

# Headstart Science.

**Moving About I.**

**CHECKPOINT**

By the end of the lesson, students will be able to:

**Vectors**

- Distinguish between scalar and vector quantities in equations
- Identify the usefulness of using vector diagrams to assist solving problems
- Add, Subtract and Resolve Vectors

**Distance and Displacement; Speed and Velocity; Acceleration**

- Define average velocity as:  $v_{av} = \frac{\Delta s}{\Delta t}$
- Distinguish between the instantaneous and average speed of vehicles and other bodies
- Compare instantaneous and average speed with instantaneous and average velocity

# MOVING ABOUT

In *Moving About*, we explore the fundamental physics behind motion, and introduce the basic principles and quantities involved with moving objects. In this first lesson, we distinguish between vector and scalar quantities:

## VECTORS

In order to understand motion, we must first be familiar with the concept of vectors, and how to manipulate them.

### VECTOR AND SCALAR

In physics, there are two types of quantities that are most often used – scalar quantities and vector quantities:

A **Scalar** quantity only has .....

A **Vector** quantity has both ..... and .....

For instance, the quantity 2km would be a scalar quantity. But if we said 2km North, this would be a vector quantity. Vector quantities are usually denoted by symbols such as  $\vec{v}$  or  $\vec{v}$ , whereas the scalar quantity would be denoted simply as  $v$ . The arrows above the  $v$  indicate the need for a direction.

**Talent Tip:**

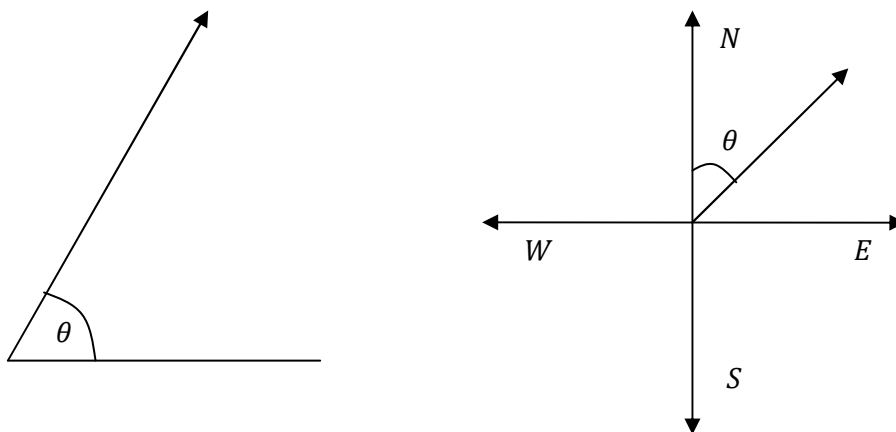
### Question 1 (12 marks)

Indicate whether the following are scalar or vector quantities: speed, velocity, distance, displacement, time, mass, weight, force, momentum, energy, temperature, pressure.

<b>Scalar</b>	<b>Vector</b>

### VECTOR REPRESENTATION

In order to specify the direction of a vector quantity in two dimensions, we will usually measure the angle from a certain set of axes. For instance, when throwing a ball into the air, we measure the angle of elevation. In geography, we may measure from North or South:



**Vector Representation**

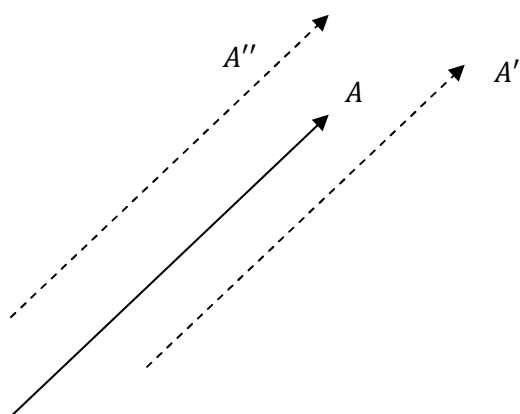
A vector can be represented by an arrow.

The length of the vector is a measure of its .....

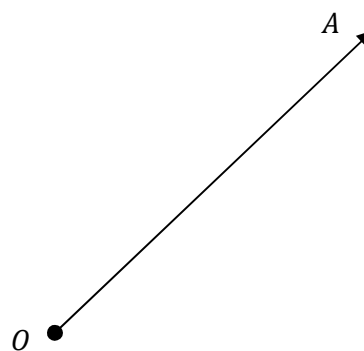
The orientation of the vector is a measure of its .....

### FREE AND FIXED VECTORS

Once we have specified at the magnitude and direction of a vector, we may translate or move it anywhere, and it will still be the same vector. We call these vectors ‘free vectors’. If a vector is fixed to point, however, it is called a fixed vector.



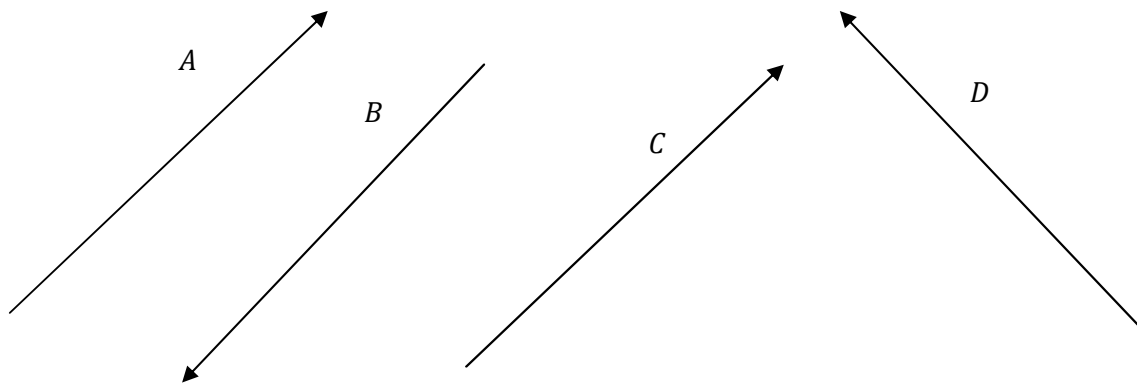
Free Vectors



Fixed Vector OA (fixed to O)

**Question 2 (4 marks)**

Consider the following vectors that all have the same length:



a) Which of the vectors are equivalent and why? **2**

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b) Given that they all have the same length, why aren't all the vectors the same? **1**

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c) Why is it that we can *translate* (shift) a vector, but that we can't rotate it? **1**

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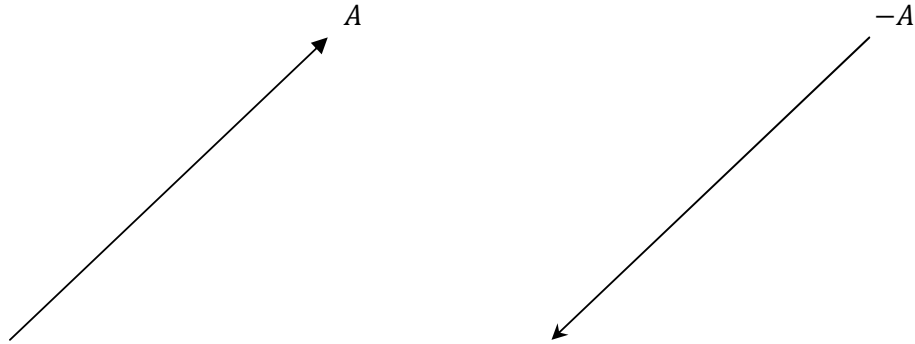
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### THE NEGATIVE VECTOR

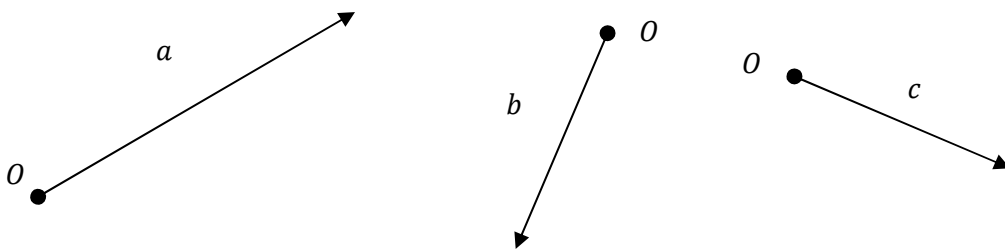
Although we can move a vector, we may not rotate it, as that will change its direction.

We can also find the negative vector, by reversing the direction, as shown below:



#### Question 3 (3 marks)

For vectors a and b below:



a) Draw an equivalent free vector

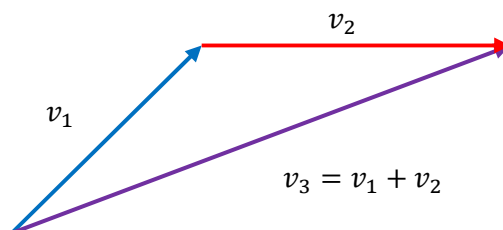
1

b) Draw the negative vector  $-a$  and  $-b$  and  $-c$

3

## VECTOR ADDITION

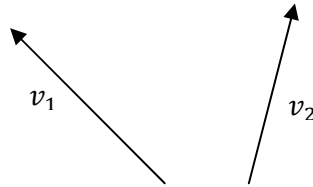
Now that we are familiar with the concept of vectors, it is important to know how to manipulate them. Vectors are added **tip-to-tail**. In order to add vectors, we must first align the vectors so that the head of  $v_1$  touches the tail of  $v_2$ . The vector  $v_1 + v_2$  is found by then joining the tail of  $v_1$  to the head of  $v_2$ :



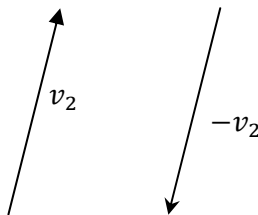
**VECTOR SUBTRACTION**

We can also use the tip-to-tail method to find the difference of two vectors, as shown below:

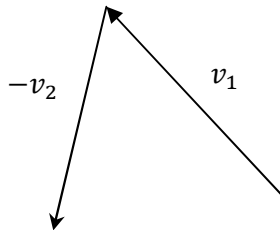
Suppose we wish to find  $v_1 - v_2$



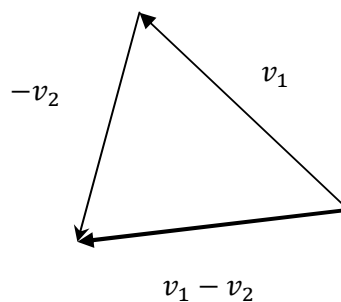
**STEP 1:** First find the negative vector  $-v_2$



**STEP 2:** Orient the vectors 'tip-to-tail'



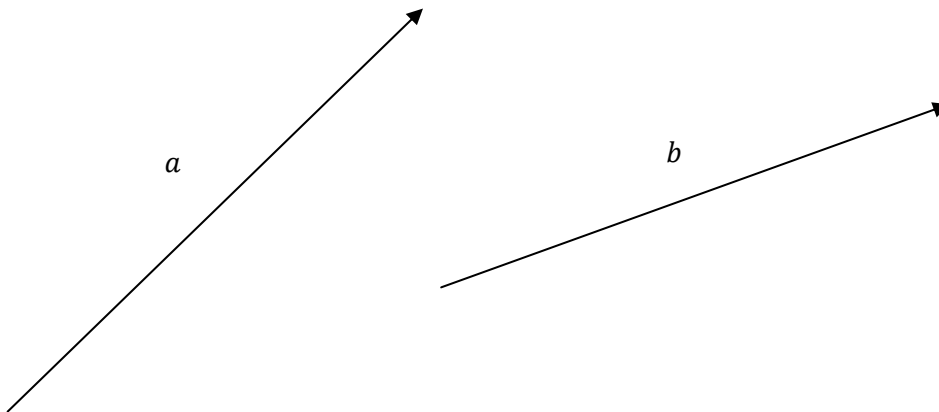
**STEP 3:** Connect the tail of  $v_1$  to the head of  $-v_2$





**Question 4 (3 marks)**

Consider the following vectors:



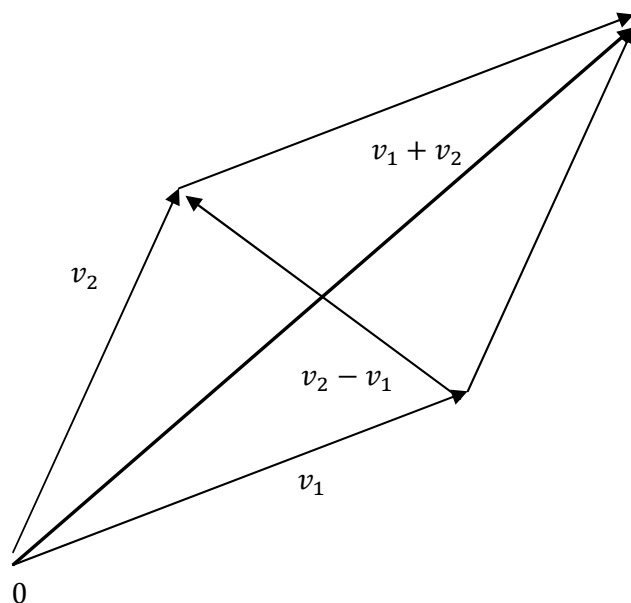
Using a ruler,

- |                            |          |
|----------------------------|----------|
| a) Find the vector $a + b$ | <b>1</b> |
| b) Find the vector $a - b$ | <b>1</b> |
| c) Find the vector $b - a$ | <b>1</b> |

## VECTOR PARALLELOGRAM METHOD

A simple method of find the sum and difference of vectors is to construct a vector parallelogram.

The diagonals of the resulting parallelogram are the vector sum and differences:



### The Vector Parallelogram Method

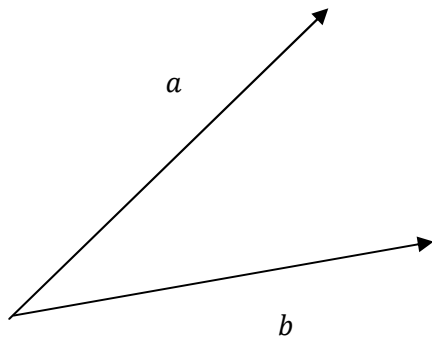
We can use the vector parallelogram method to find the sum or difference of any two vectors. Suppose you are given fixed vectors  $a$  and  $b$ . To construct the parallelogram, draw two FREE vectors equivalent to complete the parallelogram.

- The long diagonal represents the sum of the two vectors
- The short diagonal represents the difference of the two vectors. Note very carefully, the direction of the arrow determines if this vector is  $a - b$  or  $b - a$ .

**Question 5 (6 marks)**

By constructing a vector parallelogram, find:

a)  $a + b$

**2**

b)  $a - b$

**2**

c)  $b - a$

**2**

**Question 6 (2 marks)**

During a bushwalk, a camper walks 200 m due North, 200m due East and 500m SW.

a) Draw a scale diagram of the situation

**1**

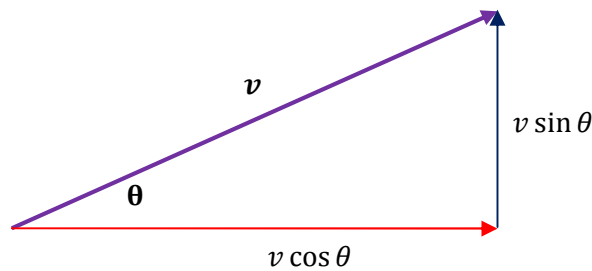
b) Hence (using a ruler) approximate the displacement of the individual.

**1**

[HINT: you must also find the direction, i.e. the angle or bearing]

**VECTOR RESOLUTION**

Just as we can add vectors to produce a vector sum, it should be fairly intuitive that we split or **resolve** a vector into two or more component vectors. One of the most useful ways to resolve vectors is to split them into horizontal and vertical components. For instance, in projectile motion (which you study in Year 12), the horizontal and vertical components are independent, and hence the motion is more easily analyzed by resolving the vectors.



**Question 7 (2 marks)**

A ball is thrown at  $30^\circ$  at a speed of  $50\text{ms}^{-1}$ . Find the initial vertical and horizontal velocities

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**Question 8 (2 marks)**

An intercontinental ballistic missile is launched at  $15^\circ$  at a speed of  $2000\text{ms}^{-1}$ . Find the initial vertical and horizontal velocities of the missile

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## VECTORS IN MOTION

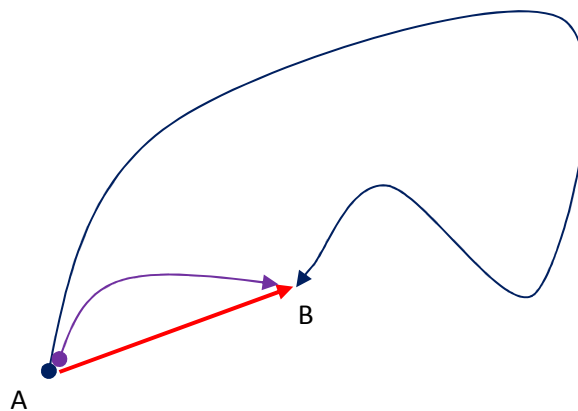
We now look at vector quantities used in motion. You have probably dealt with the fundamental quantities of speed, distance and time in junior science. We now look at the vector quantities, displacement and velocity, which differ in that they have a direction.

### DISPLACEMENT VS DISTANCE

In analyzing journeys, you will first need to appreciate the difference between distance and displacement:

Displacement tells us only of the .....

Distance tells us .....



**Question 9 (2 marks)**

John travels due 60km.

a) What is the distance he travels? 1

.....

b) What is his displacement? 1

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Sometimes, distance and displacement have the same magnitude and differ only in the direction. However, this is not always the case, and it is dangerous to assume that distance and displacement have the same size, as the following cases demonstrate:

**Question 10 (2 marks)**

A man walks due east 12km before heading due north 5km.

- a) What distance does he travel? **1**

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- b) What is his displacement? **2**

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**Question 11 (3 marks)**

A plane is travelling at 300 km/h due South. An easterly wind is blowing at 100km/h. Calculate the net displacement of the plane after 2 hours.

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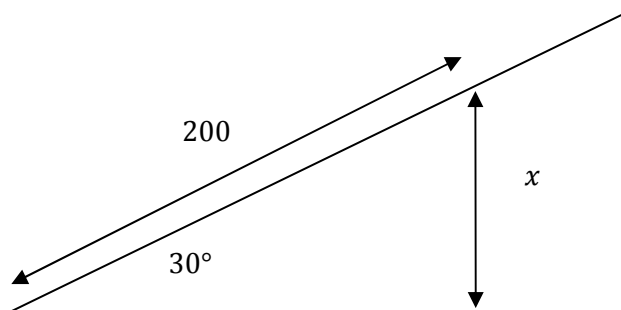
**Finding Magnitude and Direction**

When dealing with vectors that are at right angles to each other, to find the:

- **Magnitude**, use Pythagoras Theorem ( $a^2 = b^2 + c^2$ )
- **Direction**, use  $\tan \theta = \frac{y}{x}$

**Question 12 (1 mark)**

A car has driven 200 m up a hill that is inclined at an angle of 30 degrees. How high is the car from the ground?



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**SPEED AND VELOCITY**

Likewise, both speed and velocity refer to the rate of change of distance /displacement travelled.

Speed, is a scalar quantity whereas velocity is vector.

**Speed and Velocity Formula**

$$\text{speed} = \text{—————}$$

$$\text{velocity} = \text{—————}$$

Also, students should note that the correct S.I. Unit for velocity is  $ms^{-1}$  NOT km/h, even though km/h is typically used.

**Question 13 (Conceptual)**

- a) Express in 1km/h in m/s.

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- b) Express 1m/s in km/h.

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**Conversion between km/h to m/s**

To convert from km/h to m/s, divide by 3.6

To convert from m/s to km/h, multiply by 3.6

**Question 14 (4 marks)**

Michael Johnson, the world record holder for the 400 m sprint, can sprint a lap of the track in 43.18 seconds.

a) What distance does he travel? **1**

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a) What is his average speed? **1**

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b) What is his displacement? **1**

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c) What is his average velocity? **1**

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**Question 15 (7 marks)**

John travels due north at an average of  $60 \text{ km/h}$  for 2 hours, then due south for an average of  $20 \text{ km/h}$  for 30 minutes before going due East for  $80 \text{ km/h}$  for three hours.

- a) Calculate the total distance John travels **1**

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- b) Calculate the net displacement **3**

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c) Calculate the average speed of the journey **1**

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d) Calculate the average velocity of the journey. **2**

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## AVERAGE AND INSTANTANEOUS VELOCITY

The same definitions apply for velocity, except that velocity must also include a *direction*. Hence,

Average velocity

$$\vec{v}_{av} = \frac{\vec{\Delta s}}{\Delta t}$$

Symbol	Quantity	S.I. Units
$\vec{v}_{av}$	Average Velocity	$ms^{-1}$
$\vec{s}$	Displacement (vector)	$m$
$t$	Time	$s$

Likewise, the **instantaneous velocity** is the velocity at that instant. It has the same magnitude as the instantaneous speed, but also includes direction

**Question 17 (6 marks)**

A man moves 2 metres north in 5 seconds, then 6 metres south in 3 seconds. What is his:

a) Average speed? **2**

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b) Average velocity? **2**

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c) Instantaneous speed at 3 seconds? **1**

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d) Instantaneous velocity at 3 seconds? (all to 2 decimal places) **1**

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**Question 18 (5 marks)**

A car travels north for 60 kilometres in 1 hour, then east for 30 kilometers in 0.5 hours. What is its:

- a) Average speed **2**

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- b) Average velocity (to the nearest metre per second) **3**

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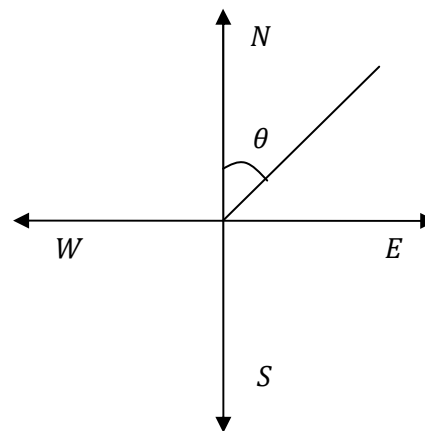
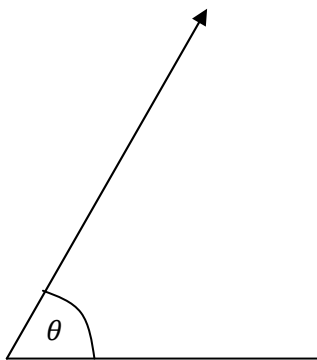
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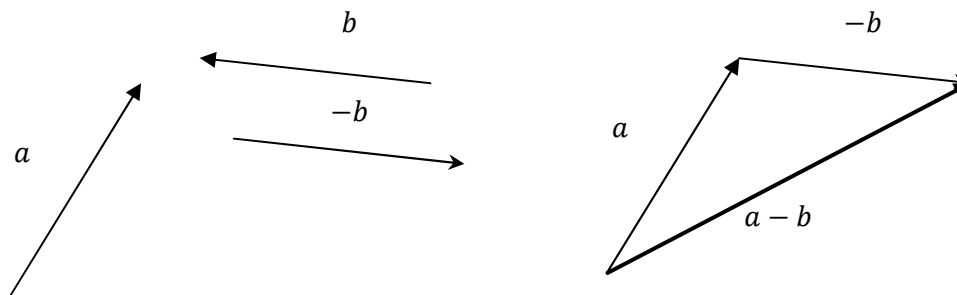
## SUMMARY OF LESSON

### VECTORS

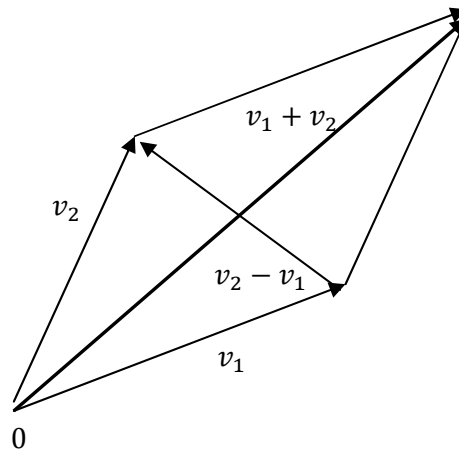
- There are two types of quantities in Physics:
  - **Scalar:** quantities that only have magnitude
  - **Vectors:** quantities that have both magnitude and direction
- We can represent a vector by a ray
- The size of the ray represents its magnitude
- The angle represents its direction
- Vectors can be added using the tip-to-tail method, as shown below:



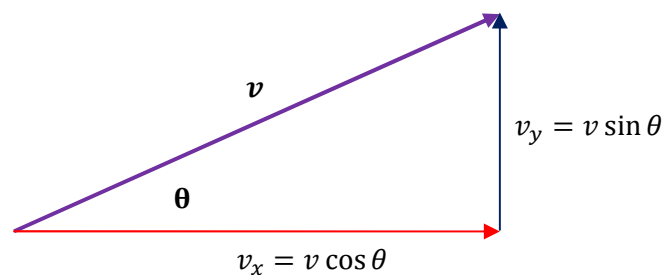
- Vectors can also be subtracted, by creating a negative vector and adding them together



- The Vector parallelogram provides an easy way to remember vector addition and subtraction:



- Vectors may also be resolved into perpendicular components:



## DISTANCE AND DISPLACEMENT

- Distance (scalar) measures how far an object has travelled
- Displacement (vector) measures the objects net change in position

## SPEED AND VELOCITY

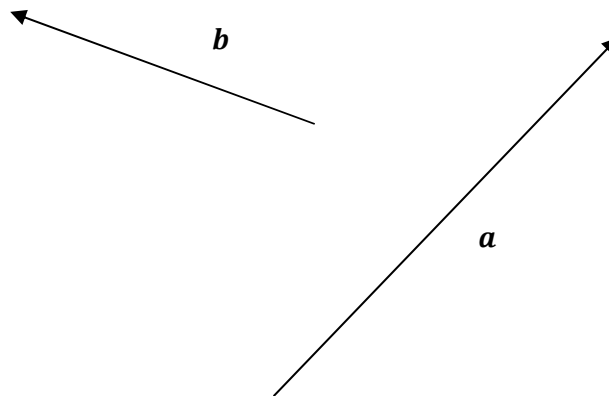
- Speed and velocity measure the rate of change of distance and displacement with respect to time:

- $Speed = \frac{distance}{time}$

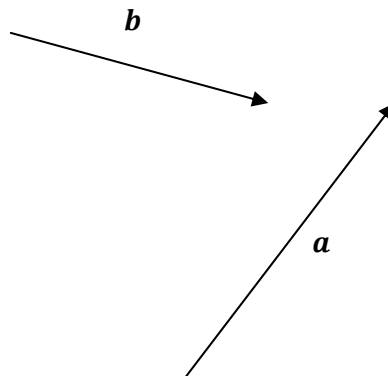
- $Velocity = \frac{Displacement}{time}$

## HEADSTART HOMEWORK

1. For the following vectors, find using vector addition  $a + b$  and  $a - b$



2. Use the vector parallelogram method to find  $a + b$  and  $a - b$



3. Distinguish between
- Distance and displacement
  - Velocity and Speed
  - Average and instantaneous speed
4. John travels 12 km North in 20 minutes and 5 km East in 5 minutes. Find his:
- Distance
  - Displacement
  - Average speed
  - Average velocity
5. An Intercontinental Ballistic Missile is launched at 3 km/s at an angle of  $20^\circ$ . Draw a vector diagram of the situation. Hence, calculate its vertical and horizontal velocities (using vector resolution)
6. A projectile is launched with a vertical velocity of 8 m/s and a horizontal velocity of 6 m/s. Calculate its velocity.



