Summary 1: One Dimensional Motion

Part I

Motion on a straight path

An object is said to be in motion with respect to another object (or point) - which is called the observer or reference - when its position changes with respect to the other object (or point).

So the description of motion depends on the observer, which is called the reference.

The trajectory is the path followed by the object.

A frame of reference is a system of axes attached to a reference point O.

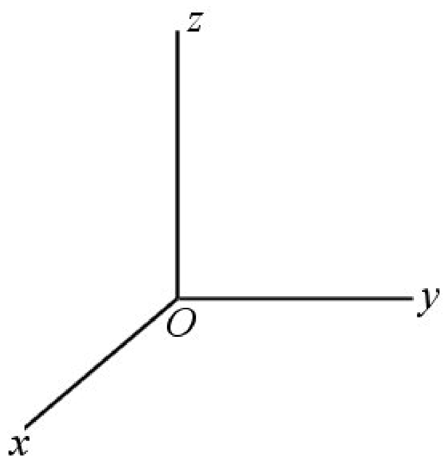

Figure 1. A frame of reference

1. Speed and velocity

The speed is the rate of covering distance with respect to time.

$$speed = \frac{distance\ covered}{time\ taken} \tag{1}$$

For example, a car covers 50km during half hour, then the speed of the car is $\frac{50km}{0.5h} = 100km/h$.

1.1. Average speed and instantaneous speed

When an object covers a total distance d during a time interval t, then the average speed

$$average\,speed = \frac{d}{t} \tag{2}$$

The instantaneous (or actual) speed at a specific instant is the speed calculated during an infinitesimal time interval around that instant

$$instantaneous\,speed = \frac{distance\,covered}{infinitesimal\,time\,duration} \tag{3}$$

With infinitesimal time duration we mean very small time duration (usually of order of few milliseconds).

For example, an electron moves a distance 50cm (0.5m) during 10ms (0.01s), then the instantaneous (actual) speed of the electron is $\frac{0.5m}{0.01s} = 50m/s$.

1.2. Velocity and speed

Velocity is a speed in a specific direction. For example: 20m/s due north, 100km/h due east, etc..

The speed is the magnitude of the velocity.

The base SI unit of speed and velocity is the meter per second (m/s). Other units are km/h, m/min, cm/s, etc..

2. Displacement

On a straight line, the displacement is a distance in a specific direction. The distance is the magnitude of the displacement.

The base SI unit of displacement is the meter (m). Other units are km, cm, etc..

3. Acceleration

When the velocity changes during a time interval, then the acceleration is the rate of change of velocity

$$acceleration = \frac{change\,in\,speed}{time\,interval} \tag{4}$$

For example, if the speed changes from 20m/s to 30m/s during 5 seconds, then the change in speed is 10m/s and the acceleration is $\frac{10m/s}{5s} = 2m/s^2$.

The base SI unit of acceleration is the meter per second squared (m/s^2).

Part II

Motion on the x-axis

4. Position

The position of a particle on the x-axis is given by its abscissa.

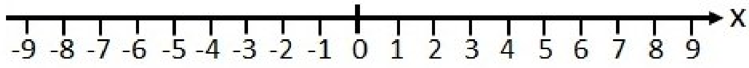

Figure 2. x-axis

The base SI unit of abscissa is the meter (m).

5. Displacement Δx

The displacement on the x-axis is given by

$$\Delta x = x_f - x_i \tag{5}$$

where x_i is the initial position (initial abscissa) and x_f is the final position (final abscissa).

For example, if a particle moves from abscissa 5m to abscissa 2m, then the displacement is $\Delta x = x_f - x_i = 2 - 5 = -3m$.

The base SI unit of displacement is the meter (m).

6. Average velocity and instantaneous velocity

6.1. Average velocity

The average velocity on the x-axis is given by

$$v_{av} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i} \tag{6}$$

where t_i is the initial instant of time (usually zero as set by the timer) and t_f is the final instant of time.

For example, a particle moves from abscissa 100m at instant 0s to abscissa 55m at instant 5s, then the average velocity is $v_{av} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i} = \frac{55-100}{5-0} = \frac{-45}{5} = -9m/s$.

6.2. Instantaneous velocity

The instantaneous velocity on the x-axis is given by

$$v_{inst} = \frac{\Delta x}{\Delta t} \;\; where\, \Delta t\, is\, very\, small \tag{7}$$

Unless otherwise stated, we usually denote instantaneous velocity by v .

For example, if the displacement of a particle during 10ms (0.01s) is 0.1m then the instantaneous velocity is $v = \frac{\Delta x}{\Delta t} = \frac{0.1}{0.01} = 10m/s$.

6.3. Average acceleration

The average acceleration on the x-axis is given by

$$a_{av} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i} \tag{8}$$

where v_i is the initial velocity at t_i and v_f is the final velocity at t_f.

For example, a particle started at instant 0s with velocity -5m/s and then at 5 seconds later its velocity was -7m/s, then its average acceleration is $a_{av} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i} = \frac{-7-(-5)}{5-0} = \frac{-2}{5} = -0.4 m/s^2$.

6.4. Instantaneous acceleration

The instantaneous acceleration on the x-axis is given by

$$a_{inst} = \frac{\Delta v}{\Delta t} \quad where\ \Delta t\ is\ very\ small \tag{9}$$

Unless otherwise stated, we usually denote instantaneous acceleration by a .

For example, a particle started at instant 0s with velocity -5m/s and then at 5 milliseconds (0.005s) later its velocity was -5.2m/s, then its instantaneous acceleration is $a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i} = \frac{-5.2-(-5)}{0.005-0} = \frac{-0.2}{0.005} = -40 m/s^2$.

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