

EXPERIMENT 3: VECTOR ADDITION

Much of our work in physics these three semesters will be done using vectors. Vectors are a mathematical method to give much information in compact form. An important part of understanding and working with vectors is to be able to add vectors, and to visualize their addition. We will use three distinct methods to add vectors in this experiment: graphical, analytical and experimental.

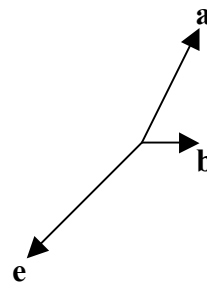
BACKGROUND

You should read or review Sections 3-1 to 3-6 in your textbook before starting this experiment. There are two graphical methods used, the parallelogram method (illustrated in figure 3-3 on p 40 of the text), and the head-to-tail method (illustrated in figure 3-6, p 40 of the text, and in Sample Problem 3-5). The parallelogram method is most useful for adding two vectors; the head-to-tail method is useful for any number of vectors to be added. Both methods involve using a scale (for example, 1cm = 15 N), a ruler and a protractor for measuring angles, as shown in the Class Assignment, problem 51.

In the analytical method, a variety of methods may be used. Vectors may be resolved into components, either with or without unit vectors, and then the components are added. Sample Problem 3-4 on p 45 of the text shows this method. Alternately, the vectors to be added may be entered into a vector-capable calculator, such as the TI-85 or TI86, and the vectors are added by the calculator. Finally, the vector addition may be sketched graphically, but added by trigonometry, for example by using the law of cosines.

In the experimental method, the vectors added are force vectors. (We define force later in Chapter 5, but for now, we can think of it like any other vector: a magnitude and a direction). The (two-dimensional) vectors are placed on a “force table” which applies the forces to be added to a ring in the middle of the force table.

We then look for another force vector which balances the two or three vectors we are adding. This balancing vector is called the equilibrant, because it balances (*equals* in magnitude) the vectors being added. It should be noted that the equilibrant has the same magnitude but the opposite direction as the sum vector, or the resultant. In the figure at right, **a** and **b** are to be added. The vector **e** is the equilibrant, opposite to what we would get by a head-to-tail addition of **a** and **b**. If all three of these vectors (**a**, **b**, and **e**) are placed on the force table, they will be in equilibrium (balance). Note that **e** is not the resultant, or sum, vector, but is opposite to it.



ADVANCE STUDY ASSIGNMENT

1. Sketch the head to tail addition of vectors **a**, **b** and **e** from the Background section above.
2. What is the result you obtained in your sketch in ASA 1? Based on the discussion in the Background section, is that result what you might have expected?

3. If you have a mass of 5.6 kg, what weight force is associated with that mass? (Procedure 1 tells how to do this calculation.)

PROCEDURE A, for experimental addition

1. For each force given, find the mass equivalent from the equation $F = mg$, where $g = 9.80 \text{ m/s}^2$. The forces given are listed above the Data Table on the next page. Now for each vector addition, place the given masses on two or three hangers (don't forget to include the mass of the hangers), and find the equilibrant force which balances the resultant of the forces being added. The equilibrant force should be determined by a dynamic balancing method. In this method, we adjust the equilibrant, magnitude and direction, until it seems to balance the addends, with a pin holding the center ring. When you think you have balance, remove the pin, and with your hand move the pin a few cm to one side and release. Next, move the pin a few cm to three other directions, and release each time. If the ring either returns to center each time, or stops randomly around the center, you can consider the forces balanced. If the ring always stops on one side of the center, you neither to adjust either the mass or the angle of the equilibrant.
2. Place the equilibrant force and angle in the data table in the appropriate box. As described above, the resultant force has the same magnitude, but the opposite direction as the equilibrant. Place the resultant force in the correct box, for each VA.
3. For the vector resolution situation, we will place the equilibrant (opposite of the given vector) on the force table, and then place masses at 0° and 90° for the x- and y-components (or 180° and 270° if either component is negative). Record the forces (mg, not the masses) on the data table in the correct boxes.

PROCEDURE B, for graphical addition (These procedures may be done in the lab, using lab rulers and protractors, or at another location, if you have a protractor available.)

4. For all parts of the graphical method, you should choose a suitable scale, such as $10.0 \text{ cm} = 1.00 \text{ N}$. Then you draw the vectors on one half of a sheet of graph paper, labeled VA1 (or VA2, or VR), to scale, with the proper angle from the positive x-axis. Add the vectors by the methods described below, and measure the results and place your measurements on the data table in the correct box.
5. For vector addition 1 (VA1), add the two vectors by the parallelogram method, completing a rectangle by drawing sides parallel to the two vectors to be added, as shown in Fig 3-3 in your textbook. The resultant is then the diagonal of the rectangle.
6. For VA2, add the two vectors by the head to tail method, as shown in Sample Problem 3-5 on page 39 of the textbook.
7. For VA3, add the three vectors by the polygon method (also the head to tail method).
8. For VR, draw the vector on an x-y coordinate axis, and find the components graphically on the axes.

PROCEDURE C, for analytical addition (This may also be done in the lab or elsewhere.)

9. For VA3, show the addition of the 3 vectors without using the vector capabilities of your calculator. Use trigonometry to determine the x- and y-components of the three vectors, then express them in unit-vector notation. Finally, add the vectors by adding the **i** and **j** components of the vectors. Then use the Pythagorean theorem and inverse tangent to change to magnitude and direction.

10. For the other VA and for the VR, you should use a vector capable calculator to perform the calculations. Show in the calculation section how you enter the vectors in your calculator and the results. For example, for VA1 you would write

$$(1.47 \text{ N} \angle 90.0^\circ) + (0.98 \text{ N} \angle 0.0^\circ) = \text{T185}$$

and then the answer. If you do not have a suitable calculator, borrow a classmate's, or the instructor's.

In the following, VA stands for vector addition, and VR stands for vector resolution.

VA 1: **a** = 1.47 N at an angle of 90.0°, **b** = 0.98 N at an angle 0.0°.

VA 2: **a** = 1.47 N, 35.0°; **b** = 0.98 N, 0.0°.

VA 3: **a** = 1.47 N, 0.0°; **b** = 0.98 N, 40.0°; **c** = 1.96 N, -65.0°.

VR: **a** = 1.96 N, -222.0°

	GRAPHICAL		ANALYTICAL		EXPERIMENTAL	
					Equilibrant	Resultant
Vector addition 1						
Vector addition 2						
Vector addition 3						
Vector resolution	x-comp	y-comp	x-comp	y-comp	x-component	y-component

QUESTIONS

1. Which method, graphical or experimental, give results closer to the analytical method? Explain why you think this is so.
2. Write three vectors of you own choosing and sketch (without protractor) the graphical addition of these three vectors. Show the equilibrant and resultant on your sketch.