

# Object in Equilibrium

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## Equipment

- Computer with spreadsheet software

## Objectives

- *To verify the condition of static equilibrium.*

## Introduction

Scalars are quantities completely specified by a magnitude. Examples include temperature, mass, and time. Vectors are quantities represented by both a magnitude and a direction. Examples include displacement, velocity, and force.

While working with scalar quantities one can just algebraically add, subtract, multiply or divide numbers. However, when working with vectors one need to account for the direction of the vector and therefore a simple addition or subtraction would be incorrect. To add vectors, one should follow the rules of vector addition. A vector quantity could be expressed in two general ways: magnitude-direction form (or polar coordinates) and vector components form. Between the two, the vector components form is probably more convenient for the manipulations. A vector could be resolved into components through trigonometry where each component is a projection of the vector in each dimension and is expressed as a product of the vector's magnitude and a corresponding trigonometrical function, **sin** or **cos**. If the component is adjacent to the angle in use, it is a **cos** function; however, if the component is opposite to the angle in used, then it is a **sin** function. The components of different vectors but projected in the same dimension are in the same direction and could be manipulated just as scalars. When the identical manipulations are done to each set of components, it produces the corresponding components of the resultant. In turn, the magnitude and direction of the resultant could be calculated from the components by the means of Pythagorean Theorem.

A force (typically represented by the symbol  $\vec{F}$ ) is an example of a vector quantity. An object is in **equilibrium** when the sum of all forces acting on the object is zero. In equilibrium, a stationary object will remain stationary. To verify equilibrium, it is necessary to add all the forces acting on the object following the rules of vector addition. If the vector sum of all forces is about zero and the stationary object remains at rest, the condition of equilibrium is satisfied.

Before starting this experiment, improve your knowledge of the rules of vector manipulations. Your review should include the addition of vectors and two ways of representing vectors: vector components and magnitude-direction. Spreadsheet may help with the task, learn Vector Addition in a Spreadsheet from a video Trig with Excel posted in Auxiliary Downloads (<https://www.youtube.com/watch?v=h6zEvLD7Y1o&t=349s>) . Remember that when calculating components in Excel, the angle should be converted to radians.

Example: `=B2*cos (radians (C2) )`

## Part 1: Object in equilibrium is submitted to three Non-perpendicular forces of equal magnitude

1. The directions and magnitudes of Force 1 and Force 2 are given in Table 1 where all ***angles are with respect to positive X-axis.***
2. Calculate x- and y-components of Force 1 and Force 2; afterward, total each corresponding column to find x- and y- components of the Resultant of the two forces.
3. Calculate the magnitude and direction of the Resultant. See “Trig with Excel Tutorial”
4. ***Predict*** components of Force 3 or Neutralized necessary to balance the Resultant and achieve equilibrium. (Hint: the components of the Neutralizer should be opposite to the components of the Resultant.)
5. Calculate the magnitude and direction of the resultant just as you did with the Resultant.

Force	Magnitude (N)	Direction (°)	x-component	y-component
Force $\vec{F}_1$	100	60		
Force $\vec{F}_2$	100	120		
Resultant				
Predicted Neutralizer $\vec{F}_3$				

**Table 1.** Calculations of a Neutralizer for two non-perpendicular forces of equal magnitude.

6. Compare the magnitude of the neutralizer to the magnitude of forces 1 and 2.
7. Use either drawing software or a blank sheet of paper and a protractor to draw ***in scale*** Force 1, Force 2, Resultant, and Neutralizer. Take a picture of the drawing and include it into your report as Figure 1 with an appropriate label.
  - How to draw to scale: if you will use 1cm or inch to represent 50N, you will need do draw an arrow of 2cm or 2 inches long to represent 100N force.
  - The arrows representing Force 1, Force 2, and Neutralizer should originate from the same point and be of the same color.
8. Investigate the pattern in the angles and include your findings in the abstract.

## Part 2: Object in equilibrium is submitted to three Non-perpendicular forces of different magnitudes.

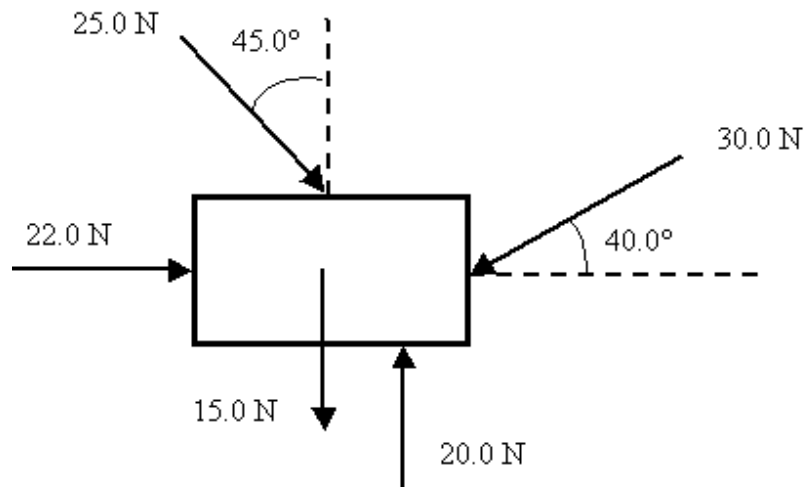
1. The directions and magnitudes of Force 1 and Force 2 are given in Table 2 where all **angles are with respect to positive X-axis**.
2. Calculate x- and y-components of Force 1 and Force 2; afterward, total each corresponding column to find x- and y- components of the Resultant of the two forces.
3. Calculate the magnitude and direction of the Resultant. See “Trig with Excel Tutorial”.
4. **Predict** components of Force 3 or Neutralized necessary to balance the Resultant and achieve equilibrium. (Hint: the components of the Neutralizer should be opposite to the components of the Resultant.)
5. Calculate the magnitude and direction of the resultant just as you did with the Resultant.

Force	Magnitude(N)	Direction (°)	x-component	y-component
Force $\vec{F}_1$	150	60		
Force $\vec{F}_2$	100	320		
Resultant				
Predicted Neutralizer $\vec{F}_3$				

**Table 2.** Calculations of a Neutralizer for two non-perpendicular forces of equal magnitude.

6. Compare the magnitude of the neutralizer to the magnitude of forces 1 and 2.
7. Use either drawing software or a blank sheet of paper and a protractor to draw **in scale** Force 1, Force 2, Resultant, and Neutralizer. Take a picture of the drawing and include it into your report as Figure 2 with an appropriate label.
  - How to draw to scale: if you will use 1cm or inch to represent 50N, you will need do draw an arrow of 2cm or 2 inches long to represent 100N force and an arrow of 3cm or 3 inches long to represent 150N force.
  - The arrows representing Force 1, Force 2, and Neutralizer should originate from the same point and be of the same color.
8. Investigate the pattern in the angles and include your findings in the abstract.

### Part 3: Object submitted to multiple forces.



**Figure 1.** A block submitted to five forces

1. Use Figure 1 to record magnitudes and directions of five forces into Table 3.  
**Record angles with respect to +X-axis.** (Hint: 40° given for 30.0N force is NOT with respect to +X-axis).
2. Calculate x- and y-components of each force and total each corresponding column to find x- and y- components of the Resultant.
3. Calculate the magnitude and direction of the Resultant.
4. Based on the calculation of the resultant, conclude if the object is in equilibrium.

Force	Magnitude(N)	Direction (°)	x-component	y-component
Force $\vec{F}_1$				
Force $\vec{F}_2$				
Force $\vec{F}_3$				
Force $\vec{F}_4$				
Force $\vec{F}_5$				
Net Force (or Resultant)				

**Table 3.** Calculation of the resultant of five forces

## Requirements for the Report:

- The **abstract section** must contain the following explanations in paragraph form:
  - The calculations (x-components, y-components, magnitudes, directions, resultant, neutralizer)
  - Define mathematically or in words the relationship between resultant and neutralizer
  - How each part utilized the condition of static equilibrium (define)
- The **data section** must include
  - 3 Tables (labeled and captioned)