

Non-Perpendicular Vector Displacements

The following exercises are designed to help you see how vectors are added both graphically and by components. Although these exercises use displacement vectors, the methods can be generalized to deal with any vectors as long as you remember that you can *only* add or subtract vectors representing the same physical quantity (displacement with displacement; velocity with velocity; force with force; and so on).

- **Form groups of 3 (or whatever number your instructor tells you) people.**
- **Each group will need**
 - either a 1-meter stick, a 2-meter stick, or 10 m tape measure**
 - a protractor**
 - blue masking tape**
 - 9 pieces of colored yarn (3 red, 3 yellow, and 3 orange/gold)**
 - Use orange yarn for all vector displacements, red yarn for x -components of all displacements, and yellow yarn for y -components of all displacements.
 - 3 arrow heads cut from either scratch paper or cardboard.**

Choose an xy coordinate system so that the x -axis is horizontal and parallel to one wall and the y -axis is horizontal and perpendicular to the chosen x axis. Placing your origin at the corner of a tile makes this easy.

Exercise 1: Addition of Two Non-Perpendicular Vectors both in 1st Quadrant

In this exercise, your group will be adding two vectors geometrically. You will check these results by adding the components of these vectors.

We want each group member to get experience with all experimental aspects of the lab. Write each group member's name on a blank below. Each person will have assigned tasks to do for the lab.

Person 1: _____

Person 2: _____

Person 3: _____

You are going to add two displacements tail to tip to find the resultant (net displacement). You will also break each vector down into x & y components and check that the x components of the two displacements add up to the x component of the net displacement, and that the y components do the same.

First Choose a place for your origin (starting point) near one wall (again, the corner of a tile will be convenient). Mark this with two pieces of tape oriented along the directions of the coordinate axes.

Second Person 1: Attach one end of a piece of orange yarn to the origin. From the origin, walk 3 paces at an angle of about 30° from the $+x$ direction toward the $+y$ direction. Tape the orange yarn where you end up and place an arrowhead to show the direction of your displacement. Person 2 can now begin the Third step. Measure and record the magnitude and direction of your displacement.

$\vec{D}_1 =$ _____ m, _____ $^\circ$ from the $+x$ direction toward the $+y$ direction

Now go back to the origin and lay down the components, D_{1x} and D_{1y} , of your displacement vector, using the correct colored yarn for each. Measure the lengths of the components and record them below.

$$D_{1x} = \text{_____} \text{ m} \quad D_{1y} = \text{_____} \text{ m}$$

Third Person 2: Attach one end of a piece of orange yarn to the tip of \vec{D}_1 . From the origin, walk 2 paces at an angle of about 60° from the $+x$ direction toward the $+y$ direction. Tape the orange yarn where you end up and place an arrowhead to show the direction of your displacement. Person 3 can now begin the Fourth step. Measure and record the magnitude and direction of your displacement.

$$\vec{D}_2 = \text{_____} \text{ m, } \text{_____}^\circ \text{ from the } +x \text{ direction toward the } +y \text{ direction}$$

Now go back to the tail of \vec{D}_2 and lay down the components, D_{2x} and D_{2y} , of your displacement vector, using the correct colored yarn for each. Measure the lengths of the components and record them below.

$$D_{2x} = \text{_____} \text{ m} \quad D_{2y} = \text{_____} \text{ m}$$

Fourth Person 3: Attach one end of a piece of orange yarn to the origin. Attach the other end of the yarn to the tip of \vec{D}_2 . This will be the net displacement. Measure and record the magnitude and direction of your displacement.

$$\vec{D}_{\text{Net}} = \text{_____} \text{ m, } \text{_____}^\circ \text{ from the } +x \text{ direction toward the } +y \text{ direction}$$

Now go back to the origin and lay down the components, $D_{\text{Net},x}$ and $D_{\text{Net},y}$, of your displacement vector, using the correct colored yarn for each. Measure the lengths of the components and record them below.

$$D_{\text{Net},x} = \text{_____} \text{ m} \quad D_{\text{Net},y} = \text{_____} \text{ m}$$

Fifth On a separate sheet of paper, each group member should sketch all vectors and their components. Include the lengths of all vectors and vector components and the values of all angles in the sketch. Check your sketches with each other to make sure they are correct. You will use these sketches to do the analysis which follows.

ANALYSIS Each member of the group should do these on a separate sheet of paper and compare results:

1. Check to see that the sum of the x-components of \vec{D}_1 and \vec{D}_2 is equal to the x-component of the net displacement. Do the same for the y-components.

2. From the end of \vec{D}_2 , what displacement would be required to get back to the origin?
3. Take the chosen vectors \vec{D}_1 and \vec{D}_2 and do the algebraic analysis on paper to find \vec{D}_{Net} and its components. What do you find for the angle between \vec{D}_{Net} and the $+x$ direction?
4. Discuss your results. Do they seem reasonable? If any results do not seem reasonable, can you give an explanation of what might be wrong?

Exercise 2: Addition of Two Non-perpendicular Vectors in Different Quadrants

Repeat the above procedure and analysis, but for the first displacement walk 3 paces at an angle of about 50° from the $+x$ direction toward the $+y$ direction and for the second displacement walk 2 paces at about 20° from the $+y$ direction toward the $-x$ direction.