LAB 4
Forces as Vectors

OBJECTIVES

(1) Experimentally verify that vector methods describe the addition of forces.
(2) Practice using vectors by adding them both graphically and analytically.
(3) Practice resolving vectors into their components.

EQUIPMENT

Force Table, masses, mass hangers, rulers, protractors, paper, and calculators.

PROCEDURE*

Part 1: Adding Two Perpendicular Vectors

Insert a nail through the washer and into the center hole in the force table (this keeps the ring from moving when unbalanced forces are applied). Set one pulley at $0°$ (x-axis) and another at $90°$ (y-axis) on the force table. Then apply two forces to the center ring by hanging 25g and 45g masses over the pulleys at 0° and 90°, respectively. In your notes:

a) Find the magnitude of the weight forces produced by these masses using the equation $w = mg$. Note that for a given force, the *magnitude* is given by $w = mg$ and the *direction* is along the string direction.

b) **Graphically** determine the magnitude and direction of the net force by drawing the vectors tip-to-tail (use an appropriate scale such as 1 cm = 0.02 N) and measuring the magnitude ($R_{graphical}$) and angle ($\theta_{graphical}$) of the resultant.

c) **Analytically** determine the magnitude $R_{analytical}$ and direction $\theta_{analytical}$ of the net force by creating a table of x- and y-components, adding the x-components to get the net x-component, adding the y-components to get the net y-component, and then finding the magnitude and direction of the net force by combining the components.

d) Compare the magnitudes $R_{graphical}$ and $R_{analytical}$ and the angles $\theta_{graphical}$ and $\theta_{analytical}$ using the percent difference:

$$\%\,diff = \frac{\left|X_{graphical} - X_{analytical}\right|}{\left(X_{graphical} + X_{analytical}\right)/2} \times 100\%$$

e) Are the two methods consistent? What are some possible sources of error?

Part 2: Experimental Testing of Vector Addition

In theory, you should be able to balance the two forces in part 1 by applying a third force which is equal in magnitude and opposite in direction (i.e. add 180º to the angle θ) to the sum you determined above.

a) Test your prediction experimentally by moving a pulley to the predicted direction and hanging the appropriate mass over it.
b) Does the ring remain balanced when the nail is removed?
c) *What is the sum of all three forces now acting on the ring?*

Part 3: Resolution of Forces into Components

On the force table, apply a *single* force in a direction between 0° and 90° and resolve this force vector into x- and y-components.

a) What two forces should be applied in the negative x- and y-directions, respectively, to balance these components?
b) Test your predictions. *Were your predictions correct?*
c) Repeat steps a and b for another force (different magnitude and direction).

Part 4: Adding Two Vectors

a) Insert a nail through the washer and into the center hole in the force table.
b) On the force table, hang 40 grams at an angle of 60° and 20 grams at an angle of 330°.
c) Resolve each force vector into x- and y-components and then find the x and y-components of the net force (the sum of these two forces).
d) What two forces should be applied in the x- and y-directions, respectively, to balance the net force?
e) Apply the appropriate two forces and test your prediction. *Was your prediction correct?*

*HINT

The key to doing this lab easily is to translate the angles on the force table to angles in your lab book. Orient the table with 0° pointing along the "x" axis and 90° along the positive y-axis. Be careful when reading degrees from the table that you use the correct ring of numbers, and be careful with your calculator because it may give you angles that are 180° from the ones you need. You need to constantly bounce back and forth between the mathematical model and the reality of the forces on the table.