Force Table

General Physics Laboratory (PHY119) Fall 2014

1 Introduction

Physical quantities are of two types, scalar and vectors. Scalars quantities have only magnitude, while vectors have both magnitude and direction. Adding or subtracting vectors are different from adding or subtracting scalars. In this experiment we will add forces, which are vector quantities, experimentally using the force table. Then we will compare the results obtained with the theoretical methods of adding vectors.

The force table is an apparatus that allow us to add vectors by applying forces on a ring placed in the middle of the table. The forces can be adjusted in magnitude by changing the masses, or in direction by moving the pulleys. The goal is to keep the ring perfectly centered, in order to consider it to be in equilibrium and then apply Newton's law on it, which state that in equilibrium, all forces should add to zero. Therefore, we can find the sum of any two forces by knowing all the forces acting on the ring.

2 Objective

1. To use the force table to find the sum or the resultant force of two forces.
2. To compare the results obtained experimentally with the theoretical methods of adding vectors.

3 Theory

There are two methods for adding forces:

3.1 Experimental Method

When an object is in equilibrium it has no acceleration, and therefore the sum of all forces acting on it equal zero,

$$\Sigma\vec{F} = 0 \ , \tag{1}$$

If two forces are acting on an object and a third force act in a way that bring the system to equilibrium. Then according to Newton's law the sum of the three is zero,

$$\vec{F_1} + \vec{F_2} + \vec{F_b} = 0 \ , \tag{2}$$

where $\vec{F_B}$ is the balancing force that brings the system to equilibrium.

From equation (2) we can find the sum of the two forces by subtracting the balancing force from both sides,

$$\vec{F_1} + \vec{F_2} = -\vec{F_B} \ , \tag{3}$$

Therefore, the resultant force ($\vec{F_R}$) is just the same magnitude as the balancing force but acts in the opposite direction.

$$\vec{F_R} = -\vec{F_B} \ , \tag{4}$$

The force table is then can be used to find the resultant force of two forces by first applying the two forces on the ring. Then the third pulley is adjusted and the masses are varied until the ring becomes perfectly centered. We know then that the resultant force is the same magnitudes as the third force but acts in the opposite direction.

3.2 Theoretical Method

3.2.1 Graphical Method

1. **Tail to Tip Method** We can add any two forces, $\vec{F_1}$ and $\vec{F_2}$, by placing the tail of $\vec{F_2}$ so that it meets the tip of $\vec{F_1}$. The sum, $\vec{F_1} + \vec{F_2}$, is the vector from the tail of $\vec{F_1}$ to the tip of $\vec{F_2}$.

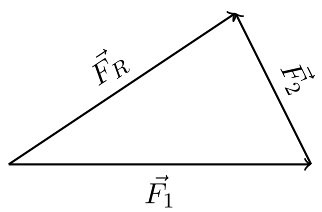

Figure 1: Tail to Tip method.

Note that you will get the same vector if you place the tip of $\vec{F_2}$ against the tail of $\vec{F_1}$. In other words, $\vec{F_1} + \vec{F_2}$ and $\vec{F_2} + \vec{F_1}$ are equivalent.

2. **Parallelogram Method** To add $\vec{F_1}$ and $\vec{F_2}$ using the parallelogram method, place the tail of $\vec{F_2}$ so that it meets the tail of $\vec{F_1}$. Take these two forces to be the first two adjacent sides of a parallelogram, and draw in the remaining two sides. The vector sum, $\vec{F_1} + \vec{F_2}$, extends from the tails of $\vec{F_1}$ and $\vec{F_2}$ across the diagonal to the opposite corner of the parallelogram.

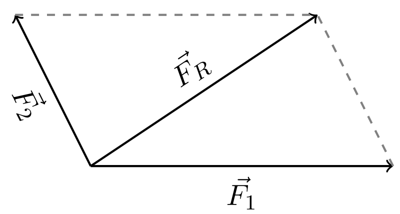

Figure 2: Parallelogram method.

3.2.2 Component Method

Forces cannot be added directly due to the difference in direction. However, if each force is resolved into a horizontal and a vertical component, these components may be just simply added to find the components of the resultant Force. Therefore, in order to use this method we should first learn how to resolve each force to its component:

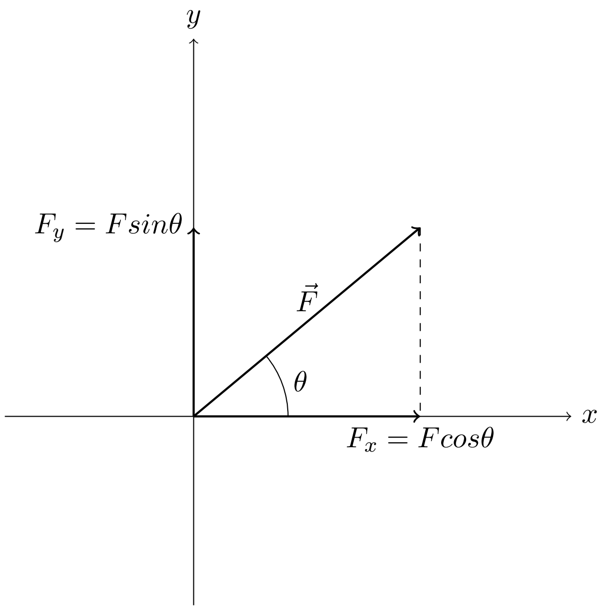

Figure 3: Resolving to components

1. Construct a two- dimensional coordinate system. This can be the usual two-dimensional Cartesian coordinate system with x and y axes.
2. Place the tail of the force in the origin, being careful not to change the direction of the force. The force should make an angle θ with the x axis.
3. Draw a right-angled triangle with the force acting as the hypotenuse.
4. Find the other sides of the triangle using the angle θ through simple trigonometry.

$$opposite = Fsin\theta, \qquad adjacent = Fcos\theta \tag{5}$$

   If $\theta > 90$ then we can use the portion of θ that is enclosed in the right-angled triangle to find the sides. Depending on the orientation of the triangle, one of the sides should represents the x component and the other side represents the y component of the force vector. In figure 3 the adjacent side represents the x component of the force, while the opposite side represent the y component.

After finding the components of the two vectors, the components of the resulting force is:

$$F_{Rx} = F_{1x} + F_{2x}, \qquad F_{Ry} = F_{1y} + F_{2y} \tag{6}$$

From Pythagorean theorem we can find the magnitude of the resultant force,

$$F_R = \sqrt{{F_{Rx}}^2 + {F_{Ry}}^2} \tag{7}$$

The direction of the resultant force can be calculated through the following expression.

$$\theta_R = tan^{-1}(\frac{F_{Ry}}{F_{Rx}}) \tag{8}$$

4 Equipment

- Force table
- stand base
- pulleys
- hangers
- slotted masses
- strings
- center ring
- protractor .

Figure 4: Force Table

5 Procedure

1. Your lab instructor will provide you with two different forces (magnitude and direction). Attach suitable slotted masses with the thin strings to the center ring of the force table. Remember that:

   $F_1 = m_1 g$ and $F_2 = m_2 g$ where $g = 9.8 m/s^2$ which is the gravitational acceleration.

2. Consider the direction of each force which is represented by the angle. The force table's edge will help you identify the angle accurately.

3. In order to balance the ring; a third force should be attached.

4. Record the magnitude and direction of the Balancing force in the following table.

	First Force	Second Force	Balancing Force
m (g)			
m (kg)			
F (N)			
θ (°)			

5. Now find the resultant force which is equal and opposite to the equilibrium force.

6. Plot both original forces on graphing paper by setting a drawing scale (1 cm = 1 N).

7. Find the resultant force graphically. The magnitude of the force is represented by the length of the vector and should be converted using the scale you have chosen. The direction is represented by the angle which you can measure using the protractor.

8. Find the resultant force using the components method.

9. Find the percentage error using the components method as the true value.

	Experimental Method	Graphical Method	Component Method	Error
F_R (N)				
θ_R (°)				