Lesson 2: Equations of uniformly accelerated motion in 1D

Equation of motion is a mathematical formula that describes how a physical system behaves over time. The equation of **motion** describes objects and systems' motion in terms of dynamic variables. These equations relate various important parameters of motion such as velocity, displacement, speed, time, and acceleration.

- An object is said to be in motion if it changes its position with respect to the same reference point or **frame of reference** with time.
- Motion can be described in two ways: Dynamics and Kinematics
- Dynamics deals with the study of the motion of the bodies taking into account the **forces** which cause the motion in the bodies.
- Kinematics deals with studying the motion of the bodies without taking into account the cause of the motion in the bodies.
- At constant **acceleration**, the kinematic equations of motion are referred to as the SUVAT equations, arising from the definitions of kinematic quantities: displacement (s), initial velocity (u), final velocity (v), acceleration (a), and time (t).

Motion is a phenomenon in which the body changes its position with respect to the same reference point or frame of reference with time.

- If the position of an object changes with respect to one particular point then the object is considered to be in a state of motion with respect to that point.
- To understand the state of motion, there are some equations that are derived by using the entities like displacement, movement, **velocity**, speed, and acceleration.
- The relation between these terms is often called the equations of motion.

Equations of Motion

There are a total of three equations of motion that can be derived by algebraic, graphic, and calculus methods. Equations of motion apply to uniformly accelerated motion. These equations are as follows:

1. **First Equation of Motion:** $v = u + at$
2. **Second Equation of Motion:** $s = ut + 1/2\ at^2$
3. **Third Equation of Motion:** $v^2 = u^2 + 2as$

Where

- **v** is the final Velocity
- **u** is the initial velocity
- **t** is the time taken
- **a** is constant acceleration or uniform acceleration
- **s** is the displacement of the body

The First equation of motion is known as the velocity-time relation and it is given by

$$v = u + at$$

Where,

- v = final velocity of the body
- u = initial velocity of the body

- t = time taken to change the velocity of the body
- a = constant acceleration

Third Equation of the motion

The Third equation of motion is known as the velocity-position relation or velocity-displacement relation and is given by

$$v^2 = u^2 + 2as$$

Where,

- v = final velocity of the body
- u = initial velocity of the body
- a = constant acceleration
- s = displacement of the body in time t

Things to Remember Based on Equations of Motion

- Equations of Motion can be derived with the help of the velocity-time graph.
- Motion is defined as the change in position or place of an object.
- If the position of an object changes with respect to a point then the object is considered to be in the state of motion with respect to that point.
- Acceleration is defined as a rate of change in the velocity of a moving object.
- The first equation of motion is - v-u = at.
- The second equation of motion is- $s = ut + \frac{1}{2} at^2$
- The third equation of motion is $v^2 = u^2 + 2as$

Determining the stopping distance of a vehicle

- When brakes are applied to a moving vehicle, the distance it travels before stopping is called stopping distance.
- Calculating stopping distance is important for avoiding potential hazardous situations.
- There are many factors that can affect the stopping distance of a moving vehicle. Here are some;

1. Speed of the vehicle
2. Weight of the vehicle
3. Road conditions (slick, icy, snow, dry, wet)
4. Vehicle brake conditions (old or worn pads and rotors)
5. Braking technology in the vehicle
6. Tire conditions

Experiments have a= μ g. shown that for dry roads, the coefficient of friction is about 0.7, and for wet roads it is about 0.4.

The stopping distance is then the sum of reaction distance and braking distance.

- The reaction distance is the distance you travel from the point of detecting a hazard until you begin braking or swerving.

- The time between being where we first start measuring, and where the car begins braking, is called the reaction time.

Example 2.1

An object dropped from a cliff falls with a constant acceleration of 10 m/s^2. Find its speed 5 s after it was dropped.

Solution

v=u+at
Here u=0, a=10 m/s^2, t= 5 s
v=10×5=50m/s

Example 2.2

A bike accelerates uniformly from rest to a speed of 7.10 m/s over a distance of 35.4 m. Determine the acceleration of the bike.

Given

u = 0 m/s
v = 7.10 m/s
s = 35.4 m

Required

a = ?

Solution

According to the Third Equation of Motion:

$v^2 = u^2 + 2as$

(7.10)2 = (0)2 + 2*(a)*(35.4)

50.4 = (70.8)*a

(50.4)/(70.8) = a

a = 0.712 m/s^2

Example 2.3

An engineer is designing the runway for an airport. Of the planes that will use the airport, the lowest acceleration rate will likely be 3 m/s^2. The takeoff speed for this plane will be 65 m/s. Assuming this minimum acceleration, what is the minimum allowed length for the runway?

Given

$u = 0$ m/s

$v = 65$ m/s

$a = 3$ m/s^2

Required

$s = ?$

Solution

As per the Third Equation of Motion

$v^2 = u^2 + 2as$

$(65)^2 = (0)^2 + 2*(3)*s$

$4225 = (6)*s$

$(4225)/(6) = s$

$d = 704$ m

- **Note that** all negative accelerations are not always decelerations.
- Negative acceleration can also occur due to the change in direction with respect to a certain fixed reference point.