Newton's Laws II

Name

PES 1150 Prelab Questions

Lab Station: 005

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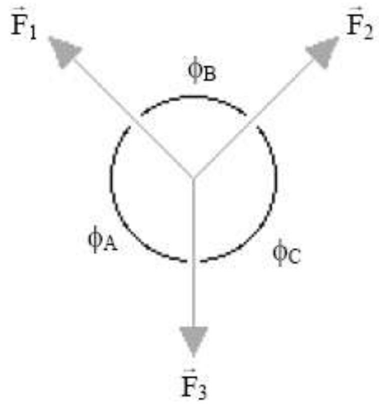
- **Use the following values and the information in your manual to test Newton's Laws.**

$\Phi_A = 117^o$ $m_1 = 12.6$ g
$\Phi_B = 140^o$ $m_2 = 11.5$ g
$\Phi_C = 103^o$ $m_3 = 8.3$ g

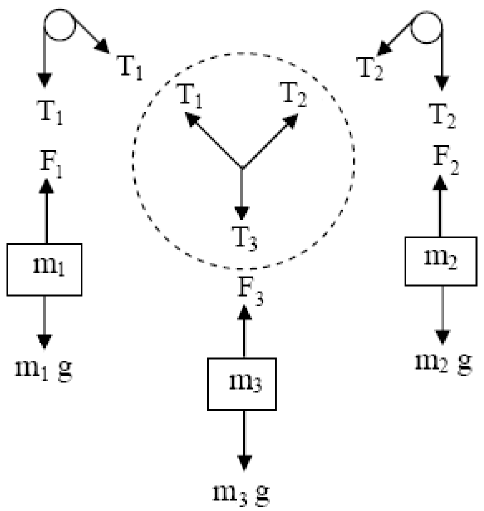


** NOTE: For this lab it is crucial to have very clear drawings. It will help to be consistent through your sketches and keep standard notations and labels. It is also helpful to keep the explanations well labeled and clear of clutter (e.g., it is easy to leave out a negative sign or not keep the directions or magnitudes straight – so be especially careful). The problems provided in this pre-lab are quite long when completely written out. Unlike previous pre-labs it is imperative that you explicitly write everything out for this problem (i.e., you can't just write down an answer). All the steps have been provided below – make sure you don't leave anything important out! {I guess what I'm trying to say is, usually my pre-lab examples are relatively long due to the fact that I include extra information for your sake of learning; however, in this pre-lab it's long – and everything is needed. ☹}**

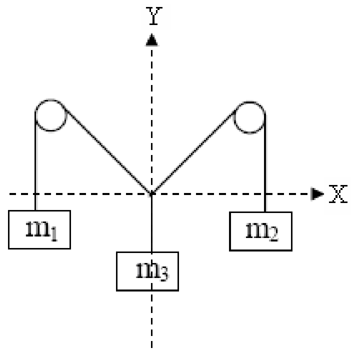
The ***easiest*** way to do this will be to convert the phis into thetas and the masses into forces:

Angle [deg]	Force [Newtons]
Θ_1 = ??	F_1 = ??
Θ_2 = ??	F_2 = ??
Θ_3 = ??	F_3 = ??

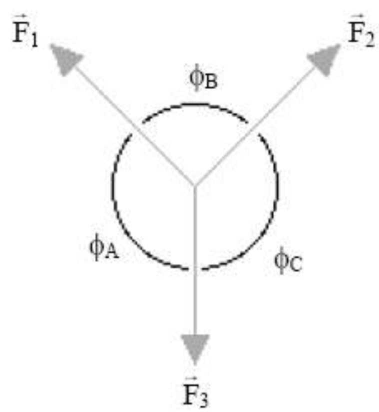
First, let's consider the set up for the lab:

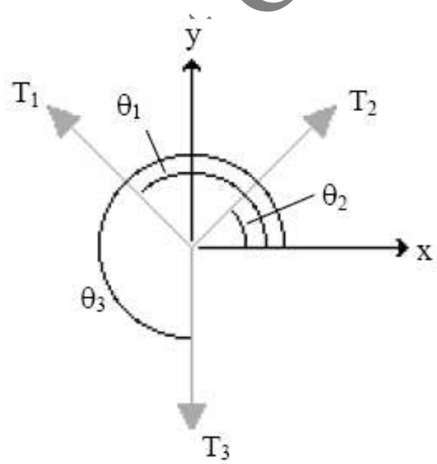


We need to establish a coordinate frame and then use Newton's Laws to find all the forces acting in this X/Y-coordinate frame and finally use the measurements to plug in the values and see if the theory holds. (Note that for this lab we will assume that the two pullies are frictionless and the connective strings are weightless. [This will of course introduce some minor error to our result.])



Let's consider the angles and see if we can find some relationship between thetas (measured from the coordinate x-axis) and phis (measured between strings.)





First, I looked at Theta 3. Notice that this angle is constant:

$$\boxed{\theta_3 = 270^o}$$

Next, I noticed that the angle Theta 2 is right next to a ninety degree angle (below it) – and those two just happened to add up to phi-C.

$$\boxed{\theta_2 = \phi_C - 90^o}$$

The difficult one was Theta 1 – but since we already knew the angle of Theta 2, we can see that phi-B plus Theta 2 is precisely Theta 1 (and we already have a relationship for Theta 2.

$$\boxed{\theta_1 = \phi_B + \theta_2 = \phi_B + \phi_C - 90^o}$$

From the hint for Lab 5 and the equations in the manual, we know that the following equations are derived for this static system by Newton's Laws:

For forces in the x-direction:

$$F_1 \cos(\theta_1) = -F_2 \cos(\theta_2)$$

For forces in the y-direction:

$$(F_1 \sin(\theta_1)) + (F_2 \sin(\theta_2)) = F_3$$

We will use these two equations, plug in the values, and see if the equalities hold for each of these two equations. So, if Newton's Laws are true, the value on the left side of the equations should be identical to the number on the right side of the equations.

For forces in the x-direction:

$$\boxed{F_1 \cos(\theta_1) \stackrel{?}{=} -F_2 \cos(\theta_2)}$$

For forces in the y-direction:

$$\boxed{(F_1 \sin(\theta_1)) + (F_2 \sin(\theta_2)) \stackrel{?}{=} F_3}$$

Test Newton's Laws from Measurements

We are given (or in the case of the lab will measure using a scale and protractor) the following measurements of the angles and masses of the system. Using the two equations above for the total forces in the x-direction and the total forces in the y-direction, we can test Newton's Laws:

Angle [deg]	Mass [grams]
$\Phi_A = 117^o$	$m_1 = 12.6$ g
$\Phi_B = 140^o$	$m_2 = 11.5$ g
$\Phi_C = 103^o$	$m_3 = 8.3$ g

First, we need to get the masses into kilograms, so when we multiply it by an acceleration (namely the acceleration due to gravity) we will have units of Newtons.

Examples:

$$m_1 = 12.6\ g = (12.6\ g)\left(\frac{1\ kg}{1000\ g}\right) = 0.0126\ kg$$

$$F_1 = (0.0126\ kg)\left(9.81\frac{m}{s^2}\right) = 0.123606\ N$$

Angle [deg]	Force [Newtons]
$\Theta_1 = 153^o$	$F_1 = 0.123606$ N
$\Theta_2 = 13^o$	$F_2 = 0.112815$ N
$\Theta_3 = 270^o$	$F_3 = 0.081423$ N

For forces in the x-direction:

$$F_1 \cos(\theta_1) = -F_2 \cos(\theta_2)$$

$$(0.123606\ N)\cos(153^o) = -(0.112815\ N)\cos(13^o)$$

$$(0.123606\ N)(-0.891007) = -(0.112815\ N)(0.974370)$$

$$\boxed{-0.110134\ N \stackrel{?}{=} -0.109924\ N}$$

With consideration of reasonable error introduced by human measurements, angle and mass rounding, the fact that the strings are not massless, and the fact that the pullies are not frictionless – these values are almost *identical*. So, **Newton's Law for Forces in the x-direction appears to hold true**.

For forces in the y-direction:

$$(F_1 \sin(\theta_1)) + (F_2 \sin(\theta_2)) \stackrel{?}{=} F_3$$

$$(0.123606\ N)\sin(153^o) + (0.112815\ N)\sin(13^o) \stackrel{?}{=} 0.081423\ N$$

$$(0.123606\ N)(0.4539905) + (0.112815\ N)(0.224951) \stackrel{?}{=} 0.081423\ N$$

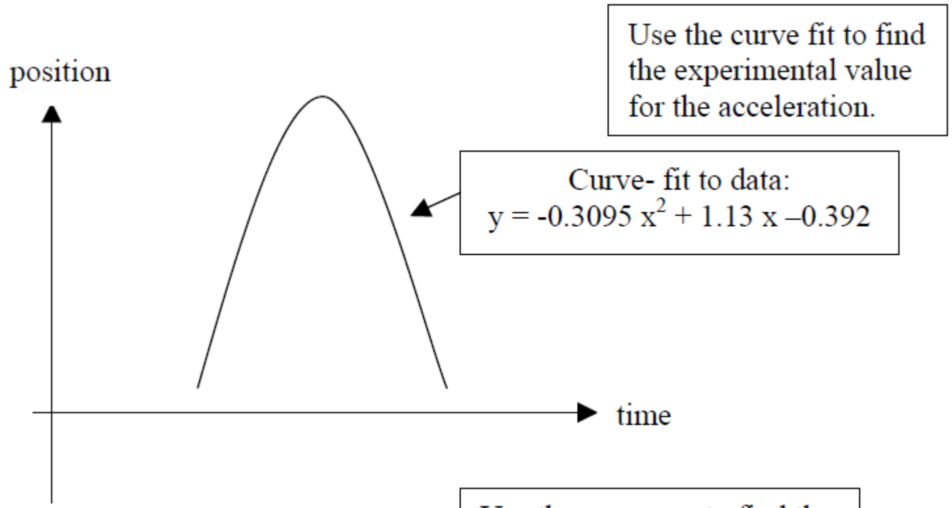
$$(0.0561159\ N) + (0.0253778\ N) \stackrel{?}{=} 0.081423\ N$$

$$0.0814937\ N \stackrel{?}{=} 0.081423\ N$$

$$\boxed{0.0814937\ N \cong 0.081423\ N}$$

Again, with consideration of reasonable error introduced by human measurements, angle and mass rounding, the fact that the strings are not massless, and the fact that the pullies are not frictionless – these values are almost *identical*. So, **Newton's Law for Forces in the y-direction appears to hold true**.

- **Find the measured acceleration from this experimental data. Compare the measured value to the expected value. How close are they?**



$m_1 = 169.7$ g

$m_2 = 149.1$ g

Use these masses to find the expected value for the acceleration.

Finding Acceleration from Experimental Data using Graphs:

** We should be pretty good at this by now! ** Using the curve-fit to data above, we got the following best fit line:

$$y = \left(-0.3095\frac{m}{s^2}\right)t^2 + \left(1.13\frac{m}{s}\right)t + (-0.392\,m)$$

If we compare the equation for kinematic 2D motion for the y-position with the found trendline, we can easily see by evaluation that the following constants correlate directly:

$$y = \frac{1}{2}a_y t^2 + v_{o,y}t + y_o$$

$$y = \left(-0.3095\frac{m}{s^2}\right)t^2 + \left(1.13\frac{m}{s}\right)t + (-0.392\,m)$$

Thus:

a_y [m/s^2]	$v_{o,y}$ [m/s]	y_o [m]
-0.619	1.13	-0.392

Hence the "measured acceleration" is:

$$\boxed{a_y = -0.619 \frac{m}{s^2}}$$

Finding Expected Acceleration from Experimental Data using Masses and Newton's Laws:

Using the hints for lab 5, we know that an atwood machine has the following relationship for acceleration using Newton's Laws:

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$$a_y = \frac{(m_2 - m_1)}{(m_1 + m_2)} g$$

We are given the following measurements of the masses of the system. Using the equation above for the acceleration in the y-direction of a dynamic system, we can calculate the expected acceleration.

Masses [g]
m_1 = 169.7 g
m_2 = 149.1 g

Notice that the units of the masses will cancel out (so we don't have to convert these to kilograms – but you can if you *really* want to.)

$$a_y = \frac{(m_2 - m_1)}{(m_1 + m_2)} g$$

$$a_y = \frac{((149.1\ g) - (169.7\ g))}{((169.7\ g) + (149.1\ g))} \left(9.81 \frac{m}{s^2}\right)$$

Hence the "expected acceleration" is:

$$\boxed{a_y = -0.6338958 \frac{m}{s^2}}$$

Compare the measured value to the expected value:

To compare the measured value with the expected value, we must do a percent difference.

$$a_{y,MEASURED} = -0.619 \frac{m}{s^2} \qquad a_{y,EXPECTED} = -0.6338958 \frac{m}{s^2}$$

Using the percent difference, we can compare the "measured" acceleration with the "expected" acceleration.

$$\%\ difference = \frac{|a_{Expected}| - |a_{Measured}|}{|a_{Expected}|} x100\% = \frac{\left(-0.6338958\ \frac{m}{s^2}\right) - \left(-0.619\ \frac{m}{s^2}\right)}{\left(-0.6338958\ \frac{m}{s^2}\right)} x100\%$$

$$\boxed{\%\ difference = 2.3499\%}$$

By examining our result of the percent difference calculation, we can see that we are not far off from the expected value of the acceleration. The value is just slightly lower (by exactly 2.3%) than the expected value. Again, with consideration of reasonable error introduced by human measurements, mass rounding, the fact that the strings are not massless, and the fact that the pully is not frictionless – this percent difference is well within reasonable limitations.