



NEET — JEE MAINS - ADVANCED

Chapter 2 : Motion in a Straight Line (Notes)

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Notes

GSEB and CBSE Board Exam preparation subjective notes · Class 11 Physics · NCERT Chapter 2

Q.1 What is rectilinear motion? When can a body be treated as a point object? What is kinematics? (2 Marks)

Motion: Motion is the change in position of an object with time.

Rectilinear motion: The motion of an object along a **straight line** is called rectilinear motion (one-dimensional motion). Examples: a car on a straight road, a ball dropped from a height.

Point object: An object can be treated as a point object if its **size is much smaller than the distance it moves** in a reasonable duration of time. Example: a car travelling a few hundred km, or the earth revolving around the sun.

Kinematics: The branch of mechanics in which we study ways to describe motion **without going into the causes** of motion. (The causes of motion — forces — are studied in Chapter 4, Laws of Motion.)

Key Examination Points for Full Marks:

- To describe motion, choose an **origin** and a **positive direction**. For motion along a line, position to the right of the origin is positive and to the left is negative.
- Position, displacement, velocity and acceleration in one dimension can be positive or negative; the sign shows the direction.

Q.2 Distinguish between distance (path length) and displacement. (2 Marks)

Path length (distance): The total length of the path actually travelled by an object. It is a **scalar**, always positive.

Displacement: The change in position, $\Delta x = x_2 - x_1$. It is a **vector**; in one dimension its sign gives the direction.

Path length (Distance)	Displacement
Total length of the actual path covered.	Shortest distance between initial and final positions.
Scalar quantity.	Vector quantity.
Always positive (never zero for a moving body).	Can be positive, negative or zero.
Depends on the path followed.	Depends only on initial and final positions.

Relation: Path length $\geq$ |displacement|. They are **equal** only when the object moves in one direction along a straight line (no turning back).

Example: A man walks 5 m east and then 3 m west. Path length = 8 m; displacement = 2 m east. If he returns to the starting point, displacement = 0 but path length is not zero.

SI unit: metre (m) for both. **Dimensions:** [L].

Q.3 Define average velocity and average speed. Show that average speed $\geq$ |average velocity|. (3 Marks)

Average velocity: The change in position (displacement) divided by the time interval:

$$\bar{v} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}$$

It is a **vector**, in the direction of the displacement. It can be positive, negative or zero. On an x-t graph, it is the **slope of the straight line** joining the two points.

Average speed: The total path length travelled divided by the total time interval:

$$\text{Average speed} = \frac{\text{Total path length}}{\text{Total time interval}}$$

It is a **scalar** and is always positive.

Proof that average speed $\geq$ |average velocity|: For the same time interval, path length $\geq$ |displacement|. Dividing both by the same Δt ,

$$\frac{\text{Path length}}{\Delta t} \geq \frac{|\Delta x|}{\Delta t} \Rightarrow \text{Average speed} \geq |\bar{v}|$$

The equality holds when the object moves in **one direction only** (does not turn back).

Key Examination Points for Full Marks:

- **SI unit:** m s^{-1} for both. **Dimensions:** $[\text{L T}^{-1}]$.
- If a body returns to its starting point, its average velocity is **zero**, but its average speed is **not zero**. This is why average speed is defined using path length, not as the magnitude of average velocity.

Q.4 Define instantaneous velocity. How is it obtained from a position-time graph? Define instantaneous speed. (3 Marks)

Instantaneous velocity: The velocity at an instant, defined as the **limit of the average velocity** as the time interval Δt becomes infinitesimally small:

$$v = \lim_{\Delta t \rightarrow 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

It is the **rate of change of position with respect to time** at that instant.

Graphical method (Fig. 2.1): For $x = 0.08t^3$, to find v at $t = 4$ s (point P), take $\Delta t = 2$ s centred at 4 s. The slope of chord P_1P_2 gives the average velocity over 3 s to 5 s. As Δt decreases (1 s, 0.5 s, ...), the chord P_1P_2 becomes Q_1Q_2 , T_1T_2 , and in the limit $\Delta t \rightarrow 0$ it becomes the **tangent** at P.

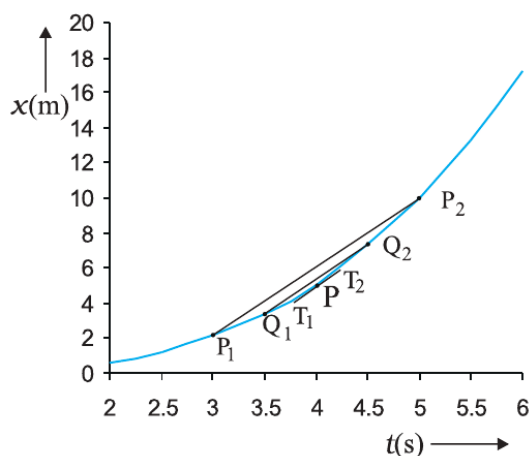


Fig. 2.1: Determining velocity from position-time graph. Velocity at $t = 4$ s is the slope of the tangent to the graph at that instant

The velocity at an instant is the slope of the tangent to the x - t graph at that instant.

Numerical method (Table 2.1): As Δt is reduced from 2.0 s to 0.01 s, $\Delta x/\Delta t$ approaches the limiting value 3.84 m s^{-1} , which is dx/dt at $t = 4.0$ s ($v = 0.24t^2 = 3.84 \text{ m s}^{-1}$).

Instantaneous speed: The **magnitude of instantaneous velocity**. Example: velocities $+24.0 \text{ m s}^{-1}$ and -24.0 m s^{-1} both have a speed of 24.0 m s^{-1} .

Key Examination Points for Full Marks:

- Instantaneous speed is **always equal** to the magnitude of instantaneous velocity, because over an infinitesimally small interval the path length equals the magnitude of displacement (no time to turn back).
- For **uniform motion**, the velocity is the same as the average velocity at all instants.

Illustration (NCERT Example 2.1): For $x = a + bt^2$ ($a = 8.5 \text{ m}$, $b = 2.5 \text{ m s}^{-2}$): $v = 2bt = 5.0t \text{ m s}^{-1}$. At $t = 0$, $v = 0$; at $t = 2.0$ s, $v = 10 \text{ m s}^{-1}$. Average velocity between 2.0 s and 4.0 s $= \frac{x(4) - x(2)}{2} = 6b = 15 \text{ m s}^{-1}$.

Q.5 Define average and instantaneous acceleration. Explain x - t graphs for positive, negative and zero acceleration. (3 Marks)

Average acceleration: The change in velocity divided by the time interval:

$$\bar{a} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}$$

On a v - t graph, it is the slope of the straight line joining (t_1, v_1) and (t_2, v_2) .

Instantaneous acceleration:

$$a = \lim_{\Delta t \rightarrow 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$

The acceleration at an instant is the slope of the tangent to the v - t curve at that instant.

SI unit: m s^{-2} . **Dimensions:** $[L T^{-2}]$.

History: It was first thought that change in velocity should be measured with distance. Galileo, from his studies of free fall and motion on inclined planes, concluded that the rate of change of velocity **with time** is constant for all freely falling objects, while change with distance is not. This led to the concept of acceleration as the rate of change of velocity with time.

Key Examination Points for Full Marks:

- Velocity has magnitude and direction, so acceleration can result from a change in **speed**, a change in **direction**, or both.

- Acceleration can be positive, negative or zero.

x-t graphs (Fig. 2.2):

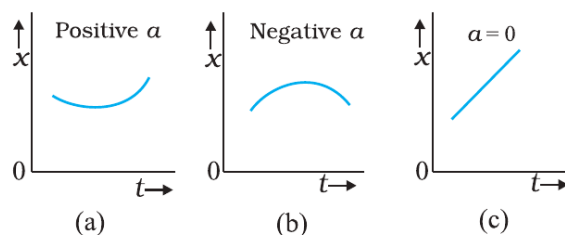


Fig. 2.2: Position-time graph for motion with (a) positive acceleration; (b) negative acceleration, and (c) zero acceleration

- **Positive acceleration:** the graph curves **upward**.
- **Negative acceleration:** the graph curves **downward**.
- **Zero acceleration:** the graph is a **straight line**.

Q.6 Draw and explain velocity–time graphs for motion with constant acceleration. (3 Marks)

For constant acceleration, the average acceleration equals the constant acceleration. If the velocity is v_0 at $t = 0$ and v at time t :

$$a = \frac{v - v_0}{t - 0} \Rightarrow v = v_0 + at$$

So the v–t graph is a **straight line**, whose slope is the acceleration.

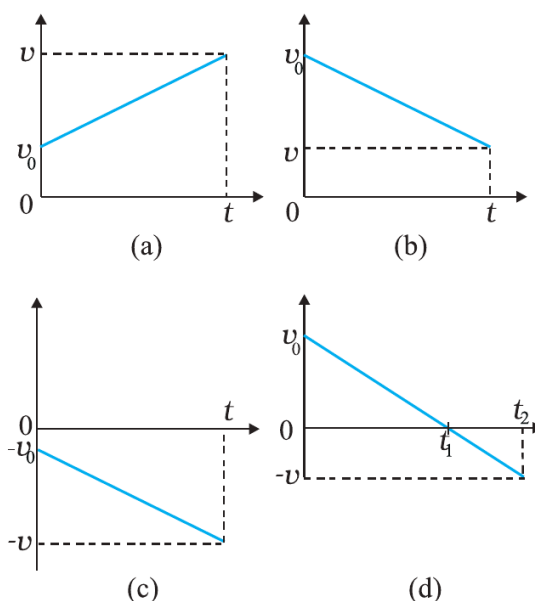


Fig. 2.3: Velocity-time graph for motions with constant acceleration. (a) Motion in positive direction with positive acceleration, (b) Motion in positive direction with negative acceleration, (c) Motion in negative direction with negative acceleration, (d) Motion of an object with negative acceleration that changes direction at time t_1

- **(a)** Moving in the positive direction with **positive** acceleration: speed increases.
- **(b)** Moving in the positive direction with **negative** acceleration: speed decreases.
- **(c)** Moving in the negative direction with **negative** acceleration: speed increases (in the negative direction).
- **(d)** Negative acceleration that **changes direction** at t_1 : from 0 to t_1 the object moves in the +x direction (slowing down); from t_1 to t_2 it moves in the opposite direction (speeding up).

Key Examination Points for Full Marks:

- The **sign of acceleration does not tell** whether speed is increasing or decreasing. If acceleration is in the **same** direction as velocity, the object speeds up; if **opposite**, it slows down.
- Real x - t , v - t , a - t graphs are **smooth**: velocity and acceleration cannot change abruptly at an instant. Sharp kinks in textbook graphs are idealisations.

Q.7 Show that the area under the velocity–time graph gives the displacement.(2 Marks)

Statement: The area under the v - t curve between two instants represents the **displacement** of the object over that time interval.

Uniform velocity (Fig. 2.4): For an object moving with constant velocity u , the v - t graph is a straight line parallel to the time axis. The area under it from $t = 0$ to $t = T$ is a **rectangle** of height u and base T :

$$\text{Area} = u \times T = uT$$

which is the displacement in time T .

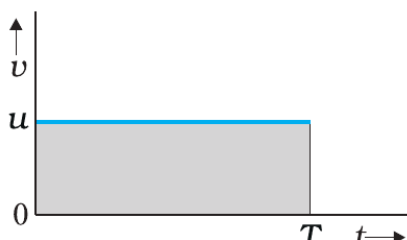


Fig. 2.4: Area under v - t curve equals displacement of the object over a given time interval

Why is an area a distance? The vertical axis is velocity (m s^{-1}) and the horizontal axis is time (s). Their product has the unit of length (m), i.e. dimensions $[L T^{-1}][T] = [L]$.

Key Examination Points for Full Marks:

- A general proof (for any v - t curve) uses calculus: $x = \int v dt$.
- Area **above** the time axis is positive displacement; area **below** is negative. The total distance is the sum of the magnitudes of the areas.
- The **slope** of the v - t graph gives acceleration; the **area** under it gives displacement.

Q.8 Derive the equations of motion for uniformly accelerated motion by the graphical method. (3 Marks)

Consider an object moving with uniform acceleration a , with velocity v_0 at $t = 0$ and v at time t (Fig. 2.5).

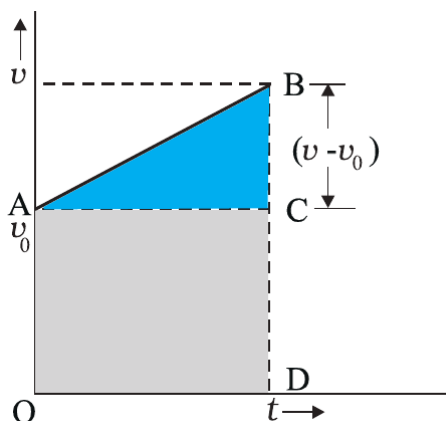


Fig. 2.5: Area under v - t curve for an object with uniform acceleration

First equation (velocity–time): Slope of the v - t line = acceleration:

$$a = \frac{v - v_0}{t} \Rightarrow \boxed{v = v_0 + at}$$

Second equation (position-time): Displacement = area under the v - t curve = area of triangle ABC + area of rectangle OACD:

$$x = \frac{1}{2}(v - v_0)t + v_0t$$

But $v - v_0 = at$, so

$$x = \frac{1}{2}at \cdot t + v_0t \Rightarrow \boxed{x = v_0t + \frac{1}{2}at^2}$$

Average velocity form: The area can also be written as

$$x = \frac{v + v_0}{2}t = \bar{v}t, \quad \bar{v} = \frac{v + v_0}{2} \quad (\text{constant acceleration only})$$

Third equation (velocity-position): From the first equation, $t = (v - v_0)/a$. Substituting:

$$x = \left(\frac{v + v_0}{2}\right)\left(\frac{v - v_0}{a}\right) = \frac{v^2 - v_0^2}{2a} \Rightarrow \boxed{v^2 = v_0^2 + 2ax}$$

If the object starts at $x = x_0$ (not 0), replace x by $(x - x_0)$:

$$v = v_0 + at, \quad x = x_0 + v_0t + \frac{1}{2}at^2, \quad v^2 = v_0^2 + 2a(x - x_0)$$

Q.9 Derive the equations of motion for constant acceleration using the method of calculus. (3 Marks)

First equation: By definition, $a = \frac{dv}{dt}$, so $dv = a dt$. Integrating (with $v = v_0$ at $t = 0$):

$$\int_{v_0}^v dv = \int_0^t a dt = a \int_0^t dt \quad (a \text{ is constant})$$

$$v - v_0 = at \Rightarrow \boxed{v = v_0 + at}$$

Second equation: $v = \frac{dx}{dt}$, so $dx = v dt$. Integrating (with $x = x_0$ at $t = 0$):

$$\int_{x_0}^x dx = \int_0^t v dt = \int_0^t (v_0 + at) dt$$

$$x - x_0 = v_0t + \frac{1}{2}at^2 \Rightarrow \boxed{x = x_0 + v_0t + \frac{1}{2}at^2}$$

Third equation: Write

$$a = \frac{dv}{dt} = \frac{dv}{dx} \frac{dx}{dt} = v \frac{dv}{dx} \Rightarrow v dv = a dx$$

Integrating:

$$\int_{v_0}^v v dv = \int_{x_0}^x a dx \Rightarrow \frac{v^2 - v_0^2}{2} = a(x - x_0)$$

$$\boxed{v^2 = v_0^2 + 2a(x - x_0)}$$

Advantage: The calculus method can also be used for motion with **non-uniform acceleration** (by integrating the given $a(t)$ or $a(x)$).

Key Examination Points for Full Marks:

- The five quantities v_0 , v , a , t and x are related by these kinematic equations.
- The quantities are **algebraic** (may be positive or negative). The equations hold in all cases of one-dimensional motion with constant acceleration, provided proper signs are used.



- The definitions $v = dx/dt$ and $a = dv/dt$ are exact and always true; the kinematic equations are valid **only for constant acceleration**.

Q.10 Discuss the motion of an object under free fall. Draw its a-t, v-t and y-t graphs. (3 Marks)

Free fall: An object released near the surface of the earth is accelerated downward by gravity. If air resistance is neglected, the object is in **free fall**. If the height of fall is small compared with the earth's radius, g is constant (9.8 m s^{-2}), so free fall is **motion with uniform acceleration**.

Equations: Take the upward direction as positive, so $a = -g = -9.8 \text{ m s}^{-2}$. The object is released from rest at $y = 0$ ($v_0 = 0$):

$$v = 0 - gt = -9.8t \text{ m s}^{-1}$$

$$y = 0 - \frac{1}{2}gt^2 = -4.9t^2 \text{ m}$$

$$v^2 = 0 - 2gy = -19.6y \text{ m}^2\text{s}^{-2}$$

Graphs (Fig. 2.7):

- (a) **a-t:** a horizontal line at -9.8 m s^{-2} (constant acceleration).
- (b) **v-t:** a straight line through the origin with negative slope (velocity grows uniformly in the downward direction).
- (c) **y-t:** a **parabola** curving downward (distance increases as t^2).

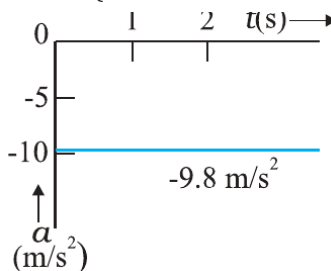


Fig. 2.7 (a): Variation of acceleration with time

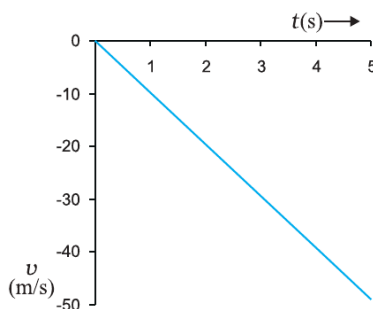


Fig. 2.7 (b): Variation of velocity with time

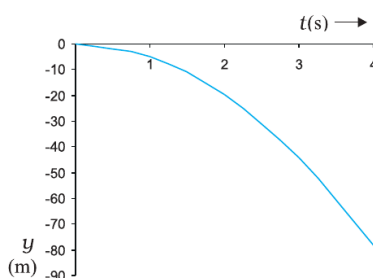


Fig. 2.7 (c): Variation of distance with time

Key Examination Points for Full Marks:



- In free fall, all bodies (heavy or light) fall with the **same acceleration** g , if air resistance is neglected.
- A body thrown up has **zero velocity at the highest point**, but its acceleration is still g (downward). Zero velocity does not mean zero acceleration.

Q.11 State and prove Galileo's law of odd numbers.

(2 Marks)

Statement: The distances traversed, during equal intervals of time, by a body falling from rest, stand to one another in the same ratio as the odd numbers beginning with unity, namely **1 : 3 : 5 : 7 : ...**

Proof: Divide the time of fall into equal intervals τ . Since the initial velocity is zero,

$$y = -\frac{1}{2}gt^2$$

Let $y_0 = -\frac{1}{2}g\tau^2$ be the position after the first interval τ .

t	y	y in terms of y_0	Distance in successive intervals	Ratio
0	0	0	—	—
τ	$-\frac{1}{2}g\tau^2$	y_0	y_0	1
2τ	$-4\left(\frac{1}{2}g\tau^2\right)$	$4y_0$	$3y_0$	3
3τ	$-9\left(\frac{1}{2}g\tau^2\right)$	$9y_0$	$5y_0$	5
4τ	$-16\left(\frac{1}{2}g\tau^2\right)$	$16y_0$	$7y_0$	7
5τ	$-25\left(\frac{1}{2}g\tau^2\right)$	$25y_0$	$9y_0$	9

The distances in successive intervals are $y_0, 3y_0, 5y_0, 7y_0, \dots$ i.e. in the ratio **1 : 3 : 5 : 7 : 9 : 11 ...**

General form: Distance in the n -th interval is proportional to $(2n - 1)$.

This law was established by **Galileo Galilei (1564–1642)**, who was the first to make quantitative studies of free fall.

Q.12 Derive an expression for the stopping distance of a vehicle. What is reaction time?

(2 Marks)

Stopping distance: When brakes are applied to a moving vehicle, the distance it travels before stopping is called the **stopping distance**. It is an important factor for road safety.

Derivation: Let the initial velocity be v_0 and the deceleration (due to braking) be $-a$. Using $v^2 = v_0^2 + 2ax$ with $v = 0$:

$$0 = v_0^2 + 2(-a)d_s \Rightarrow \boxed{d_s = \frac{v_0^2}{2a}}$$

(Written with a negative, $d_s = -\frac{v_0^2}{2a}$.)

Result: Stopping distance is **proportional to the square of the initial velocity**. Doubling the initial velocity increases the stopping distance by a factor of **4** (for the same deceleration). This is why speed limits are set, for example, in school zones.

For a car of a particular make, the braking distances were 10 m, 20 m, 34 m and 50 m at 11, 15, 20 and 25 m/s — nearly consistent with $d_s \propto v_0^2$.

Reaction time: The time a person takes to observe, think and act. Example: the time between seeing a boy suddenly appear on the road and slamming the brakes.

Measuring reaction time (NCERT Example 2.7): A friend drops a ruler vertically through the gap between your thumb and forefinger; you catch it after it falls a distance d . The ruler is in free fall ($v_0 = 0$):

$$d = \frac{1}{2}gt_r^2 \Rightarrow t_r = \sqrt{\frac{2d}{g}}$$

For $d = 21.0$ cm: $t_r = \sqrt{\frac{2 \times 0.21}{9.8}} \approx 0.2$ s.

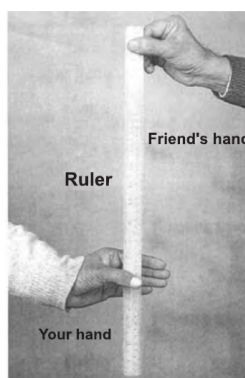


Fig. 2.8: Measuring the reaction time

Q.13 A ball thrown up at 20 m s^{-1} from a 25 m high building: find its maximum height and time to reach the ground. (3 Marks)

This is **NCERT Example 2.3**. Take the y -axis vertically upward with zero at the ground (Fig. 2.6). $v_0 = +20 \text{ m s}^{-1}$, $a = -10 \text{ m s}^{-2}$, $y_0 = 25 \text{ m}$.

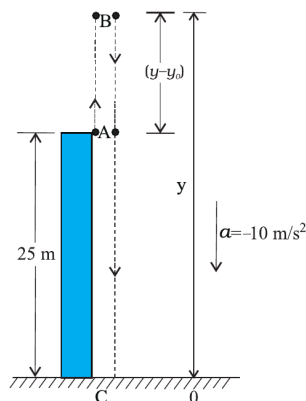


Fig. 2.6: Ball thrown up from the top of a building

(a) Maximum height: At the top, $v = 0$. Using $v^2 = v_0^2 + 2a(y - y_0)$:

$$0 = (20)^2 + 2(-10)(y - y_0) \Rightarrow y - y_0 = 20 \text{ m}$$

So the ball rises 20 m above the point of launch (45 m above the ground).

(b) Total time — First method (split into upward and downward parts):

- **Upward (A to B):** $v = v_0 + at$: $0 = 20 - 10t_1 \Rightarrow t_1 = 2$ s.
- **Downward (B to C):** free fall from $y_0 = 45$ m to $y = 0$, starting from rest: $0 = 45 + \frac{1}{2}(-10)t_2^2 \Rightarrow t_2 = 3$ s.

Total time = $t_1 + t_2 = 5$ s.

Second method (whole motion at once, using initial and final positions):

$$y = y_0 + v_0 t + \frac{1}{2} a t^2 \Rightarrow 0 = 25 + 20t - 5t^2$$

$$5t^2 - 20t - 25 = 0 \Rightarrow t^2 - 4t - 5 = 0 \Rightarrow t = 5 \text{ s}$$

(the other root, $t = -1$ s, is not physical).

Note: The second method is better because we do not have to worry about the path, since the acceleration is constant throughout.

Q.14 Explain the importance of sign convention in kinematics. Write the important points to ponder. (2 Marks)

1. **The origin and the positive direction of an axis are a matter of choice.** Specify this choice first, before assigning signs to displacement, velocity and acceleration.
2. **If a particle is speeding up**, acceleration is in the **direction of velocity**; if its speed is decreasing, acceleration is **opposite** to velocity. This is independent of the choice of origin and axis.
3. **The sign of acceleration does not tell** whether the speed is increasing or decreasing. Example: with upward as positive, g is negative. A falling particle speeds up under this negative acceleration, while a particle thrown upward slows down under the same negative acceleration.
4. **Zero velocity at an instant does not imply zero acceleration.** A particle thrown up has zero velocity at its highest point, but its acceleration is still g .
5. In the kinematic equations, the quantities are **algebraic**. The equations apply in all situations of one-dimensional motion with constant acceleration, if the values are substituted **with proper signs**.
6. The definitions $v = dx/dt$ and $a = dv/dt$ are **exact and always correct**; the kinematic equations hold **only when the magnitude and direction of acceleration are constant**.

Formula Sheet — Motion in a Straight Line

Quantity	Formula	SI Unit
Displacement	$\Delta x = x_2 - x_1$	m
Average velocity	$\bar{v} = \frac{\Delta x}{\Delta t}$	m s^{-1}
Average speed	$\frac{\text{Total path length}}{\text{Total time}}$	m s^{-1}
Instantaneous velocity	$v = \frac{dx}{dt}$ (slope of x-t)	m s^{-1}
Average acceleration	$\bar{a} = \frac{\Delta v}{\Delta t}$	m s^{-2}
Instantaneous acceleration	$a = \frac{dv}{dt} = \frac{d^2x}{dt^2} = v \frac{dv}{dx}$	m s^{-2}
Displacement from v-t	$x = \int v dt = \text{area under v-t}$	m
First equation	$v = v_0 + at$	m s^{-1}
Second equation	$x = v_0 t + \frac{1}{2} at^2$	m



Quantity	Formula	SI Unit
Third equation	$v^2 = v_0^2 + 2ax$	$\text{m}^2 \text{s}^{-2}$
Average velocity (constant a)	$\bar{v} = \frac{v_0 + v}{2}; x = \bar{v}t$	m s^{-1}
Distance in n-th second	$s_n = v_0 + \frac{a}{2}(2n - 1)$	m
Free fall from rest	$v = gt, h = \frac{1}{2}gt^2, v^2 = 2gh$	—
Thrown up with u	$H_{\max} = \frac{u^2}{2g}, t_{\text{up}} = \frac{u}{g}, T = \frac{2u}{g}$	m, s
Stopping distance	$d_s = \frac{v_0^2}{2a}$	m
Reaction time	$t_r = \sqrt{\frac{2d}{g}}$	s
Relative velocity	$v_{AB} = v_A - v_B$	m s^{-1}

Dimensions: Displacement [L]; velocity and speed $[\text{L T}^{-1}]$; acceleration $[\text{L T}^{-2}]$. **Conversions:** $1 \text{ km h}^{-1} = 5/18 \text{ m s}^{-1}$; $36 \text{ km h}^{-1} = 10 \text{ m s}^{-1}$; $72 \text{ km h}^{-1} = 20 \text{ m s}^{-1}$.

NEET / JEE Quick Points and Tricks

- Slopes and areas:** Slope of x - t = velocity; slope of v - t = acceleration; area under v - t = displacement; area under a - t = change in velocity.
- Average speed for equal distances** at speeds v_1 and v_2 : $\frac{2v_1v_2}{v_1+v_2}$ (harmonic mean). **For equal times:** $\frac{v_1+v_2}{2}$.
- Round trip:** Average velocity = 0; average speed = total distance ÷ total time.
- Ball thrown up with speed u :** time up = time down = u/g ; it returns with the same speed u ; at the top, $v = 0$ but $a = g$.
- Galileo's ratio:** Distances in successive equal intervals from rest = 1 : 3 : 5 : 7; total distances after $t, 2t, 3t = 1 : 4 : 9$.
- Distance in the n-th second:** $s_n = u + \frac{a}{2}(2n - 1)$. For free fall from rest: $s_n = \frac{g}{2}(2n - 1)$.
- Stopping distance** $\propto v_0^2$: double the speed $\rightarrow$ 4 times the stopping distance. Bullet losing half its speed in a block: further penetration before stopping = $\frac{1}{3}$ of the first distance.
- Two balls released/thrown from the same height:** one dropped and one thrown down with u (or up with u) — use relative motion: relative acceleration is zero, so relative velocity is constant.
- Variable acceleration:** If a is given as a function of t , integrate $dv = a dt$. If a is given as a function of x or v , use $a = v \frac{dv}{dx}$.
- Retarding motion** $a = -kv$: velocity decreases exponentially, $v = v_0 e^{-kt}$; total distance = v_0/k .
- x - t graph shapes:** straight line $\rightarrow$ uniform velocity; parabola opening up $\rightarrow$ positive acceleration; a line parallel to t -axis $\rightarrow$ at rest. A **vertical** x - t line is impossible (infinite speed); a graph going **back in time** or showing two positions at one time is impossible.
- Relative velocity:** Same direction $\rightarrow v_A - v_B$; opposite directions $\rightarrow v_A + v_B$. Time for one train to overtake another of total length L : $\frac{L}{v_A - v_B}$.



13. **Dropped from a rising balloon/lift:** the object first moves **up** with the balloon's velocity, then falls; use $y = ut - \frac{1}{2}gt^2$ with u = balloon's velocity.
14. **Ball dropped from height h and another thrown up from the ground with u** meet after $t = h/u$.