LAB 3: Adding Vectors and Forces as Vectors*

Equipment List:
protractor
ruler
force table
set of masses
triple-beam balance

Purpose: To learn how to add vectors graphically and component method and compare these predictions with an experimental test.

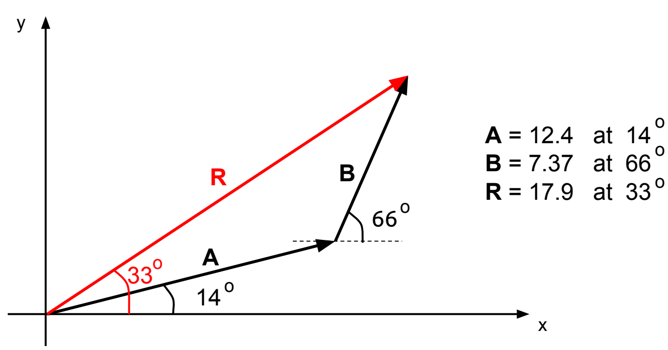

Figure 1: An example of two vectors added graphically.

Adding Vectors Graphically: The method for adding two vectors graphically is the following.

1. Select an appropriate scale. (Ex. 20 cm = 5 N)
2. In your lab book draw axes aligned with the graph paper.
3. Starting at the origin of your axes, use the protractor to find the angle of the first vector, **A**, then using the ruler, draw its length to scale and in the proper direction.
4. Starting from the end of the vector **A**, draw vector **B** to the same scale and in the proper direction. The angle of **B** is measured from the x-direction (see diagram in Figure 1).

*Based on the lab by Prof. Luna.

5. The resultant vector $\mathbf{R} = \mathbf{A} + \mathbf{B}$ is the vector drawn from the tail of vector $\mathbf{A}$ to the tip of vector $\mathbf{B}$.

6. Measure the length of the vector $\mathbf{R}$ on your graph paper. Calculate the magnitude of the resultant vector $\mathbf{R}$ using the selected scale. Measure its direction (relative to the x-direction) with a protractor.

To add more than two vectors, repeat step 4 until all the vectors are drawn, then draw the resultant vector from the start of the first vector to the end of the final vector.

Procedure:

Part 1: Comparing the component and graphical methods

Consider the following situation. A car travels 20 km at 60° north of west, then 35 km at 45° north of east. We wish to find the resultant displacement by two methods.

1. Express each displacement vector in unit vector notation. Take the $+x$-axis due east and the $+y$-axis due north.

2. Use the component method to obtain the resultant displacement vector in unit vector notation. Calculate the magnitude and direction.

3. Use the graphical method to add the displacements vectors using an appropriate scale and coordinate system. Obtain the resultant vector and calculate the magnitude and direction.

4. Calculate the percentage error between the graphical and component method, taking the component method to be the expected or "theoretical" value, using this formula:

$$\%\text{ error} = \frac{|\mathbf{R}_{\text{gr}} - \mathbf{R}_{\text{comp}}|}{|\mathbf{R}_{\text{comp}}|} \times 100\%$$

   where in the numerator is the magnitude of a vector subtraction and in the denominator is the magnitude of the resultant vector according to the component method.

Part 2: Force vectors

In this part you will use three different methods to find the resultant force vector and compare the results from each.

Consider three forces acting on a particle:

$$\begin{aligned}
\mathbf{F}_1 &= m_1\mathbf{g} \text{ at } 30^\circ \qquad \text{where } m_1 = 300\text{ g} \\
\mathbf{F}_2 &= m_2\mathbf{g} \text{ at } 110^\circ \qquad \text{where } m_2 = 450\text{ g} \\
\mathbf{F}_3 &= m_3\mathbf{g} \text{ at } 230^\circ \qquad \text{where } m_3 = 400\text{ g}
\end{aligned}$$

In this experiment, the particle is a metal ring placed around the peg in the center of the force table. The resultant or net force from these three forces is given by $\mathbf{F}_{\text{net}} = \mathbf{F}_1 + \mathbf{F}_2 + \mathbf{F}_3$.

First, do an experiment.

1. Find the appropriate masses and hangers to create these three forces.

2. Measure the three masses m_1, m_2, and m_3 on the triple-beam balance and calculate the corresponding forces $\mathbf{F}_1$, $\mathbf{F}_2$, and $\mathbf{F}_3$ in Newtons associated with each hanging mass.
3. Attach three pulleys to the force table and add the masses to the pulleys to represent $\mathbf{F}_1$, $\mathbf{F}_2$, and $\mathbf{F}_3$.
4. Attach the fourth pulley to the force table and hang another mass over it. Adjust the angle and mass on the hanger until you find the fourth force $\mathbf{F}_b$ that will balance the three forces on the metal ring.
5. Based on the force $\mathbf{F}_b$, determine the net force $\mathbf{F}_{\text{net,exp}}$ on the particle from $\mathbf{F}_1$, $\mathbf{F}_2$, and $\mathbf{F}_3$ only.

Next, find the net force using the component method.

1. Express each force $\mathbf{F}_1$, $\mathbf{F}_2$, and $\mathbf{F}_3$ in unit vector notation. Take the origin to be at the center of the force table (at pivot point) with the $+x$ axis along 0° and $+y$-axis along 90°.
2. Use the component method to obtain the resultant force vector $\mathbf{F}_{\text{net,comp}}$ in unit vector notation. Calculate the magnitude and direction.

Finally, find the net force using the graphical method.

1. Add the vectors $\mathbf{F}_1$, $\mathbf{F}_2$, and $\mathbf{F}_3$ graphically in your lab book using an appropriate scale and coordinate system.
2. Obtain the resultant vector $\mathbf{F}_{\text{net,gr}}$. Calculate the magnitude and direction.
3. Calculate the percentage errors between each pair of the graphical method, component method, and the experimental value.