

# LAB 3

## 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  $0^\circ$  ( $x$ -axis) and another at  $90^\circ$  ( $y$ -axis) on the force table. Then apply two forces to the center ring by hanging 100g and 200g masses over the pulleys at  $0^\circ$  and  $90^\circ$ , respectively. 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. In your notes:

- Draw a set of  $x$ - $y$  axes and define a suitable scale for drawing force vectors (try  $1 \text{ cm} = 0.2 \text{ N}$ ).
- Graphically** determine the magnitude and direction of the net force by drawing the vectors tail-to-tip and measuring the magnitude ( $R_{\text{graphical}}$ ) and angle ( $\theta_{\text{graphical}}$ ) of the resultant.
- Analytically** determine the magnitude  $R_{\text{analytical}}$  and direction  $\theta_{\text{analytical}}$  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.
- Compare the magnitudes  $R_{\text{graphical}}$  and  $R_{\text{analytical}}$  and the angles  $\theta_{\text{graphical}}$  and  $\theta_{\text{analytical}}$  using the percent difference:

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

*Are the two methods consistent?*

## 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  $180^\circ$  to the angle  $\theta$ ) 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?*

**Change places with your partner(s) and repeat Parts 1 – 2 for different initial forces.**

## Part 3: Resolution of Forces into Components

On the force table, apply a *single* force in a direction between  $0^\circ$  and  $90^\circ$  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.
- c) Have each partner repeat this for a force (you should have at least 4 different forces). You should enter the results from each force into your lab notebook.

### **\*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  $0^\circ$  pointing along the “x” axis and  $90^\circ$  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  $180^\circ$  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.