MOHAWK COLLEGE

Experiment 2: Forces and Vectors

PURPOSE

To study the vector principles of forces and to study forces in static equilibrium.

APPARATUS

Force Table with Weights, Pulleys, Hangers, and Threads

THEORY

Certain physical quantities can be classified as scalars or vectors. Scalars have only magnitude, but vectors have both magnitude and direction. In general a vector may be written as $\vec{r}\angle\theta$ where *r* is the magnitude or size of the vector, and θ is the angle as measured from the +x-axis (the positive x-axis has an angle of zero by definition). The example in Figure 1 shows the position of a car. If you said the car traveled two kilometers, the final position of the car could be anywhere along the blue dashed circle. By stating the position as 2 km at an angle of 30° North of East we identify the unique position or displacement of the car from the starting point.

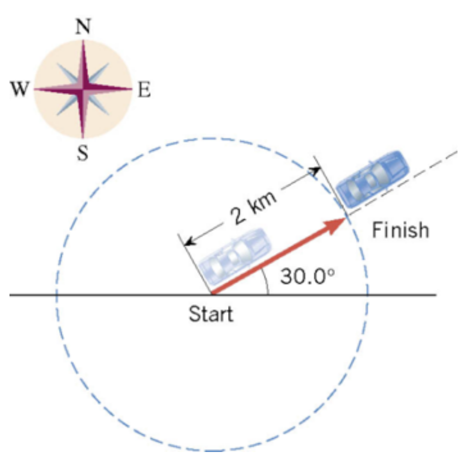

Figure 1 Definition of a Vector

Alternatively, a vector can be described by its' unit x and y components. A component is a piece of the total vector that lies along a defined directional axis such as the x-axis or y-axis. Figure 2 shows a car that has displacement $\vec{r}$ from the starting point. Vector $\vec{r}$ can be described as the sum of two perpendicular vectors: a vector $\vec{x}$ along the x-axis (East direction or 0°) and vector $\vec{y}$ along the y-axis (North Direction or 90° above x-axis).

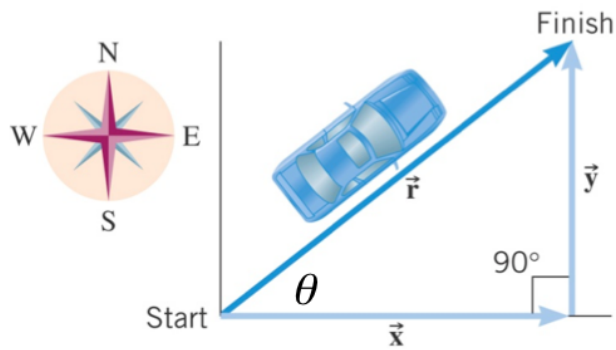

Figure 2 Components of a Vector

By using basic trigonometry, we can easily find the components of any vector. The following equations assume that the angle is measured in a counter-clockwise manner from the positive x-axis.

$$\vec{x} = \vec{r}\ cos\theta$$

$$\vec{y} = \vec{r}\ sin\theta$$

The resultant force can be determined using the Pythagorean Theorem, knowing the $\vec{x}$ and $\vec{y}$ vector components.

$$\vec{r}^2 = \vec{x}^2 + \vec{y}^2$$

Forces are vectors. An object which is subjected to multiple forces will behave as if only one force is acting on it, and that one force has a magnitude and direction determined by adding all applied forces together (remember they are vectors, we must add them as vectors!).

Suppose we had two forces acting on an object, $\vec{F}_1$ and $\vec{F}_2$. Each force has an $\vec{x}$ and a $\vec{y}$ vector component. For example, $\vec{F}_1$ can be broken into $\vec{x}_1$ and $\vec{y}_1$ and $\vec{F}_2$ can be broken into $\vec{x}_2$ and $\vec{y}_2$. To find the $\vec{x}$ and a $\vec{y}$ components of resultant force $\vec{r}$ we can sum the $\vec{x}$ vector components and sum the $\vec{y}$ vector components of the two vectors.

$$\vec{r}_x = \vec{x}_1 + \vec{x}_2 \qquad and \qquad \vec{r}_y = \vec{y}_1 + \vec{y}_2$$

We can then combine $\vec{r}_x$ and $\vec{r}_y$ to determine the magnitude and direction of the resultant force $\vec{r}$ using the Pythagorean theorem.

$$\vec{r}^2 = \vec{r}_x^2 + \vec{r}_y^2$$

The direction or angle of the resultant force can be determined using trigonometry.

$$tan\theta = \frac{\vec{r}_y}{\vec{r}_x}$$

Experiment Description

A force table, shown in Figure 3, is a device that allows us to explore forces in static equilibrium. Forces are created by suspended different masses at specific angles on the force table. Weights are suspended by strings over pulleys and will move freely when the system is not balanced. Strings supporting the weights are attached to a common metal ring. If the system is in equilibrium, the ring will not move when centered on the middle post of the force table. A total of up to 4 forces can be created on the force table.

Figure 3 Force table and suspended weights

PROCEDURE

1. In the first part of the experiment you will only need to use three of the pulleys and hangers on the force table. Remove the fourth hanger and let the string rest on the tabletop. To set a mass at a specific angle, loosen the screw beneath the pulley, move the pulley to the desired angle, and then retighten the screw. The first step will be to hang three masses on the force table. Each mass must account for the weight of the hanger

used to suspend the weights. The three forces should be in equilibrium, meaning the sum of the x and y vectors should equal zero and cancel each other out.

Place a 150 g mass on a pulley at 45 degrees on the table. Place a second mass of 105 g masses at 180 degrees, and a third mass of 105 g at 270 degrees. Centre the brass ring on the peg in the middle of the table and release the ring. The ring should not move. If the ring moves, check your masses and angles. Calculate, tabulate and sum the unit x and y vectors for the three forces and record results in Table 1.

2. In this part we will only need two of the pulleys. Remove the hangers from two of the strings and let them rest on the top of the force table.

   In this pat of the experiment the objective is to determine how much mass must be added to one of the hangers before the system becomes unbalanced. Place a 200 g mass (including mass of hanger) at 0°. Place a second 200 g mass at 180°. These forces should be balanced. Add a small amount of mass to one of the pulleys (in 5 gram increments or smaller). Centre the ring on the middle post and release the ring. If the ring does not move increase the weight on the same pulley, centre the ring, and release it. Continue this process until the ring moves when released. This is the maximum mass that can be added to the hanger before the system becomes unbalanced. Record your results in Table 2.

3. Determine the maximum change in angle for one of the pulleys before the system becomes unbalanced. Place a 200 g mass (including mass of hanger) at 0°. Place a second 200 g mass at 180°. These forces should be balanced. Move one of the pulleys slightly clockwise by one or two degrees. Centre the brass ring and release it. Continue changing the angle for the same pulley in small increments until the system becomes unbalanced. Record your results in Table 2.

4. In the last part of this experiment the objective it to determine a balancing force for five sets of forces. One at a time set up the force combinations found in Table 3 on the force table. Using trial and error, find a force that balances out the other 2 or 3 forces. You will need to find both the correct amount of mass and the correct angle for the additional force to balance the other forces. Record your results in Table 3.

DATA TABLES

Table 1 Components of a vector

Mass/Angle	X component	Y component
150 g 45°		
105 g 180°		
105 g 270°		
Sum		

Table 2 Change in mass and angle required to unbalance system

Mass Added to Pulley (g)	Observation
5	System balanced or unbalanced?
10	
15	
Change in Angle (Degrees)	**Observation**
1	System balanced or unbalanced?
2	
3	
4	

Table 3 Determination and Verification of Balancing Force

Forces for Trial 1	**X component**	**Y component**
200 g at 5°		
110 g at 200°		
Balancing Force =		
Sum of Components		
Forces for Trial 2	**X component**	**Y component**
110 g at 345°		
200 g at 65°		
50 g at 165°		
Balancing Force =		
Sum of Components		
Forces for Trial 3	**X component**	**Y component**
100 g at 290°		
100 g at 250°		
100 g at 270°		
Balancing Force =		
Sum of Components		
Forces for Trial 4	**X component**	**Y component**
150 g at 15°		
100 g at 40°		
300 g at 90°		
Balancing Force =		
Sum of Components		
Forces for Trial 5	**X component**	**Y component**
200 g at 150°		
150 g at 300°		
300 g at 65°		
Balancing Force =		
Sum of Components		

CALCULATIONS

1. For Table 1, find the X and Y components of each force, and sum them together.

2. For the results in Table 3 find the X and Y component of all vectors (Including the balancing force) and sum the component to see if they cancel out.

QUESTIONS

1. Do your observations match the results obtained in Table 1?

2. Considering the results from Table 2, are the component sums from Table 3 close enough to zero to be considered valid?

2. Discuss sources of error for this experiment. What might be affecting your results?