Physics 203 - Lab 2 - Vectors

Introduction

Force Tables

The Force Table allows us to manipulate and measure the effects of vector quantities.

Goals

The object of this lab is to gain a thorough understanding of vector addition. This is accomplished by using the force tables to establish equilibrium for a particle, and correlate this equilibrium condition with the math of vector addition. Two methods of vector addition are discussed: graphical and analytical.

Equipment check

Please make sure your station has all of the following items. If not, check again, then talk to your lab instructor.
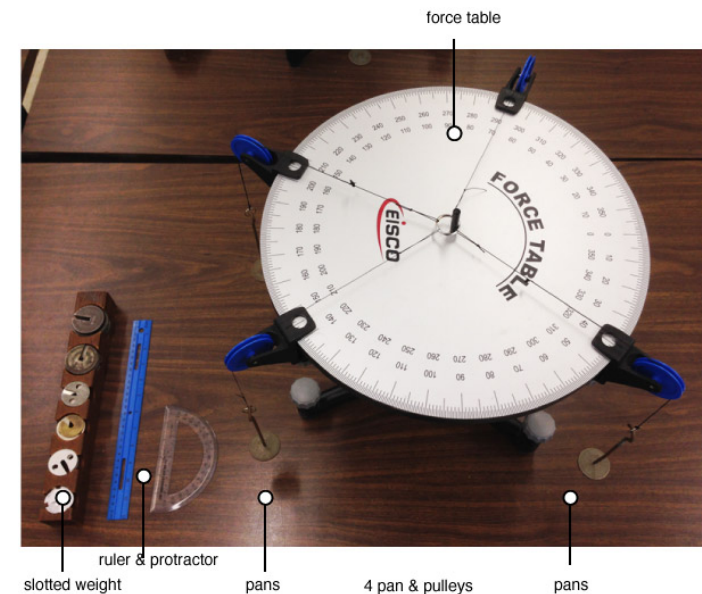
Intro to Vectors

Physical quantities that require both a magnitude and direction for their description are vector quantities. A great example of a vector quantity is the wind velocity. Since the wind can blow in a direction, and with a certain speed, we will need to use both a magnitude and a direction to describe this physical quantity.
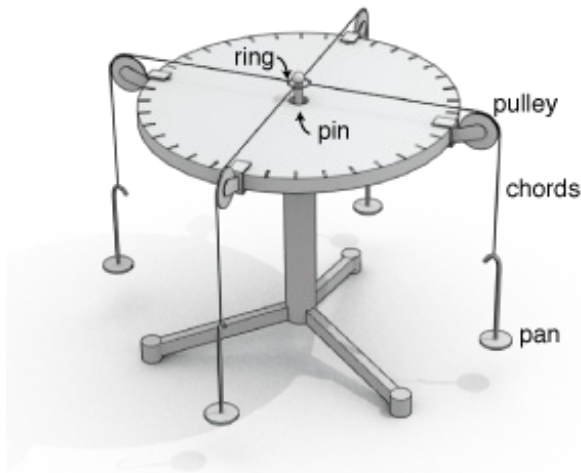
Adding Vectors

Vectors must be added by special rules that take both parts of the description into account.

Below are two blue vectors, and the vector sum, a dashed black line. Try manipulating the blue vectors and observing what happens to the sum.

About the Force Table

Let's understand exactly how the force table works. A mass is placed in each *pan* (each pan has a mass of 50g). This mass experiences a force due to gravity given by its mass times g. This force is acting in the vertical direction. In order to redirect the force to act in a horizontal direction (i.e parallel to the surface of the table), chords and pulleys are used. Thus, the tensions from the chords on the ring at the center are equal in magnitude to the force due to gravity on the pan + mass:

$$T_1 = m_1 g$$

Attaching several pan/pulley systems to the table allows us to pull on the ring with different tensions in different directions.

What will the tension be, in Newtons, if a 20 gram mass is attached to the 50g tray?

Tension [N] = _____

Instructions for use:

1. The central ring has spokes that connect the inner and outer edges. When connecting the cords be sure that the hooks have not snagged on a spoke. In that case the cord will not be radial. Also whenever you change a pulley position, check that the cord is still radial.
2. Be sure that when you position a pulley, that both edges of the clamp arc snugly against the edge of the force table. Check that the cord is on the pulley.
3. There are two tests for equilibrium.
    A. The first test is to move the pin up and down and observe the ring. If it moves with the pin, the system is NOT in equilibrium and forces need to be adjusted.
    B. The second test is to remove the pin. However, this should be done in two stages. First just lift it but hold it in the ring to prevent large motions. If there is no motion, remove it completely. If the ring remains centered then the system is in equilibrium.
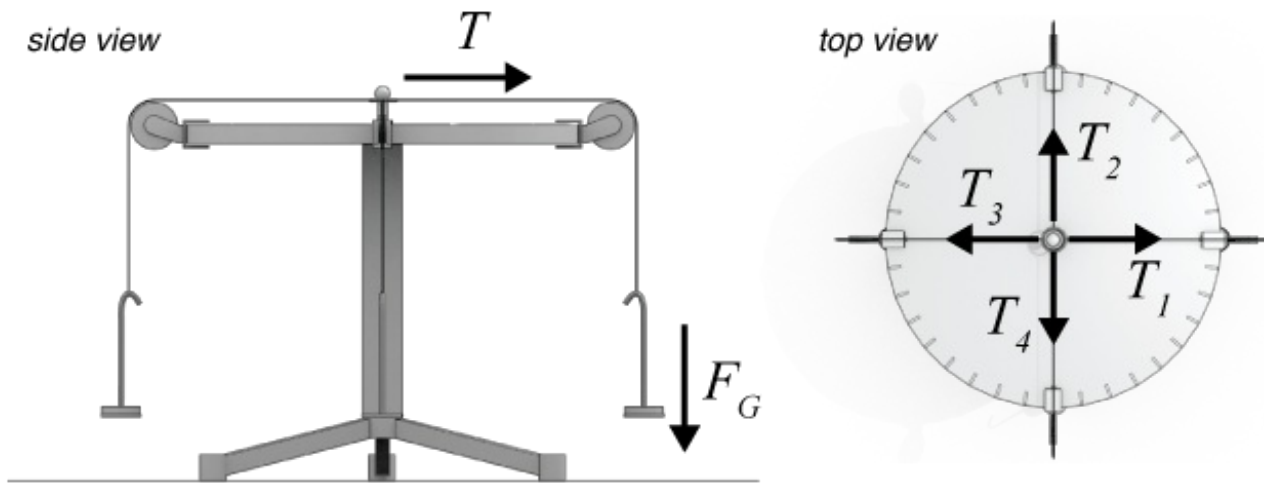
Exp. 1: Sensitivity of the instrument

Let's measure how precise the force tables are.

1. Arrange two pulley systems, Pan 1 at 0° and Pan 2 at 180°.
2. In Pan 1, place 50 grams. In Pan 2, also place 50 grams.
3. Now, in Pan 2 add 1 gram and check for equilibrium. It's most likely still in equilibrium, right?
4. Find the maximum mass you can place in pan 2 and still maintain experimental equilibrium.

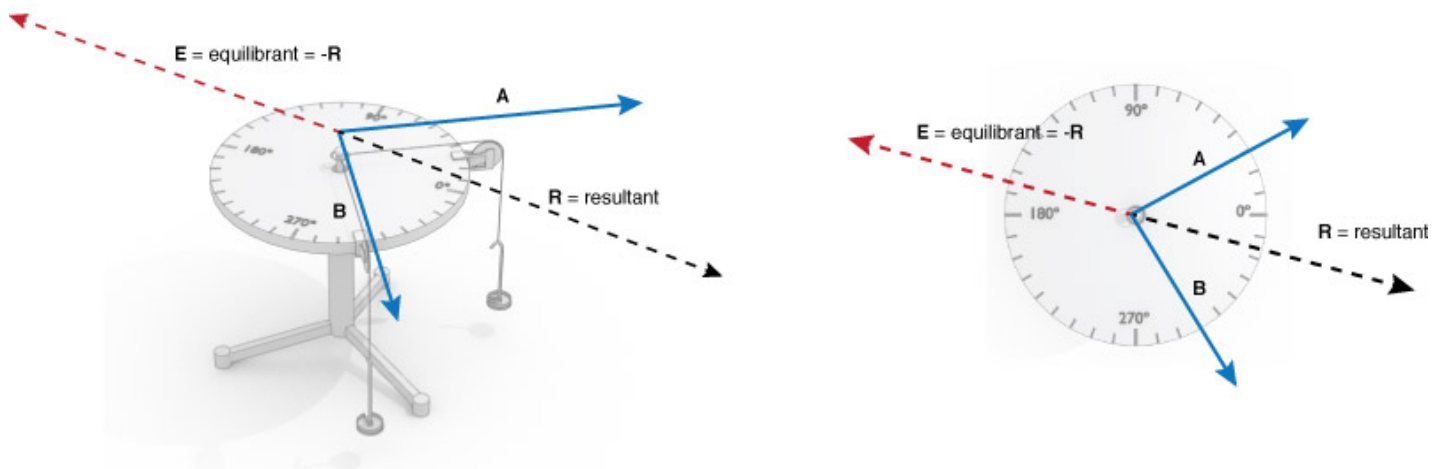Record this value below. This is the sensitivity to weight of the force table.

Sensitivity [g] = _____

Report Question 1

What factors could contribute to this sensitivity?

Resultant Vs. Equilibrant

A point to be aware of is that the force needed to balance the system is **not** the resultant of the weights, but the negative of that vector, also called the equilibrant.

Response:

If the resultant of 2 mass/tray systems points in a direction 234° measured counter-clock-wise (CCW) from the 0° line, in what direction should the equilibrant point?

Direction of Equilibrant [°] =_____

Experiment 2: Symmetric Arrangement

1. Using the number generator below, pick two initial masses and directions. Write these down in your notebook!

   [Generate Numbers]

   Mass 1: x grams
   Direction 1: x °
   Mass 2: x grams
   Direction 2: x °

2. Set up two pans and mass systems based on these values.
3. **Experimentally** balance the system. (i.e. without performing any math or analytical operations, find a third pan/mass system that will balance the first two.)

Mass needed to balance the System [g] =_____

Use the simulated force table below to predict how much mass you should need and compare this to the value you found experimentally. Make sure to include the mass of the pans in when setting up the forces. (You can use $g \approx 10m/s^2$ for this)

By how many grams was your experiment different from this simulation?

Grams difference = _____

> ### *Report Question 2*
>
> Report the difference between what you've experimentally measured and what the simulation predicted. Are they within the expected sensitivity of the instrument?

Vector Components

Our mathematical framework for dealing with multiple vectors involves using vector components. If we have an x-y coordinate axis, any vector on this axis can be *decomposed* into its x and y components. The simulation below shows one vector decomposed into its x and y components.

Question: Components

On the simulation above, pick a magnitude and direction for the dark purple vector. Pick a direction that points in both x and y, i.e. not vertical or horizontal. Using trigonometry, calculate the magnitudes and direction of the vector components. Verify that your calculations match the predicted values of the components in the simulation. (Hovering the mouse overt the arrow tip will display its magnitude and direction)

We'll need vector components to do more complicated calculations as the next section shows.

Experiment 3: Vector Components

This experiment will demonstrate the concept of vector components.

1. With the pin in the force table (i.e. so the ring doesn't move), hang one 50 gram mass from a pan at an angle of 35 degrees (CCW from the 0° line). This will create a force acting on the ring. We can call it F_1.
2. The next step is to analytically calculate the x and y components of this force. In other words, find F_{1x} and F_{1y}. Enter the magnitudes of these components in the boxes below.

   F_{1x} =_____

$F_{1y} =$ _____

3. Now that you know what the x and y component magnitudes are of force F_1, you can hang masses at 180 ° and 270 ° to balance each of the components of F_1 based on the calculations. Do it and confirm that the system is in equilibrium by pulling out the pin.

Report Question 3

Include the results and work of this calculation in the lab report. Also, draw a graphical vector diagram that shows how the system should be in equilibrium.

Multiple Forces

Exp. 4: Return to the Force Table

Now let's apply these concepts to the force table. If we have 3 known forces acting, we should be able to analytically predict a fourth force to add so that the system is in equilibrium, i.e. $F_{net} = 0$.

Press the blue button below to generate 3 sets of random masses and directions

Generate Numbers

Vector $\overrightarrow{A}$

Mass 1: x grams
Direction 1: x °

Vector $\overrightarrow{B}$

Mass 2: x grams
Direction 2: x °

Vector $\overrightarrow{C}$

Mass 3: x grams
Direction 3: x °

Now, use component algebra to calculate a forth vector, $\overrightarrow{D}$, that when added to the system will result in equilibrium

The Equation you are essentially trying to solve is: $\overrightarrow{A} + \overrightarrow{B} + \overrightarrow{C} + \overrightarrow{D} = 0$

Once you have arrived an answer, enter the components of the vector in the boxes below

$|D_x| = =$ _____
$|D_y| = =$ _____

Use trig to convert your answer back to a magnitude and degree format. Add all four mass/pan systems (3 from the above, the fourth from your prediction) to the table, and verify that the prediction does indeed balance the system.

Report Question 4

Give the details of this calculation and compare your analytical results with the the experimental results.

Draw a vector diagram that shows the table arrangement.