Vectors-Force Table

Introduction

Vector quantities are distinguished by the fact that they have both a magnitude and a direction. In this experiment we will employ the intuitive example of a force to provide a concrete illustration of the discussion in the lecture regarding the addition of vectors and the decomposition of vectors into components.
In this lab the vectors will be forces that arise from attaching masses to a ring which itself is centered around the pole in the center of a force table. Each mass will exert a pull on the ring that is proportional to the mass and in a directional along the string. These masses produce the force (weight) via Newton's formula

$$F_g = mg,$$

where $g = 9.8\ m/s^2$ and m is a mass in kilograms. The resulting units is $kg\ m/s^2$ and is abbreviated as Newton (N):

$$N = kg\ m/s^2$$

Therefore, in the metric system, weight is measured in Newtons. If more than one weight is hung on the table, we can determine the total (net) force acting on the ring by taking the vector sum of all the acting vectors. This net force is also called the **resultant**. To visualize the concept of net force, imagine two people playing tug of war on a rope. If one person pulls with a force of 200N to the right and the other pulls in the opposite direction with a force of 250N, the net force on the middle of the rope would be 50N to the left.

Experiment

Set up the Force Table

In this lab we will use hanging masses which exert forces on a metal ring around the pole in the center of the force table. If the weights are hung in such a way that the metal ring does not move or touch the center pole, then all the weights balance each other out. **This means that the net force is equal to zero, a condition called equilibrium.**

The edge of the force table is marked by a 360° decomposition of the full circle. We can use the polar coordinate system in order to specify a two-dimensional vector $\vec{v}$ by

$$\vec{v} = (v, \theta)$$

where v is the magnitude of the vector v, and θ is the angle specifying the direction of the vector with respect to a reference axis. For our force vectors the weight $\vec{F}_g$, the magnitude is just $F_g = m\ g$.

We will consider a number of different vectors on the force table. Our starting point will be a pair of vectors denoted by $\vec{A}$ and $\vec{B}$ which are specified as follows

$$\vec{A} = (F_g = 1.96\text{N}, \theta = 45°)\ \text{hanging mass } m = 200\text{g}$$
$$\vec{B} = (F_g = 0.98\text{N}, \theta = 150°)\ \text{hanging mass } m = 100\text{g}$$

Data

1) The negative of a vector (equilibrant)

Set up vector $\vec{A}$ on the force table. The negative of the force $\vec{A}$, also called the **equilibrant** of $\vec{A}$, is the force which, when added to $\vec{A}$, exactly balances vector $\vec{A}$. This means that the net force acting on the ring will be equal to zero. Using a second hanging mass, determine the negative of $\vec{A}$ by finding the force that allows the ring to be suspended without touching the pole. Record the magnitude and direction of the equilibrant of $\vec{A}$.

Equilibrant of $\vec{A}$: Magnitude ____________________ Direction _________________

2) Components of a vector

Consider a two-dimensional, rectangular (i.e. the normal Cartesian) coordinate system which has its origin at the center of the force table, and whose positive x-and y-axes point in the directions 0° and 90° respectively. *The x-and y-components of* $\vec{A}$ *are those vectors which lie along the x-and y-axes and which together have the same effect on the ring as the single vector* $\vec{A}$*.*

You will now experimentally determine the x and y components of vector A by replacing it with vectors pointing in the x and y directions. Leaving the equilibrant of the vector $\vec{A}$ that you determined experimentally in place, remove force vector A and replace it with two weights, one at 0° (pointing along the x-axis) and one at 90° (pointing along the y-axis) and determine what masses must be hung along these directions to once again reduce the net force on the ring to zero.

What are the measured values of the x-and y-components of $\vec{A}$? (i.e. what are the forces exerted on the ring by the hanging masses you placed along the coordinate axes?) Record the values of the force along the x-axis and the force along the y-axis in the chart in Analysis, Part 1 (remember that force is just mg).

3) Addition of two vectors

Set up force vectors $\vec{A}$ and $\vec{B}$ on the force table. Now place a third mass on the force table and determine at what angle it must be placed, and how much mass must be used in order to suspend the ring without touching the pole (i.e. achieve equilibrium or a net force of zero). This third force represents the equilibrant of the vector sum of forces $\vec{A}$ and $\vec{B}$. This means that the **negative** of this third force is the **resultant** of the vectors $\vec{A}$ and $\vec{B}$. Record the angle of this resultant and the force resulting from the mass hanging on the pulley.

Resultant of $\vec{A}$ and $\vec{B}$: Magnitude ______________________ Direction ___________________

Analysis

Part 1: Comparing physical and computed vector components

Compute the Cartesian components x and y of the vector $\vec{A}$ trigonometrically, and compare your computational result with your experimental result

$\vec{A}$	x-component	Y-component
Experimental		
Computational		
% error		

Remember that the % error is computed by this formula:

$$\%\text{error} = \frac{|\text{measured value - accepted value}|}{\text{accepted value}} \times 100\%$$

Use the computed values as your accepted values.

Part 2: Comparing physical and geometric vectors

Use a careful scale drawing of the forces $\vec{A}$ and $\vec{B}$ placed head-to-tail, to obtain the resultant of $\vec{A}$ and $\vec{B}$. Then use trigonometry to add the vectors. Compare your geometrical and experimental result with your calculated result by computing the percent error.

In order to compute the error here you can either use Cartesian coordinates (x, y) for the resultant vector or the angular (Polar) coordinates, i.e. the magnitude and the angle.

$\vec{A} + \vec{B}$:	x-component	Y-component	Magnitude	Direction
Experimental				
Graphical				
Computational				
% error experimental				
% error graphical				