Force Table Experiment

Introduction

In this experiment you will use a *force table* to learn how vectors are used to represent forces, and practice adding vectors algebraically and graphically.

Theory

Figure 1

Forces are vector quantities, described by both their magnitude and direction. We will use masses suspended from strings to exert force on an object – a metal ring. The *resultant* is a single force calculated as the vector sum of the forces exerted on the object. We will be able to calculate the magnitude and direction of the resultant vector on the force table by examining the *equilibrant*, which is a single force that establishes equilibrium by balancing two or more forces. *So, the equilibrant has the same magnitude, but opposite direction as the resultant.*
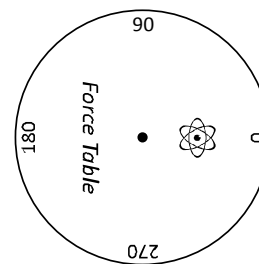
> Before starting, make sure you are looking at your force table with 0° to the right, as shown in Figure 1 (note that there are two angle circles on the force table; you'll be using the *inner* scale around the edge), and that the bubble level shows that the force table is level.

Addition of Two Vectors

Figure 2

You will add two vectors $\left(\vec{F}_1, \vec{F}_2\right)$ and calculate the magnitude and direction of the resultant $\left(\vec{F}\right)$ and equilibrant $\left(\vec{F}_{eq}\right)$, both algebraically and graphically. The forces will first be measured on the force table.
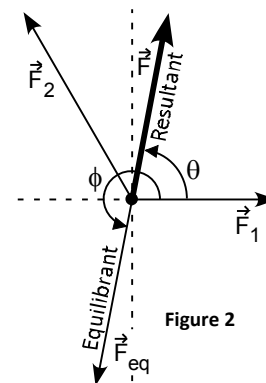
Measured on Force Table:

1. Set up the vectors to be added on the force table (Figure 2): $\vec{F}_1$ is 100*g* at 0°, and $\vec{F}_2$ is 150*g* at 120°. Note that the units of "force" are left in *grams*; this will simplify your calculations and measurements. It is not necessary to convert to Newtons!

2. Attach two pulleys to represent the forces to be added, $\vec{F}_1$ and $\vec{F}_2$ with their direction as indicated in Figure 2. The third pulley will represent the *equilibrant*, used to balance the other two forces, so its position can be set approximately for now. *Do not over tighten the pulley clamps!*

3. Place the ring with three strings over the center post, and pass each string over a pulley. Attach a mass hanger to each string, and place additional mass on the two strings that will represent the magnitudes of $\vec{F}_1$ and $\vec{F}_2$ (note that the hangers have a mass of 50 *g*).

4. Estimate the angle ϕ as follows: Grab the third string (representing the equilibrant), and gently pull the string while moving it left and right with respect to the table. Do so until the ring is centered on the post. Set the third pulley to the position you determined, and hang the string representing the equilibrant over.

5. Now place additional mass on the third string representing the equilibrant. Recall that this force will balance the resultant force of $\vec{F}_1$ and $\vec{F}_2$. Adjust ϕ and the amount of force as necessary, making sure the strings pass straight over each pulley. Be sure to use the inner circle for your angle measurements.

6. The system is balanced (in a state of *static equilibrium*) when the ring is centered on the central post. Record your measurements of force and angle ϕ in the *Measurement Table* when the system is balanced.

	Force	Magnitude (g)	ϕ (°)	$\theta = \phi - 180°$ (°)
Measurement Table	$\vec{F}_{eq}$			

7. Calculate the 'measured' value of $\theta = \phi - 180°$ and record in the *Measurement Table* above.

Calculated:

8. Use trigonometry to calculate the magnitude and direction, θ, of the resultant vector, $\vec{F}$. You may find that using the *Calculation Table* below helps keep track of your calculated values; calculate F_x and F_y for each vector, then calculate the sum of the force along each axis. Use these sums to calculate the magnitude and direction of the resultant vector.

9. Calculate the angle $\phi = \theta + 180°$, which will be the angle of the equilibrant as measured on the force table (make sure you understand *why* you add 180° to θ to get ϕ), and record its value in the *Calculation Table*.

	Force	Magnitude (g)	Direction, θ (°)	F_x (g)	F_y (g)
Calculation Table	$\vec{F}_1$	100	0		
	$\vec{F}_2$	150	120		
				$\sum F_x =$	$\sum F_y =$
	$\vec{F}$			$\phi = \theta + 180° =$	

Graphical:

10. You will now add the vectors graphically. Use the intersection of two darker lines near the lower left corner of a sheet of centimeter-ruled graph paper as the origin (*Note that the standard graph paper you use for your lab reports is not centimeter ruled*). Using a scale of 1 *cm* = 10 *g*, draw $\vec{F}_1$ in its direction and scaled length, beginning at the origin. You will find it easier to draw your vectors as shown in Figure 3 so that the arrow head does not obscure the end of the vector:

Draw your vectors like THIS:

NOT LIKE THIS, which will obscure the end of your vector:

Figure 3
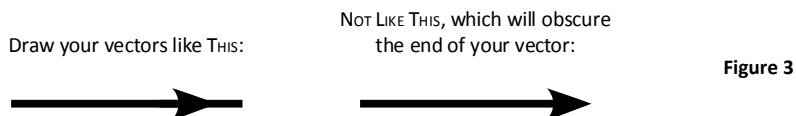
11. Now draw $\vec{F}_2$, scaled to the correct magnitude and direction (use a protractor), starting at the end of $\vec{F}_1$.

12. Draw the resultant vector, $\vec{F}$. Measure its magnitude with a ruler (in *cm*), converting back to units of grams. Measure its angle, θ, with a protractor.

   - *On the graph you've drawn, write the dimensions (in cm and grams) of your vectors, and indicate the scale used.*

Discussion

- Enter your results using the three methods in the *Summary Table* below. Calculate and record in the table the % difference between the magnitude of the force measured on the table and the calculated value.

    - *If you find this difference to be more than a few percent, you should check your calculations and force table measurements!*

Summary Table

		Measured on Table	Calculated	% Difference (Force Measured on Table and Calculated)	Measured on Graph
	F (g)				
	$\phi°$				– N/A –
	$\theta°$				

- Which method do you think is most accurate? Briefly explain why. Explain the sources of error in the other two methods.

- Why do you think the smallest mass increment provided with the force table is 5-*g*? Why didn't I give you a pile of 1-*g* masses?