Introduction to Vectors

Most quantities we measure are **scalars**. These are measured with a size or magnitude, without regard to direction. For example, temperature is a scalar. While it can be positive or negative, it does not have a direction, such as right or left.

A **scalar** is a physical quantity that has only a magnitude or size.

Sometimes it is necessary to include a direction when we give the value for a quantity. For example, saying "Lisa walked three kilometers east" is not the same as saying "Lisa walked three kilometers south."

A **vector** is a physical quantity that has a magnitude and a direction.

Force is a vector. You can pull on a door handle with a force of $25\ N\ [East]$, or you can push on the door handle with a force of $25\ N\ [West]$. While these forces have the same magnitude, they act in different directions. One force will open the door; the other force will not.

To specify a vector, you must include three pieces of information: a size, a unit, and a direction.

In physics, speed and velocity are often confused. **Speed** describes how fast an object is moving, regardless of direction. **Velocity** describes both how fast and in what direction an object is moving. It is the direction that makes them different.

Scalar or Vector

In this course, you will be introduced to many quantities. Complete the following table.

Quantity	Symbol of the Quantity	Unit	Vector or Scalar
time instant			
time interval			
distance travelled			
displacement			
mass			
length			
speed			
acceleration			
velocity			
force			
energy			

Terms for Describing Motion

Kinematics is the branch of physics that deals with the description of motion. In order to describe the motion of an object, we must understand the vocabulary.

Time

Time is a scalar quantity. In the metric system, the unit for time is the second (*s*). An **instant** of time is a clock reading, such as 3:14 PM. A **time interval** (Δt) is the amount of time that passes between two instants. For example, the time interval between 3:14:25 PM and 3:14:39 PM is 14 seconds.

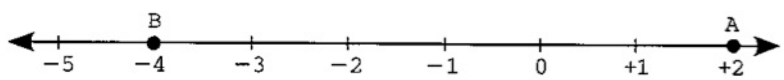
To calculate a time interval, subtract the initial time (t_i) from the final time (t_f).

$$\Delta t = t_f - t_i$$

Position, Distance, and Speed

Position is the location of an object in relation to the location of a specific point called the reference point. The **reference point** is the zero location in a coordinate system or frame of reference. Position is a vector quantity.

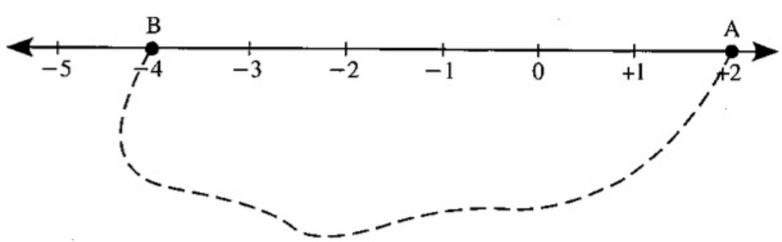
In grade 10, we study motion along a straight line. Thus, position can be thought of as the location of an object on a number line, where 0 is the reference point.



On the number line above, point A is at the position $+2\ m$, and point B is at the position $-4\ m$. If the object moved from point A to point B, then we would call A the **initial position** and B the **final position**.

Distance (d) is the length of the path travelled by an object. It is a scalar quantity, and so has no direction. The metric unit of distance is the meter (*m*).

The diagram below shows one possible path that a person might follow in moving from point A to point B.



In this diagram, the distance travelled would be the total length of the dashed line. If we knew the length of the dashed line and the time it took to travel from point A to point B, we could determine how fast the object was moving.

Speed (v) is a measure of how fast an object is travelling. Speed is calculated by dividing the distance travelled by the time it took.

$$v = \frac{d}{\Delta t}$$

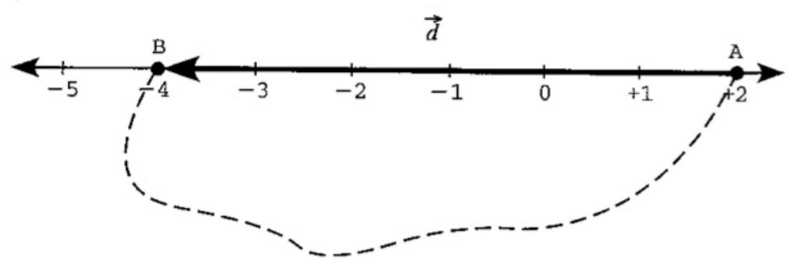
Displacement

Displacement ($\overrightarrow{\Delta d}$) represents the change in position of an object. It is a vector, and thus includes both a magnitude and a direction. The metric unit of displacement is the meter (*m*).

Distance and displacement are not the same thing. Distance is the total length of the path taken from point A to point B. Displacement is how far and in what direction you are from your starting position, **measured in a straight line**.

A person walks 200 meters east, then turns around and walks 300 meters west. The distance travelled by this person is 500 meters. The displacement of this person is 100 meters west (how far they are from their starting position, and in what direction).

In the number line example from earlier, the distance would be measured along the dashed line, while the displacement would be measured along the number line, as shown below.



The vector drawn in bold is the displacement from point A to point B, and would be read as 6 meters to the left.

To calculate the displacement of an object, subtract its initial position ($\vec{d_i}$) from its final position ($\vec{d_f}$).

$$\overrightarrow{\Delta d} = \vec{d_f} - \vec{d_i}$$

Velocity

Velocity is defined as the rate of change of position. It is calculated by dividing an object's displacement by the time interval over which the motion occurred.

$$\vec{v} = \frac{\overrightarrow{\Delta d}}{\Delta t}$$

Velocity is a vector quantity, and thus has both a magnitude and a direction. The metric unit of velocity is the meter per second (m / s).

Acceleration

Acceleration is defined as the rate of change of velocity. It is calculated by dividing the change in velocity by the time interval over which the change took place.

$$\vec{a} = \frac{\overrightarrow{\Delta v}}{\Delta t}$$

Acceleration is a vector quantity, and thus has a magnitude and a direction. The metric unit of acceleration is the meter per second squared (m / s^2).

By comparing the direction of an object's velocity and the direction of its acceleration, you can determine whether the object is speeding up or slowing down. The table below summarizes the possibilities for objects moving in a straight line.

Velocity	Acceleration	Type of Motion
+	+	speeding up
+	–	slowing down
–	+	slowing down
–	–	speeding up

In other words, if the velocity and acceleration are in the same direction, the object is speeding up. If they are in opposite directions, the object is slowing down.

Worksheet

1. A helicopter leaves its base and travels 20.0 km north. After a brief stop, it flies 35.7 km south, pauses briefly and then flies 17.0 km north. Finally it flies 6.0 km south and lands. At the end of the trip, what is the displacement of the helicopter from its base? (4.7 km south)

2. A scale is marked off in cm on a long table. A coin initially at the position labeled 100 cm is moved to the position marked -30 cm. What is the displacement of the coin? (-130 cm)

3. You move 3.27 m forward, 2.00 m forward, 7.95 m backward, 2.34 m forward, 4.56 m backward, and 4.90 m forward.

    a) What is your final displacement? (0)

    b) What is your maximum displacement from your starting position? ($+5.27$ m)

    c) What is your minimum displacement from your starting position? (0)

4. **(Challenging)** A bike has a displacement of 1.27 km after a trip consisting of three parts. The sum of the first two parts is 3.79 km, the sum of the last two parts is -7.82 km. How long is each part of the trip? (9.09 km, -5.30 km, -2.52 km).

5. What is the speed in meters per second of a car traveling at a constant speed of 96 km/h? (26.7 m/s)

6. What is the average speed for a trip of 157 km that takes 2.45 h? (64.1 km/h)

7. How far will an automobile go in 3.5 h at a constant speed of 95 km/h? (332.5 km)

8. How long can you afford to stop for lunch if you can drive a steady 104 km/h on the highway and must make a 260 km trip in 3.5 h? (1.0 h)

9. It takes 2.51 s for a laser signal to go from the Earth's surface to the Moon and back. How far is the lunar surface from the Earth's surface? Hint: The speed of light is 3.0×10^{8} m/s. (7.53×10^{8} m)

10. When a batter hits a baseball its velocity is changed from 128 km/h west to 136 km/h east.

    a) What is the change in speed of the ball? (8 km/h)

    b) What is the change in velocity of the ball? (264 km/h east)

11. A medevac helicopter travels $78\ km$ south of its base to pick up a patient. The helicopter then travels $93\ km$ north to a hospital. The entire trip takes $1.22\ h$.

    a) What is the average velocity? ($12\ km/h$ north)

    b) What is the average speed? ($140\ km/h$)

12. Two children cross a starting line at the same time, one running with a velocity of $+3.5\ m/s$ and the other with a velocity of $-4.0\ m/s$. How far apart are they after $12\ s$? ($90\ m$)

13. A motorist traveling at $90\ km/h$ applied the brakes for $5.0\ s$. If the braking acceleration was $-2.0\ m/s^2$, what was her final speed? ($15\ m/s$)

14. The Jaguar XJ220 can accelerate from 0 to $26.8\ m/s$ in $4.0\ s$. What is the average acceleration during this time interval? ($6.7\ m/s^2$)