PY 105

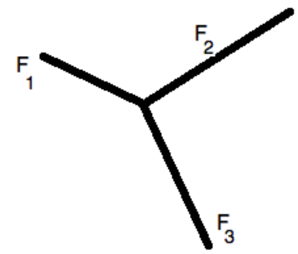
Section: Name: BU ID: .

Partner: Name: BU ID: .

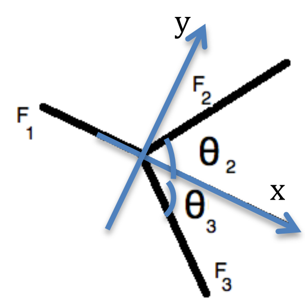
Lab 4: Forces and Newton's Laws

Part I: Equilibrium. In this part you will be investigating vectorial properties of forces.
Part IA: Proving that in equilibrium the net force is equal to ZERO.

You need a clamp, three spring scales, Y-shaped string, a sheet of paper, a protractor, a pen or a pencil. **ZERO all the scales!**



1. Attach one scale to a clamp attached to the table, connect all three scales by the Y-shaped string. Now, pull on the two scales in different directions, and let your partner place a sheet of paper under the string and copy the configuration of the strings on the paper, as well as the values of the tension forces. **ALL three forces should have DIFFERENT magnitudes.** Your picture should look similar to that on the right. Be as accurate as possible in drawing the picture and measuring the angles and the forces!



Copy your picture in the box below. In your picture: mark the forces and the angles as shown in the picture on the right, write the magnitude of each force. Measure the angles and write the values in the picture. (**Remember**: *different scales might have different units, such as, grams, kilograms, pounds, etc., you have to convert all your forces into SI units, i.e. into N).*

Note:

a) 1 g = 0.001 kg

b) 1 kg is an equivalent of

1*9.81 = 9.81 N

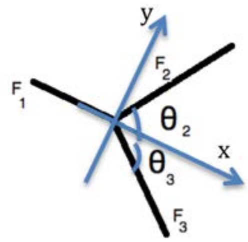
Note:
to compare two positive numbers n_1 and n_2 you can calculate the relative difference

$$\frac{|n_1 - n_2|}{n_1} * 100\%$$

We know that in equilibrium the *vectorial* sum of all *forces* must be equal to ZERO (!). Your goal is to prove this statement.

2. Using measured values for the magnitudes of the forces and the angles calculate the components of the forces relative to the x- and y- axes (your table must show *actual* values of the components, not magnitudes).

Magnitudes		
F_1	F_2	F_3



θ_2 =

θ_3 =

Components.

F_{1x}	F_{1y}	F_{2x}	F_{2y}	F_{3x}	F_{3y}

3. Prove below *that the vectorial sum of all three forces* is equal to ZERO.
Hint: (a) calculate the x- and y- components of the net force; (b) calculate the magnitude of the net force and compare it with the magnitudes of the individual forces.

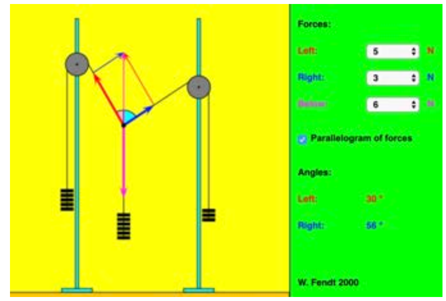
5. (A) Is *the magnitude of the sum of all three forces* equal to zero (or close to it)?

(B) Is *the sum of the magnitudes of all three forces* equal to zero?

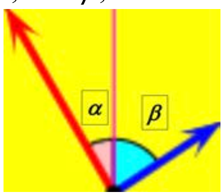
(C) Based on your answers above state if *the magnitude of the sum of all forces is equal to the sum of the magnitudes of all forces?*

Is “the magnitude of the sum” the same as “the sum of the magnitudes”?

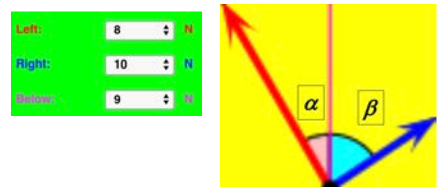
Part IB: Playing with an applet.



Open the following link
http://www.walter-fendt.de/html5/phen/equilibriumforces_en.htm
(the copy of the link can be find in file py105weblinks.doc – the latest version of the file is on the course site at learn.bu.edu).
You should see a picture similar to the one on the right.
(A) Predict (i.e. calculate) the angles α, and β, in the diagram, when all three weights will be equal to 8 N (small picture below shows the angles α, and β, which need to be found). Show your work (you need to derive two equations which you would have to solve to find the angles). Check your predication using the applet; compare your angles with the angles in the applet. HINT: do not solve the equations for angels algebraically, instead use the online tool **http://www.wolframalpha.com** (follow the example in the class; or use the instruction file available on the course site learn.bu.edu). HINT: you can find the angles algebraically if you make a statement about the values of α, and β, based on the fact that all three weights are equal.

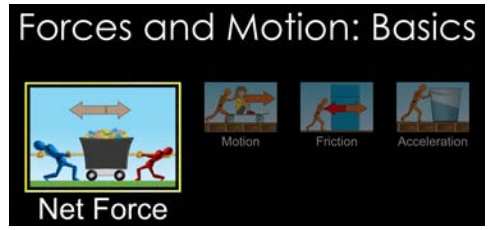


(B) Predict (i.e. calculate – using **http://www.wolframalpha.com**) the angles α, and β, in the diagram, when the weights will be equal to 8 N (left), 10 N (right), and 9 N (in the middle) respectively. Show your work (you need to derive two equations which you would have to solve to find the angles). Check your predication using the applet; compare your angles with the angles in the applet.



Part II: Investigating Newtons Second Law

Part IIA: Playing with an applet



Open the following link (the copy of the link can be find in file py105weblinks.doc)
https://phet.colorado.edu/sims/html/forces-and-motion-basics/latest/forces-and-motion-basics_en.html

You should see a picture similar to the one on the right. Click twice picture named “Acceleration”.

Check on all available readings:

Set friction to “None”

Predict (i.e.) calculate, how much time will pass after a force of 100 N will being to be applied to the box (50 kg) until the box reaches the speed of 40 m/s. Show your work.

Check your prediction.

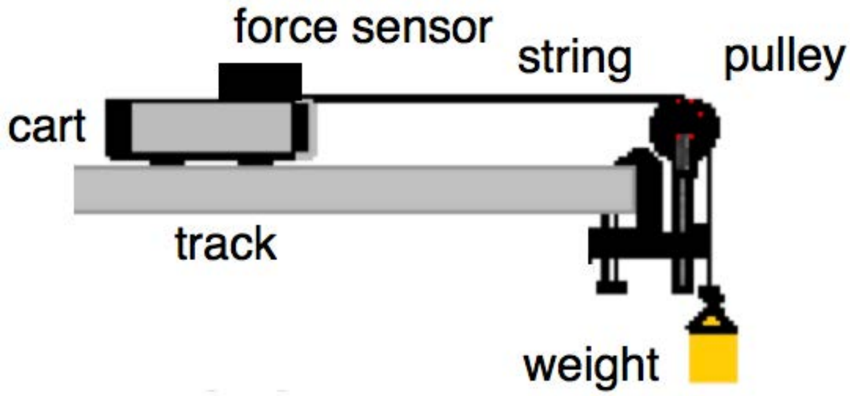
Use your watch (or a cellphone) to measure time. Quickly click twice  button. Together with the second click start your stopwatch. Observe the speedometer. If you need to repeat the “experiment” use  button to resent the app.

Explain, what and why is happening with the box after it has reached 40 m/s speed? ____________________

What will happen to the box if you add some force of fiction acting on it? Test your prediction.

Part IIB: An experiment

Newton's Law. In this experiment you will investigate the connection between the forces applied to a cart and aspects of the cart's motion along a track.



NOTE: read instructions in full, do not skip any steps, or our data will be way off (makes sure your sensors are zeroed before the experiment).

The picture on the right shows the setup (there is also a motion sensor attached to another end of the track, which is not shown in the picture). The motion sensor and force sensor are connected to a computer with the means of a LabPro interface. **The force sensor should be set to 50 N scale**; it shows the tension in the string attached to it. With the use of the motion sensor we can measure the position of the cart and calculate its acceleration.

Warm-up exercise:

1) Finish the sentence:

For a linear motion with constant *non*-zero acceleration the graph for position as a function of time is … (check all that apply, i.e. indicate all possible shapes of the curve for the graph):

a) [ ] circular b) [ ] parabolic with the branches up c) [ ] parabolic with the branches down

d) [ ] a straight line with a positive slope e) [ ] a straight line with a negative slope

f) [ ] none of the above (give your own answer)____

2) Finish the sentence:

For a linear motion with constant *non*-zero acceleration the graph for velocity as a function of time is … (check all that apply):

a) [ ] circular b) [ ] parabolic with the branches up c) [ ] parabolic with the branches down

d) [ ] a straight line with a positive slope e) [ ] a straight line with a negative slope

f) [ ] none of the above (give your own answer)____

3) Let the velocity equation be $v = -4t + 5$ (assume an object is moving linearly along x-axis; assume SI units). Write the motion equation for the object's position x as a function of time (use the fact that at $t_3 = 3$ s the position of the object is $x_3 = -2$ m).

An experiment:

1. Measure the mass of the cart *together* with a force sensor attached to it: $M_{\text{cart with sensor}}$ =_______________

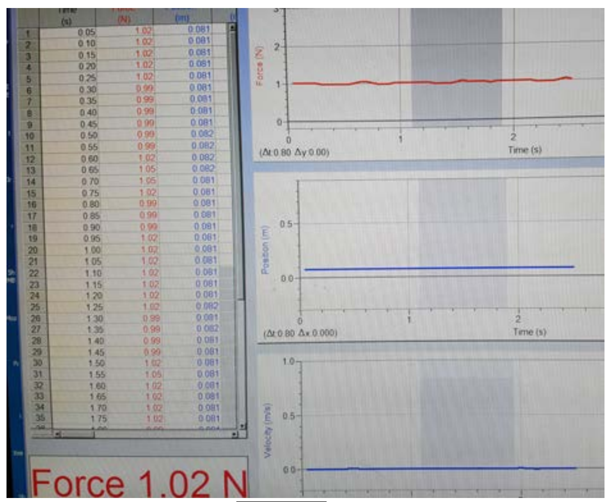
Measure the mass of one metal bar (or a cylinder, if used instead) M_{bar} = ____________________

You also will be using a weight with mass of m = 100 gram (or 50 gram).

2. Start file PY105_lab4.cmbl. This should open a window with three graphs, i.e. one for the position of a cart, one for the velocity of a cart, and one for the force of tension in a string.

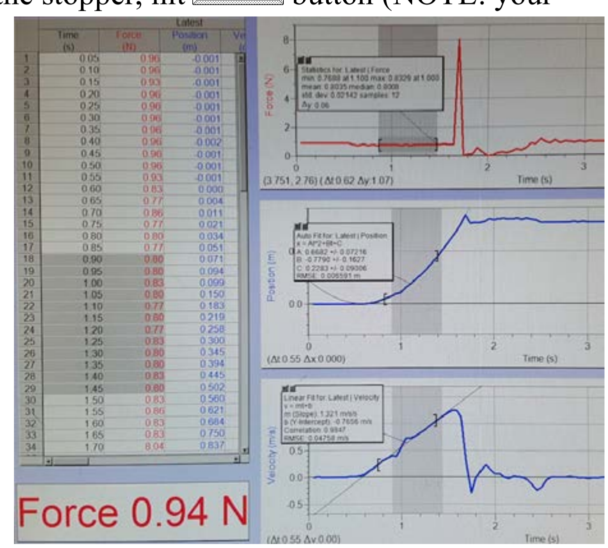
3. Place a cart on a track about 10-15 cm *away* from UMS. Detach the string. With the cart *not* moving and *no* string attached to it **<u>zero</u> all censors**. Check your force sensor, when the cart is at rest and the string is removed, the force sensor has to show a very small force, in the vicinity of 0.02 N.
Note: instructions below assume using a 100 g weight, but you could also use a 50 gram weight.

4. Attach a string to a cart and then attach to the string one 100 gram weight (refer to the picture on page 1). With the cart *not* moving (make sure there is *nothing* between the cart and the motion sensor), hit [Collect] button, wait for about 5 seconds and then hit [Stop] button. To get the average value of the force of tension select an appropriate region of the graph, hit Statistics button [STAT] and read the mean value in the box (**NOTE:** the region you select for the force should correspond to a relatively smooth region for velocity graph). You should read a number close to 1 N (do you know why?); **if not, refer to the section on calibration the force censor at the end of this manual (page 8).**



T = _____________

5. Attach a "friction pad" to the cart, reattach (if needed) the string with a 100 gram weight, place carefully one or two metal bars or cylinders on the cart (to make it heavier; note that you will need to know the total mass of the cart with the sensor and additional weights), make sure there is nothing between the cart and the motion sensor, hit [Collect] button, wait for about a second and release the cart. Just before the cart hits the stopper, hit [Stop] button (NOTE: your partner should try to catch the cart before it hits the stopper or falls off the track).



6. On the graph for *velocity* as a function of time you should see a region with a relatively straight line. <u>If this is not the case, you should repeat the measurements.</u>

Use the quadratic fit for x(t) graph and a linear fit for v(t) graph and compare the value of the acceleration you obtain form theses graphs. If the two values are close, your setup is ready, otherwise you may need to clean the groves of the track, or reset the sensors.

In the boxes provided below, draw a free-body-diagram (FBD) for the weight on the string when the cart was at rest, and then FBD for the weight when the cart (and the weight) was moving.

Write the Newton's second law (N2L) for the weight in both situations. Reason and make a prediction for the magnitude of the tension force acting on the moving cart/weight (*will it be the same, larger or smaller than the number in part 4*?). Explain.

7. On the graph for the force of tension as a function of time select a region corresponding the linear time dependence of the velocity (the velocity graph should be more a less straight and not very noisy). Hit Statistics button, 

and read the mean value (ignore other values).

$T =$ _______________

Compare this value with the value from part 4; compare with your prediction.

____

____

8. Finish the sentence: "The magnitude of the acceleration of the weight attached to the string is equal to the magnitude of the acceleration of the cart because…" (check all that apply, if any):

[ ] the weight is very light   [ ] the string has no mass   [ ] the string does not stretch

[ ] the cart is very heavy   [ ] the acceleration is constant   [ ] the motion sensor does not affect the force sensor.

[ ] none of the above (provide your own answer)____

9. On the graph for position as a function of time select an appropriate region and with the means of Curve Fit button find the acceleration of the cart (click on the position graph, select a region of the graph by clicking-and-dragging with the mouse - ideally you should select exactly the same time interval as you did for the force - and then click Curve Fit button, . Select Quadratic fit from the list and click [Try Fit]. Click [OK] to return to the main graph. You will see a box with an equation x = At^2 + Bt + C. You have to use an appropriate coefficient to get the acceleration – like in lab 2; close the box).

a = ___________

10. Draw FBD for the weight attached to the sting, use the Newton's second law for it, and the data collected in the experiment (magnitudes of the acceleration and the force of tension) and calculate the mass of the weight. If it is close to 100 gram, you are all set with the measurements, otherwise you should run the experiment again (use g = 9.8 m/s^2).

$m_{\text{calculated}}$ = ________________

11. In the space on the right draw FBD for the cart, IGNORE the force of friction, write N2L for the cart, use the N2L and the data collected in the experiment and calculate the total mass of the cart with the objects placed on it.

$M_{\text{total calculated}}$ = ______________

Compare it with the total mass of the object $M_{\text{total actual}} = M_{\text{cart with sensor}} + M_{\text{bar(s)}}$ = ____________

Equipment

Lab 4:

Part IA (12 tables): three 20 N spring scales, Y-shaped string, a clamp, paper sheets, a protractor.
Part IB (12 tables):
Part II (12 tables): a track, a motion sensor, a force sensor, a pulley, a 50 gram weight, a 100 gram weight, a 500 gram weight or a 500 gram bar, a 250 gram weight or a 250 gram bar, a string, a cart, a "friction pad", a PC with LabPro interface.

Appendix: Calibrating the force sensors (when needed).

Place the cart on a track with string attached so an attached weight would be at the highest possible position. Make sure the cart is not moving during calibration (hold it with your hand or ask your partner to do that). Now detach the string and click on Zero button. You should zero all sensors, so you should hear the motion sensor clicking as it sends out pulses to determine where the cart is. Now click on the "Logger Pro" icon near the top of the screen, make a right click on the picture of a force sensor, and click on the "Calibrate" tab. Click on "Calibrate Now". Enter 0 (zero) in the opened box, and click on "Keep". Now attach the string and carefully place a 500 g weight, let the weight become still, and enter 4.9 (do you know WHY?) into the second opened box, click on "Keep", click on "Done", and close the LabPro settings box.

Unit layout

L4: 140 minutes
PI: 70 minutes

A. 35 minutes

B. 35 minutes

PII: 70 minutes

Breaks when needed

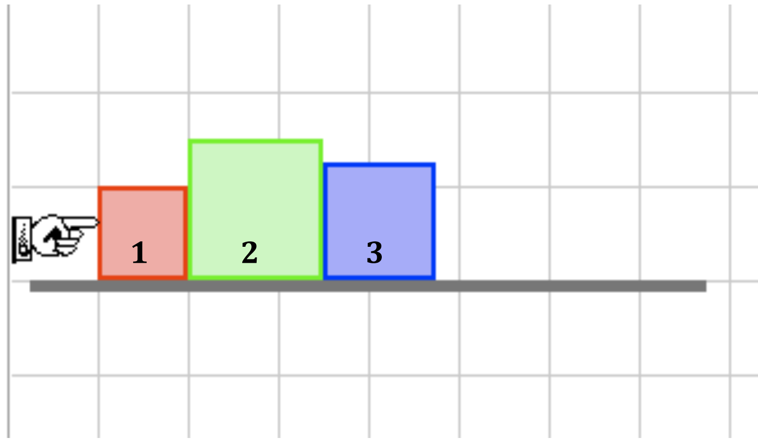
PE4: 60 minutes

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

Practice Exercise 4:

A constant force is being applied to block #1 as shown in the picture on the right. ***Neglect friction***.

1. Draw below FBD for each block.



2. $M_2 = 2M_3 = 3M_1 = 6$ kg   The force applied to block # 1 is 22 N. (a) Find the acceleration of the system. (b) Find the *net* forces acting on each block (individually). (c) Find the force acting on block 2 from block 3. (d) Find the force acting on block 1 from block 2.