# MOTION

## 1.1 Describing Motion

**Motion** is movement in any direction and, therefore is a *vector quantity.*

**Speed** is the distance that has traveled a body In unit time speed only has magnitude (size) Making it a *scalar quantity*. The unit of speed is m/s or km/hr.

**Speed** = $\frac{DISTANCE}{TIME}$

S=$\frac{d}{t}$

**Velocity** is the distance traveled in unit time in a given direction. Velocity has both magnitude (size) and direction. It is a *vector quantity*.

The unit of velocity is m/s direction. For example 4m/s east.

**Displacement** is the length from one point to another at a given direction.

**Velocity**=$\frac{DISPLACEMENT}{TIME}$

S is displacement.
V is velocity
T is time

V=$\frac{s}{t}$

**Note**: Distance is a scalar quantity, and Displacement is a vector quantity.

**Example:**

Jennie travels 550 metres to the East in 10 seconds. Find the speed and velocity Jennies used to travel.

ANS:

**Speed** = $\frac{DISTANCE}{TIME}$=$\frac{550m}{10s}$=55m/s

**Velocity**=$\frac{DISPLACEMENT}{TIME}$=$\frac{550m\ East}{10s}$= 55m/s East

**Factors that influence the speed of an object:**

1. **Force applied**: Applying force to an object can result in a change of Speed in an object.

2. **Mass of the object**: According to or a given force Newton's second law, for a given force, a more massive object will experience less acceleration compared to a less massive object.

3. **Direction of force**: The object's speed can increase if a force is applied in the direction of motion. If the force is applied in the opposite direction - of motion, it can slow down or decelerate the object.

4. **The medium in which the motion is taking place**: The state of matter that the object is traveling through can affect the speed of motion, for example, an object may experience drag forces that can influence the speed.

5. **The Gradient**: If a motion is taking place along an inclined plane/surface, the object's speed can be affected. The Steeper the gradient, the greater the acceleration or deceleration depending on the direction of motion.

## 1.2 Graphs of Motion

**Accelerating**: The rate of change in velocity or the change in velocity per unit time.

**Acceleration**=$\frac{Change\ in\ velocity}{Time}$

a=$\frac{\Delta V\ (m/s)}{t\ (s)}$

a=$\frac{V - U\ (m/s)}{t\ (s)}$

V is the final velocity
U is the initial velocity
t is the time
Acceleration is measured in $m/s^2$
Acceleration if the distance is given:

$2as = V^2 - U^2$

a is acceleration ($m/s^2$)
s is distance (m)

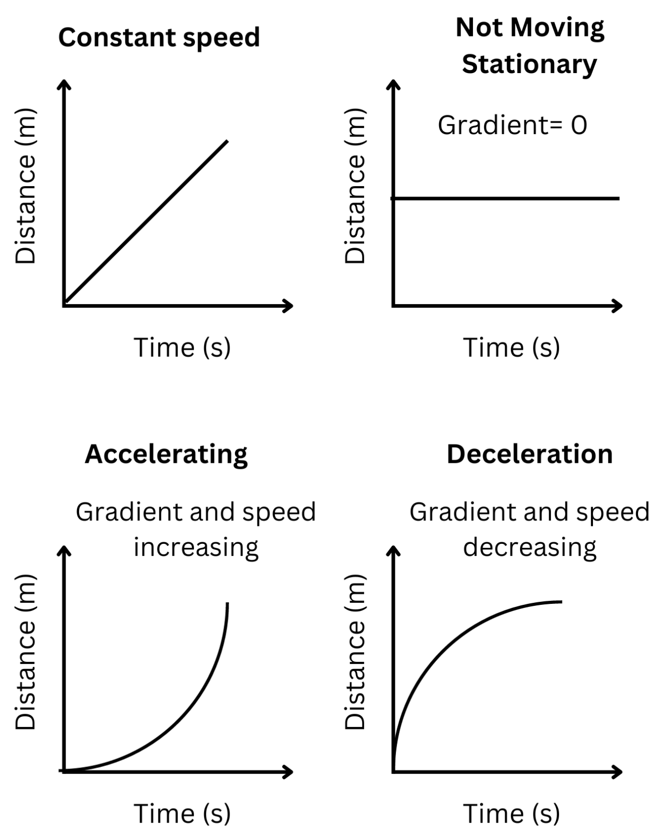
V is the final velocity (m/s)
U is the initial velocity (m/s)

**Note:** If an object starts from stationary, then its initial velocity U should be 0m/s.

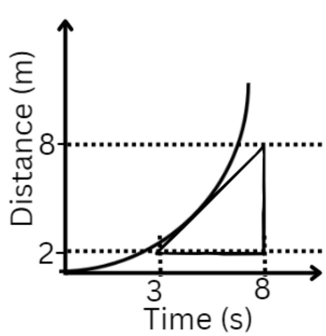
### Distance-Time Graph

The **gradient** of the line at any point tells you the speed the object is traveling.

Gradient= $\frac{\Delta Distance}{\Delta Time}$




**For example:**

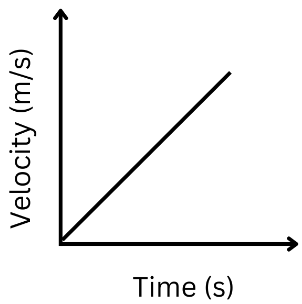



Gradient= $\frac{\Delta Distance}{\Delta Time}$= $\frac{8-2}{8-3}$=$\frac{6}{5}$= 1.2 m/s

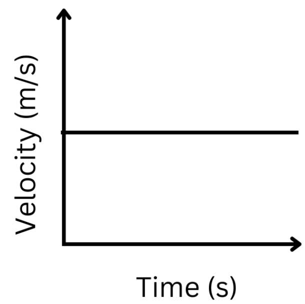
The speed of this journey is 1.2m/s

**Velocity-Time Graphs**

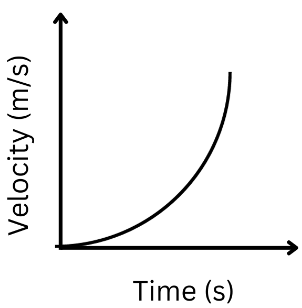
**Constant acceleration**



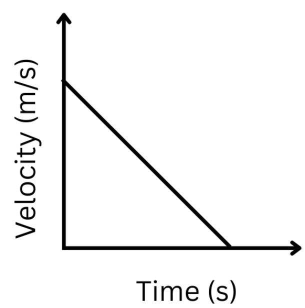

**Constant Velocity**




**Increasing rate of acceleration**



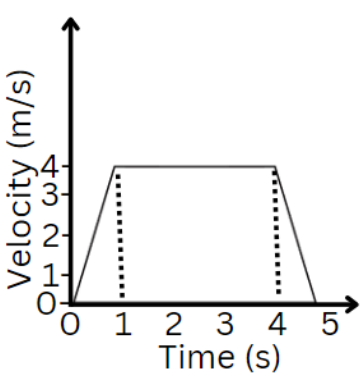

**Constant deceleration**




To find the distance traveled:

- Use the area of the shape formed in a particular time given.

**For example:**




Find the distance traveled for the first 4 seconds:

Shape: Trapezium

A= $\frac{(a+b)h}{2}$

A= $\frac{(4+3)4}{2}$

A= 14m/s

**Terminal velocity**: is a point reached whereby the velocity reaches a constant rate.
When an object falls in a uniform gravitational field, the air resistance opposing its motion increases as its speed rises, reducing its acceleration. Eventually, air resistance acting upwards equals the weight of the object acting downwards. The resultant force on the object is zero since the gravitational force balances frictional force. The object falls at terminal velocity.

## 1.3 Uniform and non-uniform Motion

**Uniform motion**: If a body travels an equal distance in equal intervals of time in the same direction.

$$d_1 = d_2$$

D is distance

**Non-uniform motion**: If a body travels Unequal distance in equal intervals of time.

$$d_1 \neq d_2$$

D is the distance

To find the speed in non-uniform motion. We find the average speed:

Average speed = $\frac{Total\ Distance}{Elapsed\ Time}$

## 1.4 Equations of motion

$V = U + a t$
$S = U t + \frac{1}{2} a t^2$
$2 a s = V^2 - U^2$
$S = \frac{1}{2} (U + V) t$

Whereby:

S is Displacement or Distance
U is Initial Velocity
V is Final Velocity
a is Acceleration
t is Time

**Examples:**

1. A car accelerates from rest with an acceleration of 4m/s² for 6s Find the Final velocity

Ans:
Initial velocity (U) = 0m/s
Acceleration (a) = $4m/s^2$
Time (t) = 6s

V= U + a t
V=0+4x6
V = 24mls

2. A ball is thrown vertically upward with an initial velocity of 20m/s Calculate the maximum height it reaches if the acceleration due to ches gravity is 9.8 $m/s^2$ for 10 seconds.

U=20m/s
t=10 sec
a=$9.8m/s^2$

S=ut + ½ $at'^2$
S=20×10 + ½ x 9.8×$10^2$
S= 200+ 19.6×100
S=200+1960
S=2160m

## 1.5 MOMENT and MOMENTUM

### Moment of a force

**Moment** of a force This is the Product of force and its Perpendicular distance from the Pivot.

Moment = Force X distance

Moment= Fxd

Its units are Nm (Newton meter)

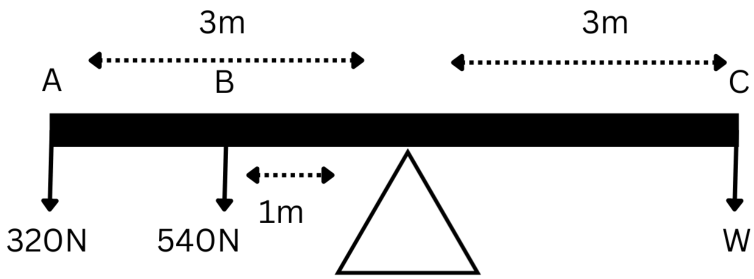
**The law of moments (Law of the lever) states that:**

When a body is in equilibrium, the sum of the clockwise moments About any point equals the sum of anticlockwise moments about the same point. There is no resultant moment on an object in equilibrium.

Clockwise moment = anticlockwise moment

$F_1 x d_1 = F_2 x\ d_2$

**Example:** The seesaw balances when Shani of weight 320 N is at A. Tom of weight 540N is at B and Harry of weight W is at C. Find W.




Clockwise moment:
Moment= Fxd
Moment= 3 x W = 3W Nm

Anticlockwise moment:
Moment = (Fxd) + (Fxd) = (540X1) + (320 x3) = 540 +960
Moment= 1500 Nm

Clockwise moment= Anticlockwise moment

3W= 1500
W= 500 N

**Note:** The further the distance, the lesser the force needed to be used E.g the distance between the door handle and the hinge is far apart so that it does not require a lot of energy to open the door.

**Conditions for equilibrium:**

- The sum of forces in one direction equals the forces in the opposite direction.

- The law of the moment must apply. When there is no resultant force and no resultant moment, an object is in equilibrium.

**Equilibrium:** When there is no resultant force and resultant moment.

## Momentum

**Momentum** is the product of the mass of a body and its velocity.

It is measured in Kilogram meter Per second (kg m/s)

Momentum = mass x velocity
P= mv
ΔP= Δ(mv)
P is rho

Momentum is a *vector quantity* and has both magnitude (size) and direction

## The Conservation of Momentum Principle

In a closed system, the total momentum before an event like a Collision is the same as the total momentum after the event

To find the Force used to change the momentum:

$$F=\frac{(mv-mu)}{t}$$

mv is the Final Momentum
mu is the Initial Momentum
t is Time

**Example 1:**

Ball A has a mass of 4500 kg and its velocity is 12m/s On the other hand ball B has a mass of 1200 kg and its velocity is 20m/s. Calculate their momentum Separately, and their velocity after collision.

Ball A is moving to the right
Ball B is moving to the left.

Ball A:
P=mv = 4500 x 12 = 54,000 Kg m/s
P= + 54,000 kg m/s

Ball B:
P=mv= 1200×20 = 24000 kgm/s
P= - 24,000kg m/s

Find their momentum

Ball A + Ball B momentum.
54,000+ - 24,000
P=+30,000 kg mls
V= p/m

Find their total mass:

$m_1 + m_2 = m_{total}$
4500+1200=5700 kg
V= 30,000kg m/s / 5700 kg
V= 5.3m/s after collision.

**Note**: If the object is moving to the right, it has positive momentum and if it is moving to the left, it has negative momentum.

**Example 2:**

Calculate the force required to accelerate a 750g ball from rest to 18m/s in 0.25s.

$F = \frac{(mv - mu)}{t}$

V= 18 mls
m= 750 g or 0.75 kg
t=0.25s

$F = \frac{(0.75\ x\ 18) - (0.75\ x\ 0)}{0.25}$

$F = \frac{13.5 - 0}{0.25}$

F=54N

## Impulse

**Impulse** is the product of force and time.

Impulse = Force x time
I = Fxt

It is measured in Newton Seconds (Ns)

Impulse = Change in Momentum
Force x Time = Mass x Velocity

A force acting on an object for a given time is equal to the mass times the change in velocity of the Object.
**Force** is the rate at which the momentum of an object changes.

Force $= \frac{Change\ in\ Momentum}{Change\ in\ Time}$

Force $= \frac{Mass\ x\ Velocity}{Change\ in\ Time}$

Acceleration$= \frac{Change\ in\ \ Velocity}{Change\ in\ Time}$

Force= m x $\frac{Change\ in\ Velocity}{Change\ in\ Time}$

Force = mass x acceleration