

## U of T Lab Practical 1

### Forces, Motion and the Scientific Method

Your Name: \_\_\_\_\_.

Names of your Practicals Partners: \_\_\_\_\_.

\_\_\_\_\_.

\_\_\_\_\_.

Based on materials in the *U of T Physics Practicals* of PHY131 / PHY132, which are relevant to the Ontario Curriculum, Grades 11 and 12, Physics University Preparation, SPH3U / SPH4U.

Note that all U of T Physics Practicals Materials (excluding instructors manuals) are available for free at: <http://faraday.physics.utoronto.ca/Practicals/>. Today you will be looking at a very small portion of the over 200 pages worth of materials available there.

Original Authors: David M. Harrison, Jason J.B. Harlow Latest revision: May 15, 2012

### How this Workshop Works

Imagine you are in your first year at U of T. You are taking one of the biggest physics courses, PHY131, which is **required** for all sciences majors (except physics majors, who take PHY151). The lectures are in convocation hall, but most of your learning actually happens in Practicals. Here is where you actually get to explore and get used to what you heard about in lectures, and discuss it with your peers in a friendly environment.

### Equipment List

Item	Qty
2.2 meter Track, Pasco ME-9452 with End Stop, Pasco ME-9808.	1
#24 Rubber Bands (4" long, 1/8" wide, 1/32" thick)	4
Collision Cart, Pasco ME-9454. Low friction wheels, very durable.	1
Cart pin	1
6-inch string	1
PASCO Fan Accessory with guard, Pasco ME-9491. 2 aluminum dummies shaped like AA batteries.	1
AA batteries	1 pack of 4
Small screwdriver for prying out batteries	1
PASCO 1.0 N Metric Spring Scale, SE-8714.	1
OHAUS 20 N Dial Spring Scale	1
Motion Sensor II, Pasco CI-6742.	1
Economy Force Sensor, Pasco CI-6746.	1
Bubble-level	1

Mechanics Module 2 – Student Guide [Instructor Guide is separate]  
This module is normally performed in weeks 3 and 4 of a 12-week semester of PHY131: Introduction to Physics.

Note: Non-U of T people can log into the computers with user name “student”, no password, log-on to “this Computer”

### **Activity 1: Introduction to the Motion Sensor**

For this Activity you will be using a computer-based laboratory system with an ultrasonic motion sensor and motion software. The motion sensor acts like a stupid bat when hooked up with a computer-based laboratory system. It sends out a series of sound pulses that are too high frequency to hear. These pulses reflect from objects in the vicinity of the motion sensor and some of the sound energy returns to the sensor. The computer is able to record the time it takes for the reflected sound waves to return to the sensor and then, by knowing the speed of sound in air, figure out how far away the reflecting object is.

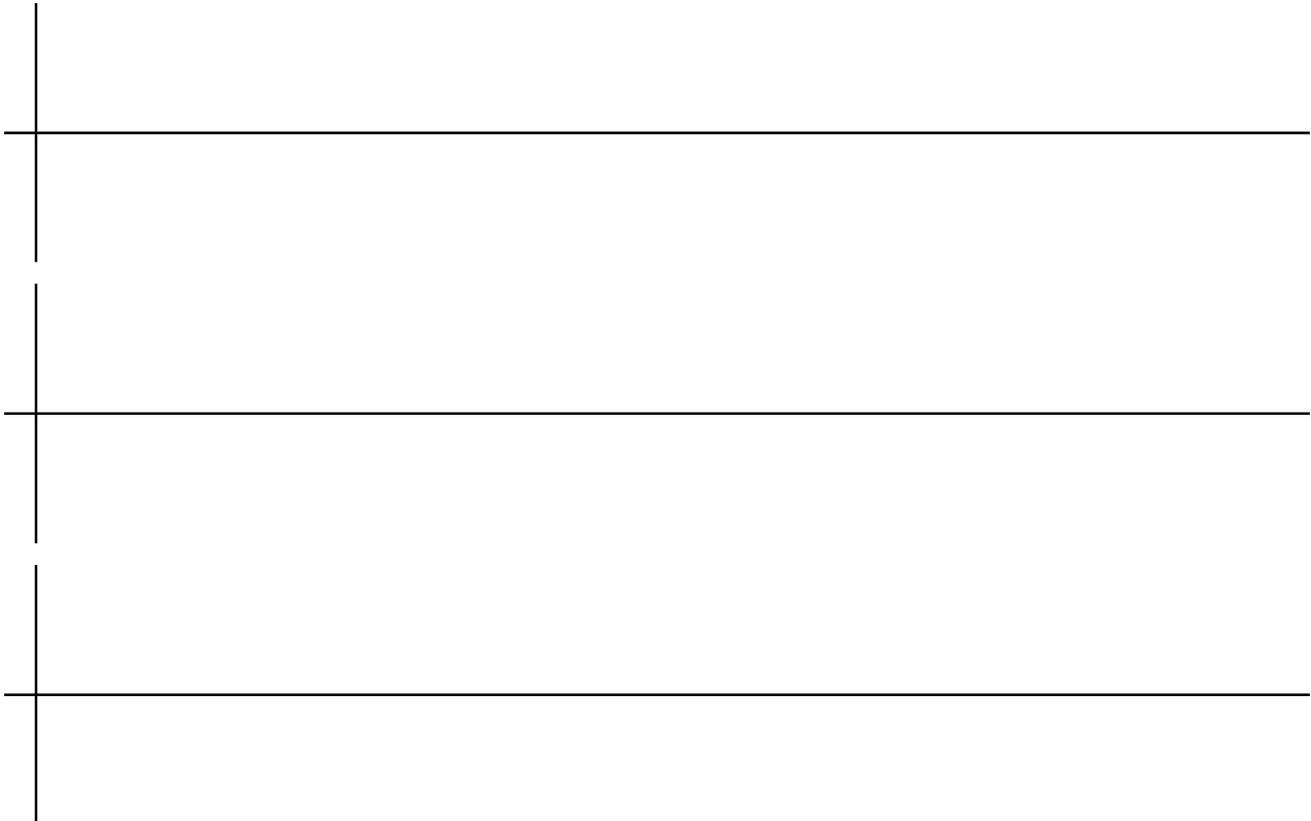
To start the motion sensor:

- double-click on the C-drive in My Computer the folder: “Labview”
- double-click on the folder: “MotionSensor”, then on the “MotionSensor” icon

Set the switch on top of the sensor to the narrow beam, which on some sensors is indicated by an icon of a cart. Click “Start Detector”, and “Collect Data”, both of which are toggle switches which turn collection on and off.

Use the system to take position-time data of the cart as one of your Team moves it towards and away from the sensor. Try to glide the cart as smoothly as possible at constant speed. The software will compute the average velocity and acceleration. Click the “Analyze” tab to see these plots.

- A. Sketch the plots of position, velocity and acceleration below. For all three plots, include the same time range.



## Activity 2: What does “force” feel like?

In this Activity you will use a *Force Sensor*. When connected to appropriate software, this device measures forces exerted on it. The device uses a *piezoelectric* material, which generates a voltage proportional to the force exerted on it. Other uses of piezoelectrics include contact microphones, the motion sensor capabilities of the *Sony Playstation 3* and *Nintendo Wii* controllers.

Pick out one of the Number 24 rubber bands as your standard rubber band. You may want to identify it by marking it with a pen or pencil. Loop the rubber band loose around your fingers as shown. Slowly separate your hands until the rubber band is not slack.

Now separate your hands by some further predetermined “standard” length that you choose. You can feel that the rubber band is exerting forces on both of your fingers. How do the magnitudes of these two forces compare?

Each member of your Team should do this simple little experiment.

To start the force sensor:

- double-click on the C-drive in My Computer the folder: “Labview”
- double-click on the folder: “ForceSensor”, then on the “ForceSensor” icon
- Click “Acquire Data”, which acts as a toggle switch.

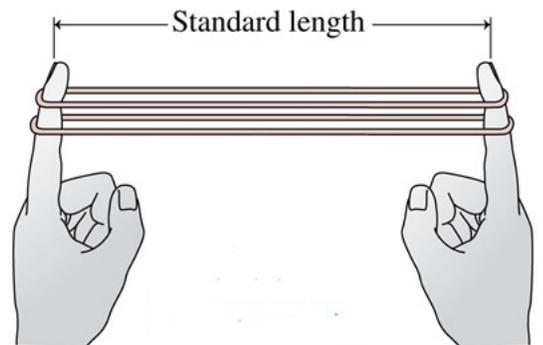
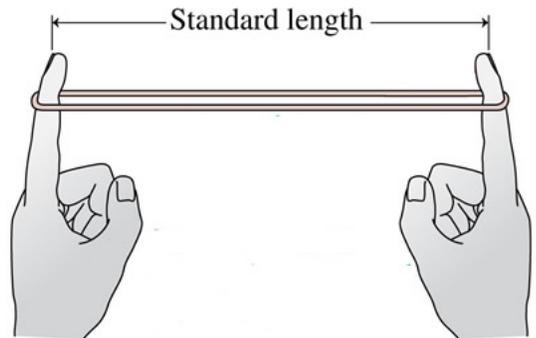
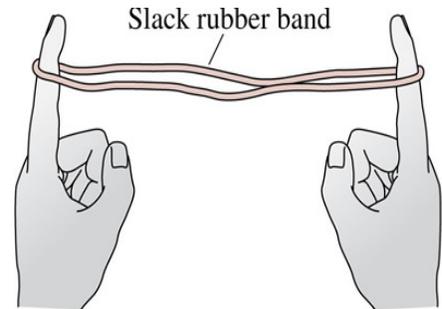
- A. When stretched by the standard length the rubber band is exerting a *standard force* on your fingers. Decide what name you wish to give to this standard force.

Name for new force unit: \_\_\_\_\_.

- B. Now loop the rubber band around the hook on the *Force Sensor* that is mounted on the vertical rod and start the Force Sensor program on the computer. Push the Tare button on the Force Sensor to zero its reading. Stretch the rubber band by the standard length and determine the force in newtons corresponding to your standard force.

Number of Newtons in one \_\_\_\_\_ = \_\_\_\_\_.

- C. Now loop two rubber bands around your fingers and stretch them by your standard length. How does the force exerted on your fingers with two rubber bands compare to just one? (Use the Force Sensor to check your feelings about the magnitudes of the forces.)

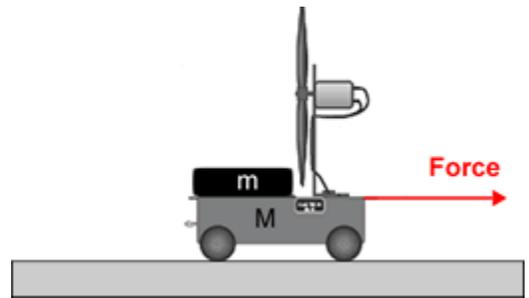


### Activity 3: Newton's Second Law: $a = F/m$

In this Activity you will use a *Fan Accessory*. The fan accessory clamps to the collision cart and produces an approximately constant force upon it.

- **Avoid a runaway Cart falling off the Track.**

Leave the Motion Sensor mounted on one end. Warm up the bearings of the wheels of the Cart by rolling it up and down the Track a few times.



- A. Put 4 AA batteries in the Fan Accessory. Carefully clip the fan accessory to the top of the collision cart, avoiding putting too much pressure on the wheels of the cart. Place the Cart on the 2.2 m Track close to the Motion Sensor but at least 0.15 m away from it. You will want the direction of the air from the fan to blow towards the Motion Sensor. Turn the fan on and use the Motion Sensor to measure the acceleration of the Cart. You may have to find the acceleration as the slope of the velocity versus time graph (rise over run) *Please don't let the cart crash!*

Measured acceleration of Cart with 4 batteries, in  $\text{cm/s}^2$ :

$a_{\text{meas}} =$

To convert  $\text{cm/s}^2$  to proper S.I. Units, divide by 100.

Measured acceleration of Cart with 4 batteries, in  $\text{m/s}^2$ :

$a_{\text{meas}} =$

Estimate the **error** (uncertainty) in your measurement of acceleration. Think of this as a “plus or minus”. For example, if you measure  $0.25 \text{ m/s}^2$ , with an error of  $0.02 \text{ m/s}^2$ , that means you think the actual acceleration is probably somewhere between  $0.23 \text{ m/s}^2$  and  $0.27 \text{ m/s}^2$ .

$\pm$  Error of Acceleration measurement, in  $\text{m/s}^2$ :

$\Delta a_{\text{meas}} =$

(Note that  $\Delta$  is the greek letter “Delta”, often used to mean “the change in”, but in this case we are using the notation that “ $\Delta a_{\text{meas}}$ ” is a number which represents “the error in  $a_{\text{meas}}$ .”)

- B. Use the spring-scale to measure the horizontal force acting on the system by the fan when it is not moving. You may wish to loop a length of string over the small metal pin in the cart in order to attach the Force Sensor or spring-scale. Is this the force acting on the system when it is moving?

Force of fan with 4 batteries, in N:

$F =$

Estimate the error of your force measurement. Every member of your group should measure the force independently. Find the range of measurements, which is the maximum minus the minimum. The error can be roughly estimated as half of the range.

$\pm$  Error of Force measurement, in N:

$\Delta F =$

C. Measure the mass of the cart, motor, fan and housing for the fan. There is a digital scale available at the front of the room.

Mass of cart system including fan, in g:  $m =$

To convert grams to proper S.I. Units, divide by 1000.

Mass of cart system including fan, in kg:  $m =$

Estimate the error of the mass measurement. You probably always get the same measurement with the digital scale, so you can just use the error that is written on the scale (this is often half of the smallest measurement possible with the smallest digit on the display).

$\pm$  Error in the mass measurement, in kg:  $\Delta m =$

D. Use Newton's 2<sup>nd</sup> Law with the force measured from Part B and the mass measured from Part C to predict the acceleration of the cart when the net force upon it is equal to the force provided by the fan. Compare this prediction to the measured acceleration in part A. Compare the prediction and measurement and discuss what might cause them to differ.

PREDICTION (based on parts A and C)

$$a_{\text{pred}} = F/m =$$

Propagate the errors in the two measurements of F and m to get the error in  $a_{\text{pred}}$ :

$$\Delta a_{\text{pred}} = a_{\text{pred}} \sqrt{\left(\frac{\Delta F}{F}\right)^2 + \left(\frac{\Delta m}{m}\right)^2}$$

$\pm$  Error in the prediction:  $\Delta a_{\text{pred}}$

Absolute value of the difference between prediction and measurement from part A:

$$|a_{\text{meas}} - a_{\text{pred}}| =$$

If this difference is much bigger than the errors in  $a_{\text{meas}}$  and  $a_{\text{pred}}$ , then there may be something wrong with your measurements, your calculations, or your error estimates. Or, you may have just proved Newton's 2<sup>nd</sup> Law to be wrong! Note that experiments with high velocity particles have been done which actually **do** prove that Newton's 2<sup>nd</sup> Law is wrong! Newton's Laws are all *approximate*; they only work if the relative speeds of all the objects is much less than 300,000 km/s. When relative speeds are very high, you must use the exact, but more complicated, laws of Special Relativity.