FREE NOTES · NCERT + JEE/NEET LEVEL

Motion in a Straight Line

Distance, displacement, speed, velocity, acceleration, teen equations of motion, free fall, graphs aur relative velocity. Har topic ke saath shortcut formulas aur solved numericals.

01 Distance vs displacement
02 Speed & velocity
03 Average speed ke special cases (seedhe MCQ me aate hain)
04 Acceleration
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01 Distance vs displacement

Motion ko samajhne ke liye pehle ek **reference point (origin)** aur direction chuno. Straight line me ek taraf + aur doosri taraf −.

	Distance (path length)	Displacement
Matlab	Asal me chala gaya poora raasta	Shuru se aakhri position tak seedha badlav: $\Delta x = x_f - x_i$
Type	Scalar	Vector
Value	Hamesha + (ya 0)	+, − ya 0 ho sakta hai
Graph se	v–t graph ke area ka total (sab +)	v–t graph ka area (upar +, neeche −)

RULE

Distance ≥ |Displacement|. Barabar tabhi jab body ek hi direction me chale aur wapas na mude.

ASSERTION-REASON KE LIYE

- Displacement 0 ho toh distance 0 ho bhi sakta hai, nahi bhi (gol chakkar).
- Distance 0 ho toh displacement pakka 0.
- Displacement non-zero ho toh distance pakka non-zero.

CIRCLE KA HISSA (ANGLE θ)

$$\text{Distance} = R\,\theta$$

$$\text{Displacement} = 2R\sin(\theta/2)$$

Aadha chakkar: distance πR, displacement 2R. Poora chakkar: distance 2πR, displacement 0.

02 Speed & velocity

AVERAGE

$$\text{Average speed} = \frac{\text{total distance}}{\text{total time}}$$

$$\text{Average velocity} = \frac{\text{total displacement}}{\text{total time}}$$

INSTANTANEOUS

$$v = dx/dt$$

x–t graph ki **slope**. Speedometer yahi dikhata hai (magnitude).

- |Instantaneous velocity| = instantaneous speed: **hamesha**.
- |Average velocity| = average speed: sirf jab direction na badle. Warna average speed > |average velocity|.
- Gol track pe ek chakkar: average velocity 0, par average speed 0 nahi.

03 Average speed ke special cases (seedhe MCQ me aate hain)

Situation	Average speed
Time t_1 me v_1, time t_2 me v_2	$(v_1t_1 + v_2t_2)/(t_1 + t_2)$
Distance x_1 v_1 se, x_2 v_2 se	$(x_1 + x_2)/(x_1/v_1 + x_2/v_2)$
Aadha **time** v_1, aadha v_2	$(v_1 + v_2)/2$ (arithmetic mean)
Aadhi **distance** v_1, aadhi v_2	$2v_1v_2/(v_1 + v_2)$ (harmonic mean)
Teen barabar distance v_1, v_2, v_3 se	$3v_1v_2v_3/(v_1v_2 + v_2v_3 + v_3v_1)$
Aadhi distance v_1 se; baaki ka aadha time v_2, aadha v_3	$2v_1(v_2 + v_3)/(2v_1 + v_2 + v_3)$

COMMON GALTI

Aadhi distance wale case me seedha $(v_1 + v_2)/2$ likh dena. Jab distance barabar ho toh **harmonic mean** lagta hai, aur ye hamesha arithmetic mean se chhota hota hai.

04 Acceleration

Velocity ke badalne ki rate. Unit m/s², vector quantity.

FORMULAS

$$a_{avg} = (v_f - v_i)/\Delta t$$

$$a = dv/dt = d^2x/dt^2 = v\,(dv/dx)$$

v–t graph ki slope = acceleration.

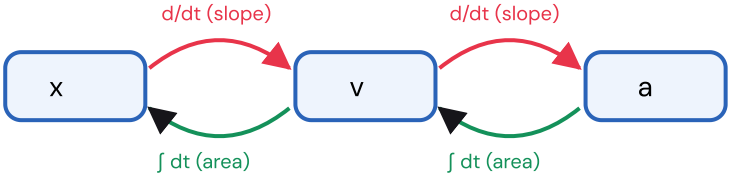
SPEED BADHEGI YA GHATEGI?

- v aur a **same direction** (angle 0°): speed badhti hai.
- v aur a **ulti** (180°): speed ghatti hai (retardation).
- v ⊥ a (90°): speed same, sirf direction badalti hai (circular motion).

DHYAN DO

Negative acceleration ka matlab hamesha "slow ho raha hai" nahi. Agar body bhi - direction me chal rahi hai, toh negative acceleration usse **tez** karega. Speed tab ghatti hai jab v aur a ke sign ulte hon.

05 Calculus: golden rule



Aage jaane ke liye differentiate (slope), peeche aane ke liye integrate (area)

Diya hai	Kaise solve karein
a = f(t)	$v = \int a\,dt$, phir $x = \int v\,dt$
a = f(v)	$dv/dt = f(v) \Rightarrow \int dv/f(v) = \int dt$
a = f(x)	$v\,dv/dx = f(x) \Rightarrow \int v\,dv = \int f(x)\,dx$

ACCELERATION CONSTANT KAB HAI?

Agar $x \propto t^2$, ya $v \propto t$, ya $v \propto \sqrt{x}$, toh acceleration constant hai. Agar x me t^3 ya usse upar ki power hai, toh acceleration badal raha hai.

06 Equations of motion (constant acceleration)

TEEN EQUATIONS

$$v = u + a\,t$$

$$s = u\,t + \tfrac{1}{2}\,a\,t^2$$

$$v^2 = u^2 + 2\,a\,s$$

Bonus: $s = (u + v)\,t / 2$, $s = v\,t - \tfrac{1}{2}\,a\,t^2$. u = shuru ki velocity, v = aakhri, s = displacement.

N-TH SECOND ME CHALI DISTANCE

$$S_n = u + (a/2)(2n - 1)$$

Units alag dikhte hain kyunki ye "1 second" ki distance hai (Δt = 1 s chhupa hai).

KAB LAGAAYEIN

Sirf jab acceleration **constant** ho. Badalte acceleration me calculus wala tareeka (section 05) use karo.

Calculus se derivation (NCERT)

$a = dv/dt \Rightarrow \int_u^v dv = a\int_0^t dt \Rightarrow v = u + at$. Phir $v = dx/dt = u + at \Rightarrow x - x_0 = ut + \tfrac{1}{2}at^2$. Aur $a = v\,dv/dx \Rightarrow \int v\,dv = a\int dx \Rightarrow v^2 - u^2 = 2a(x - x_0)$.

07 Shortcut results

Situation	Result
Rest se shuru, constant a: 1st, 2nd, 3rd... second me distance	$1 : 3 : 5 : 7 \ldots$ (odd numbers, Galileo)
Rest se shuru: 1, 2, 3 s me total distance	$1 : 4 : 9 \ (\propto t^2)$
Rest se shuru: barabar distance cover karne me lage time	$1 : (\sqrt{2}-1) : (\sqrt{3}-\sqrt{2}) \ldots$
Beech ke point (mid-point) pe velocity	$v_{mid} = \sqrt{((u^2+v^2)/2)}$
Stopping distance (speed u, retardation a)	$s = u^2/(2a) \propto u^2$
Rest → accelerate α → retard β → rest, total time T	$v_{max} = \alpha\beta T/(\alpha+\beta)$, $s = \frac{1}{2}\,\alpha\beta T^2/(\alpha+\beta)$

REACTION TIME (NCERT)

Driver ke brake dabaane tak gaadi purani speed se chalti rehti hai. Total rukne ki doori = $u \cdot t_r + u^2/(2a)$.

Speed double ⇒ braking wali doori 4 guna.

08 Motion under gravity (free fall)

Hawa ka asar na ho toh har cheez same acceleration $g \approx 9.8\ m/s^2$ se neeche girti hai, chahe bhaari ho ya halki.

SIGN CONVENTION

Upar ki direction +, toh $a = -g$ hamesha (upar jaate hue bhi, neeche aate hue bhi, aur sabse upar wale point pe bhi). Sabse upar velocity 0 hai, acceleration 0 nahi.

HEIGHT H SE CHHODA (U = 0)

$t = \sqrt{(2H/g)}$, $v = \sqrt{(2gH)}$

Aadhi height tak time $= T/\sqrt{2}$

ZAMEEN SE UPAR PHENKA (SPEED U)

$H_{max} = u^2/(2g)$

$t_{up} = t_{down} = u/g$, $T = 2u/g$

Wapas usi point pe usi speed u se aata hai.

HEIGHT H SE UPAR U SE PHENKA

$-H = u\,t - \frac{1}{2}\,g\,t^2$

$t = u/g + \sqrt{(u^2/g^2 + 2H/g)}$

HAWA KA RESISTANCE (RETARDATION A)

Upar: $g + a$, neeche: $g - a$

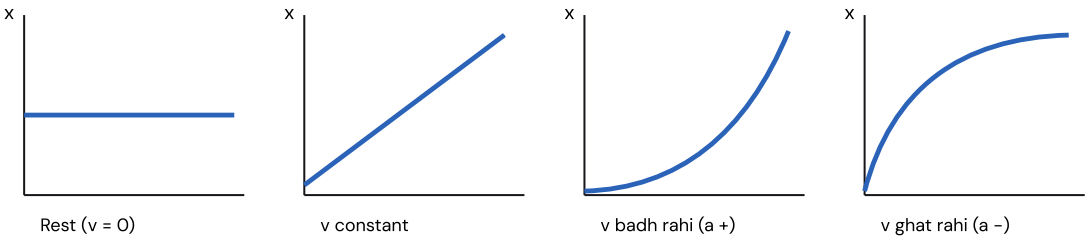
$t_{up}/t_{down} = \sqrt{((g-a)/(g+a))}$

Upar jaane me kam time, neeche aane me zyada.

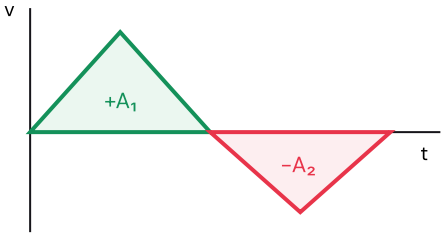
09 Graphs (x–t, v–t, a–t)

EK LINE ME

x–t ki **slope** = velocity. v–t ki **slope** = acceleration. v–t ka **area** = displacement. a–t ka **area** = velocity ka change.



Position–time graphs: curve ki dhalaan (slope) hi velocity hai



Displacement = $A_1 - A_2$, distance = $A_1 + A_2$

IMPOSSIBLE GRAPHS

- x–t graph me ek hi time pe do positions (vertical line ya peeche mudta graph).
- Speed ya distance negative.
- x–t ya v–t me achanak tod (jump) ya nukeela kona (infinite acceleration).

10 Relative velocity

B ke hisaab se A ki velocity: $v_{AB} = v_A - v_B$. Matlab B me baithe insaan ko A kitni tez dikhegi.

Situation	Relative speed
Same direction me	$\lvert v_A - v_B \rvert$ (dheere paas aate hain)
Ulti direction me	$v_A + v_B$ (jaldi paas aate hain)
Same velocity	0: ek doosre ko ruke hue dikhte hain, doori same rehti hai

TRAIN CROSSING TRICK

Ek train doosri ko cross kare: distance = $L_1 + L_2$, speed = relative speed. Pole ya insaan ko cross kare: distance = sirf train ki length.

11 JEE Extra + Tricks

JEE LEVEL

- n-th second me doori: $s_n = u + a(2n - 1)/2$.
- Galileo ka odd-number rule: rest se constant a, barabar intervals me doori 1 : 3 : 5 : 7 ...
- Stopping distance $\propto u^2$: speed double $\Rightarrow$ 4 guna doori.
- Upar feki gend u: upar jaane ka samay u/g, max height $u^2/2g$, usi speed se wapas; time of flight 2u/g.
- Relative velocity: $v_{AB} = v_A - v_B$; relative displacement = shuruaati doori ho to milte.
- Graph tricks: x–t ka slope = v; v–t ka slope = a; v–t ka area = displacement; a–t ka area = v ka badlav.

12 Solved numericals (g = 10 m/s²)

Q1. Car aadhi distance 40 km/h se aur aadhi 60 km/h se chalti hai. Average speed?
Harmonic mean: 2 × 40 × 60/(40 + 60) = 4800/100. **Ans: 48 km/h (50 nahi!)**

Q2. Ek particle ki position $x = 2t^3 - 3t^2 + 4$ (m). t = 2 s pe velocity aur acceleration?
$v = dx/dt = 6t^2 - 6t = 24 - 12 = 12$ m/s. $a = dv/dt = 12t - 6 = 18$ m/s². **Ans: 12 m/s, 18 m/s²**

Q3. Rest se 2 m/s² se chalti body 5th second me kitni distance chalegi?
$S_5 = 0 + (2/2)(2\times5 - 1) = 9$ m. **Ans: 9 m**

Q4. 72 km/h se chalti car brake lagane ke baad 4 m/s² se ruki. Stopping distance?
u = 72 × 5/18 = 20 m/s. $s = u^2/2a = 400/8 = 50$ m. **Ans: 50 m**

Q5. Ball 20 m/s se seedha upar phenki. Max height aur zameen pe wapas aane ka time?
$H = u^2/2g = 400/20 = 20$ m. $T = 2u/g = 4$ s. **Ans: 20 m, 4 s**

Q6. 45 m oonchi building se ek patthar chhoda. Zameen tak time aur speed?
$t = \sqrt{(2H/g)} = \sqrt{9} = 3$ s. $v = gt = 30$ m/s. **Ans: 3 s, 30 m/s**

Q7. 25 m oonche tower se ball 20 m/s se upar phenki. Zameen pe kab giregi?
Upar +: $-25 = 20t - 5t^2 \Rightarrow 5t^2 - 20t - 25 = 0 \Rightarrow t^2 - 4t - 5 = 0 \Rightarrow t = 5$ s (−1 nahi lete). **Ans: 5 s**

Q8. 100 m aur 150 m lambi do trains 40 m/s aur 10 m/s se ulti direction me aa rahi hain. Ek doosre ko cross karne me time?
Distance = 250 m, relative speed = 50 m/s ⇒ t = 5 s. Same direction me hoti: 250/30 ≈ 8.3 s. **Ans: 5 s**

Q9. Acceleration $a = -2v$ (SI). Shuru me v = 10 m/s. Kitni doori ke baad rukega?
$v\, dv/dx = -2v \Rightarrow dv = -2\, dx \Rightarrow 0 - 10 = -2x \Rightarrow x = 5$ m. **Ans: 5 m**

13 Common mistakes

- Average speed ko hamesha $(v_1 + v_2)/2$ maan lena. Barabar distance ho toh harmonic mean.
- Free fall me upar jaate waqt a = +g lena. Upar + maana hai toh a = −g hamesha.
- Sabse upar wale point pe acceleration 0 maan lena. Sirf velocity 0 hoti hai.
- Badalte acceleration me v = u + at laga dena.
- km/h ko m/s me na badalna (× 5/18).
- v–t graph ke neeche wale area ko distance me minus kar dena. Distance me sab area + lete hain.

14 Formula sheet

Velocity, acceleration	$v = dx/dt$, $a = dv/dt = v\,dv/dx$
Equations of motion	$v = u + at$, $s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$
n-th second	$S_n = u + (a/2)(2n - 1)$
Avg speed (half time / half distance)	$(v_1 + v_2)/2$ / $2v_1v_2/(v_1 + v_2)$
Mid-point velocity	$\sqrt{((u^2 + v^2)/2)}$
Stopping distance	$u^2/2a$ (+ $u \cdot t_r$ with reaction time)
Free fall from H	$t = \sqrt{(2H/g)}$, $v = \sqrt{(2gH)}$
Thrown up with u	$H = u^2/2g$, $T = 2u/g$
Ratios from rest	1:3:5 (each second), 1:4:9 (total)
Rest–max–rest	$v_{max} = \alpha\beta T/(\alpha + \beta)$
Relative velocity	$v_{AB} = v_A - v_B$

15 Practice questions

1. Body pehle 2 s me 20 m aur agle 2 s me 40 m chalti hai (constant a). u aur a?
2. Patthar ko 80 m ki oonchai se chhoda. Last second me kitni doori chalega?
3. x = 4t - t² (m). Body kab rukegi aur tab tak kitni door gayi?
4. Do balls ek saath chhodi, ek 20 m se aur ek 45 m se. Zameen pe pahunchne ke time me fark?
5. Bus 10 m/s se jaa rahi hai. Peeche se scooter 15 m/s se aa raha hai jo 100 m peeche hai. Kitne time me bus pakdega?

ANSWERS

1) u = 5 m/s, a = 5 m/s² · 2) 35 m (t = 4 s, S_4 = 5 × 7) · 3) t = 2 s, x = 4 m · 4) 3 - 2 = 1 s · 5) 100/5 = 20 s

16 Quick revision: exam se pehle 5 minute

BASICS

- Distance ≥ |displacement|.
- Avg velocity = displacement/time; avg speed = distance/time.
- Barabar time: AM; barabar distance: HM.
- v, a same direction ⇒ speed badhti.

EQUATIONS

- $v = u + at$; $s = ut + \frac{1}{2}at^2$; $v^2 = u^2 + 2as$.
- $S_n = u + a(2n - 1)/2$.
- Rest se: 1:3:5, total 1:4:9.
- Stopping distance $\propto u^2$.

GRAVITY

- $a = -g$ (upar +) hamesha.
- $H = u^2/2g$, $T = 2u/g$, $t_{up} = t_{down}$.
- H se gira: $t = \sqrt{(2H/g)}$, $v = \sqrt{(2gH)}$.
- Top pe $v = 0$, $a = g$.

GRAPHS

- x–t slope = v; v–t slope = a.
- v–t area = displacement.
- a–t area = Δv.
- Ek time pe do x: impossible.

Doubt hai? padhaiadda.netlify.app pe AI Doubt Solver se poocho, ya is chapter ka mock test do.