

KINEMATICS — NEET PHYSICS

Comprehensive Formula Sheet for Revision

1. BASIC DEFINITIONS

Distance, Displacement & Speed, Velocity

- **Distance:** Total path length (scalar, always positive)
- **Displacement:** Change in position (vector, $\vec{s} = \vec{s}_f - \vec{s}_i$)
- **Average Speed:** $v_{\text{avg}} = \frac{\text{Total Distance}}{\text{Total Time}}$
- **Average Velocity:** $\vec{v}_{\text{avg}} = \frac{\text{Displacement}}{\text{Total Time}}$
- **Instantaneous Velocity:** $v = \frac{ds}{dt}$ (slope of s - t graph)
- **Instantaneous Speed:** $|v| = \left| \frac{ds}{dt} \right|$

Acceleration

Average Acceleration:

$$a_{\text{avg}} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t}$$

Instantaneous Acceleration:

$$a = \frac{dv}{dt}$$

(slope of v - t graph)

2. EQUATIONS OF MOTION (Uniform Acceleration)

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

$$s = ut + \frac{1}{2}at^2 \quad (2)$$

$$v^2 = u^2 + 2as \quad (3)$$

$$s = \frac{u+v}{2} \cdot t \quad (4)$$

where u = initial velocity, v = final velocity, a = acceleration, t = time, s = displacement

Useful Derived Forms

- $s_n = u + \frac{a}{2}(2n - 1)$ (displacement in n -th second)
- $v_n^2 - v_{n-1}^2 = 2a \cdot s_n$ (consecutive second relation)
- $s = v_i t + \frac{1}{2}at^2$ (if initial position = 0)

3. GRAPHICAL ANALYSIS

Position-Time Graph (s - t)

- Slope = velocity: $v = \frac{ds}{dt}$

- Straight line = uniform velocity
- Curved line = acceleration
- Steeper slope = higher speed

Velocity-Time Graph (v - t)

- Slope = acceleration: $a = \frac{dv}{dt}$
- Area under curve = displacement
- Straight line = uniform acceleration
- Horizontal line = zero acceleration

Acceleration-Time Graph (a - t)

- Slope = jerk (rate of change of acceleration)
- Area under curve = change in velocity: $\Delta v = \int a dt$

4. MOTION UNDER GRAVITY

Free Fall (downward, $g = 10 \text{ m/s}^2$)

Equations (taking $u = 0$, downward = positive):

$$v = gt \quad (5)$$

$$h = \frac{1}{2}gt^2 \quad (6)$$

$$v^2 = 2gh \quad (7)$$

Upward & Downward Motion

$$v = u - gt \quad (\text{upward positive}) \quad (8)$$

$$h = ut - \frac{1}{2}gt^2 \quad (9)$$

$$v^2 = u^2 - 2gh \quad (10)$$

Use negative g for upward, positive for downward

Maximum Height & Time of Flight

Vertical Projection (upward):

- Max height: $H = \frac{u^2}{2g}$
- Time to reach max height: $t_{\text{max}} = \frac{u}{g}$
- Total time of flight: $T = \frac{2u}{g}$
- Velocity at height h : $v = \sqrt{u^2 - 2gh}$

Important Relations

- **At max height:** $v = 0$
- **Return to ground:** velocity magnitude = initial velocity
- **Distance in n -th second:** $s_n = g(n - 0.5)$

- **Ratio in consecutive seconds:** 1 : 3 : 5 : 7 : ...

5. RELATIVE MOTION

Relative Velocity (1D)

Relative velocity of A w.r.t. B:

$$v_{AB} = v_A - v_B$$

Similarly: $v_{BA} = v_B - v_A = -v_{AB}$

Sign Convention (1D)

- Positive direction = reference direction
- $v_{AB} > 0$ = A moving away from B
- $v_{AB} < 0$ = A moving towards B
- $v_{AB} = 0$ = A and B moving with same velocity

2D Relative Motion

- Rain problem: $v_{\text{rain,gnd}} = v_{\text{rain,man}} + v_{\text{man,gnd}}$
- Boat crossing river: $v_{\text{res}} = \sqrt{v_{\text{boat}}^2 + v_{\text{current}}^2}$
- For shortest path, boat velocity directed at angle to current

6. UNIFORM CIRCULAR MOTION

Angular & Linear Velocity

Angular velocity: $\omega = \frac{\theta}{t}$ (rad/s)

Linear velocity: $v = r\omega = \frac{2\pi r}{T}$

where r = radius, T = period, f = frequency

Centripetal Acceleration

Centripetal acceleration (towards center):

$$a_c = \frac{v^2}{r} = r\omega^2 = \frac{4\pi^2 r}{T^2}$$

Key Relations

- Period: $T = \frac{2\pi r}{v} = \frac{2\pi}{\omega}$
- Frequency: $f = \frac{1}{T} = \frac{\omega}{2\pi}$
- Angular velocity: $\omega = 2\pi f$
- Speed constant, direction constantly changes
- Acceleration centripetal (towards center)

Vertical Circular Motion

At Lowest Point (L):

$$N_L - mg = \frac{mv_L^2}{r} \quad (11)$$

$$N_L = mg + \frac{mv_L^2}{r} \quad (12)$$

Normal reaction is **maximum** at lowest point
Minimum velocity for complete loop: $v_L = \sqrt{5gr}$

At Highest Point (H):

$$N_H + mg = \frac{mv_H^2}{r} \quad (13)$$

$$N_H = \frac{mv_H^2}{r} - mg \quad (14)$$

Normal reaction is **minimum** at highest point
Minimum velocity for complete loop: $v_H = \sqrt{gr}$

Energy Conservation (Vertical Loop)

For a complete vertical circular motion starting from lowest point:

$$\frac{1}{2}mv_L^2 = \frac{1}{2}mv_H^2 + mg(2r)$$

$$v_L^2 = v_H^2 + 4gr$$

Minimum Velocity for Complete Loop

At Highest Point (Critical Condition):

$$N_H = 0 \Rightarrow v_H = \sqrt{gr}$$

At Lowest Point:

$$v_L = \sqrt{5gr}$$

Normal Reaction at Any Angle

For angle θ from vertical (at lowest point, $\theta = 0$):

$$N = mg \cos \theta + \frac{mv^2}{r}$$

At highest point ($\theta = 180^\circ$):

$$N = \frac{mv_H^2}{r} - mg$$

Horizontal Circular Motion

- No gravity component in radial direction
- Centripetal force = Net horizontal force
- **For banked road:** $\tan \theta = \frac{v^2}{rg}$
- **For conical pendulum:** $\tan \theta = \frac{v^2}{rg}$ (same formula)
- **Safe speed on unbanked road:** $v = \sqrt{\mu rg}$ (friction provides centripetal force)

7. STANDARD SHORTCUTS

Quick MCQ Tricks

- **Average velocity:** $v_{\text{avg}} = \frac{v_1 + v_2}{2}$ (uniform acceleration only)
- **Distance in n -th second:** $s_n = u + a(n - 0.5)$
- **Free fall ratio (1st, 2nd, 3rd sec):** 1 : 3 : 5
- **For equal distances:** time ratio \neq 1 : 1 generally
- **Zero displacement:** $s = 0$ when $t = 0$ or $t = -\frac{2u}{a}$

Sign Conventions

- Choose a reference direction (upward or rightward)
- Same direction = positive

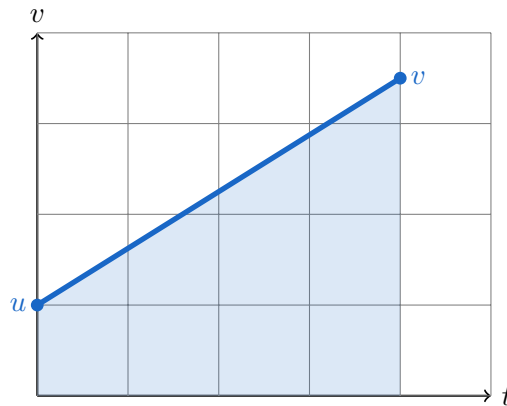
- Opposite direction = negative
- $g = -10 \text{ m/s}^2$ if upward is positive
- $g = +10 \text{ m/s}^2$ if downward is positive

Common Assumptions

- Air resistance is negligible
- g is constant (uniform)
- Earth is non-rotating
- Motion along straight line (unless stated)

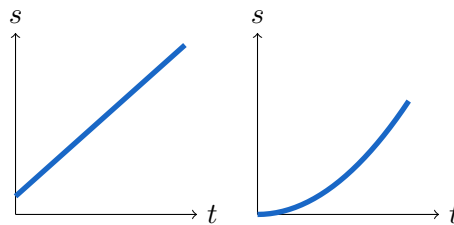
BONUS: KEY DIAGRAMS

Velocity-Time Graph for Uniformly Accelerated Motion



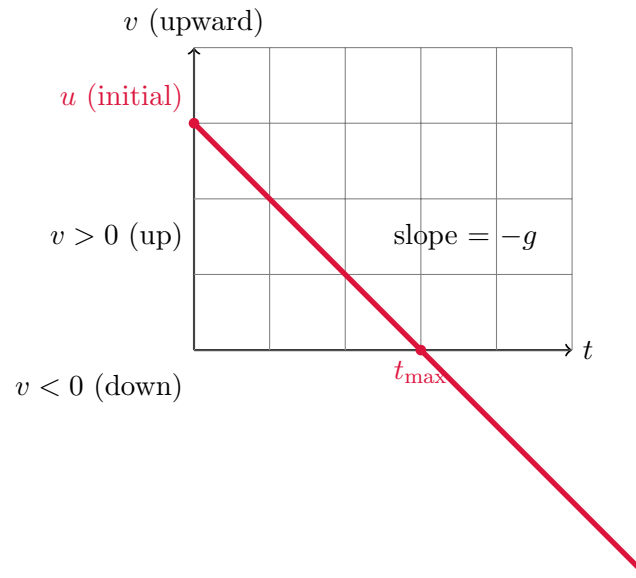
Area = displacement, Slope = acceleration

Position-Time: Constant Velocity vs Acceleration

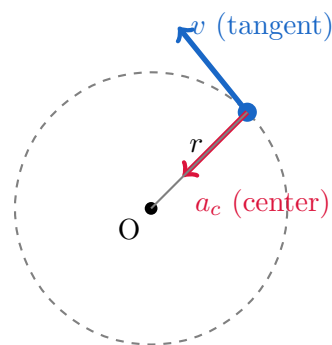


Constant velocity With acceleration

Projectile Motion: Velocity Under Gravity



Circular Motion: Velocity and Centripetal Acceleration



MOST IMPORTANT FORMULAS AT A GLANCE

Concept	Key Formula
1st Equation of Motion	$v = u + at$
2nd Equation of Motion	$s = ut + \frac{1}{2}at^2$
3rd Equation of Motion	$v^2 = u^2 + 2as$
Max Height (gravity)	$H = \frac{u^2}{2g}$
Time of Flight	$T = \frac{2u}{g}$
Free Fall (distance)	$h = \frac{1}{2}gt^2$
Relative Velocity	$v_{AB} = v_A - v_B$
Linear Velocity (circular)	$v = r\omega$
Centripetal Acceleration	$a_c = \frac{v^2}{r} = r\omega^2$

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