Experiment 2

Vectors

Preparation

Study for this week's quiz by reviewing the last experiment, reading this week's experiment carefully and by looking up force and vectors in your textbook.

Principles

A vector is a mathematical device for describing physical properties that have both **magnitude** and **direction**. Many quantities in physics are described by vectors, things like forces, velocities, electric and magnetic fields. Vectors are important in many professions. For example, architects use force vectors when the design buildings or bridges and navigators use vectors to plot courses through the air, the oceans, or even over land.

The symbol for a vector is an arrow drawn over a letter, $\overline{F}$, or boldface type, ***F***. The letter without the arrow, or in plain type, refers to the magnitude of the vector.

It is often convenient to represent vector quantities by drawing straight lines on Cartesian graph paper. The length of the line, F, corresponds to the magnitude of the vector. The angle that the line makes with the positive x axis, θ, gives its direction. You can move a vector around on the paper as long as you preserve its original length and direction. R and θ are called **polar coordinates**.

Resolving a Vector

A vector can also be specified in terms of its x and y components. These are called **Cartesian coordinates**. A vector of magnitude F and direction θ can be **resolved** into its components F_x and F_y using the equations:

$$F_x = F \cos \theta$$
$$F_y = F \sin \theta$$

Composing a Vector

If you have the x and y components and wish to find the magnitude and angle of a vector use the process called **composition**. Composition is merely the use of the Pythagorean Theorem:

$$F = \sqrt{F_x^2 + F_y^2}$$

$$\tan \theta = \frac{F_y}{F_x}$$

which can be rewritten:

$$\theta = tan^{-1}\frac{F_y}{F_x}$$

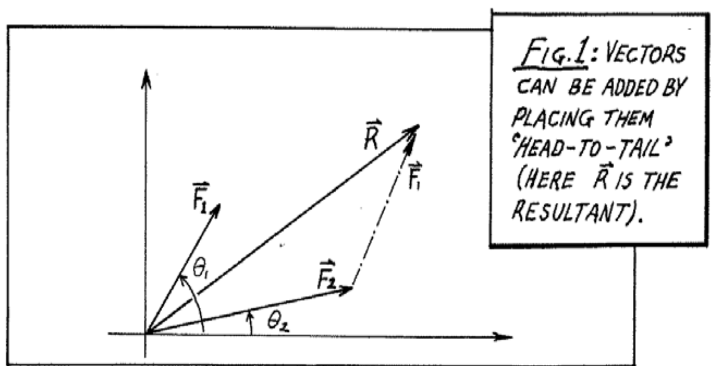
When you use your calculator to find the value of θ remember that it will give you the **principle value**, that is, a value between -90° and +90°. This corresponds to a vector located in the first or the fourth quadrant of your graph. If the vector actually lies in the second or third quadrant, add 180° to the calculator value.

Adding and Subtracting Vectors

Vectors can be added and subtracted. The sum of two or more vectors is called the **resultant vector**. The resultant is also a vector with magnitude and direction:

$$R = F_1 + F_2$$

There are two ways to add vectors. The first is the **graphical or "head-to-tail"** method. See Figures 1 and 2.



The graphical method involves a lot of drawing. Add two vectors graphically by shifting the tail of one vector to the head of the other on the graph paper, making sure that you preserve the length and orientation. The order in which you add the vectors does not matter. When you have drawn all your vectors draw a resultant line from the tail of the first vector to the head of the last vector. Find the magnitude of the vector by measuring with a ruler. Find the angle by measuring with a protractor.

The second method of vector addition is called the **analytical method.** See Figure 3.

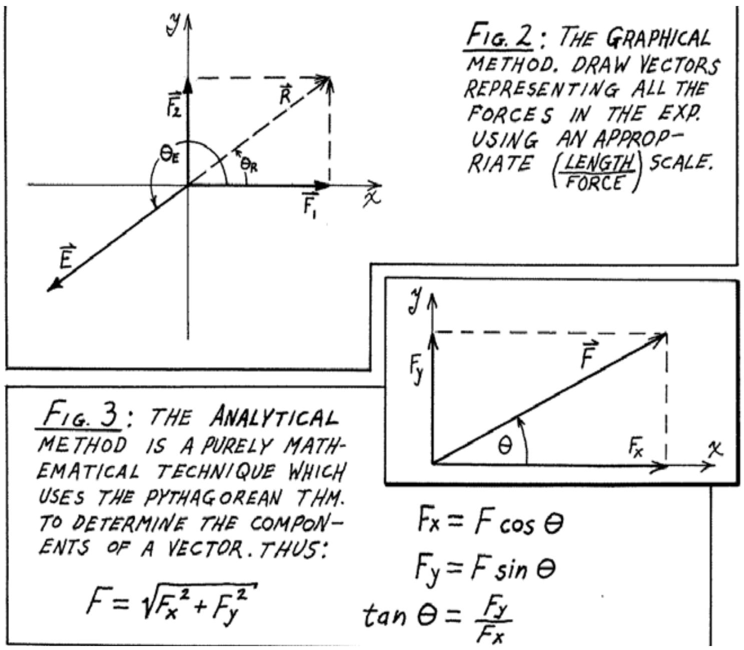


FIG. 2: THE GRAPHICAL METHOD. DRAW VECTORS REPRESENTING ALL THE FORCES IN THE EXP. USING AN APPROPRIATE $\left(\frac{\text{LENGTH}}{\text{FORCE}}\right)$ SCALE.

FIG. 3: THE ANALYTICAL METHOD IS A PURELY MATHEMATICAL TECHNIQUE WHICH USES THE PYTHAGOREAN THM. TO DETERMINE THE COMPONENTS OF A VECTOR. THUS:

To use this method resolve each vector into its *x* and *y* components. Add all the *x* components and then add all the *y* components. You will then have the *x* And y components of the resultant and you can find the magnitude and angle of the resultant with the Pythagorean Theorem.

$$R_x = F_{1x} + F_{2x} + F_{3x} + \ldots$$

$$R_y = F_{1y} + F_{2y} + F_{3y} + \ldots$$

An advantage of this method is that you can use it without having to do any drawing. It is less work and the results are usually more accurate, especially if you have a lot of vectors to add.

Once you have found the resultant, you may wish to find another vector called the **equilibrant vector.** The equilibrant vector, ***E***, is a vector that is equal to the resultant in magnitude, but opposite in direction. This means that the angle of the equilibrant will be the angle of the resultant plus 180°. The *x* and *y* components of the equilibrant will be the negative of the *x* and *y* components of the resultant. The sum of a vector and its equilibrant will always be zero. This means that if you experimentally find the equilibrant of a vector you will know the magnitude and direction of the original vector.

In this experiment you will use vectors to represent forces. It doesn't matter if you know a lot about forces; you only need to know that they are vector quantities. The apparatus for this lab is the **force table**. The force table has a round platform and a center post. A small metal ring fits over the post. You will hang masses from strings attached to this ring. The strings pass over pulleys and the hanging weights (mass times gravity) equal the forces. If the vector sum of all the forces is zero, the system will be in equilibrium (there will be no net acceleration) and the ring will not touch the center post. The hanging weight will be the magnitude of each vector. The force table is marked in degrees so that you can find the direction of each vector.

Equipment

1 force table
1 center pin
1 ring with 4 attached strings
4 pulleys
4 mass hangers
1 set of slotted masses
1 protractor

Procedure

Use the SI system of units, except when you are finding a scale for your graph which may be in units of newtons/cm. The unit of force is the newton:

$$1 \text{ newton} = 1 \frac{kg\ m}{sec^2}$$

Assume that masses are accurate to the nearest 0.001 kg and estimate tenths of degrees. Measure distances to the nearest mm.

Use g = 10 m/sec^2 when you find the weight of each hanging mass. This value for g is a convenient approximation which doesn't affect the final answers. Remember to include the mass of the mass hangers.

1. Place one pulley at $\theta = 0°$ and hang a total of 0.150 kg from it. (This will be the .050 kg mass hanger and a .100 mass.) Find the weight and call it F_1. Place a second pulley at $\theta = 90°$ and hang a total of 0.100 kg from it. Call this weight F_2. Record your measurements in the table on the answer sheet.

2. Find the equilibrant experimentally. Use a third pulley, hanger, and weights to find the magnitude and direction of the force that exactly balances the first two forces. Record these results on the answer sheet. This will give you the experimental magnitude of your vector. The angle, minus 180° will give you the experimental angle of your original vector.

3. Draw an x and y axis on your graph paper with the origin at the center of the page. In the margins locate 0°, 90°,180°, and 270°. Choose a convenient scale (1 cm = 0.25 newton works very well) and draw in $\boldsymbol{F}_1$ and $\boldsymbol{F}_2$.

4. Use the graphical method to add the two vectors. Once you have drawn the resultant, measure its direction and length and record them. Use the length and your scale to find the magnitude of the resultant in newtons. Next, draw the equilibrant.

5. Add the same two vectors using the analytical method. Show all your calculations. Record the magnitude and direction of both the resultant and the equilibrant on the answer sheet.

6. Place four pulleys on the force table and use four **different masses**. Adjust the system until it is in equilibrium. Record the angle and weight for each of the forces. Resolve each vector into its x and y components. Add all the x and y components. Find the magnitude and direction of the resultant. It's magnitude should be small.

7. Show your instructor that you have put your equipment away properly. Remember, he or she can reduce your grade if you don’t take good care of the equipment.