Vector Addition Lab

Objective:

To confirm experimentally that forces obey the laws of vector addition and to practice the techniques involved with vector addition and subtraction, both algebraically and graphically.

Procedure:

1. Level the force table. Then attach the following masses to the ring on the force table. Don't forget to include the mass of the hanger. Notice that the ring is NOT in equilibrium under the action of the three forces alone. If you removed the peg (which applies a force to the ring), the ring would accelerate.

 200 grams at an angle of 0.0 degrees.....This provides force $\vec{A}$.
 100 grams at an angle of 70.0 degrees....This provides force $\vec{B}$.
 150 grams at an angle of 150.0 degrees...This provides force $\vec{C}$.

Convert all three masses to weights in newtons for use in the calculations below. Keep in mind that the magnitudes of these forces are always in newtons, **not** grams or kilograms.

2. Graphically construct the sum $\vec{A} + \vec{B} + \vec{C}$ to scale on a piece of paper using the tip to tail method. That is, draw $\vec{A}$ to scale. Choose a scale of 3.50 cm = 1.00 N. Then, using the tip to tail method add $\vec{B}$ to $\vec{A}$ (also drawn to scale). Then add $\vec{C}$ to $\vec{A} + \vec{B}$. Finally, draw a vector from the tail of $\vec{A}$ to the tip of $\vec{C}$ and call it $\vec{R}$ for *resultant*. Measure the length of $\vec{R}$ with a ruler in cm, and convert it to N (newtons). Also, measure the angle in degrees that $\vec{R}$ makes with the positive x axis using a protractor. Write down these numbers (magnitude of $\vec{R}$ in N and the angle it makes with the positive x axis) on the diagram and enclose them clearly in a box.

 As an example, let's say you have two vectors, $\vec{G}$ and $\vec{H}$, as shown below.
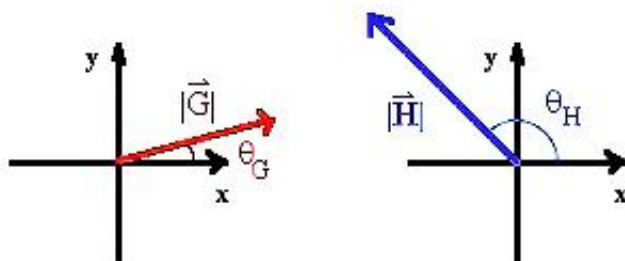
There are coordinate axes with each vector to help you visualize the angles associated with them. Note that the x- and y-axes point in the same directions for both vectors. *Once you assign the directions of the x- and y-axes, those must remain consistent throughout the problem.* You are allowed to move vectors around by repositioning the beginning (the tail) of each vector, but you cannot change the rotation of the axes, *or the direction that the vector points*. Note that the angle of each vector, θ_G and θ_H, are both measured from the positive x-axis.

To continue with adding the vectors graphically, move the tail of one vector so it is at the tip of the other vector. In the diagram below, we moved vector $\vec{H}$ so that its tail is at the tip of vector $\vec{G}$. This is allowed, because the coordinate axes and the vectors still have the same angles; we did not rotate either one.
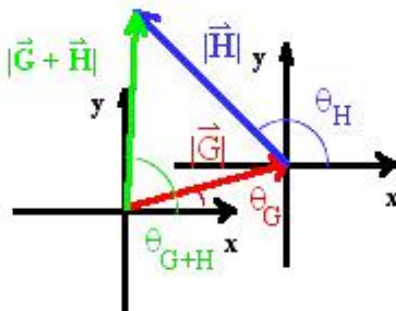
Vector $\vec{G}$ is still shown in red, and vector $\vec{H}$ in blue. Now, there is a new vector, $\vec{G} + \vec{H}$, shown in green. This was constructed by drawing a new vector from the beginning (tail) of vector $\vec{G}$ to the end (tip) of vector $\vec{H}$. This new vector is the sum of the two vectors, and its magnitude, $|\vec{G} + \vec{H}|$, and angle, θ_{G+H}, are shown in the diagram.

> **Note:** You do not draw the coordinate axes with each vector when you graphically add vectors. They are shown to help you get the right idea of how to do it.

3. Using the component method calculate $\vec{R}$ above. That is, calculate its magnitude(in N), and the angle in degrees that $\vec{R}$ makes with the **positive x axis**.
   Remember that:

$$|\vec{R}| = \sqrt{R_x^2 + R_y^2}$$
$$\theta = \tan^{-1}\frac{R_y}{R_x} \text{ but, be careful to adjust the angle to the correct quadrant.}$$

$$R_x = |\vec{R}| \cos\theta$$
$$R_y = |\vec{R}| \sin\theta$$
If you use $0° \leq \theta < 360°$, you automatically get the correct sign for R_x and R_y.

Clearly write these numbers and a box around the result. Compare these results for the magnitude and angle of $\vec{R}$ with those in Step #2 by calculating a percent error for the magnitude, and report the difference in the values for the angles. Compute the absolute difference in θ_R between step 2 and step 3. Make sure your absolute difference has the correct number of significant figures. If either difference is large, figure out why and correct the problem.

> **Remember:** you can only add x-components to other x-components, and y-components to other y-components. *Be careful not to mix them when adding!*

4. Now we wish to put the ring in equilibrium. To do so we need to add another force to $\vec{A}$, $\vec{B}$, and $\vec{C}$ which is the opposite of $\vec{R}$. Call it $\vec{E}$ for *equilibriant*. $\vec{E}$ will have the same magnitude as $\vec{R}$ but will point in the opposite direction. Set up all the forces $\vec{A}$, $\vec{B}$, $\vec{C}$, and $\vec{E}$ on the force table. Is the ring in equilibrium? If not, figure out why not. CALL ME OVER AT THIS TIME to verify the equilibrium and to record the number of your mass set.

5. As in step #3 use components to calculate the magnitude of vector $\vec{D} = \vec{C} - 2\,\vec{A}$. Also, calculate the angle in degrees that $\vec{D}$ makes with the positive x axis. Write these numbers and indicate your answers in a clear manner.

Consider these questions as you work on step 5:
- What does multiplying a vector by -1 do to the vector? How would $\vec{B}$ and $-\vec{B}$ be related?
- What does multiplying a vector by a positive number do? Does the magnitude change? What about the direction?

You should look at step 5 as follows:

$\vec{D} = \vec{C} - 2\,\vec{A}$ is actually two equations:
- $D_x = C_x - 2A_x$
- $D_y = C_y - 2A_y$

You will always have as many equations as you have *dimensions* for your vectors. This is part of what makes one-dimensional problems easier.

6. As in step #2 draw $\vec{A}$, $\vec{C}$, and $\vec{D}$ to scale on a diagram; use the same scale of 3.50 cm = 1.00 N. Measure the length of $\vec{D}$ in cm and convert to N. Also, measure the angle that $\vec{D}$ makes with the positive x-axis. Write down these numbers clearly and box in the result. Finally, calculate a percent error between the component calculations (taken to be the true, theoretical values) and your measured (experimental) values for $\vec{D}$ (in N). Calculate an absolute difference between the θ_D values.

Your report for this lab should include:
- Make sure all vector diagrams are drawn neatly, to scale, and are clearly labeled as Step 2 and Step 6.
- Type at least one example (either step 3 or step 5) for combining vectors by the component method. Your data sheets from lab should show all your calculations.
- What is the precision with which you can read the ruler, the protractor, and the angles on the force table? The errors on the hanging masses should be taken as ±0.5g.
- When writing your conclusions, state whether you were able to get the ring in equilibrium in step 4. Find the percent difference between the magnitude of the theoretical equilibrium vector from step 3 and the experimental equilibrium vector for step 4. Do not find the percent difference in angle – only provide the actual difference in degrees.
- Include percent error in magnitude between step 5 (theoretical) and step 6 (experimental), and the difference (not percent difference) in angle.