The Force Table: Practice with Vectors

Physics 114

September 26, 2025

The goal of this lab is to gain experience in adding vectors; both graphically and by using components. The apparatus we will use is called a force table (see Figure 1), a device which allows multiple forces to be applied to a metal ring. The forces are applied to the ring by strings which are connected to weights which hang over pulleys at the edge of the table. The table has an easily readable angle scale along its perimeter so that the **direction** of the force vector can be recorded. Although the **magnitude** of the vector is the value of the weight, we can instead use the value of the hanging mass in grams as our value for the force's magnitude.

Figure 1: The force table.

Exercise 1: Graphical Addition

In this exercise, you will be given two known forces $\vec{F}_a$ and $\vec{F}_b$ which will be applied to the ring and will need to find the magnitude and direction of a third force $\vec{F}_c$ so that the sum of the forces is zero. You will do this in two ways; the first will be experimental, and the second will use a graphical method.

Experimental estimation

Set up the apparatus with two forces $\vec{F}_a$ and $\vec{F}_b$ given by

$$F_a = 550 \text{ g at } 0^\circ$$

$$F_b = 300 \text{ g at } 140^\circ.$$

There is a pin which can be placed through the ring into a hole in the center of the table to hold the ring in place while you make adjustments. Be sure to account for the mass of the weight hanger when you apply the two forces.

Now, *experimentally* determine the needed third force $\vec{F}_c$, which will balance $\vec{F}_a$ and $\vec{F}_b$—when you find this force, the ring will remain centered on the force table. You will have to use trial and error to find $\vec{F}_c$. A good starting point is to use between 300 g and 400 g oriented at roughly 200°. Adjust the magnitude and direction of $\vec{F}_c$ until the system is balanced, and estimate the uncertainties on both the magnitude and the direction. Uncertainties should be determined by finding the range of angles and masses that leave the system balanced. Report your experimental value of $\vec{F}_c$ (you'll need to report two numbers: the mass is the magnitude and the angle is the direction) with uncertainties.

Graphical solution

When the ring is in equilibrium, the sum of the forces on the ring must be equal to zero:

$$\vec{F}_a + \vec{F}_b + \vec{F}_c = 0.$$

Using the values given for $\vec{F}_a$ and $\vec{F}_b$, use a ruler and a protractor to graphically add $\vec{F}_a$ and $\vec{F}_b$ together. Then, draw in the needed third vector, $\vec{F}_c$, so that the sum of the three is zero. Use a scale where 1 cm = 50 g. Measure the magnitude and direction of the vector $\vec{F}_c$. Estimate the uncertainties from the precision of the ruler (*e.g.*, the mass equivalent of a few tenths of a millimeter) and protractor (probably several tenths of a degree, depending on the quality of the protractor and your eyesight). Report the graphical value of the magnitude and direction of $\vec{F}_c$ with uncertainties.

Question 1: Does the value of $\vec{F}_c$, determined graphically, equal (to within uncertainties) the value you experimentally determined?

Exercise 2: Addition by components

Using the values for $\vec{F}_a$ and $\vec{F}_b$, compute the x and y components of each vector. Use the standard coordinate system where the x-axis is at $0°$, and the y-axis is at $90°$. The net force is the sum of the x and y components of the two forces:

$$\sum F_x = F_{ax} + F_{bx}$$

$$\sum F_y = F_{ay} + F_{by}$$

From these sums, determine the components of the force $\vec{F}_c$ that balances $\vec{F}_a$ and $\vec{F}_b$. Calculate the magnitude and direction of $\vec{F}_c$ from its components.

Since we wish to compare the calculated magnitude and direction of $\vec{F}_c$ to the measured values from Exercise 1, we need to consider how the uncertainties in placing masses a and b affect the calculation of $\vec{F}_c$. This is a particularly long and tedious propagation of errors problem that I won't make you do. If we assume that the uncertainty in the placement of each mass a and b is 1 gram and 0.3 degrees, a careful error propagation shows that the uncertainties on the calculated magnitude and direction of $\vec{F}_c$ are approximately 3 grams and 0.5 degrees. Report the addition-by-components values of the magnitude and direction of $\vec{F}_c$ with their uncertainties.

Question 2: Does the value of $\vec{F}_c$, determined using addition by components, equal (to within uncertainties) the value you experimentally determined?

Exercise 3: Calculating a balancing force

In this last portion, you will calculate the value of a forth force needed to balance three others. Then you will check the results of your calculation by applying all four forces to the ring on the force table. If you are correct, the ring will remain stationary at the center of the table. The three given forces are:

$$F_d = 400 \text{ g at } 330^\circ$$
$$F_e = 300 \text{ g at } 40^\circ$$
$$F_f = 200 \text{ g at } 135^\circ.$$

Using addition by components, calculate the force $\vec{F}_g$ so that the sum of all four forces is zero. Check your result by determining $\vec{F}_g$ experimentally using the force table. Determine uncertainties on the calculated and measured magnitude and direction of $\vec{F}_g$ using the same methods as the previous exercises. In particular, the uncertainty on the addition-by-components calculation of $\vec{F}_g$ is 3 grams and 0.5 degrees.

Question 3: Does the value of $\vec{F}_g$, determined experimentally, equal (to within uncertainties) the value you calculated using components?

Informal Lab Report Requirements

On a separate piece of paper, include the following in this order:

1. Your name, the title of the lab, and the names of your partners.
2. The measurements of the magnitude and direction of $\vec{F}_c$, with uncertainties in plus-minus notation, in the *Experimental estimation* part of Exercise 1.
3. The measurements of the magnitude and direction of $\vec{F}_c$, with uncertainties in plus-minus notation, in the *Graphical solution* part of Exercise 1.
4. The answer to **Question 1**.
5. Neat and detailed calculations (show your work) of the components of $\vec{F}_c$ in Exercise 2, and report the result with uncertainties in plus-minus notation.
6. The answer to **Question 2**.
7. Neat and detailed calculations (show your work) of the components of $\vec{F}_g$ in Exercise 3, and report the result with uncertainties in plus-minus notation.
8. The measurements of the magnitude and direction of $\vec{F}_g$, with uncertainties in plus-minus notation, in Exercise 3.
9. The answer to **Question 3**.
10. The graphical vector diagram you produced in the *Graphical solution* part of Exercise 1. Indicate the scale on the diagram.