Atomic Energy Education Society, Mumbai

Class XI Chapter- 3
Module- 3

Motion in a straight line

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Motion in a Straight Line
Topics Covered in Module - 3

1) Equation of Motion of graphical method
2) Free Fall
3) Relative motion

First Equation of Motion

In this, the body is moving with an initial velocity of u at point A. The velocity of the body then changes from A to B in time t at a uniform rate. In the above diagram, BC is the final velocity i.e. v after the body travels from A to B at a uniform acceleration of a. In the graph, OC is the time t. Then, a perpendicular is drawn from B to OC, a parallel line is drawn from A to D, and another perpendicular is drawn from B to OE (represented by dotted lines).

Following details are obtained from the graph :

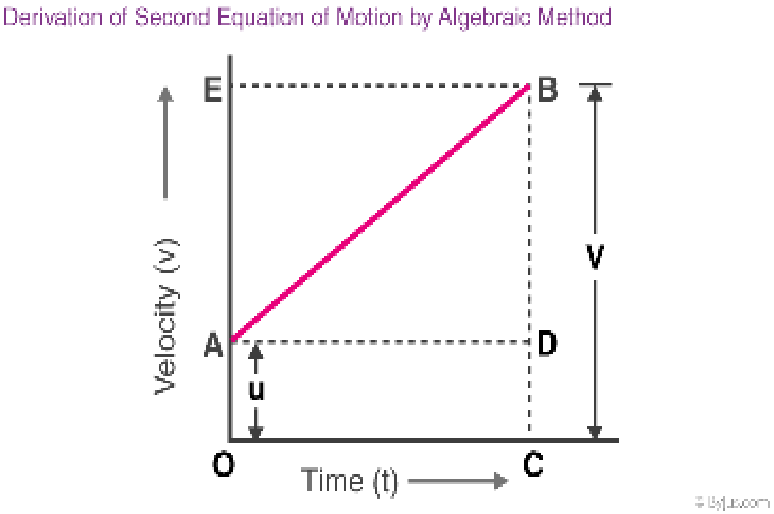
The initial velocity of the body, u = OA

The final velocity of the body, v = BC

From the graph, BC = BD + DC

So, v = BD + DC

v = BD + OA (since DC = OA)



Finally, since OA = u, we get,

$$v = BD + u \quad (1)$$

Now, since the slope of a velocity-time graph is equal to acceleration a,

So, a = slope of line AB

$$a = BD/AD$$

Since AD = AC = t, the above equation becomes:

$$BD = at \quad (2)$$

Now, combining Equation 1 & 2, the following is obtained:

$$\boldsymbol{v = u + at}$$

Second equation of Motion

In this diagram, the distance travelled (S) = Area of figure OABC

Area of OABC = Area of rectangle OADC + Area of triangle ABD

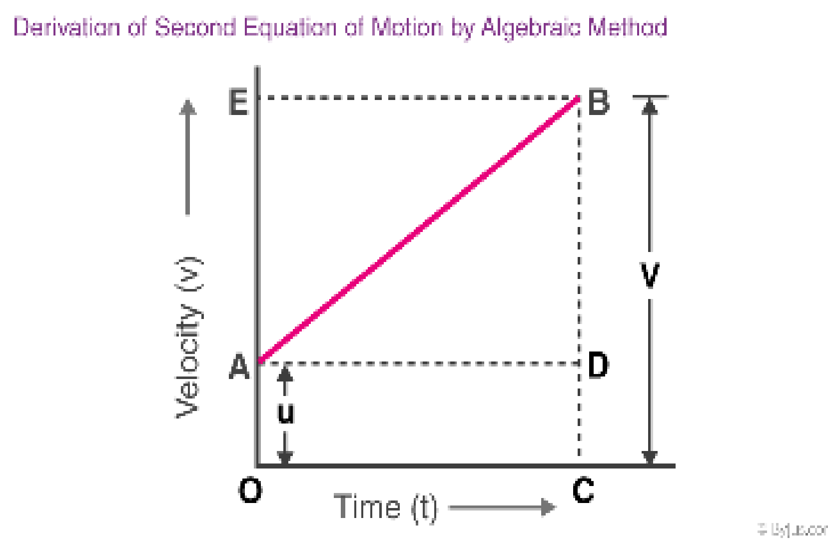
Now, the area of the rectangle OADC = OA × OC = ut

And, Area of triangle ABD = (1/2) × Area of rectangle AEBD

Area of triangle ABD = $(1/2)\ at^2$ (Since, AD = t and BD = at)

Thus, the total distance covered will be:

$$S = ut + (1/2)\ at^2$$



Third equation of motion

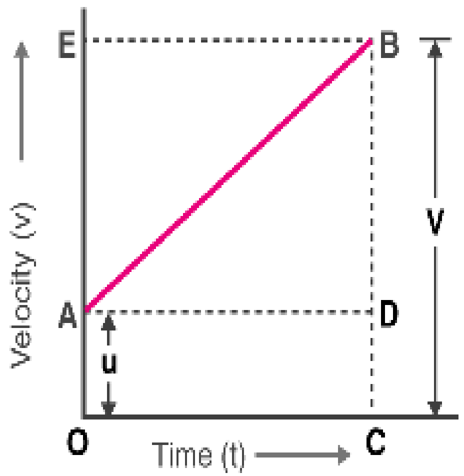
The total distance travelled, S = Area of trapezium OABC

So, S = 1/2(Sum of Parallel Sides) × Height

$$S = (OA+CB) \times OC$$

Since, OA = u, CB = v, and OC = t

Derivation of Third Equation of Motion by Algebraic Method



The above equation becomes

$$S = 1/2(u+v) \times t$$

Now, since $t = (v - u)/ a$

The above equation can be written as:

$$S = 1/2(u+v)\times(v-u)/a$$

Rearranging the equation, we get

$$S = 1/2(v+u)\times(v-u)/a$$

$$S = (v^2-u^2)/2a$$

Third equation of motion is obtained by solving the above equation:

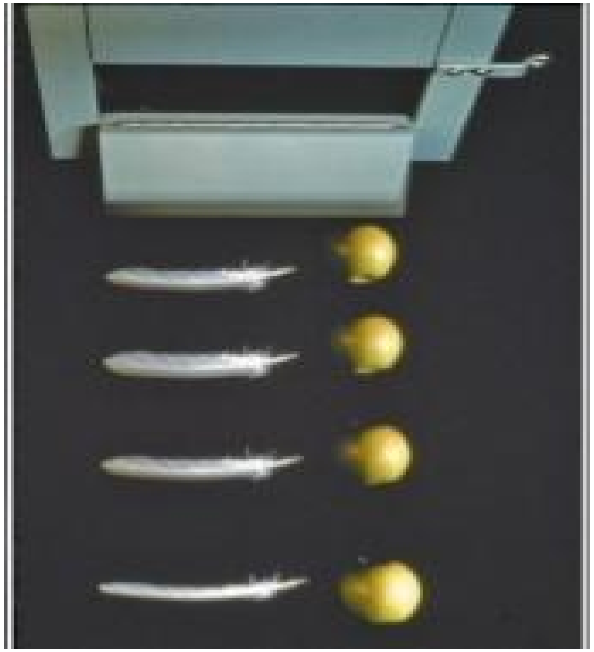
$$\mathbf{v^2 = u^2+2aS}$$

Free Fall

The motion of object moving under the influence of gravity only, and no other forces, is called free fall.

Two objects dropped from the same height will, if air resistance can be neglected, hit the ground at the same time and with same speed.

Consequently, any two objects in free fall, regardless of their mass, have the same acceleration.



In the absence of air resistance, any two objects fall at the same rate and hit the ground at the same time. The apple and feather seen here are falling in a vacuum.

$$\vec{a}_{\text{free fall}} = (9.80\ \text{m/s}^2\text{, vertically downwards})$$

Figure(a) shows the motion diagram of an object that was released from rest and falls freely.

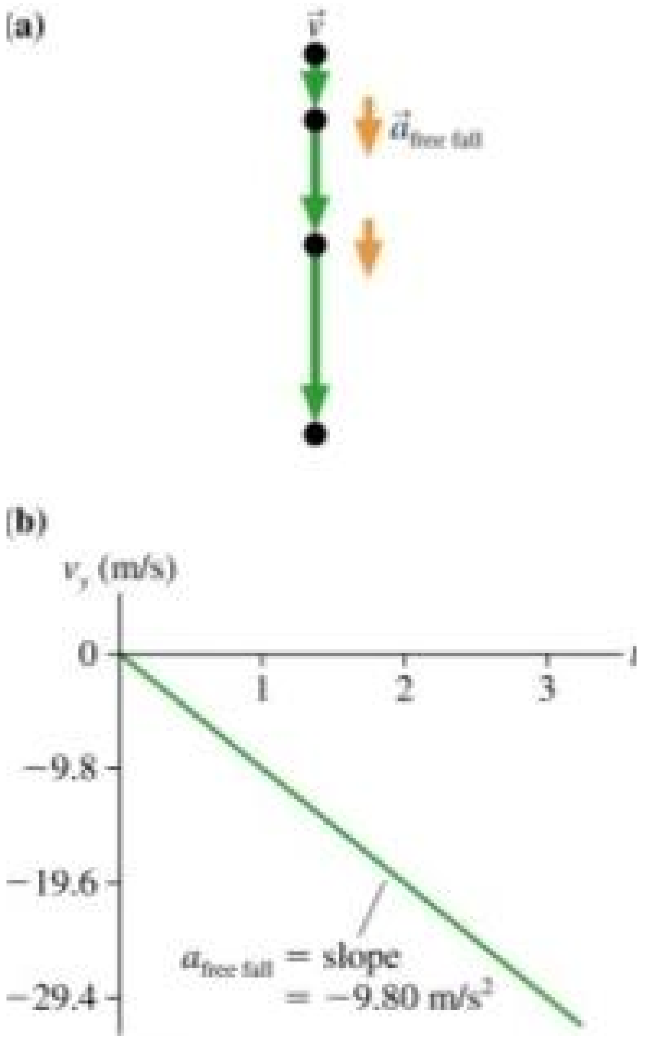
Figure(b) shows the object's velocity graph.

The velocity graph is a straight line with a slope:

$$a_y = a_{free\ fall} = -g$$

Where g is a positive number which is equal to 9.80 m/s2 on the surface of the earth.

Other planets have different values of g.



RELATIVE VELOCITY

Consider two objects A and B moving uniformly with average velocities v_A and v_B in one dimension, say along x-axis. (Unless otherwise specified, the velocities mentioned in this chapter are measured with reference to the ground). If $x_A(0)$ and $x_B(0)$ are positions of objects A and B, respectively at time t = 0, their positions $x_A(t)$ and $x_B(t)$ at time t are given by:

$$x_A(t) = x_A(0) + v_A t$$

$$x_B(t) = x_B(0) + v_B t$$

Then, the displacement from object A to object B is given by

$$x_{BA}(t) = x_B(t) - x_A(t)$$

$$= [\, x_B(0) - x_A(0) \,] + (v_B - v_A)\, t.$$

It tells us that as seen from object A, object B has a velocity $v_B - v_A$ because the displacement from A to B changes steadily by the amount $v_B - v_A$ in each unit of time. We say that the velocity of object B relative to object A is $v_B - v_A$:

$$\mathbf{v}_{BA} = \mathbf{v}_B - \mathbf{v}_A$$

Similarly, velocity of object A relative to object B is:

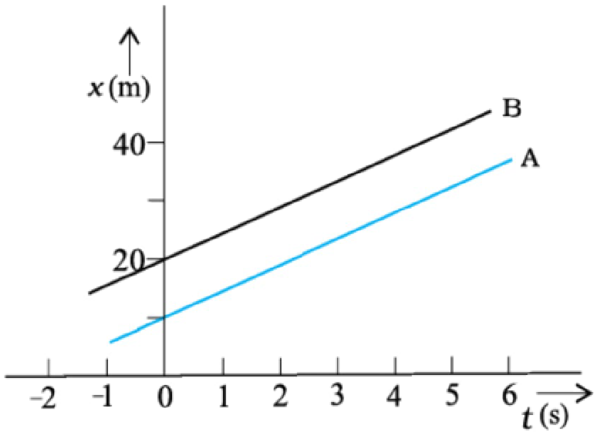
$$\mathbf{v}_{AB} = \mathbf{v}_A - \mathbf{v}_B$$

This shows:

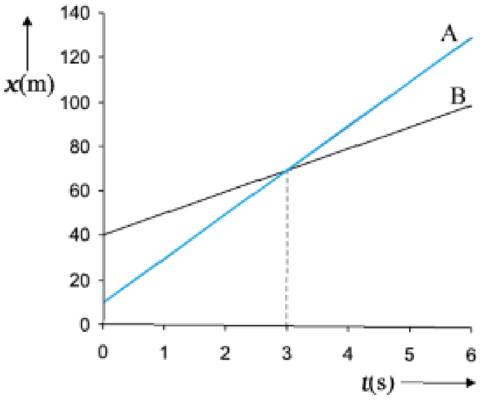
$$\mathbf{v}_{BA} = -\mathbf{v}_{AB}$$

Some Special Cases:

(a) If $v_B = v_A$, $v_B - v_A = 0$



(b) If $v_A > v_B$, $v_B - v_A$ is negative



(c) Suppose v_A and v_B are of opposite signs