UNIT 2
KINEMATICS

LONG QUESTIONS

Q.1 Define Translatory motion and its types. (LHR 2011, 2012, 2013 GRW 2013, 2015)

Ans: Such type of motion in which a body moves along a line without any rotation. The line may be straight or curved.

Examples

- Motion of a car in straight line
- Motion of electron around the nucleus
- Motion of gas molecules
- Aeroplane moving straight is in translational motion

Types of Translatory Motion

There are three types of translatory motion.

(i) Linear motion **(LHR 2014)**
(ii) Circular motion
(iii)Random motion **(LHR 2013, 2014)**

(i) Linear motion

If the motion of a body is in straight line, it is known as linear motion.

Examples

- The motion of freely falling bodies
- A car moving along the straight line

(ii) Circular motion

If a body moves in a circle then its motion is known as circular motion.

Examples

- A stone attached with thread, when whirled, it will move along a circular path.
- A toy train moving on a circular track.
- A bicycle or car moving along a circular track
- Earth moving around the sun in solar system

(iii) Random motion

The disordered or irregular motion of an object is called random motion.

Examples

- The flight of an insect and birds
- Brownian motion of gas or liquid molecules
- Motion of dust or smoke particles in air

Q.2 Explain Distance – time Graph.

Ans: The term distance and displacement are used interchangeably when the motion is in straight line. Similarly, if the motion is in a straight line then speed and velocity are also used interchangeably.

In distance – time graph, time is taken along horizontal axis while the vertical axis shows the distance covered by the object.

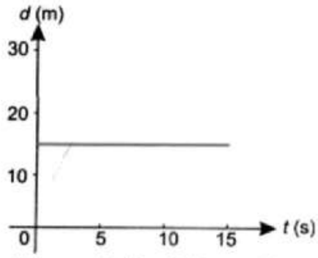

Figure 2.18: Distance-time graph when the object is at rest.

Object at Rest

In the graph shown in figure, the distance moved by the object with time is zero. That is the object is at rest. Thus a horizontal line parallel to time axis on a distance – time graph shows that speed of the object is zero.

Object moving with Constant Speed

The speed of an object is said to be constant if it covers equal distances in equal intervals of time. The distance – time graph as shown in figure is a straight line. Its slope gives the speed of the object.

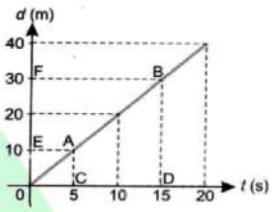

Figure 2.19: Distance-time graph showing constant speed.

Object moving with variable speed

When an object does not cover equal distances in equal intervals of time then its speed is not constant. In this case the distance – time graph is not a straight line as shown in figure. The slope of the curve at any point can be found from the slope of the tangent at that point.

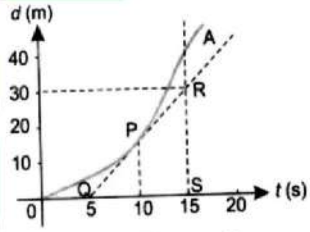

Figure 2.20: Distance-time graph showing variable speed.

Q.3 Explain Speed – Time Graph.

Ans: In a speed – time graph, time is taken along x – axis and speed is taken along y–axis.

Object moving with constant speed

When speed of an object is constant with time, then the speed – time graph will be a horizontal line parallel to time – axis as shown in figure. In other words, a straight line parallel to time axis represents constant speed of the object.

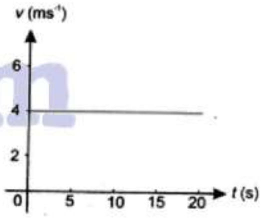

Figure 2.22: Speed-time graph showing constant speed.

Object moving with uniformly changing speed (uniform acceleration)

Let the speed of an object be changing uniformly. In such a case speed is changing at constant rate. Thus its speed-time graph would be a straight line as shown in figure. A straight line means that the object is moving with uniform acceleration. Slope of the line gives the magnitude of its acceleration.

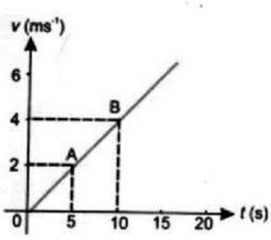

Figure 2.23: Graph of an object moving with uniform acceleration.

Distance travelled by a moving object

The area under a speed – time graph represents the distance travelled by the object. If the motion is uniform then the area can be calculated using appropriate formula for geometrical shapes represented by the graph.

Q.4 Derive first equation of motion using speed time graph. (GRW 2013)

- **Ans: Proof:**

Suppose a body is moving with initial velocity v_i in a straight line with uniform acceleration a. Its velocity becomes v_f after time t. The motion of the body is described by speed – time graph as shown in figure.

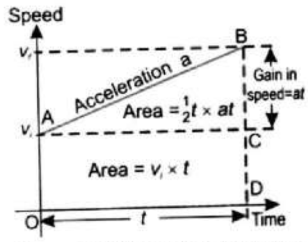

Figure 2.26: Speed-time graph. Area under the graph gives the distance covered by the body.

$$\text{Slope of line AB} = \frac{BC}{AC}$$

We know that slope of line in speed-time graph gives the magnitude of acceleration.

$$\therefore \text{ Acceleration} = \frac{BC}{AC}$$

$$a = \frac{BC}{AC}$$

As AC = OD and BC = BD – CD

So, $a = \dfrac{BD - CD}{OD}$

As $BD = v_f$, $CD = v_i$ and $OD = t$

Hence $a = \dfrac{vf - vi}{t}$

Or $v_f - v_i = at$

Therefore, $v_f = v_i + at$

which is required first equation of motion.

Q.5 Derive second equation of motion using speed-time graph. (LHR 2012, 2013)

Ans: Proof:

Suppose a body is moving with initial velocity v_i in a straight line with uniform acceleration a. Its velocity becomes v_f after time t. The motion of the body is described by speed – time graph as shown in figure.

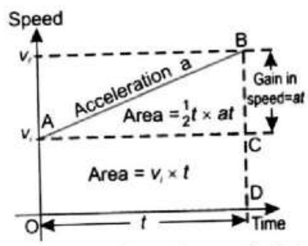

Figure 2.26: Speed-time graph. Area under the graph gives the distance covered by the body.

In speed – time graph the total distance s travelled by the body is equal to the total area of trapezium OABD under the graph. i.e.

Area of the rectangle OACD = OA x OD

$= v_i \times t$

Area of the triangle ABC $= \frac{1}{2}$ (AC x BC)

$$= \frac{1}{2}(OD \times BC)$$

$$= \frac{1}{2} \text{ t x at}$$

$$= \frac{1}{2} a t^2$$

Area of trapezium OABD = area of rectangle OACD + area of triangle ABC

Putting the values in the above equation, we get

$$s = v_i t + \frac{1}{2} at^2$$

which is required second equation of motion.

Q.6 Derive third equation of motion using speed-time graph. **(GRW 2015)**

Ans: Proof:

Suppose a body is moving with initial velocity v_i in a straight line with uniform acceleration a. Its velocity becomes v_f after time t. The motion of the body is described by speed – time graph as shown in figure.

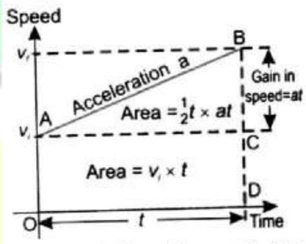

Figure 2.26: Speed-time graph. Area under the graph gives the distance covered by the body.

In speed – time graph the total distance s travelled by the body is equal to the total area of trapezium OABD under the graph.

Area of trapezium OABD $= \frac{1}{2}$ [sum of parallel sides][Perpendicular distance between parallel sides]

$$s = \frac{1}{2}(BD + OA)(OD)$$

Or $\quad 2S = (BD + OA)(OD)$

Multiply both sides by $\frac{BC}{OD}$, we get (as $\frac{BC}{OD} = a$)

$$2\left(\frac{BC}{OD}\right)S = (BD + OA)(OD)\left(\frac{BC}{OD}\right)$$

$$2\left(\frac{BC}{OD}\right)S = (BD + OA)(BC)$$

$$2\left(\frac{BC}{OD}\right)S = (BD + OA)(BD - CD)$$

As $\quad OA = CD = Vi$

$\frac{BC}{OD} = a,$

and $\quad BD = v_f$

Putting the values in the in the above equation, we have

$$2 aS = (v_f + v_i)(v_f - v_i)$$

$$2aS = v_f^2 - v_i^2$$

Which is required third equation of motion.