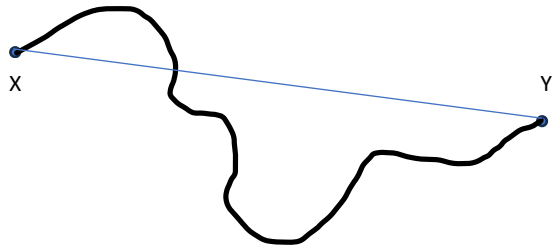
Kinematics

Kinematics is the study of moving objects. A body is at rest when its position does not change with respect to time. A body in motion will have its position change with respect to time.

The state of rest or motion of a body is measured with respect to a frame of reference – thus for a person standing on the railway platform, a train passenger (A) is in motion while for a fellow passenger in the train, A is at rest.

When an object travels from Point X to Point Y, the total path covered is called the distance. The length of the path joining X to Y along a straight line is called displacement. If the starting and the ending point are the same, for example, we take a walk and come back to the starting point, distance is the total path covered and hence non-zero while displacement will be zero.



Distance is a scaler quantity – it has only magnitude (total path covered) but no direction.

Displacement, on the other hand, is a vector and it has both magnitude and direction. Its direction is along the line joining the 2 points, from the starting point to ending point. In the given example displacement vector will be along the line XY.

Associated with distance & displacement, we have 2 quantities which give a measure of the motion of a body. These are speed & velocity. Speed is a scaler and hence has only magnitude but no direction while velocity is a vector with both magnitude & direction.

Average speed is total distance covered divided by the time taken to cover that distance. Average velocity is total displacement divided by the time taken for that displacement. In both cases, the time remains the same – the total time taken. Please note that time is considered to be a scaler.

Speed thus is given by the quotient of 2 scaler quantities – distance & time – hence it is a scaler too.

Velocity is given by the quotient of a vector (displacement) in the numerator and a scaler (time) in the denominator. Thus, velocity is a vector. The direction is velocity is same as the direction of the displacement.

Acceleration is another quantity which is used to define the rate of change of velocity. It thus defines the rate at which velocity changes. Acceleration is a scaler quantity. Average acceleration is given by quotient of Change in Velocity over Change in time.

Kinematics gives us a set of equations which can be used to define the motion of a body. In this lesson we will focus on:

- Uniform acceleration which means that acceleration does not change (in magnitude or direction) during the motion and the equations specific to this scenario
- Motion in a straight line (1D motion)

There are 3 equations of motion called the kinematic equations for motion in a straight line.

1. $v = u + a * t$
2. $s = u * t + ½ * a * t^2$
3. $v^2 = u^2 + 2 * a * s$

Here v = final velocity, u = initial velocity, a = acceleration (or deceleration), t = time taken and s = displacement (or position of the body).

Eg. Consider a car travelling in a straight line. It starts from rest and accelerates uniformly at 2 m/ sec^2. After how much time will it attain a speed of 20 m/ sec.

In this problem, since the car starts from rest, the initial velocity u = 0 m/sec. We know the acceleration is 2 m/sec^2. We know the final velocity needed is 20 m/sec and we have to find the time "t" needed to attain this final velocity.

This the first law seems appropriate to use here.

$20 = 0 + 2 * t$ or $20 = 2t$ or $t = 10$ secs

This the car will reach a velocity of 20 m/sec after 10 seconds.

Additionally, the distance covered by the car to reach this velocity of 20 m/ sec can be found out by using equation 2 or 3. Let this distance be "s" and we know the time (t) taken = 10 secs

Using equation 2: $s = 0 * 10 + ½ * 2 * 10^2$ or $s = 100$ m

Using equation 3: $v^2 = u^2 + 2 * a * s$ or $20^2 = 0^2 + 2 * 2 * s$

$400 = 4 * s$ or $s = 100$ m

From Physics textbook:

Question 5:

A car is moving at 12.5m/s and accelerates uniformly on a straight road at the rate of 0.85m/s^2 What will be the speed after 4.6 seconds?

Here, we have that initial velocity (u) = 12.5m/s, t = 4.6s, a = 0.85m/s^2 and v is to be found. So we must use equation 1.

Using equation 1: v = 12.5+4.6*0.85 = 12.5+3.91 = 16.41m/s

(For more information refer to Physics for the IB Diploma)