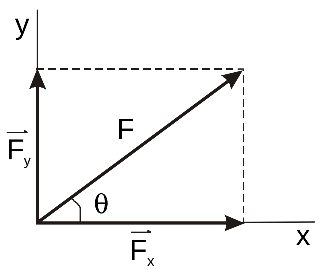
Vectors

Introduction

One of the most important concepts in physics is the concept of vector quantities, including their visualization and their mathematical manipulation. *The purpose of this experiment is to give the student practice in the addition of vector quantities, in finding components and in visualizing these processes.* Forces will be used as an example of a vector quantity.

Like velocity and acceleration, force is also a vector quantity. In this experiment you will study the properties of forces as vectors. The condition for static equilibrium (a body at rest will remain at rest) is that the *vector* sum of the forces acting on the body is zero. Stated analytically, $\mathbf{F}_1 + \mathbf{F}_2 + \mathbf{F}_3 + ... = 0$, or $\Sigma_i \mathbf{F}_i = 0$. Stated another but fully equivalent way, the condition on the components of the vectors is that the sum of the *x*-components of all the forces acting on the object must be zero, and independently the sum of the *y*-components and of the *z*-components must each equal zero, or $\mathbf{F}_{1x} + \mathbf{F}_{2x} + \mathbf{F}_{3x} + ... = 0$, $\mathbf{F}_{1y} + \mathbf{F}_{2y} + \mathbf{F}_{3y} + ... = 0$ and $\mathbf{F}_{1z} + \mathbf{F}_{2z} + \mathbf{F}_{3z} + ... = 0$. Note that the condition on the components is an *algebraic* sum, so that some of the components must be positive and some negative such that their sum is zero.

You should be familiar with the concepts of vector addition and vector components from your work in class. The diagram below illustrates how the components relative to a given choice of *x* and *y* axes are found for a vector **F**.



$\mathbf{F_x} + \mathbf{F_y} = \mathbf{F}$

$F_x = F \cos\theta$

$F_y = F \sin\theta$

$\tan\theta = F_y/F_x$

One kind of force is the weight of an object. This is simply the gravitational attractive force on the mass of the object produced by the mass of the Earth. The direction of this force (weight) is always downward. However, if the weight is attached to the end of a flexible string and the string is tied to an object, the force is transmitted along the string and produces a force on the object equal to the weight (assuming no frictional forces in pulleys, etc.) in the direction that the string is pulling at the point at which it is tied. A diagram of the apparatus (force table) used in this experiment is shown below.

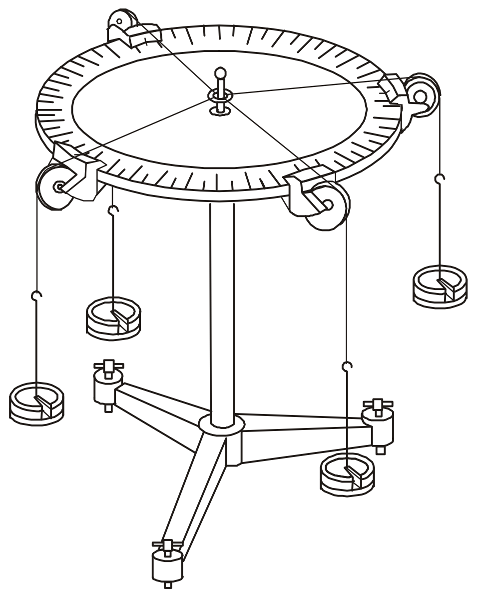
The *weight* and *mass* of an object are different properties and a clear distinction must be made between them, as will be carefully covered later in this course. The mass of the weights used in this experiment is stamped on the weight. The relationship $W = mg$ is used to convert the mass units to force units, where m is the mass in *kg* and $g = 9.8\ N/kg$. (N = Newton, the unit of force in the SI system). Note that you must include the *weight of the hanger* as part of the force.

Equipment

Force table, weights, ruler, protractor.

Procedure

For each part of this experiment draw a vector diagram to scale. Always choose your *xy* plane to be the plane of the forces on the ring so that all *z* components are zero.



1. (a) Hang a 0.2 *kg* mass at 110°. What is the weight of this 0.2 *kg* mass? Hang a second mass such that the ring is in equilibrium, i.e., the ring remains centered when the masses are released. What is the direction (in degrees) and the magnitude of the force which holds the first mass in equilibrium?

   (b) Calculate the *x* and *y* components of the force at 110° in part l(a) for the positive *x*-axis at 0° and the *y*-axis at 90°. Write down these components. Replace the force acting at 110° by its components on the force table. Is the ring in equilibrium?

   (c) Calculate the components of the force at 110° in part l(a), if the positive *x*-axis is at 70°. At what angle on the force table is the *y*-axis? Set up these components on the force table. Are they in equilibrium with the original equilibrant force? At this point you should realize that the components of a vector provide a representation of that vector no matter what the choice of coordinates.

2. Mount a pulley at 20° and suspend a 0.98 *N* weight from the string. Mount another pulley at 140° and suspend a 1.96 *N* weight from it. Draw a vector diagram to scale and find the resultant graphically by the head-to-tail or parallelogram method. Determine the direction of the resultant force. For a more accurate result now find the resultant using components. With the *x*-axis at 0° calculate the sums of the *x* and then the *y* components to find the components of F_x and F_y of the resultant *F*. From your knowledge of F_x and F_y you should then be able to calculate the magnitude and direction of *F* from trigonometry. Set up a force on the force table equal in magnitude and 180° from the resultant determined by components and determine if the ring is in equilibrium.

3. Set up the pulleys at 20° and 140° as in part 2, using the same weights. Mount a third pulley at 220° and suspend 1.47 *N* over it. Find the sum of the *x* and *y* components for all three vectors. Use 0° as the positive *x*-axis. Set up the negative of the resultant and check for equilibrium.

In the context of the results you have obtained, discuss the following questions. Are the components of a vector unique? Are the components of a force equivalent, in their effect, to the force itself? Does the order in which you add two or more vectors affects the resultant of these vectors.