

Name _____
Class _____ Date _____

Vector Addition

Objective

To find the resultant sum of a number of vectors by graphical and analytical means and to study the equilibrium of an object in a plane.

Pre-Lab Assignment

In this experiment, you will be studying an object—a ring—in equilibrium under the influence of several forces whose vector sum (resultant) will be approximately zero. Please do the following simple exercise in preparation for the lab:

A force F_1 of 200 N directed at 30° to the $+x$ -direction, F_2 of 100 N directed at 45° with respect to the negative x -axis and upward, and a force F_3 of 150 N along the negative x -axis is applied to an object. Find the resultant of the forces graphically and by the component method. What additional force vector, sometimes called the equilibrant, is needed to keep the object in equilibrium?

To be done in the Lab

On the Force Table given to you, you will arrange masses hanging on strings with the configuration stated in your prelab assignment (or others given by the instructor) and adjust a fourth string so that its direction and the mass attached will keep the ring in the center of the Force Table, i.e., in equilibrium. You may take masses, in grams, proportional to the forces, in Newtons, in the above assignment, e.g., you may choose masses of 200, 100, and 150 g or some multiple of these.

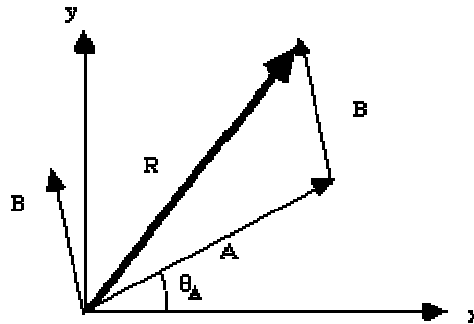


Fig. 1. Graphical sum of two vectors, $R = A + B$

Theory

Vectors are physical quantities which have magnitude as well as direction and a rule for combining them which we call vector addition. To represent a vector completely, we need to specify its magnitude and the direction with respect to a reference direction (the positive x - axis). Let us take two vectors **A** and **B** shown in Fig. 1. To add **A** to **B**, we have to move one vector parallel to itself until the foot of one falls over the head of the other. The line joining the free foot to the free head is then the resultant **R**. This simple process can be carried over to any number of vectors.

The analytical sum of vectors can be represented by resolving vectors into components. For example **A** can be resolved into x- and y-components.

$$A_x = A \cos\theta_A, \quad A_y = A \sin\theta_A \quad (1)$$

where θ_A is the angle vector **A** makes with the +x-axis. The x- and y-components of the resultant are then given by

$$R_x = A_x + B_x + \dots \quad (2)$$

$$R_y = A_y + B_y + \dots \quad (3)$$

The magnitude of the resultant then follows from the theorem of Pythagoras:

$$R = \sqrt{R_x^2 + R_y^2} \quad (4)$$

and since the magnitude of any vector is a positive quantity, the positive root is

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indicated in (4).

The angle θ_R which the resultant makes with the +x-axis is then given by

$$\theta_R = \tan^{-1} \frac{R_y}{R_x} \quad (5)$$

This angle is ambiguous to $\pm 180^\circ = \pm \theta$ radians since the tangent is positive in the 1st and 3rd quadrants and negative in the 2nd and 4th quadrants. You must be aware of the correct quadrant.

Apparatus

Ruler, protractor, paper, force table and pulleys, string and center ring, weights, weight hangers.

Procedure:

A set of three forces is assigned for which you will be asked to find the resultant theoretically. A fourth force is then set up on the force table in addition to the other three to achieve equilibrium for the center ring. The magnitude and direction of the fourth force is compared with the resultant of the other three to check if it is equal in magnitude and opposite in direction. The steps are described as follows:

1. Level the force table and put on pulleys and ring. For making sure that the force table is leveled, balance the center ring using two equal and opposite forces and then three equal forces at 120° . Shake the ring to minimize the effect of friction.
2. Arrange three given forces on the force table and find their resultant graphically and analytically by drawings in your lab book. Now, use the fourth force to balance the ring by changing its magnitude and direction. Compare the values. Arrange your results in a neat, tabular form. You will be comparing: 1. The analytical result (assumed exact if done properly) 2. The graphical result 3. The experimental result (force table).

Describe and summarize your results and discuss sources of error.