocity directed up the track, i.e. towards UMS. Before making each run, make some changes in the angle, and/or a weight, and/or friction. For the first run of the experiment 3 the cart should stop about 10 cm in front of USM, and you should stop taking data right when it happens. For the second run of the experiment 3 the cart should stop about 10 cm in front of UMS and then run down the track, and you should stop taking data when the cart is close to the middle of the track. For each experiment, draw a picture; show the x-axis, the initial position, the final position, the initial velocity, the final velocity, and the acceleration of the cart.

Draw below a picture for experiment 3 run 1.

State below your expectation for each quantity you will be calculating using your measurements.

I expect		(choose one)
displacement		<input type="checkbox"/> $< 0$ <input type="checkbox"/> $= 0$ <input type="checkbox"/> $> 0$
average velocity	to be	<input type="checkbox"/> $< 0$ <input type="checkbox"/> $= 0$ <input type="checkbox"/> $> 0$
average speed		<input type="checkbox"/> $< 0$ <input type="checkbox"/> $= 0$ <input type="checkbox"/> $> 0$
average acceleration		<input type="checkbox"/> $< 0$ <input type="checkbox"/> $= 0$ <input type="checkbox"/> $> 0$

Run the experiment, take the data and write the results in the table on page 7. Were your expectations correct? Comment.

Draw below a picture for experiment 3 run 2.

State below your expectation for each quantity you will be calculating using your measurements.

I expect		(choose one)
displacement	to be	<input type="checkbox"/> $< 0$ <input type="checkbox"/> $= 0$ <input type="checkbox"/> $> 0$
average velocity		<input type="checkbox"/> $< 0$ <input type="checkbox"/> $= 0$ <input type="checkbox"/> $> 0$
average speed		<input type="checkbox"/> $< 0$ <input type="checkbox"/> $= 0$ <input type="checkbox"/> $> 0$
average acceleration		<input type="checkbox"/> $< 0$ <input type="checkbox"/> $= 0$ <input type="checkbox"/> $> 0$

Run the experiment, take the data and write the results in the table below. Were your expectations correct?

Comment.

Print out the screen for your last experiment.

***m/A and b/B values should be round up to 1 digit!***

Experi ment	<i>A</i>	<i>B</i>	<i>C</i>	<i>m</i>	<i>b</i>	<i>m/A</i>	<i>b/B</i>
1							----X---
							----X---
2							----X---
							----X---
3 run1 run 2							
	<b><i>m/A and b/B values should be round up to 1 digit!</i></b>						

**Analyze the data in the table and write below your conclusion**

In the table above find some data which are (almost) not affected by the changes you made (i.e. the same for *all* runs). Based on your observations, establish relationships between: *A* and *m*, *B* and *b*, a motion equation  $x(t) = At^2 + Bt + C$  and a velocity equation  $v(t) = mt + b$ ; state below your findings.

## Equipment

### Lab 2:

**Part I (12 tables):** measure tape, stopwatch, big protractor, laser pointer, a ruler;

**Part II (12 tables):** constant acceleration apparatus (an UMS, a long track, a cart).

## Unit layout

**L2:** 160 min

**PI:** 80 min

**PIa:** 40 min

**PIb:** 40 min

**PII:** 80 min

**PE2:** 40 minutes

### Breaks when needed

### Practice Exercise 2

Based on what you have learned, write below the velocity equation for motion equation  $x = 2 + 8t - 2t^2$ . Assume the x-axis points to the right. Clearly state the magnitude and the direction of the initial velocity and of the acceleration of the object.

Sketch the graph for the position and for the velocity as a function of time. Calculate instantaneous position and velocity at  $t = 0, 1, 2$  and  $3$  s.

Based on your work find the time when the object momentarily stops (its instantaneous velocity becomes zero, that happens just before the object reverses the direction of its motion).

Sketch the motion diagram for the time interval  $t = (0,1)$ , and for the time interval  $t = (0,3)$ . Calculate the average velocity and average speed for the time interval  $t = (0,1)$ , and for the time interval  $t = (0,3)$ .