

# Vector Addition and Physical Significance

Your Name \_\_\_\_\_

Partners' Names \_\_\_\_\_

TA's signature allowing you to take the quiz or leave \_\_\_\_\_

Obtained reasonable experimental results?	yes	<input type="checkbox"/>
Answered questions?	yes	<input type="checkbox"/>
Cleaned your table?	yes	<input type="checkbox"/>

## Introduction

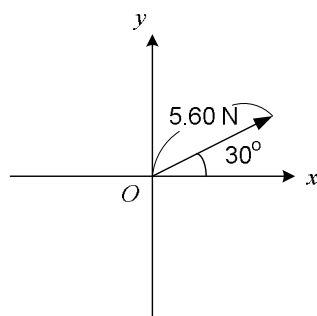
Numbers can be added or subtracted. However, some physical quantities cannot be calculated by such way. Let us think about pushing a car by two people. Suppose they are able to push it with 700 newtons. (Newton is a unit of force.) Can they always push the car together with simply the sum of their forces,  $700 + 700$  newtons? The answer is: It is not necessarily they can. If they push the car with completely opposite directions, the car will hardly move. Directions play a large role in this situation. Such value containing both magnitude and direction is called vector. Most of the physical quantities are vectors and it can deal with related calculations more easily. Displacement, velocity, and acceleration are vectors in this sense. Some physical quantities only have magnitude and they are called scalar. We also call some of the scalar part differently from the vector quantities, such as distance and speed. If there are two vectors whose magnitudes and directions are equal, they are identical vectors even though they are located at different place. To calculate vector addition quantitatively, it is convenient to obtain each component in terms of the coordinate system. Vector addition can also be dealt with graphically.

### Objectives:

- To learn physical and mathematical properties of vector
- To learn how to add vectors
- To verify that a static equilibrium of vectors results in zero as the sum of these vectors

## 1. The x- and y-components of vectors

In a two-dimensional space, a vector can be expressed by its x- and y-components.  
e.g.

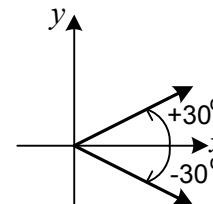


The vector has a magnitude, 5.60 N, and is directed  $30^\circ$  from the positive x-axis. Therefore, each component of the vector will be:

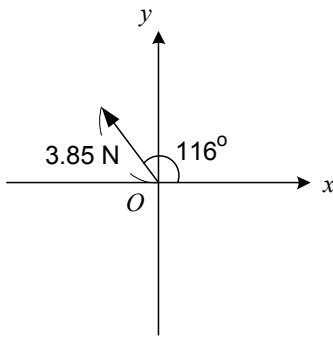
$$x\text{-component: } 5.60 \text{ N} \times \cos 30^\circ = \underline{4.85 \text{ N}}$$

$$y\text{-component: } 5.60 \text{ N} \times \sin 30^\circ = \underline{2.80 \text{ N}}$$

**Note:** The angle taken from the positive x-axis counterclockwise is positive, but when it is taken clockwise, it will be negative angle. Also, for trig. functions,  $-30^\circ$  gives an equal result to  $+330^\circ$ .



Obtain the components for the following cases:

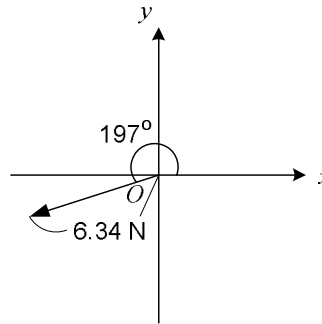


x-component = \_\_\_\_\_

y-component = \_\_\_\_\_

x-component = \_\_\_\_\_

y-component = \_\_\_\_\_



**Question:**

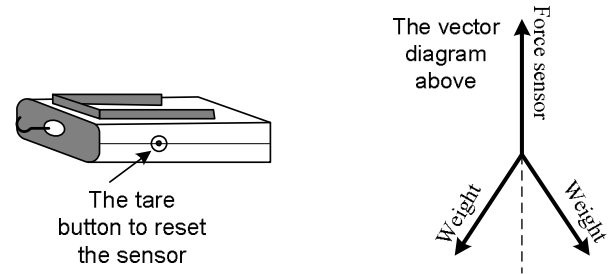
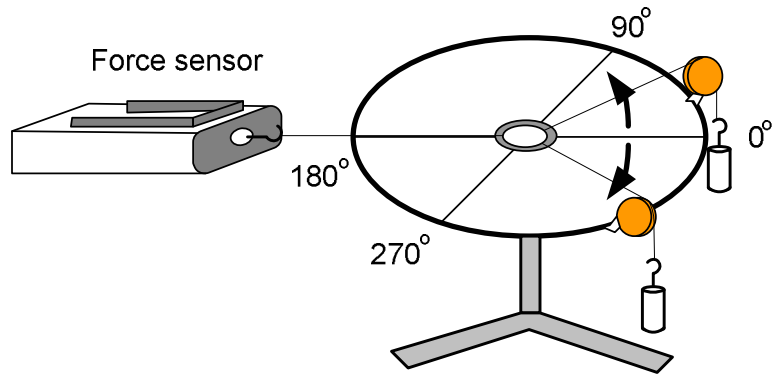
Describe a general procedure to obtain the  $x$ - and  $y$ -components of a vector. Where do you take the angle? When do you use sine or cosine? How do you explain this to your friends?

**2. Significance of using vectors**

- ① Set up the following experiment.
- ② Use the same mass for the hanging masses.

\* Start up DataStudio and select force sensor. Display “3.14 Digits” from displays.

- ③ The initial angles of both are small against the force sensor.  
[Reset the force sensor before measuring by pushing the tare button as shown.]
- ④ Then, increase the angles as shown, and see how the value of force sensor is changed.



**Question:**

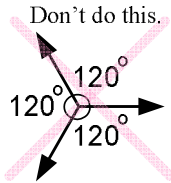
The two forces created by the hanging masses are equal. Thus, the force sensor is supposed to detect sum of each force. However, by changing the angles of the forces, the force measured by

the force sensor varies. Explain why this happens and importance of the consideration of the vector concept. (Imagine you and your friend pull a car as above.)

### 3. Static equilibrium with three forces

① Use different masses and angles for each hanging mass.

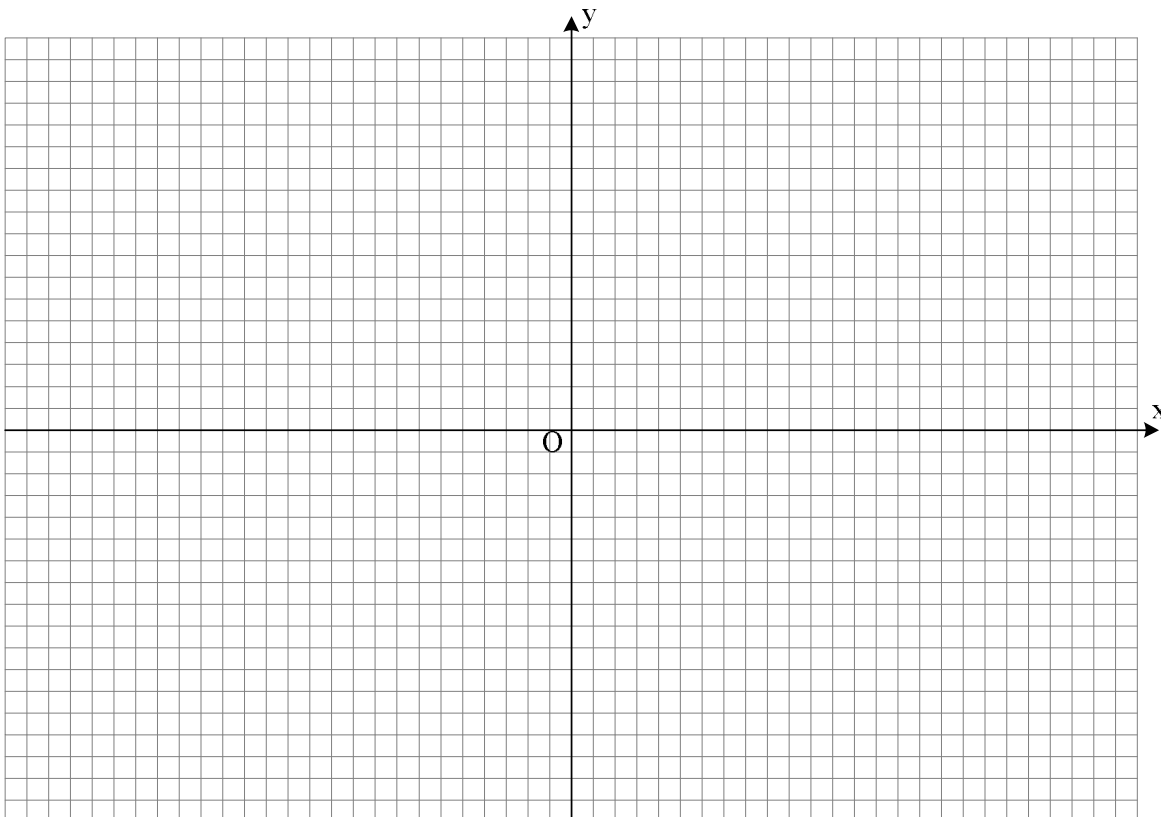
	Mass (kg)	Force (=9.81 m/s <sup>2</sup> ×Mass)	Angle	F <sub>x</sub> (Go back to the first part.)	F <sub>y</sub> (Go back to the first part.)
Force 1					
Force 2					
Force 3					
Sum of x- and y- components of each force ⇒					



#### Question:

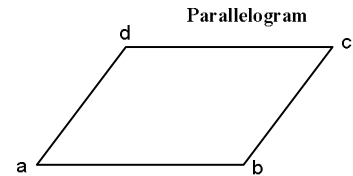
Do the force components add up to zero? (*You are supposed to obtain zero theoretically.*)

- Draw the force vectors on the following graph and determine their sum graphically.

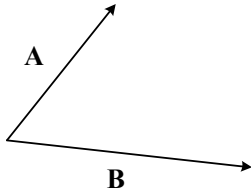


## How to add vectors graphically

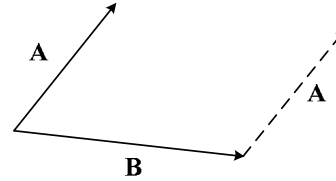
Definition of parallelogram is that side  $\overline{ab}$  must be parallel with side  $\overline{dc}$  and the length has to also be equal. Likewise, sides  $\overline{ad}$  and  $\overline{bc}$  are equal and parallel.



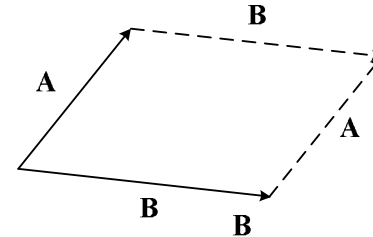
Two vectors can make a parallelogram as follows:



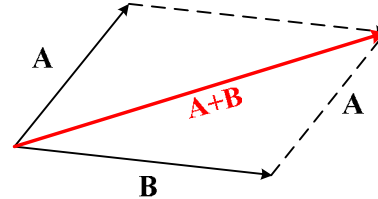
Vector A can be moved as shown.  $\Rightarrow$



Likewise, vector B can be replaced as shown. All of these construct a parallelogram.



The addition of vectors A and B can be found as follows. It has to be drawn from the start point of the vectors so it can be the diagonal of the parallelogram.



For the last part of this lab,...

**The data shown below are only for the explanation purpose. Please do not use this for your own results.**

- After taking data, you have the information of all of the vectors (the magnitudes and directions). The force column corresponds to the magnitude; and the angle column corresponds to the direction.

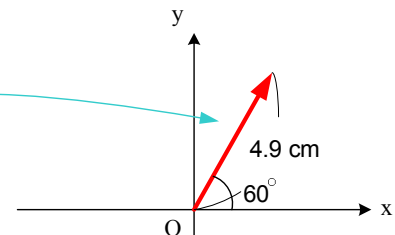
### 1. Static equilibrium with three forces

	Mass (kg)	Force (=9.8m/s <sup>2</sup> ×Mass)	Angle
Force 1	0.50 kg	4.90 N	60°
Force 2	0.50 kg	4.90 N	180°
Force 3	0.50 kg	4.90 N	300°
Sum of x- and y- components of each force $\Rightarrow$			

- Draw each force vector as follows: Force 1 has magnitude, 4.9 N, and direction 60°. For convenience' sake, draw a

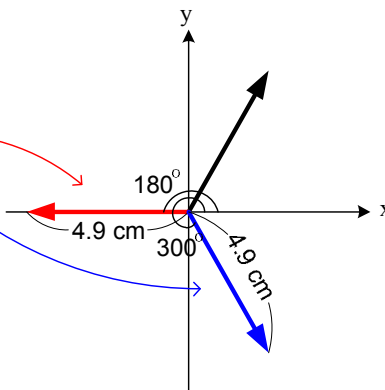
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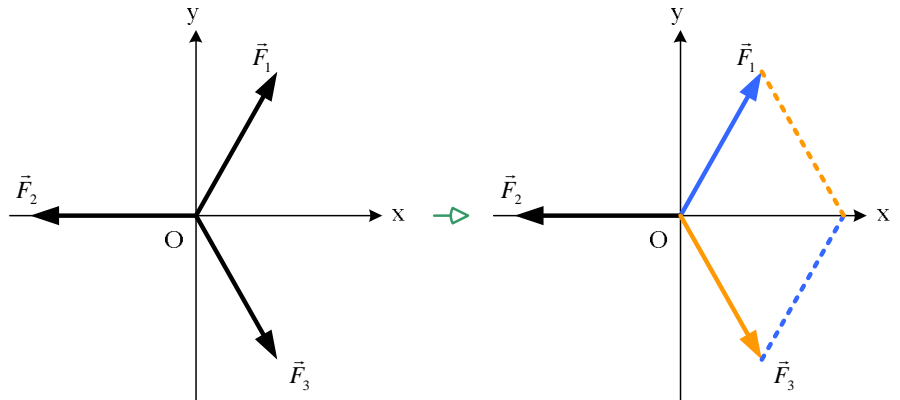
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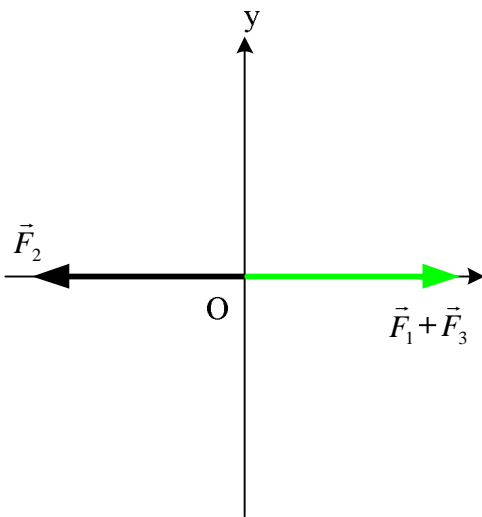
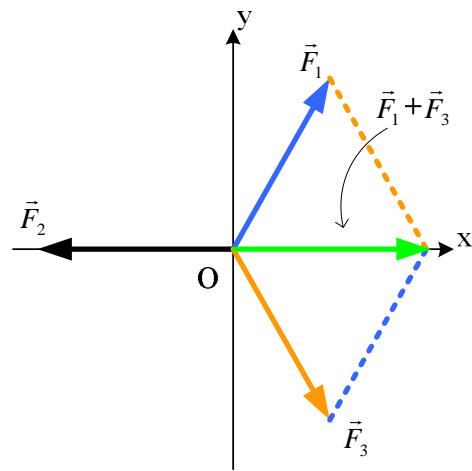
vector on paper like 4.9 cm.

3. Perform the same procedure for the second and third vectors. The angles are always taken from the positive side of  $x$ -axis.

4. After you draw all of the vectors, pick out two vectors. Then, make a parallelogram as shown.



5. The diagonal will be the sum of two vectors. (Be careful about how you take the diagonal. The starting point of the vector is the origin.)



6. Two vectors added becomes one vector as shown. Repeat the same procedure as above until you obtain one final vector. Now, there are two vectors, which are  $\vec{F}_1 + \vec{F}_3$  and  $\vec{F}_2$ . If either one of them is tilted, you can make a parallelogram. However, in this example, these vectors are an equal magnitude and opposite directions. Therefore, the sum of two vectors has cancelled each other.

7. The sum of three vectors becomes a zero vector as shown. However, practically, considering the experimental uncertainty, you likely obtain a small vector from origin as the error.

