

PHY 251
Lab 2 – Vectors

Objectives:

The purpose of this experiment is to study two different methods to perform vector addition: graphically and by components. The magnitude and direction of several forces acting on an object will be determined by drawing the proper vector diagram, and the object will be observed to be in equilibrium when the resultant force acting on the object is zero.

Theory:

A **vector** is a quantity that possesses both **magnitude** and **direction**. A vector may be represented by drawing a straight line in the direction of the vector, the length of the line being made proportional to the magnitude of the vector, with an arrowhead placed at the end of the line to show the direction. Some examples of vector quantities include displacement, velocity, acceleration, and **force**. When a system of forces, all passing through the same point, acts on an object, they may be replaced by a single force called the **resultant**.

Vectors may be added graphically. For example, if two or more forces act at a point, a single force may act as the equivalent of the combination of forces. The resultant is a single force which produces the same effect as the sum of several forces (see Figure 1). The **equilibrant** is a force equal and opposite to the resultant (see Figure 1). A vector may also be broken up into **components**. The components of a vector are two vectors in different directions, usually at right angles, which will give the original vector when added together (see Figure 2).

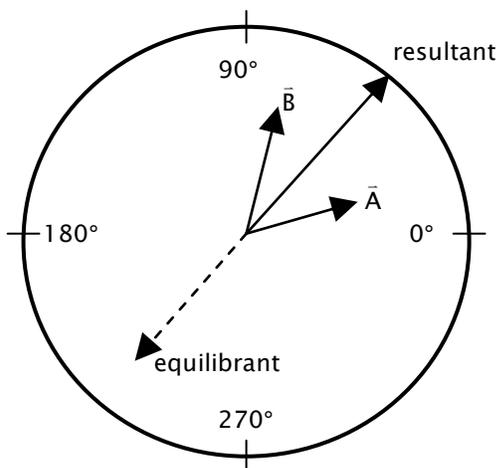


Figure 1

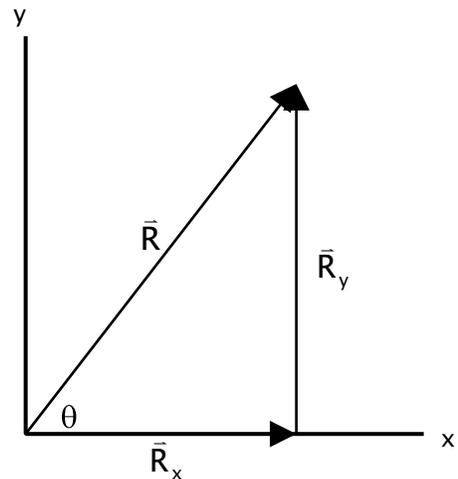


Figure 2

The operation of adding vectors graphically consists of constructing a figure in which a line is drawn from some point as origin to represent the first vector (as specified above), then from the arrowhead end of this line and at the proper angle with respect to the first vector, another line is

drawn to represent the second vector, and so on with the remaining ones (this is also called the tip-to-tail method). The resultant is the vector drawn from the origin of the first vector to the arrowhead of the last (see Figure 3 where R is the resultant vector). If a closed polygon is formed by the vectors being added, then the resultant is zero; and if these vectors represent forces, the particle acted upon is in equilibrium.

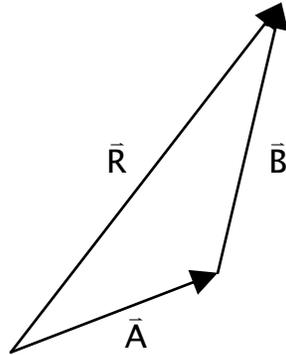


Figure 3

Vectors may also be added analytically by calculating the x and y components of each vector, getting the algebraic sum of all the x components and the algebraic sum of all the y components where $R_x = (A_x + B_x)$ and $R_y = (A_y + B_y)$ (Figure 4 may help you understand why this works).

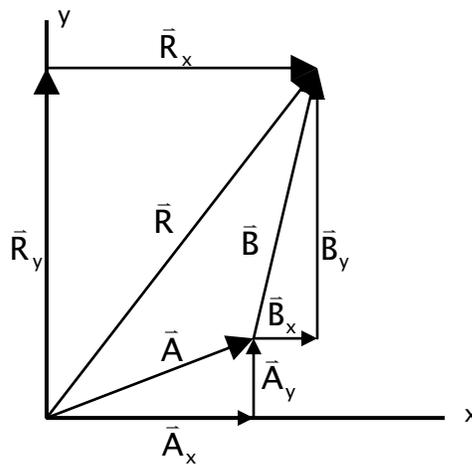


Figure 4

The apparatus used in this experiment consists of a horizontal force table graduated in degrees and provided with pulleys which may be set at any desired angles. A string passing over each pulley supports a weight holder upon which weights may be placed. A pin holds a small ring to which the strings are attached and which acts as the particle. When a test for equilibrium is to be made, the pin is removed. If the forces are in equilibrium, the particle will not be displaced.

The SI unit for force is the newton, but the masses provided to be used as weights are in grams. To simplify, **for the purposes of this lab only, we will let grams represent units of force.**

Apparatus:

Force table	Four pulleys
Set of slotted masses	Four hangars
Protractor	Ruler

Procedure:

1. Place a pulley on the 20° mark on the force table and suspend 100 g on the string over it. Place a second pulley on the 120° mark and suspend 200 g there. Using graph paper furnished, draw a vector diagram to scale, using a scale factor of $5.00 \text{ cm} = 100 \text{ grams}$, and determine graphically the direction and magnitude of the resultant. Set the origin of your coordinate system at the center of the graph paper.
2. Check the result of Procedure 1 by setting up the equilibrant on the force table. This will be a force equal in magnitude to the resultant, but pulling in the opposite direction. Set up a third pulley 180° from the calculated direction of the resultant, and suspend weights over it equal to the magnitude of the resultant. Make sure that all the strings are pointing exactly at the center of the pin, otherwise the angles will not be right. While holding the fourth string up out of the way, cautiously remove the center pin to see if the ring remains in equilibrium.
3. Place the first two pulleys as in Procedure 1, with the same weights as before. Place a third pulley on the 220° mark and suspend 150 g over it. Draw a vector diagram to scale and determine graphically the direction and magnitude of the resultant. This may be done by adding the third vector to the sum of the first two, which was obtained in Procedure 1. Now set up the equilibrant on the force table and test it as in Procedure 2.
4. Clamp a pulley on the 30° mark on the force table and suspend 200 g over it. Also clamp a pulley at the point 180° away from the first and put 200 g on it as well. Observe that the system is in equilibrium. By means of a vector diagram drawn to scale, find the magnitude of the components of the 30° force along the 0° and 90° directions. Set up these forces on the force table as they have been determined. These two forces are equivalent to the original force. Now remove the original 30° force and test the system for equilibrium.

Calculations:

1. Calculate the resultant in Procedure 1 using the method of components. Compare this result with your graphical result.
2. Calculate the resultant in Procedure 3 using the method of components. Compare this result with your graphical result.

Questions:

1. State the condition for equilibrium of a particle.
2. In Procedure 3, could all four pulleys be placed in the same quadrant or in two adjacent quadrants and still be in equilibrium? Explain.