# KINEMATICS UNIT REVIEW

## WHAT MUST BE AUTOMATIC

- **The derivative ladder:** x(t) → v = dx/dt → a = dv/dt, power rule term by term, units riding every step (m → m/s → m/s²).
- **The accumulation table:** v-t strips are (m/s)(s) = m → displacement; a-t strips are (m/s²)(s) = m/s → velocity CHANGE. Add the initial value yourself.
- **The kinematic equations and their license:** valid only while a is constant — check by differentiating. Derived by accumulating a rectangle, then a ramp.
- **Signs:** v and a same sign → speeding up. At a turnaround v = 0 while a ≠ 0.
- **Free fall:** a = –g = –9.8 m/s² (up positive), written once, algebra carries it.
- **Projectiles:** r(t) componentwise — constant-v in x, free-fall in y, one shared clock. Speed = √(vx² + vy²), never zero mid-flight.

SELF-TEST **Sixty-Second Ladder — one line each**

No partial work needed — these should be reflexes by now. (Meters and seconds throughout.)

| | |
|---|---|
| 1. x(t) = 5t² + 3t. Find v at t = 2 s. | |
| 2. What quantity accumulates under an a-t graph? Prove it with the units of one strip. | |
| 3. v(t) = 7 – 4t. Are the kinematic equations legal for this motion? How do you know? | |
| 4. A projectile at the top of its arc has vx = 9 m/s. What is its speed there? | |
| 5. x(t) = t³ – 12t (t ≥ 0). When is the particle momentarily at rest? | |
| 6. v(t) = 6t². Find the displacement from t = 0 to t = 2 s. | |

**The three review traps:** forgetting $+v_0$/$+x_0$ after an accumulation; using a kinematic equation across a phase change or on variable a; and reading "negative acceleration" as "slowing down" without checking v's sign.

## SYNTHESIS FRQ — EVERY SKILL AT ONCE

AP FRQ · SYNTHESIS **Off the Cliff, One Last Time**

A ball rolls off a 29.4 m cliff moving horizontally at 12 m/s. Take the base of the cliff as the origin, x horizontal in the direction of motion, y upward, t = 0 at launch.

**(a)** Write the position vector r(t) — both components, with the numbers in place.

**(b)** Differentiate to get v(t), and state what each component is doing physically.

**(c)** Find the landing time and the landing distance from the cliff base.

**(d)** Find the impact speed from the components.

**(e)** Sketch x-t, y-t, and $v_y$-t for the flight, and justify the shape of $v_y$-t from the ball's acceleration in one sentence.

# TEST-STYLE PRACTICE MIX

### P1 Braking (no clock)

A car moving at 26 m/s stops in 65 m. Find the magnitude of its (constant) acceleration, and state which kinematic equation you chose and why.

### P2 Up and Down

A ball is thrown straight up at 24.5 m/s and caught at the same height. Find the total flight time and the maximum height. ($g = 9.8$ m/s².)

### P3 · CALC Derivative Ladder

A particle's position is $x(t) = 2t^3 - 6t$ (meters, seconds). Find **(a)** its velocity at $t = 2.0$ s and **(b)** its acceleration at $t = 2.0$ s. State the units of each coefficient in $x(t)$.

### P4 · CALC Accumulation Ladder

A sled has $a(t) = 3t^2$ (m/s², seconds) and $v_0 = 4.0$ m/s. Find its velocity at $t = 2.0$ s. Write the units of one strip before you integrate, and name what you accumulated.