

Answer Key: Interpreting Motion Graphs

Course: Physics (Grades 9–12) **Subject:** Science **For teacher use only** Science

How to use this key

Answers are grouped by section and question number. Many items are open-ended; accept any response that shows correct reasoning even if the wording differs. All calculations are worked out in full with units. Notes flag where more than one answer is defensible and list common misconceptions to watch for. Estimated grading time: ~6–8 min per packet. A calculator is allowed, but every value here is doable by hand.

Start Notice & Wonder grade for effort · ~2 min

1 Notice/wonder about Graph A.

Full credit for any reasonable notice + wonder. **Ideal:** Notice — "the line goes up, then flattens out, then goes up more steeply." Wonder — "why is the last part steeper?" Accept any on-topic pair. *Science note (not required):* the changing steepness (slope) shows the object's velocity changing between segments.

2 What a flat line means on a position–time graph.

Accept any reasonable prior idea. **Target:** a horizontal (flat) line on a position–time graph means the position is **not changing**, so the object is **stopped** (velocity = 0). Do not penalize an incomplete first idea here — this is a warm-up, and Q9 revisits it directly.

Build Read the Science ~1 min

3 Graph A, segment 2 (4 s to 7 s).

During segment 2 the position stays at **40 m** — the line is flat — so Object A is **stopped (not moving)** from 4 s to 7 s. The slope of that segment is **0**, which equals a velocity of **0 m/s**. (Accept "at rest," "parked," "position not changing.")

Apply Use the Graphs ~3 min

4 Read values off Graph A.

- a) $t = 0 \text{ s} \rightarrow 0 \text{ m}$
- b) $t = 4 \text{ s} \rightarrow 40 \text{ m}$
- c) $t = 7 \text{ s} \rightarrow 40 \text{ m}$ (unchanged from $t = 4 \text{ s}$ — the flat segment)
- d) $t = 10 \text{ s} \rightarrow 100 \text{ m}$

5 Average velocity, Graph A segment 1 (0 s $\rightarrow$ 4 s) (worked).

average velocity = $\Delta\text{position} \div \Delta\text{time} = (40 \text{ m} - 0 \text{ m}) \div (4 \text{ s} - 0 \text{ s})$
 $= 40 \text{ m} \div 4 \text{ s} = 10 \text{ m/s}$.

(Full credit for the formula, correct substitution with units, and 10 m/s.)

6 Average velocity of segment 3 (7 s → 10 s) and which is faster (worked).

average velocity (seg 3) = $\Delta \text{position} \div \Delta \text{time} = (100 \text{ m} - 40 \text{ m}) \div (10 \text{ s} - 7 \text{ s})$
= $60 \text{ m} \div 3 \text{ s} = \mathbf{20 \text{ m/s}}$.

Segment 3 (20 m/s) is faster than segment 1 (10 m/s). You can tell because segment 3 is the **steeper** line — on a position–time graph a steeper slope means a greater velocity. *Defensible alternate:* a student who reports segment 3 is twice as fast (20 vs. 10 m/s) earns full credit.

7 Acceleration, Graph B segment 2 (4 s → 8 s) (worked).

acceleration = $\Delta v \div \Delta t = (30 \text{ m/s} - 10 \text{ m/s}) \div (8 \text{ s} - 4 \text{ s})$
= $20 \text{ m/s} \div 4 \text{ s} = \mathbf{5 \text{ m/s}^2}$.

(Full credit for the formula, correct substitution with units, and 5 m/s^2 . Accept $+5 \text{ m/s}^2$; the sign shows speeding up.)

8 Match the motion to the graph.

a) **A** — Graph A (position–time) shows a flat middle section (stopped, 4–7 s) followed by a steeper rise (segment 3), i.e., covering ground faster than before.

b) **B** — Graph B (velocity–time) is the one whose *velocity itself* changes: steady 10 m/s, then rising to 30 m/s, then steady 30 m/s. *Watch:* students who pick the wrong graph often confuse a rising position line with rising velocity; steer them to which axis says "velocity."

9 Error analysis — segment 2 of Graph A (fixed).

The mistake: the student confused a line that is **high on the graph** (a large *position* value) with a line that is **steep** (a large *velocity*), and read a flat line as "fast and steady."

Correct interpretation: in segment 2 the line is **horizontal at 40 m** from 4 s to 7 s. A flat line on a **position–time** graph means the position is **not changing**, so the slope is 0 and the object is **stopped** — velocity = **0 m/s**. Being "high up" (at 40 m) only tells you the object is 40 m from the start, not that it is moving fast. *Full credit* for naming the confusion (position/height vs. slope/velocity) and stating the object is stopped at 0 m/s.

Explain CER (Q10) ~2 min

10 Describe Object A's motion over 10 s.

Model answer. Claim: Object A first moves forward at a steady 10 m/s, then stops and stays still for a few seconds, and finally moves forward again even faster, at 20 m/s. **Evidence:** (1) From $t = 0 \text{ s}$ to $t = 4 \text{ s}$ the position rises from 0 m to 40 m. (2) From $t = 4 \text{ s}$ to $t = 7 \text{ s}$ the position stays at 40 m, and from $t = 7 \text{ s}$ to $t = 10 \text{ s}$ it rises from 40 m to 100 m. **Reasoning:** The slope of a position–time graph equals velocity. Segment 1's slope is $40 \text{ m} \div 4 \text{ s} = 10 \text{ m/s}$; the flat segment 2 has slope 0, so the object is stopped; segment 3's slope is $60 \text{ m} \div 3 \text{ s} = 20 \text{ m/s}$, the steepest, so it is the fastest part.

Defensible alternates: Accept any claim that names the three phases in order (move, stop, move faster) supported by two correct position–time readings and slope-based reasoning. A student may cite the 10 m/s and 20 m/s slopes directly as evidence.

CER scoring rubric (3 points)

Score	Claim	Evidence	Reasoning
3	Clear claim naming all three phases of Object A's motion in order (move, stop, move faster).	Two accurate position–time readings from Graph A (e.g., 0 m at 0 s and 40 m at 4 s; 40 m held to 7 s; 100 m at 10 s).	Correctly uses "slope of a p–t graph = velocity" to justify each phase, including flat = stopped and steeper = faster.

Score	Claim	Evidence	Reasoning
2	Claim stated, mostly clear; may miss one phase.	One solid reading, or two with a minor error.	Some correct slope-to-velocity linkage but incomplete or a small misconception.
1	Vague or partly correct claim.	Evidence weak, non-numeric, or not from Graph A.	Little or flawed reasoning; slope not tied to velocity.
0	No/incorrect claim.	No evidence.	No reasoning.

Close ACE ~1 min

ACE Articulate / Connect / Extend.

Articulate: accept any accurate statement, e.g., "on a position–time graph the slope is the velocity; on a velocity–time graph the slope is the acceleration."

Connect: a segment with constant velocity is Graph A segment 2 (flat at 40 m, velocity 0 m/s), or Graph B segment 1 (flat at 10 m/s) or segment 3 (flat at 30 m/s). The named values should match the flat line.

Extend: any coherent three-step trip with a matching p–t description (e.g., "walk steadily = straight rising line; wait at a corner = flat line; run = steeper rising line"). More than one answer is defensible.

Extend Early finisher & block extension (optional)

EF Sketch your own motion graph.

Reward a labeled position–time graph (time axis in seconds, position axis in meters) that includes at least one flat segment (stopped) and one segment visibly steeper than another, plus a sentence correctly identifying the steepest segment as the fastest and tying steepness to slope/velocity.

Block Displacement as area under Graph B (worked).

Total displacement = area under the v–t line, split into pieces:

- **Segment 1 (0–4 s):** rectangle = velocity $\times$ time = $10 \text{ m/s} \times 4 \text{ s} = 40 \text{ m}$.
- **Segment 2 (4–8 s):** velocity rises $10 \rightarrow 30 \text{ m/s}$ over 4 s.
rectangle (bottom) = $10 \text{ m/s} \times 4 \text{ s} = 40 \text{ m}$; triangle (top) = $\frac{1}{2} \times \text{base} \times \text{height} = \frac{1}{2} \times 4 \text{ s} \times (30 - 10) \text{ m/s} = \frac{1}{2} \times 4 \text{ s} \times 20 \text{ m/s} = 40 \text{ m}$.
segment 2 area = $40 \text{ m} + 40 \text{ m} = 80 \text{ m}$. (Equivalent: trapezoid = $\frac{1}{2} \times (10 + 30) \text{ m/s} \times 4 \text{ s} = 80 \text{ m}$.)
- **Segment 3 (8–10 s):** rectangle = $30 \text{ m/s} \times 2 \text{ s} = 60 \text{ m}$.

Total displacement = $40 \text{ m} + 80 \text{ m} + 60 \text{ m} = 180 \text{ m}$.

Why area = distance: velocity $\times$ time = distance for each thin strip of the graph; adding all the strips (the area under the line) adds up all the little distances, giving the total displacement. (Full credit for correct piece areas with units and a total of 180 m.)

Watch Common misconceptions

- **Confusing a position–time graph with a velocity–time graph.** On a p–t graph the slope is velocity; on a v–t graph the slope is acceleration and the *height* is velocity. Students often read Graph A's rising line as "velocity rising" — it is *position* rising. Always ask "what does the vertical axis say?"
- **"A horizontal line on a position–time graph means constant speed."** No — a flat line on a **p–t** graph means the position is not changing, so the object is **stopped** (velocity 0). A flat line means constant speed only on a **v–t** graph.
- **"Higher on the graph = faster."** Height on a p–t graph is *position* (how far from start), not speed. Speed is the **steepness** (slope). This is the exact error fixed in Q9.

- **"Steeper always means more of everything."** Steeper does mean faster on a p–t graph (greater velocity) and greater acceleration on a v–t graph — but students should name *which* quantity, and keep units straight (m/s vs. m/s²).
- **Dropping units.** Velocity is m/s, acceleration is m/s². Watch for answers like "5" without units in Q7, or mixing them up.

Teacher follow-up based on likely errors

If many students read Graph A's flat segment as "moving fast" (Q3, Q9), re-teach that on a position–time graph a flat line = stopped and steepness = velocity, using the board to contrast "high" with "steep." If the slope calculations in Q5–Q7 are shaky, model rise-over-run aloud with units ($\Delta\text{position} \div \Delta\text{time}$ for velocity; $\Delta v \div \Delta t$ for acceleration). If students pick the wrong graph in Q8, drill "read the vertical axis first." The Q9 error-analysis and the CER (Q10) responses show who can distinguish position from velocity — the highest-value idea to reinforce next class.

HS_PHYS_MotionGraphs_01 — Interpreting Motion Graphs Teacher Answer Key