Chapter-08 : Motion

Motion : Motion is the change in position of a body with time.

- Motion can be described in terms of the distance moved or the displacement.
- Distance moved is the actual length of the path travelled by a body.
- Displacement is the length of the shortest path travelled by a body from its initial position to its final position.

Uniform motion : If a body travels equal distances in equal intervals of time, it is said to be in uniform motion.

Non-uniform motion : If a body travels unequal distances in equal intervals of time, it is said to be in non-uniform motion.

Speed : Speed of a body is the distance travelled by the body in unit time.

Speed = Distance / Time

- If a body travels a distance 's' in time 't' then its speed 'v' is

$$v = s / t$$

- The SI unit of speed is metre per second m/s or ms^{-1}

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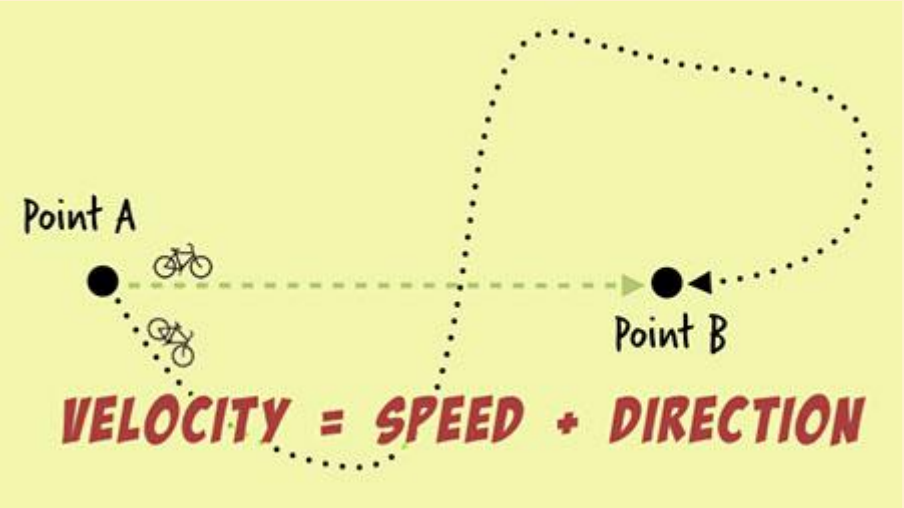
- Since speed has only magnitude it is a scalar quantity.

- Average speed is the ratio of the total distance travelled to the total time taken.
- Average speed = Total distance travelled / Total time taken

Speed with direction : The rate of motion of a body is more meaningful if we specify its direction of motion along with speed. The quantity which specifies both the direction of motion and speed is velocity.



- Velocity of a body is the displacement of the body per unit time.

  Velocity = Displacement / Time taken
- Since velocity has both magnitude and direction, it is a vector quantity.
- Average velocity is the ratio of the total displacement to the total time taken.

  Average velocity = Total displacement / Total time taken
- Average velocity is also the mean of the initial velocity 'u' and final velocity 'v'.

  Average velocity = (Initial velocity + Final velocity) / 2

  $v_{av} = (u + v) / 2$

Speed and velocity have the same units m/s or ms^{-1}

Rate of change of velocity : During uniform motion of a body in a straight line the velocity remains constant with time. In this case the change in velocity at any time interval is zero (no change in velocity).

- During non-uniform motion the velocity changes with time. In this case the change in velocity at any time interval is not zero. It may be positive (+ve) or negative (-ve).
- The quantity which specifies changes in velocity is acceleration.
- Acceleration is the change in velocity of a body per unit time or the rate of change of velocity.

  Acceleration = Change in velocity / Time
- If the velocity of a body changes from initial value 'u' to final value 'v' in time 't' then acceleration 'a' is

  $a = (v - u) / t$
- The SI unit of acceleration is ms^{-2}

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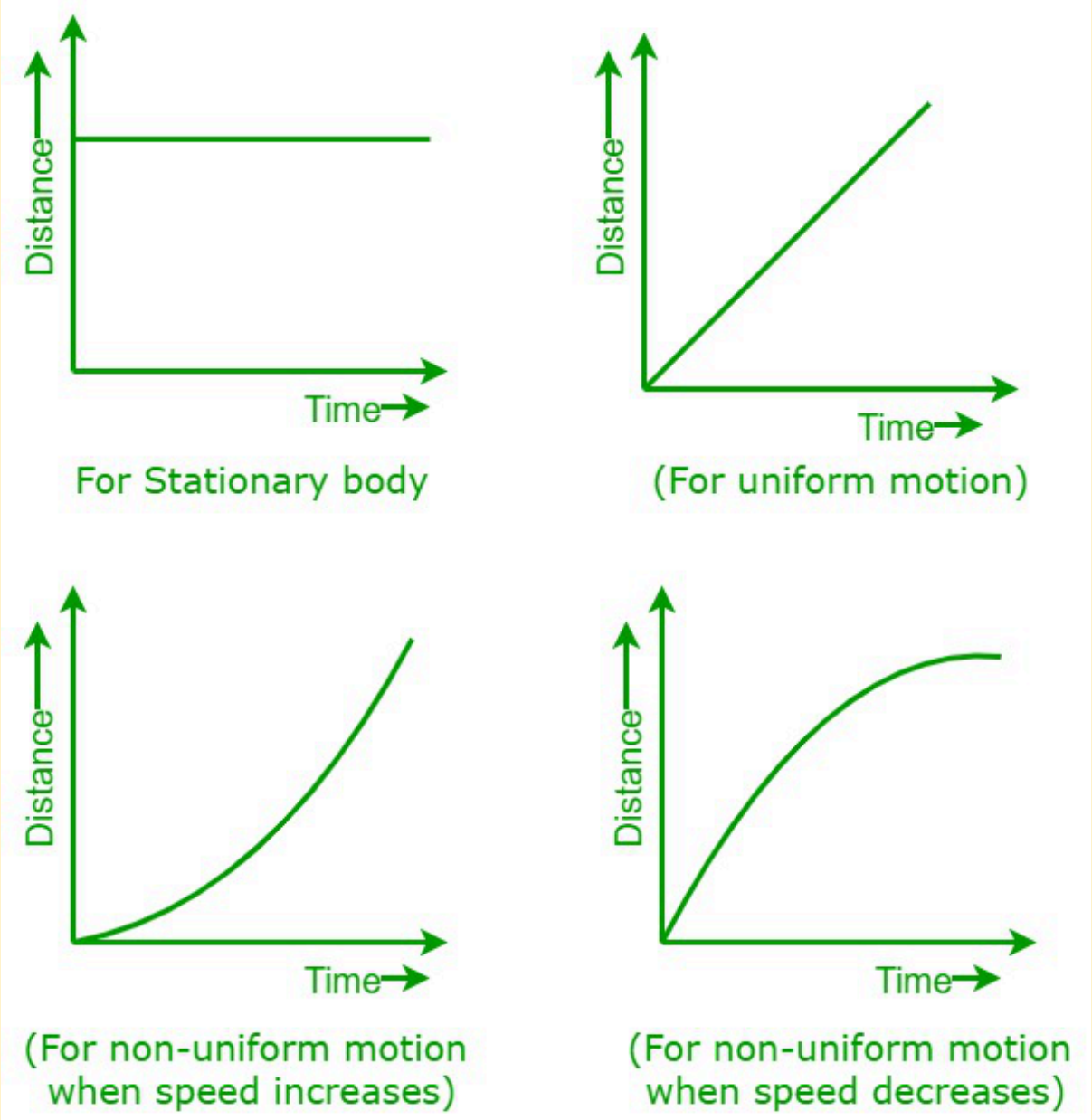
Uniform acceleration : If the change in velocity is equal in equal intervals of time it is uniform acceleration.

Non-uniform acceleration : If the change in velocity is unequal in equal intervals of time it is non-uniform acceleration.

Distance–Time graphs : The change in the position of a body with time can be represented on the distance time graph. In this graph distance is taken on the y–axis and time is taken on the x–axis.

- The distance-time graph for uniform speed is a straight line (linear). This is because in uniform speed a body travels equal distances in equal intervals of time. We can determine the speed of the body from the distance–time graph.

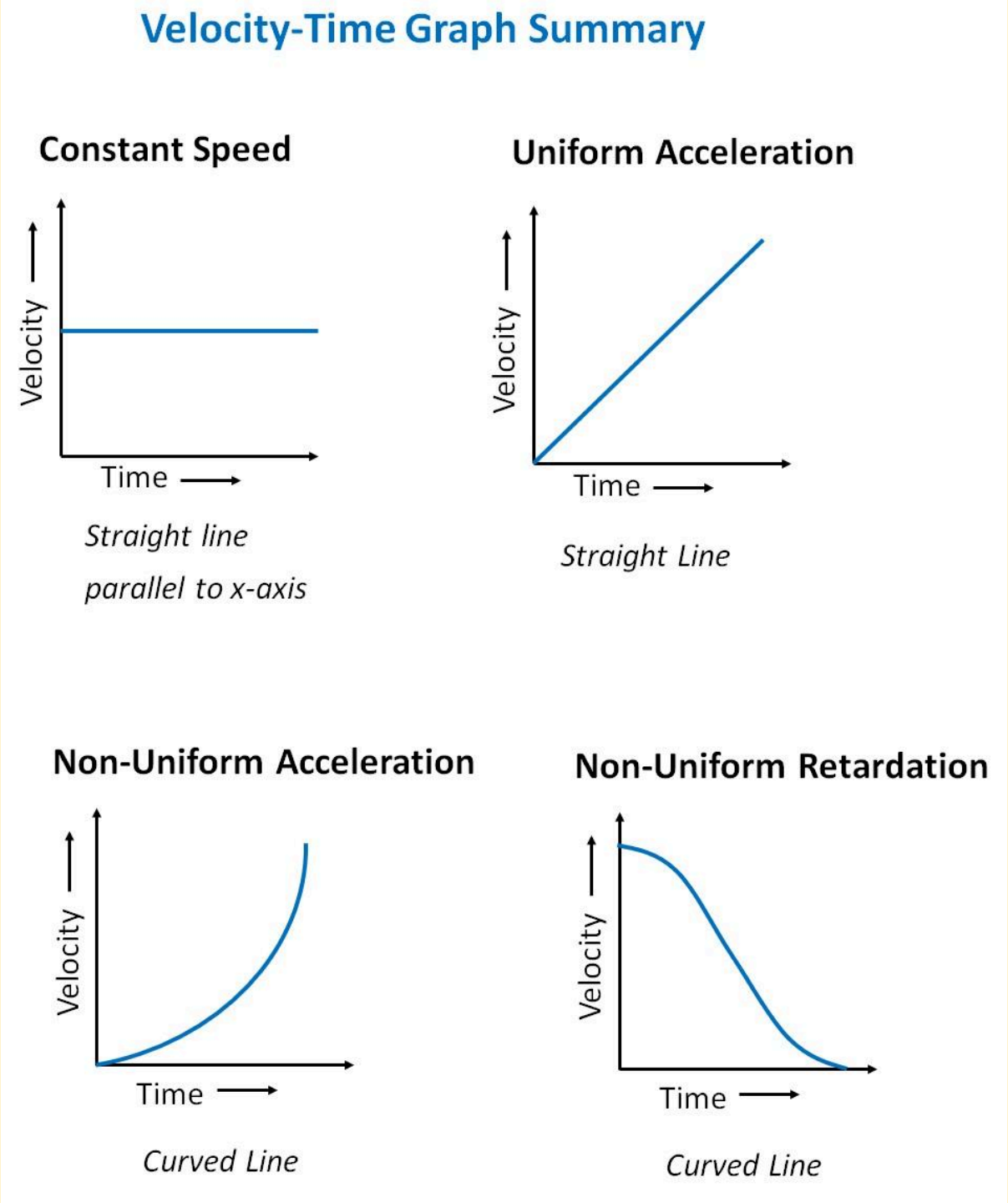


- For the speed of the body between the points A and B, distance is $(s_2 - s_1)$ and time is $(t_2 - t_1)$.

$$v = s / t \qquad \text{or,} \qquad v = (s_2 - s_1) / (t_2 - t_1)$$

- The distance-time graph for non-uniform motion is non-linear. This is because in non-uniform speed a body travels unequal distances in equal intervals of time.

Velocity–time graphs : The change in the velocity of a body with time can be represented on the velocity-time graph. In this graph velocity is taken on the y–axis and time is taken on the x–axis.



- If a body moves with uniform velocity, the graph will be a straight line parallel to the x-axis. This is because the velocity does not change with time.
- If a body whose velocity is increasing with time, the graph is a straight line having an increasing slope. This is because the velocity increases by equal amounts with equal intervals of time.
- The area under the velocity–time graph is the distance (magnitude of displacement) of the body.
- If a body whose velocity is decreasing with time, the graph is a straight line having an decreasing slope. This is because the velocity decreases by equal amounts with equal intervals of time.
- If a body whose velocity is non-uniform, the graph shows different variations. This is because the velocity changes by unequal amounts in equal intervals of time.

Equations of motions by graphical method : The motion of a body moving with uniform acceleration can be described with the help of three equations called equations of motion.

Equation for velocity–time relation : $v = u + at$

Equation for position–time relation : $s = ut + \frac{1}{2} at^2$

Equation for position–velocity relation : $2as = v^2 - u^2$

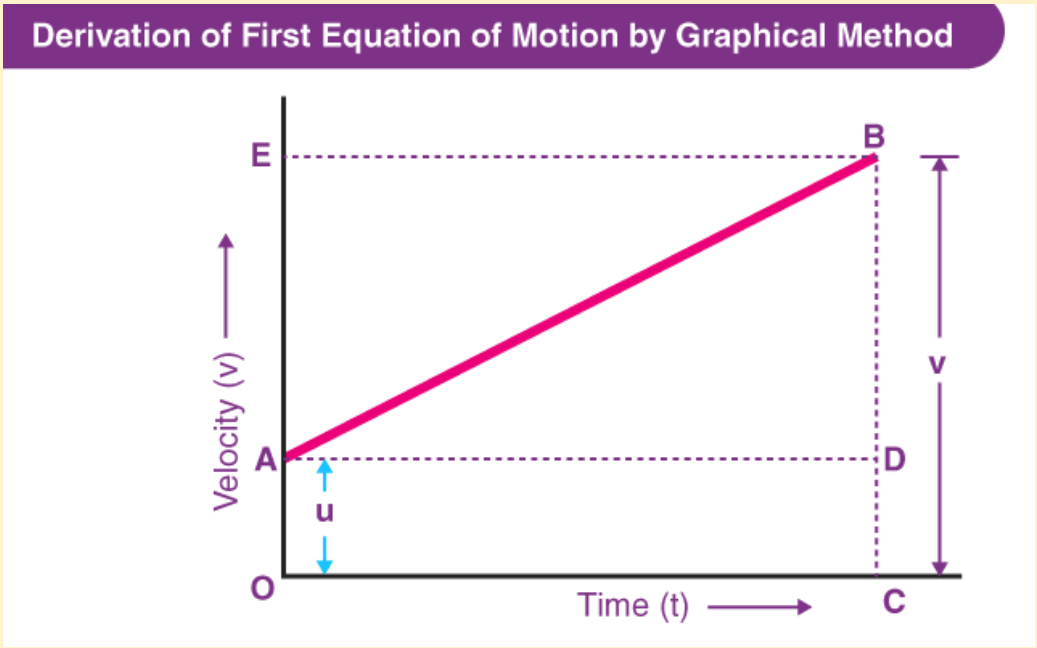
Where, u = initial velocity

v = final velocity

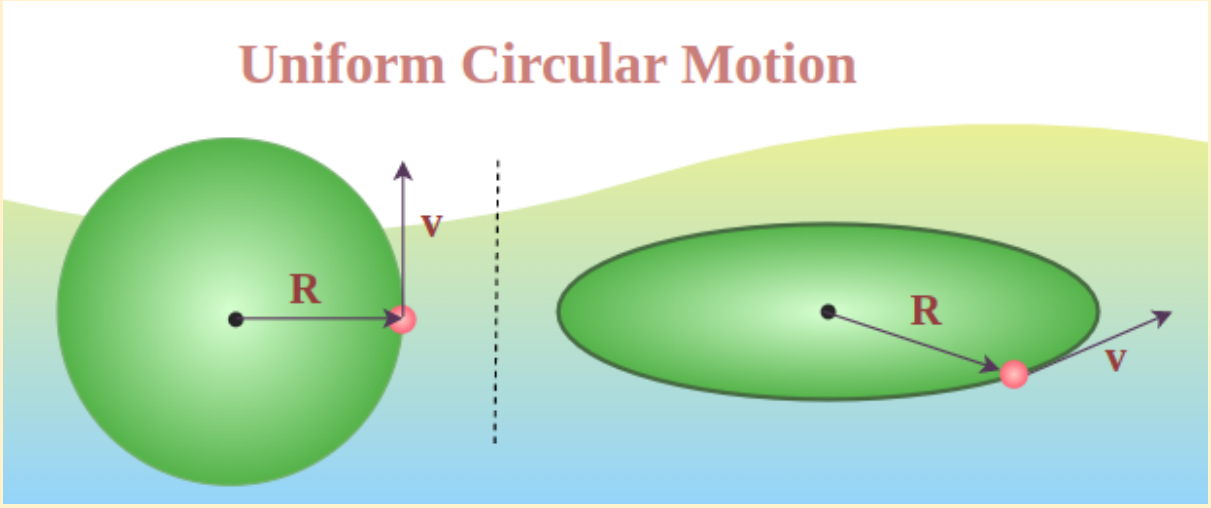
a = acceleration

t = time

s = distance travelled



Circular motion : The motion of a body in a circular path is called circular motion.



Uniform circular motion : If a body moves in a circular path with uniform speed, its motion is called uniform circular motion.

- Uniform circular motion is accelerated motion because in a circular motion a body continuously changes its direction.
- The circumference of a circle of radius 'r' is given by 2πr. If a body takes time 't' to go once around the circular path, then the velocity 'v' is given by

$$v = 2\pi r / t$$