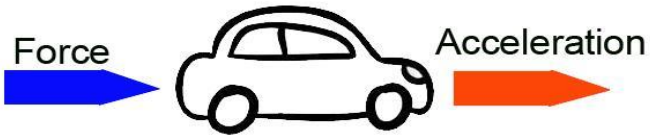
All About Acceleration

We use the word acceleration in our everyday lives. There is an accelerator in our bikes and cars. We use it to increase the speed of the vehicle when we must go fast. We use brakes when we must reduce speed or stop the vehicle.

Acceleration is defined as the *rate of change of velocity*. This means that acceleration is change in speed divided by time.

Imagine you are driving a car. Pressing the accelerator makes the car go faster. It takes some time for the velocity to increase from initial velocity to the final velocity.



This change in velocity from **initial** to **final** in the given **time** is what we call as acceleration.

If the velocity in the beginning was 'u', and after 't' seconds, it increased to velocity, 'v', then this means that -

$$\text{acceleration(a)} = \frac{\text{final velocity(v)} - \text{initial velocity(u)}}{\text{time(t)}}$$

Example

A car is moving at $60\ km/h$ and increases the velocity to $80\ km/h$ in $30\ seconds$. The acceleration in that period of $30\ s$ is –

$$a = \frac{22.22 - 16.66}{30}$$

$$\Rightarrow a = 0.1853\ m/s^2$$

where $60\ km/h$ and 80 km/h are converted to SI units of m/s as 22.22 m/s and 16.66 m/s respectively.

If the car is moving at a constant velocity for some time, then its acceleration is zero.

Unit of Acceleration

The SI unit of velocity is metre per second or m/s. Unit of time is second, s. Therefore, unit of acceleration is,

$$acceleration = \frac{velocity\ change\ (\frac{m}{s})}{time\ (s)}, \qquad \frac{m}{s^2}$$

Acceleration is a vector having a magnitude and direction.

A vector is a quantity that has both magnitude (numerical value) and direction. A scalar has only magnitude.

Speed is a scalar, and velocity is a vector.

This means that there is an acceleration:

- if the velocity changes, or
- if the direction changes even if the velocity remains constant, or
- if both velocity and direction change

The earth can be said to be accelerating because it is constantly changing direction as it rotates around the sun. A bike turning a corner is accelerating even if it has not changed the velocity in magnitude.

The Relation Between Force and Acceleration

Force means the push or pull on objects. A force can move, increase speed, decrease speed, change direction, stop a moving object, or change the shape of an object. So, there is a direct relation between force and acceleration.

This is given by Newton's second law of motion, which states that force on an object is the product of its mass and acceleration.

$$\text{Force} = \text{mass x acceleration}$$

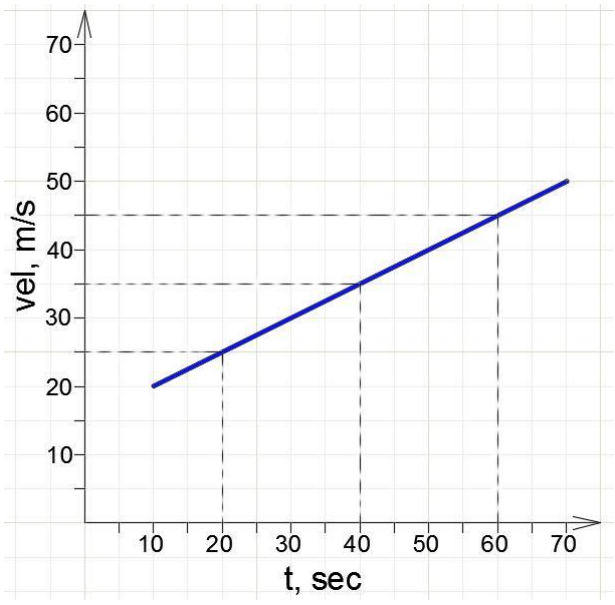
Types of Acceleration

a. **Uniform Acceleration**:

It is also termed as constant acceleration. There are two ways where acceleration can be found uniform.

i. A stone that is dropped from the top of a tall building falls freely at a constant acceleration.

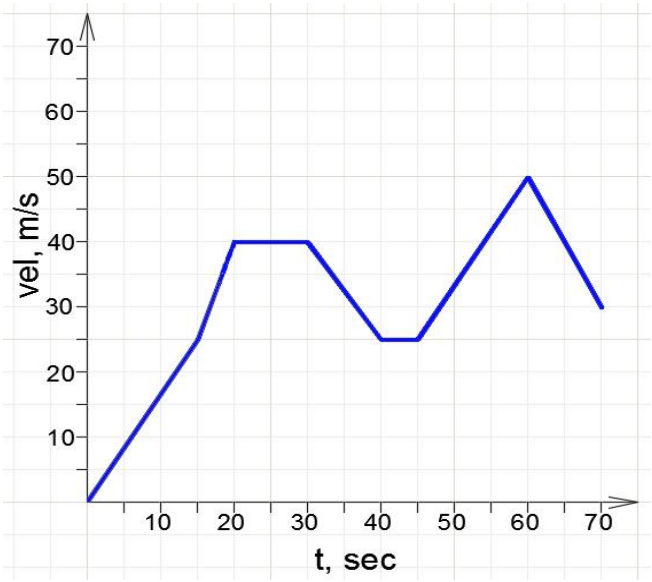
ii. A body revolving around a central axis may have the same velocity, but it is changing direction. So, it has a constant acceleration.



In the period between 20 and 40 $seconds$, the velocity has increased from 25 m/s to 35 m/s. Similarly, from 40 to 60 $seconds$, velocity rose from 35 m/s to 45 m/s. Acceleration is constant at 0.5 m/s^2.

b. **Non-uniform Acceleration**:

Depending on the road conditions and traffic, a vehicle does not move with constant velocity, but accelerates or brakes. This causes acceleration to vary. So, it is also called variable acceleration.



The velocity is different for different time intervals. This makes the acceleration non-uniform.

Since acceleration keeps varying from time to time, we must find the average value of acceleration. Average acceleration is defined as the ratio of total change in velocity to the total time.

Example

Duration (s)	Velocity (m/s)	Acceleration (m/s^2)
5	10	2
2	12	1
5	12	0
4	10	−0.5
10	20	1

The velocity given is at the end of each duration, that is the final velocity. This will be the initial velocity for the next duration. The acceleration for 1st duration is –

$$\frac{10-0}{5} = \frac{10}{5} = 2\ \mathrm{m/s^2}$$

The values calculated are instantaneous acceleration, for that period.
Average acceleration is the sum of the instantaneous velocities by the sum of time periods.

$$\text{average acceleration (a)} = \frac{10+12+12+10+10}{5+2+5+4+10} = \frac{64}{26} = 2.461\ \mathrm{m/s^2}$$

Acceleration can even be negative when velocity reduces from $12\ m/s$ to $10\ m/s$.

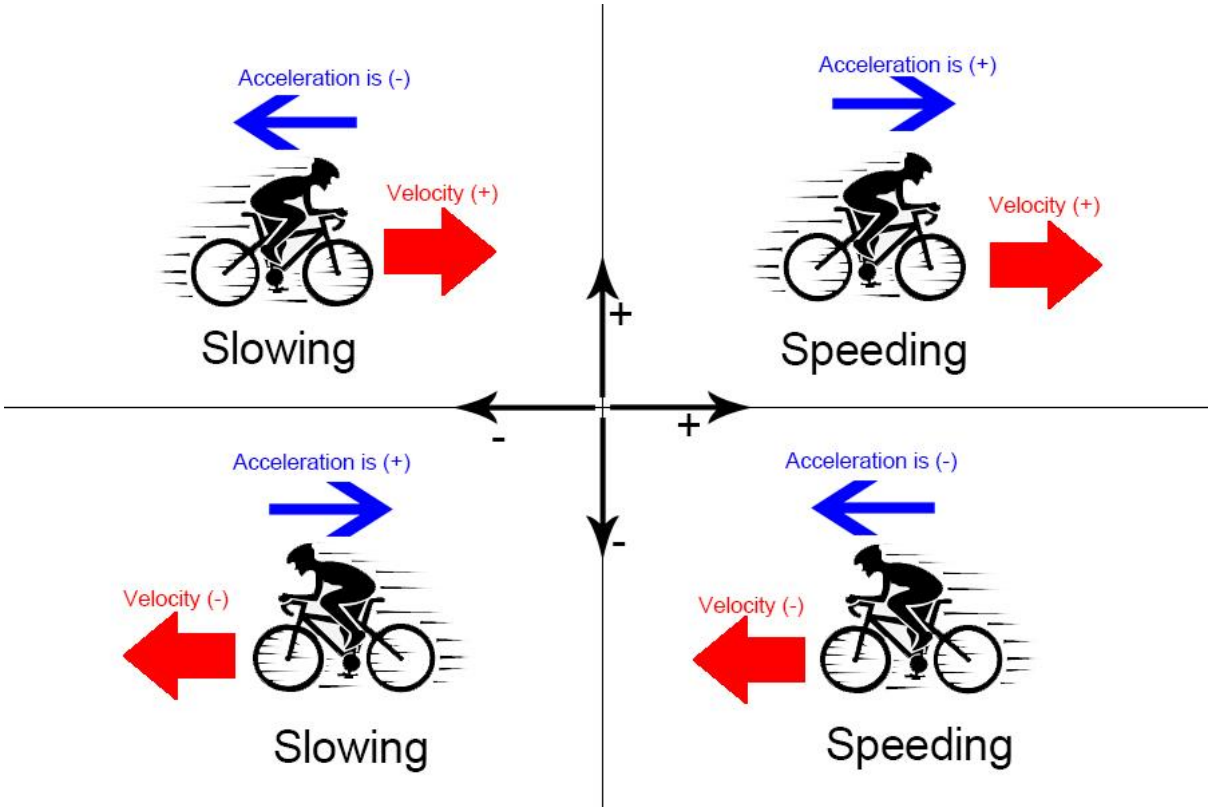
$$\frac{10-12}{4} = \frac{-2}{4} = -0.5\ \mathrm{m/s^2}$$

Acceleration and Direction

The positive or negative value of acceleration quantity **does not** tell if the object is speeding up or slowing down. The magnitude along with direction is taken together to know if it is speeding up or slowing down.

To understand this, let us take a graph sheet that is divided into four quadrants.

i. Directions **right** of origin and **top** of origin (upward direction) are taken as **positive**.
ii. Directions **left** of origin and **below** origin (downward direction) are taken as **negative**.
iii. Also, let us consider **speeding** up as **positive** and **slowing** down as **negative**.



Direction of movement	Velocity	Acceleration
Right (+)	Speeding up (+)	Positive
Right (+)	Slowing down (-)	Negative
Left (-)	Speeding up (+)	Negative
Left (-)	Slowing down (-)	Positive

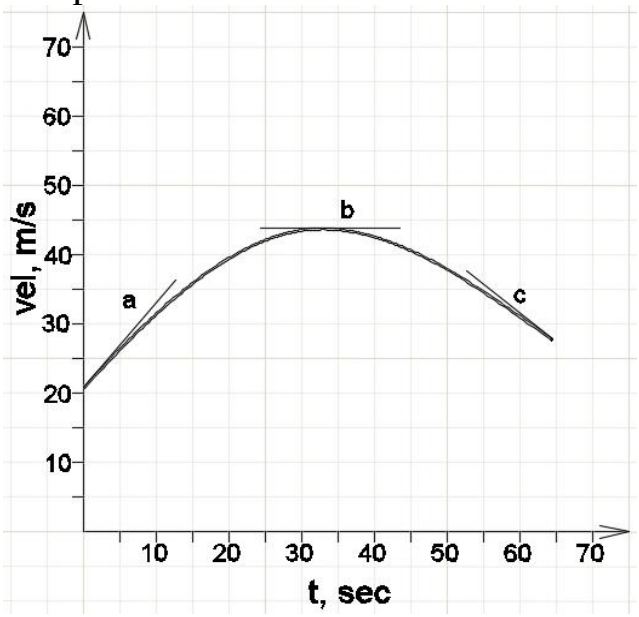
Right means the same direction as that of velocity and left means opposite direction as that of velocity.

In the left direction, acceleration and velocity are in the same direction. So, acceleration is positive though the body is slowing. A positive acceleration does not always mean faster, or negative acceleration does not always mean slower.

Deceleration and Negative Acceleration – What is the Difference?

Deceleration and negative acceleration are **not the same**. In deceleration, the body always slows down. Braking of a vehicle to slow it down is an example of deceleration. But in negative acceleration, the body may slow down or even speed up, as seen from the above table.

Velocity – Time Graph



It is the graph drawn by plotting the instantaneous values of velocities at that instant of time.

i. If the slope of the graph is rising, it is positive acceleration, as slope ‘a’.
ii. The slope ‘b’ shows negative acceleration.
iii. If slope is horizontal, then acceleration is zero, as velocity is constant and there is no change in it. It is slope ‘c’ in the graph.
iv. If the graph is a straight line, it is constant or uniform acceleration.

Acceleration due to Gravity

This refers to acceleration of objects falling freely towards the earth. At each instant, the velocity increases at a constant rate. So, it is uniform acceleration. Since we considered downward direction as negative, acceleration due to gravity is negative acceleration. It is given by –

$$g = 9.81\ m/s^2$$