

Reading Motion Graphs: Position, Velocity, Acceleration



Course purpose: interpret position–time, velocity–time, and acceleration–time graphs for one-dimensional motion.



Roadmap:

- Decode shape, slope, and area
- Connect the three graphs into one motion story
- Avoid the misreadings physics education research documents most often



Why it matters: lab reports, exams, introductory physics and engineering coursework.

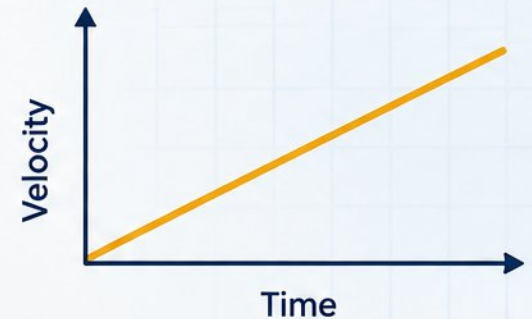
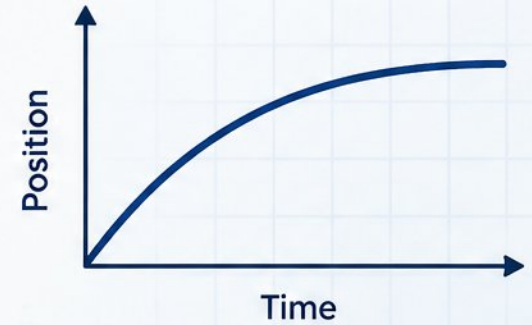


How to use this training:

- Work the paired graph examples before checking answers
- Run the self-checks at the end of each section



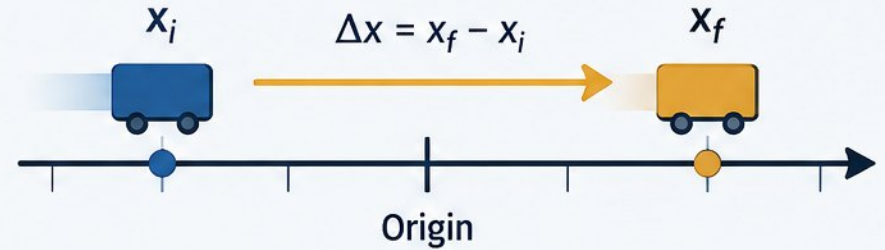
Ground rule: always check axis labels, units, and scale first.



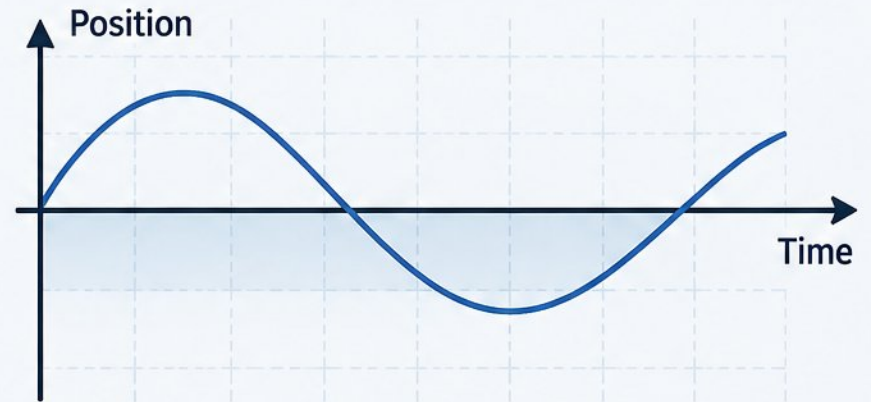
Position, Displacement, and Sign Conventions

- 1 Position is location relative to a chosen origin; displacement is $\Delta x = x_f - x_i$ in meters
- 2 Distance traveled is path length (scalar); displacement is a vector with direction
- 3 Choose a positive direction first; origin shifts graph values, not physical conclusions
- 4 A position–time graph shows position, not the path's shape; below the axis means negative side
- 5 Key vocabulary: axes, origin, intercept, value at a time, coordinate, interval vs. point

Position and Displacement

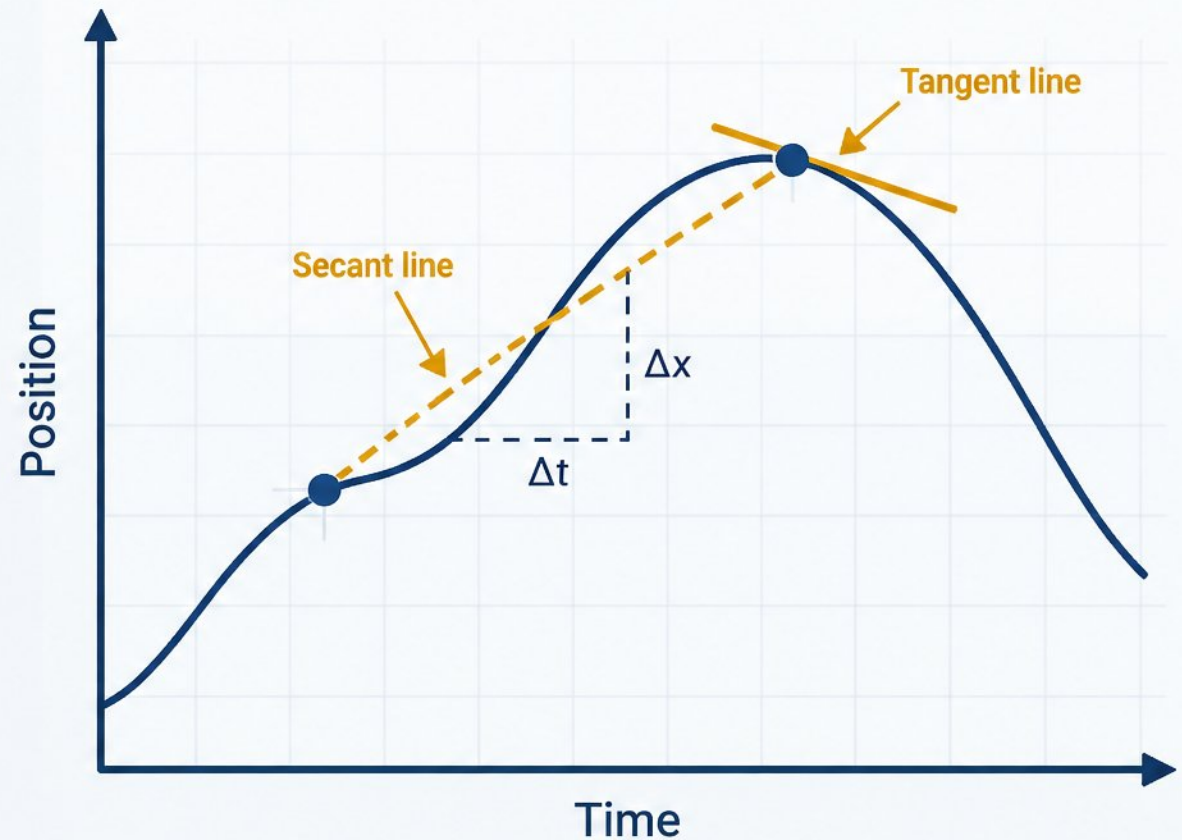


Position–Time Graph (Conceptual)



Slope as Velocity: Reading Position–Time Graphs

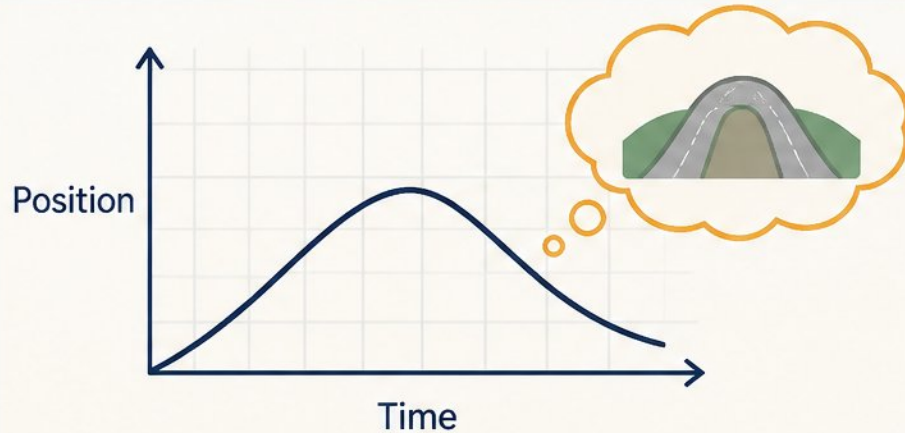
- Average velocity: slope of the secant line, $\Delta x / \Delta t$
- Instantaneous velocity: slope of the tangent line at one point
- Steeper slope = greater speed; zero slope = object at rest
- Slope sign gives direction: positive up, negative down
- Turning point: slope changes sign, velocity passes through zero



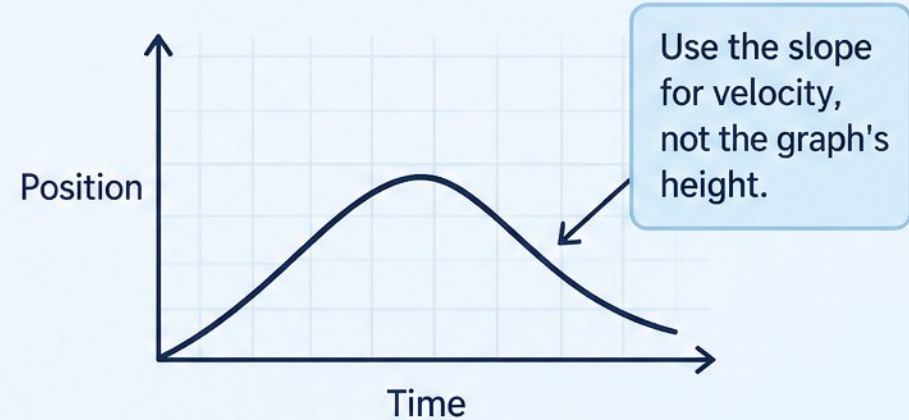
- Position-time curve
- - - Secant line (average velocity)
- Tangent line (instantaneous velocity)

Common Mistake: The Graph Is Not a Picture

Misinterpretation: A hill in the road?



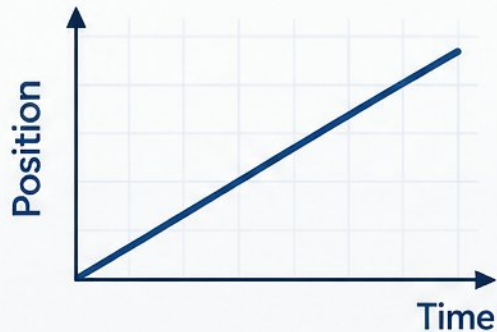
Correct interpretation: Read the graph.



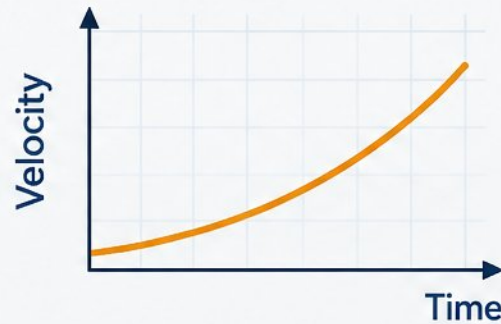
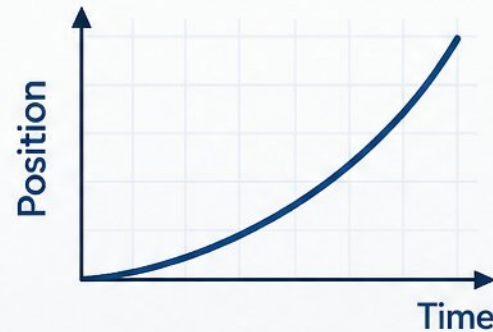
- 1 Graph-as-picture:** a 'hill' on a position–time graph is not a hill in the road.
- 2 Slope–height confusion:** use the slope for velocity, not the graph's height.
- 3 Interval–point confusion:** a time range asks for an interval, not one instant.
- 4 Dividing x / t for speed** only works for straight lines through the origin.
- 5 Reference-point confusion:** the origin is where $x = 0$, not the graph's last point.

From Position–Time to Velocity–Time

Straight Position Line



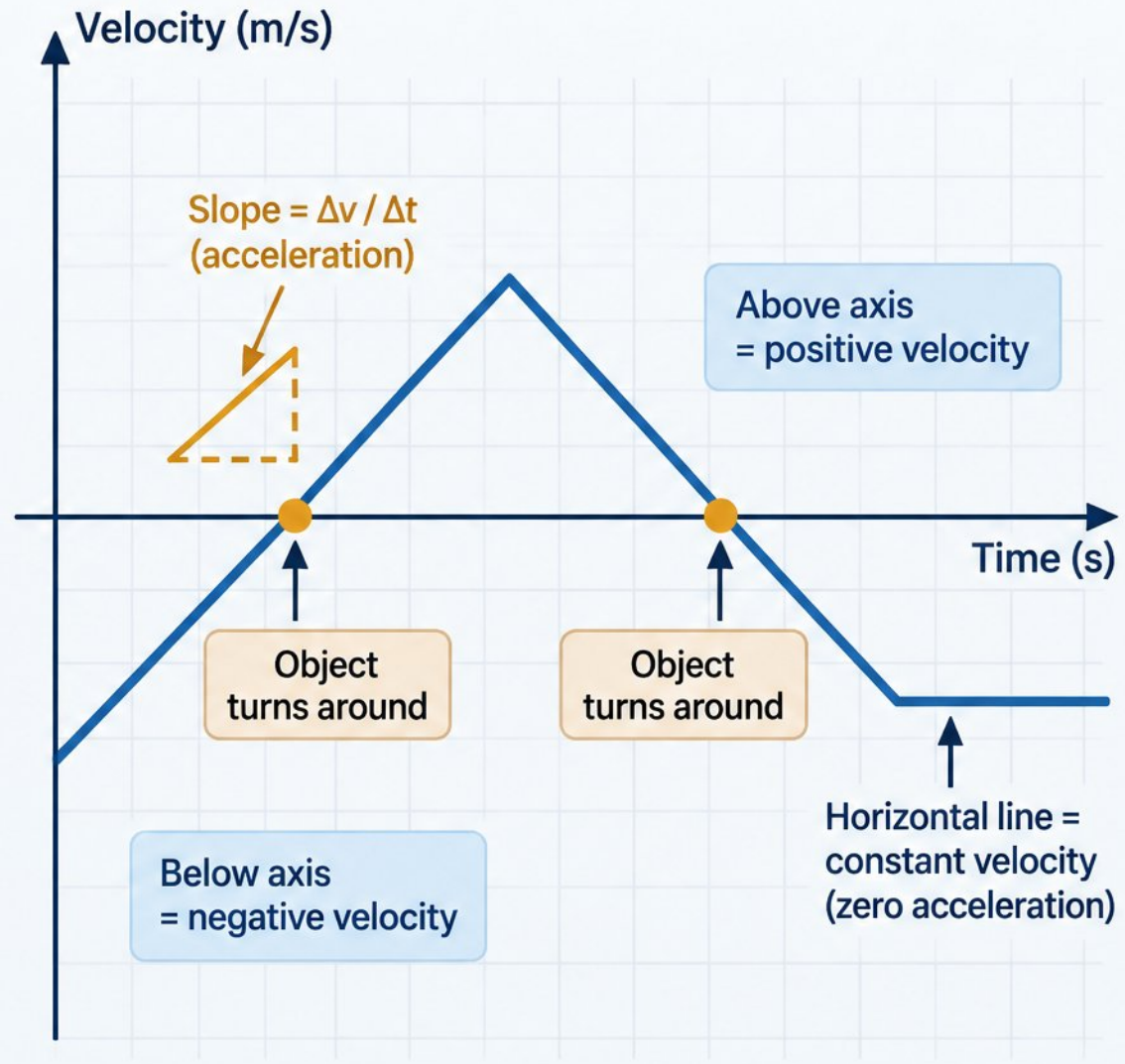
Curved Position Graph



- Velocity graph value = instantaneous velocity at that moment
- Value comes from the slope of the position–time graph
- Straight position line → horizontal velocity line
- Curved position graph → sloped or curved velocity graph
- Position slopes up: velocity above axis; down: below
- Shapes differ — same motion, different curves on different axes

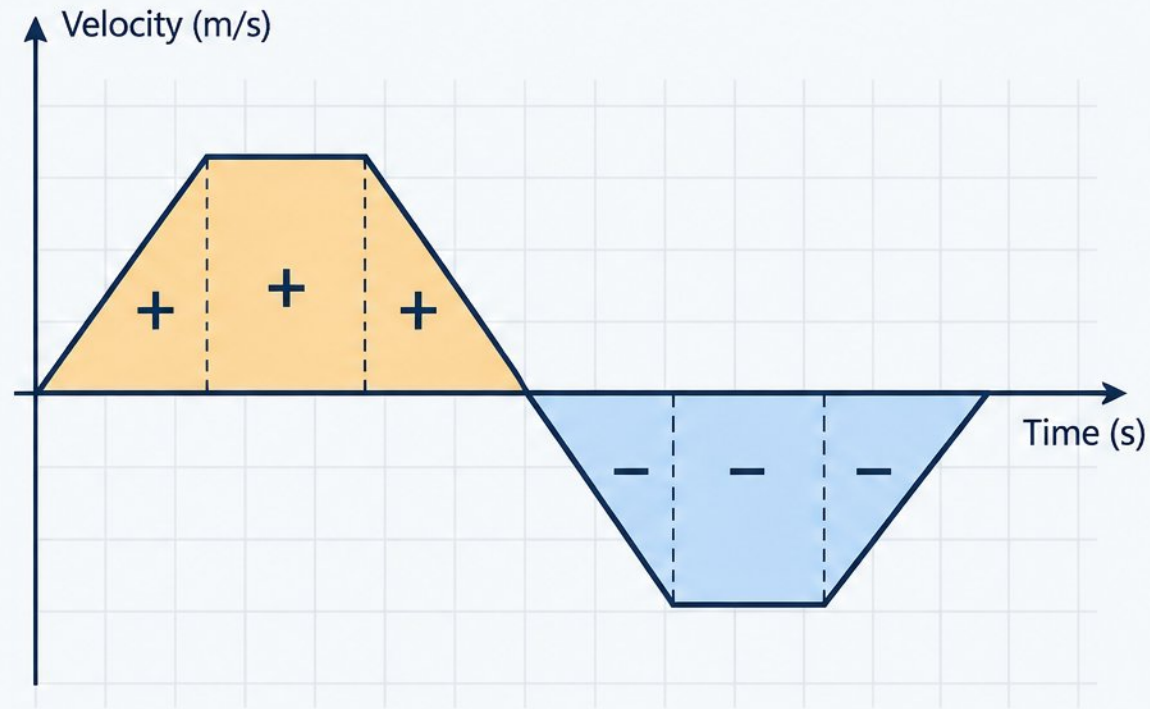
Velocity–Time Graphs: Slope, Direction, and Speed vs. Velocity

- Slope of a velocity–time graph = acceleration: slope = $\Delta v / \Delta t$, in m/s^2 .
- Graph value (height) gives direction and magnitude: above the axis is positive, below is negative.
- Speed is magnitude of velocity; negative velocity is motion in the opposite direction, not “slower.”
- Horizontal velocity line means constant velocity and zero acceleration — at rest only if on the axis.
- Where the velocity graph crosses the time axis, the object turns around.

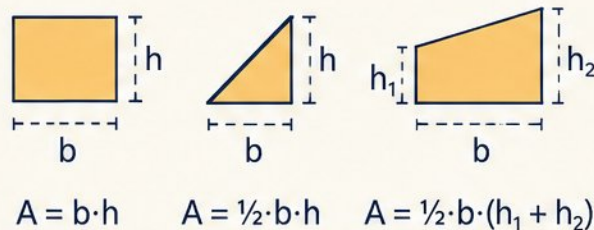


Area Under a Velocity–Time Graph: Displacement and Distance

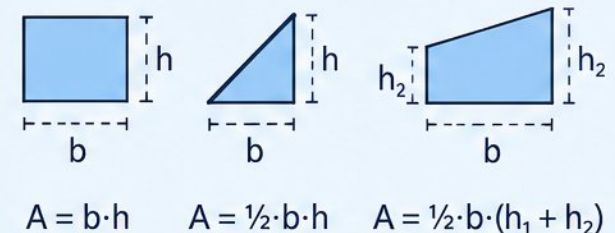
- Area between line and time axis = displacement; $(\text{m/s}) \times \text{s} = \text{m}$
- Split regions into rectangles, triangles, trapezoids:
 $A = b \cdot h$, $\frac{1}{2} \cdot b \cdot h$, $\frac{1}{2} \cdot b \cdot (h_1 + h_2)$
- Above axis: positive displacement.
Below axis: negative.
- Add signed areas for net displacement; add magnitudes for total distance
- Equal + and – areas cancel: net displacement zero, but motion occurred



Areas above the time axis (positive)



Areas below the time axis (negative)



Acceleration–Time Graphs and the Slope of Velocity

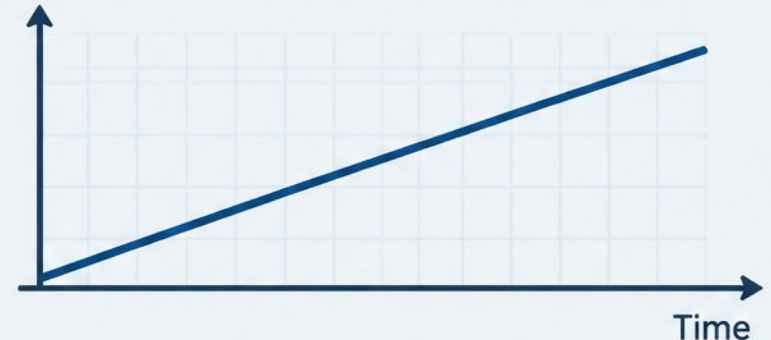
- Acceleration is the rate of change of velocity; on a v - t graph it is the slope
- On an a - t graph, the value itself is the acceleration
- Constant acceleration = horizontal a - t line + straight sloped v - t line
- Zero acceleration means constant velocity: rest or steady motion
- a - t graph alone cannot reveal direction of motion; check the v - t graph

Acceleration vs. Time (a - t)



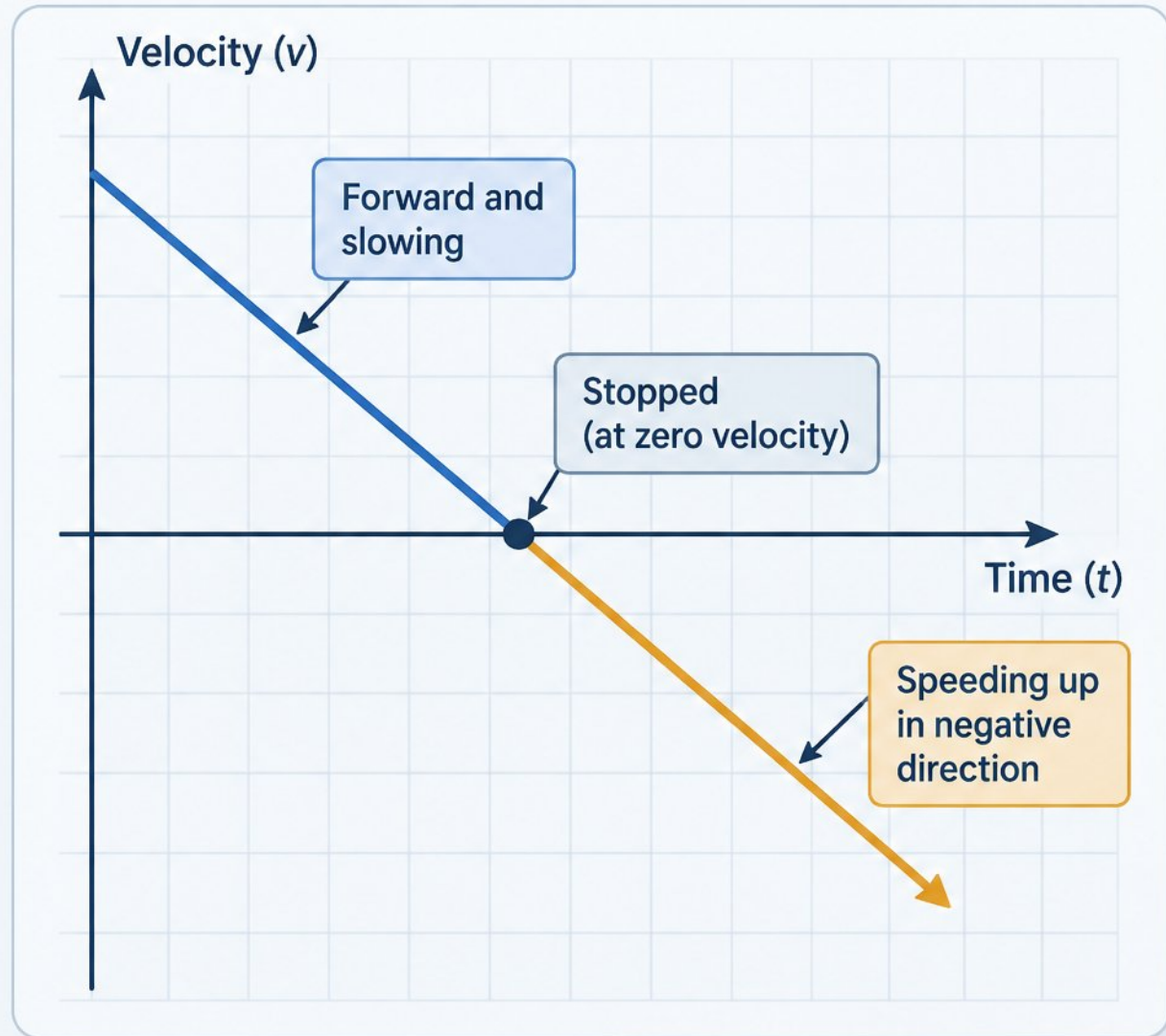
Slope = Acceleration

Velocity vs. Time (v - t)

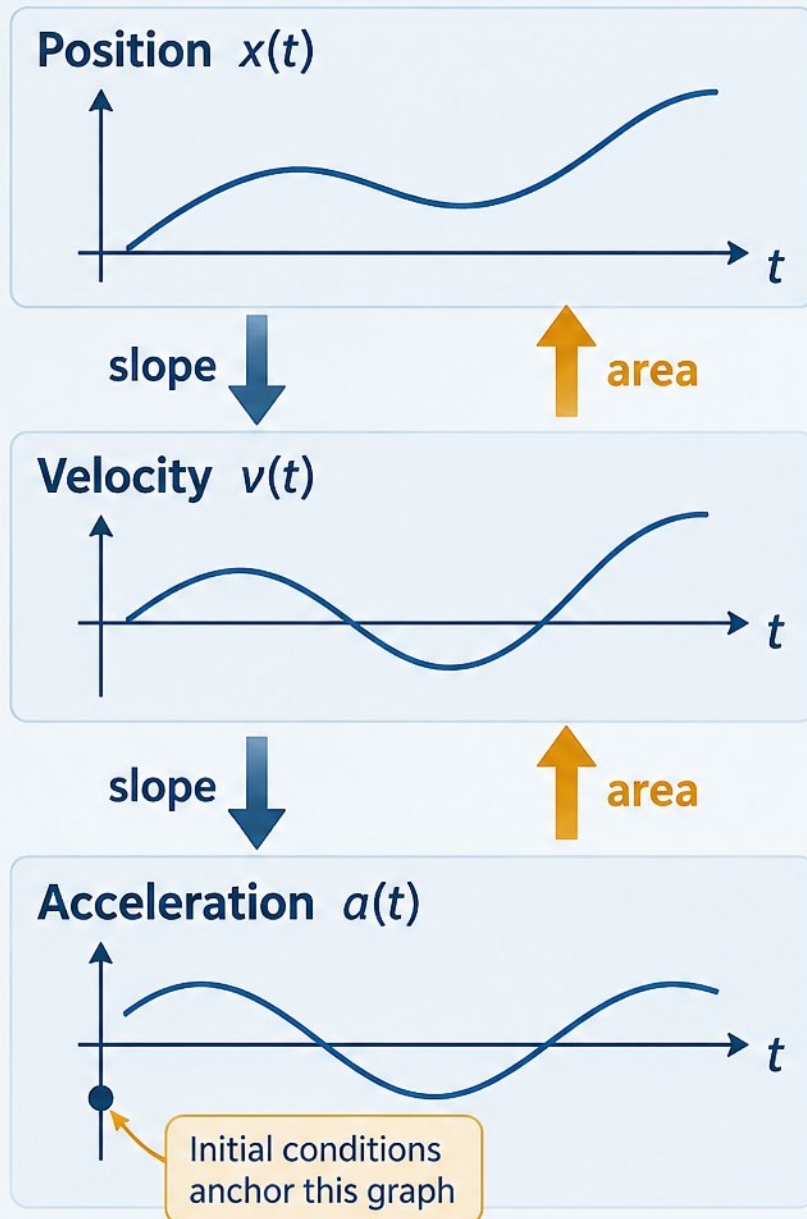


Speeding Up, Slowing Down, and Turning Around

- Same sign of v and a = speeding up; opposite signs = slowing down
- Visual check: line heading toward time axis = slowing; away = speeding up
- Turn-around: velocity crosses zero; acceleration usually is not zero there
- Read velocity value and slope together; one alone misleads
- Worked sequence: forward and slowing → stop → speeding up in negative direction



Graph Translation: Slope Down, Area Up

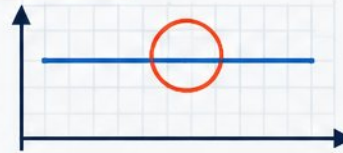


- **Downward chain:** slope of position gives velocity; slope of velocity gives acceleration.
- **Upward chain:** area under acceleration gives Δv ; area under velocity gives Δx .
- Going upward needs **initial conditions** to anchor each new graph.
- **Consistency check:** slope of one graph equals value of the next.
- **Sign check:** positive and negative areas must agree across all three graphs.

Misreadings That Persist: A Diagnosis Checklist

- 1** Velocity–acceleration confusion: constant velocity drawn with nonzero acceleration

Incorrect



Correct

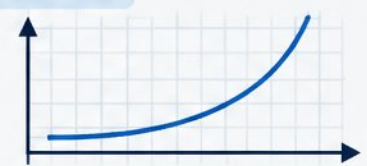


- 2** Mismatched shapes: all three graphs sketched with basically the same shape

Incorrect

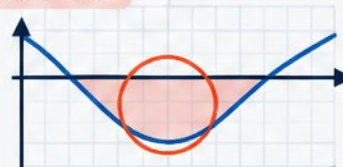


Correct

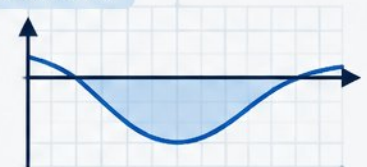


- 3** Area below the axis read as positive, corrupting net displacement

Incorrect



Correct



- 4** Axis labels, units, or rescaled grid ignored — wrong slopes and areas

Incorrect



Correct



- 5** Assuming positive acceleration always means speeding up; acceleration alone shows no direction

Incorrect



Correct



Instruction and Practice: Motion Sensors and Graph Matching



Motion sensor plus graphing software: learners generate live position and velocity curves



Graph matching: show a target graph, describe the motion, reproduce it with a partner



Scaffold in order: single graph → position to velocity → full three-graph sketches



Fan carts and inclined tracks give clean acceleration and turnaround cases



Build in direction checks; teachers often overestimate student mastery

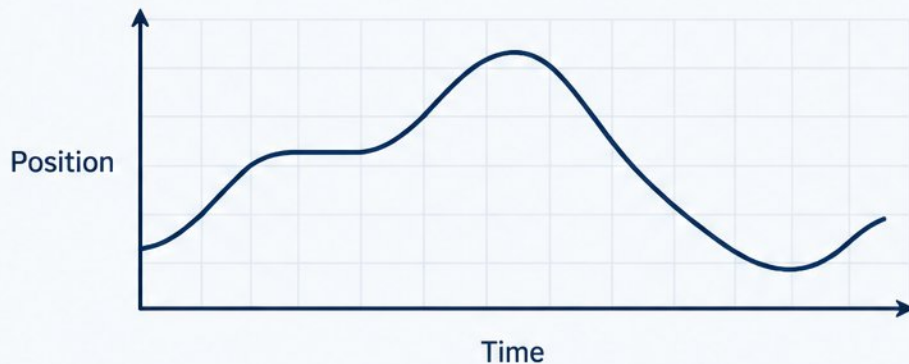


Guided Practice: Slope, Area, and Sign in Mixed Graph Sets

1

Practice 1

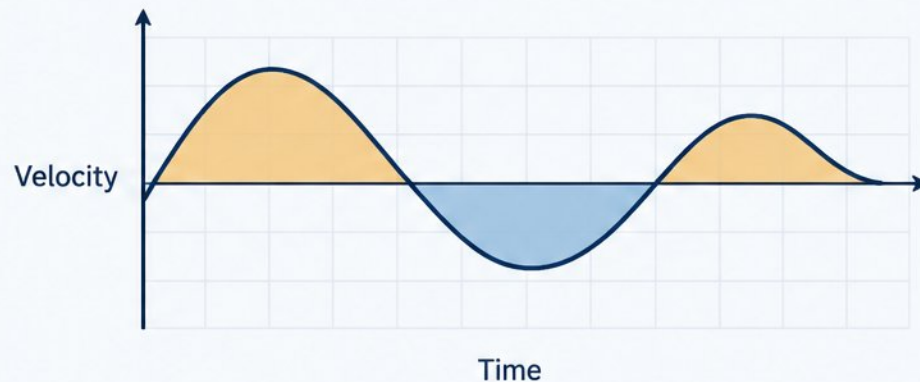
Position graph: at-rest intervals, fastest interval, direction changes, position values



2

Practice 2

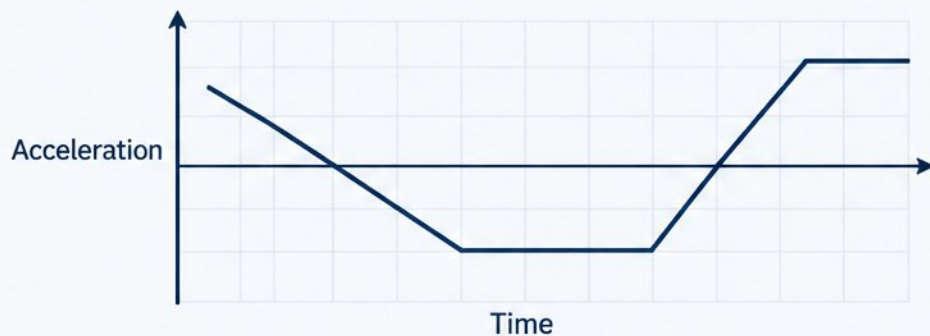
Velocity graph area: net displacement vs. total distance



3

Practice 3

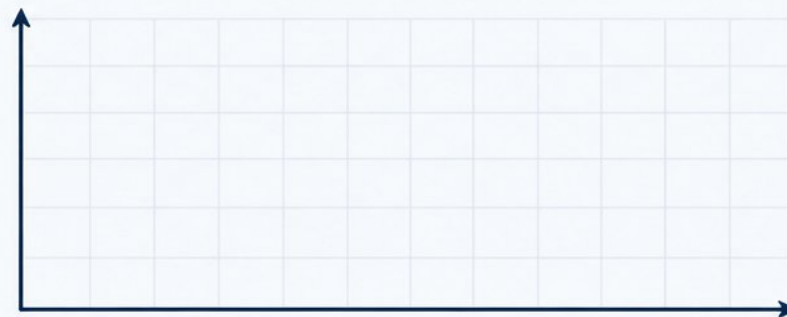
Acceleration reasoning: three linear segments, speeding up vs. slowing down



4

Practice 4

Translation: sketch velocity and acceleration from a described motion



Self-check

Labels, chosen strategy (slope vs. area vs. value), justified signs, second-graph check

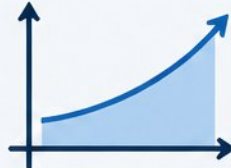


Your Action Plan: Next Steps After This Training

Four rules:



slope down



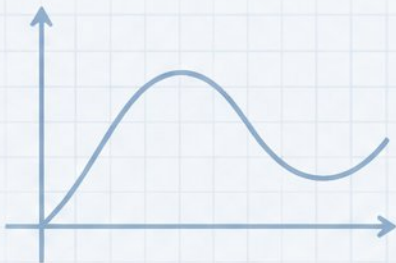
area up



sign carries direction



check consistency



Students

- Redo one mixed practice set from memory
- Then apply graph reading to a lab report or problem set



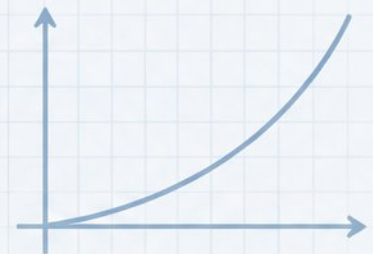
Educators

- Run a short diagnostic on velocity and acceleration direction
- Add one graph-matching activity per unit



Adult learners

- Master sign conventions and physical meaning first
- Go deeper: TUG-K items, motion sensors, constant-acceleration labs



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