AP Physics: Lab #4

Vector Components of Forces

Name ____________________________ Hour ________

Lab Partners ____

Purpose:

* Add and subtract vector quantities using graphical and analytical methods.
* Verify the concept of static equilibrium.

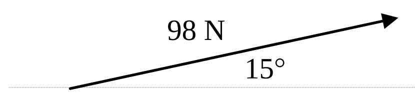
Equipment:

Force table
Electronic balance
Assorted masses

Introduction:

The physical quantities used in scientific study can be classified into two major categories: *scalars* and *vectors*. A *scalar* is any quantity that can be completely described using only a magnitude. For example, time, volume, mass, and temperature are all scalar quantities.

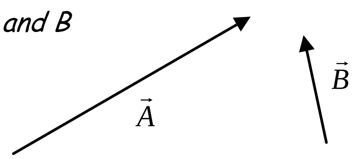
A *vector*, in contrast, cannot be completely described without both the magnitude and direction of the quantity. Velocity, acceleration, and force are all examples of vector quantities. A vector can be represented graphically by an arrow. The length of the arrow represents the magnitude of the vector, while the direction of the arrow represents the direction of the vector.



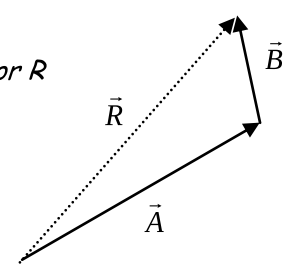
In order for vectors to be a useful scientific tool, it must be possible to add multiple vectors to obtain a vector sum, or resultant vector. This can be accomplished using either *graphical* or *analytical* methods.

To *graphically* add two or more vectors, first represent each vector with an arrow of the appropriate length and direction. Then redraw the vectors using the "head to tail" method, connecting the vectors without changing their length or direction. This forms a new vector arrow, representing the resultant vector. The length of the resultant vector arrow represents its magnitude and the direction of the resultant vector arrow represents its direction. An example of graphical addition of vectors is shown below, where the original vectors *A* and *B* are combined to form resultant vector *R*.

Vectors A and B



Resultant Vector R

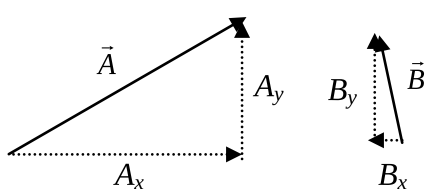


To *analytically* add two or more vectors, first use the cosine and sine functions to calculate the *x* and *y* components of each vector to be added. Then add the *x* components to obtain the *x* component of the resultant, and add the *y* components to obtain the *y* component of the resultant. When the *x* and *y* components of the resultant are determined, the magnitude of the resultant can be found with the Pythagorean Theorem and the direction of the resultant can be found with the inverse tangent function. The equations used for the analytical method are shown below, where the original vectors *A* and *B* are combined to form resultant vector *R*.

Calculating Vector Components

$$V_x = \vec{V} \cdot \cos\theta$$

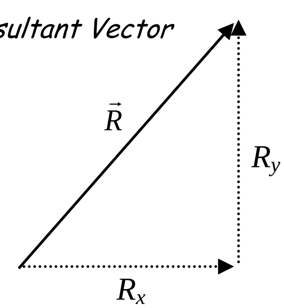
$$V_y = \vec{V} \cdot \sin\theta$$



Determining the Resultant Vector

$$\vec{R} = \sqrt{R_x^2 + R_y^2}$$

$$\theta = \tan^{-1}\left(\frac{R_y}{R_x}\right)$$



Introduction *(cont)*:

This lab will use vectors to study the effects of Newton's Laws on a force table. The net force acting on an object is the vector sum of all individual forces acting on that object. Newton's 2nd Law states that the acceleration experienced by that object is proportional to and in the same direction as the net force. It is modeled in this equation:

$$F_{net} = \sum F = m \cdot a$$

According to the equation above, any object with a net force of zero will experience an acceleration of zero. If this object begins in a state of rest, this object will remain at rest, and is said to be in static equilibrium.

Procedures:

Use the base, protractor, center ring, and pin to set up the force table on a lab stool, as shown in the diagrams at right.

Obtain the mass amounts and angles for two individual forces from your teacher and record them in Data Table A. Set up the two given forces at the correct angles on the force table. Observe the motion of the center ring.

Without attaching the third force, calculate the magnitude and angle of the equilibrant force needed to produce a state of static equilibrium on the center ring.

Have your instructor initial your prediction, then add the calculated equilibrant force to the two forces already on the force table. Remove the pin and observe the motion of the center ring. If necessary, adjust the equilibrant force so that the center ring is in a state of static equilibrium.

Repeat the above procedure for the three individual forces given in Data Table B.

Calculations:

The calculations below must be completed during lab:

Calculate the force exerted by each of the given mass amounts.

Calculate the *x* and *y* components for each individual given force. Use this information to calculate the *x* and *y* components of the resultant force and the magnitude and angle of the resultant force for each vector combination.

Calculate the equilibrant force and mass amount required to produce static equilibrium for each vector combination.

The calculations below may be completed after lab:

For Data Table A, create a graphical solution showing the two original individual forces in head-to-tail form and the resultant vector. Use your graphical solution to determine the magnitude and direction of the resultant vector, and include the graphical solution with your lab report.

Analysis:

To summarize the lab report, answer the application questions below in complete sentences. In addition, include a brief statement of the overall results for the lab.

- Were any of your predictions incorrect? If so, address possible areas of error in your calculations or experimental procedures.
- Compare the magnitude and direction of the resultant force determined analytically in Data Table A to the magnitude and direction of the same resultant force found with the graphical method. Which method (graphical or analytical) appears to be the better method to determine the resultant force?
- Discuss the motion of the center ring *before* the equilibrant force was applied in Data Table A. How does Newton's 2nd Law apply to your observations? What was the net force acting on the center ring *after* you added the equilibrant force? How did this net force affect the motion of the center ring? How does this net force relate to the concept of static equilibrium?
- Suppose that the magnitudes of the two given forces in Data Table A remained the same, but the directions were altered. Give two new angles that would produce a . . . smaller resultant force . . . larger resultant force. Using the two given forces, what is the magnitude of the . . . largest possible resultant force? . . . smallest possible resultant force? How would the largest and smallest resultant forces be formed?

Data Table A: Two Unequal Forces

		FORCE VECTORS	
	Mass	Magnitude	Direction
Force #1	50 g		
Force #2	100 g		
Resultant Force			
Equilibrant Force			

FORCE COMPONENTS	
x-component	*y*-component

Data Table B: Three Unequal Forces

		FORCE VECTORS	
	Mass	Magnitude	Direction
Force #1	50 g		
Force #2	100 g		
Force #3	100 g		
Resultant Force			
Equilibrant Force			

FORCE COMPONENTS	
x-component	*y*-component

Lab Report:

Title Page, Objectives, & Overall Report – 5 pts
Procedures – 3 pts
Data Table – 5 pts
Calculations & Graphical Solutions – 11 pts
Analysis – 10 pts