

Interpreting Motion Graphs

Course: Physics (Grades 9–12) **Subject:** Science **Time:** ~50 min standard · ~90 min block **Work mode:** Independent · pencil only Science

Start Here

This is a **paper investigation**. You will read two motion graphs, pull numbers off the axes, and use them to describe and calculate how objects move — all with a pencil. You do **not** need a lab, a computer, or any materials besides this packet, a pencil, and (if you like) a **calculator**. There are **no hazards** — nothing is measured, mixed, or built. Work by yourself. The arithmetic is chosen so you can do most of it by hand; a calculator is allowed but not required. Read values carefully off the graph gridlines, always keep your **units** (meters, seconds, m/s, m/s²), and write in complete sentences where you are asked to explain. If a question is hard, skip it, keep going, and come back. Reading a question quietly aloud to yourself is allowed and encouraged.

Start Notice & Wonder 5 min

Think about a car trip: sometimes the car is stopped at a light, sometimes it is cruising steadily, and sometimes it is speeding up. A graph can show all three.

1 Look ahead at **Graph A** (a position–time graph) on the next page. Without doing any math, write **one thing you notice** and **one thing you wonder** about how the line changes as time goes on.

2 On a graph of an object's position over time, what do you think a **flat (horizontal) line** means the object is doing? Give your best first idea — you will check it later.

Build Read the Science 8–12 min

Reading motion graphs: slope, area, and the formulas

Motion graphs turn a story of movement into a picture. Two kinds appear in this packet.

- **Position–time (p–t) graph:** time is on the horizontal axis, **position** (how far from a starting point, in meters) is on the vertical axis. The **slope** of the line equals the object's **velocity**. A **steeper** line means a **faster** speed; a **flat (horizontal)** line means the position is not changing — the object is **stopped** (velocity = 0). A line that slopes downward means the object is moving back toward the start.
- **Velocity–time (v–t) graph:** time is on the horizontal axis, **velocity** (in m/s) is on the vertical axis. Here the **slope** equals the **acceleration**. A flat line means constant velocity (zero acceleration); a line sloping up means speeding up. The **area under** the v–t line equals the **displacement** (how far the object traveled).

Slope = (change in the vertical value) ÷ (change in the horizontal value) = "rise over run." On a p–t graph, slope = **velocity**. On a v–t graph, slope = **acceleration**.

Speed formula: speed = distance ÷ time (units: m ÷ s = m/s). Average velocity over a segment uses the same idea: average velocity = (change in position) ÷ (change in time) = $\Delta\text{position} \div \Delta\text{time}$.

Acceleration formula: acceleration = (change in velocity) $\div$ (change in time) = $\Delta v \div \Delta t$ (units: (m/s) $\div$ s = m/s²).

Displacement from a v–t graph: displacement = area under the line. For a rectangle, area = velocity $\times$ time. For a triangle, area = $\frac{1}{2} \times \text{base} \times \text{height}$. Add the pieces together to get the total displacement (in meters).

Word Bank

position

where an object is, measured as its distance from a starting point (in meters, m).

velocity

how fast position is changing, with a direction (in m/s); the slope of a position–time graph.

acceleration

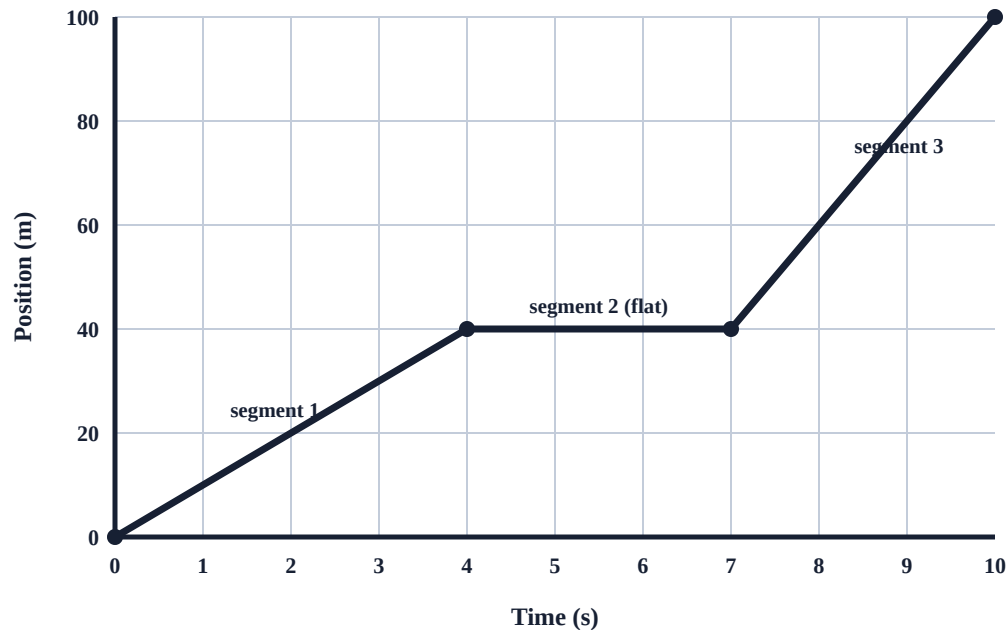
how fast velocity is changing (in m/s²); the slope of a velocity–time graph.

slope

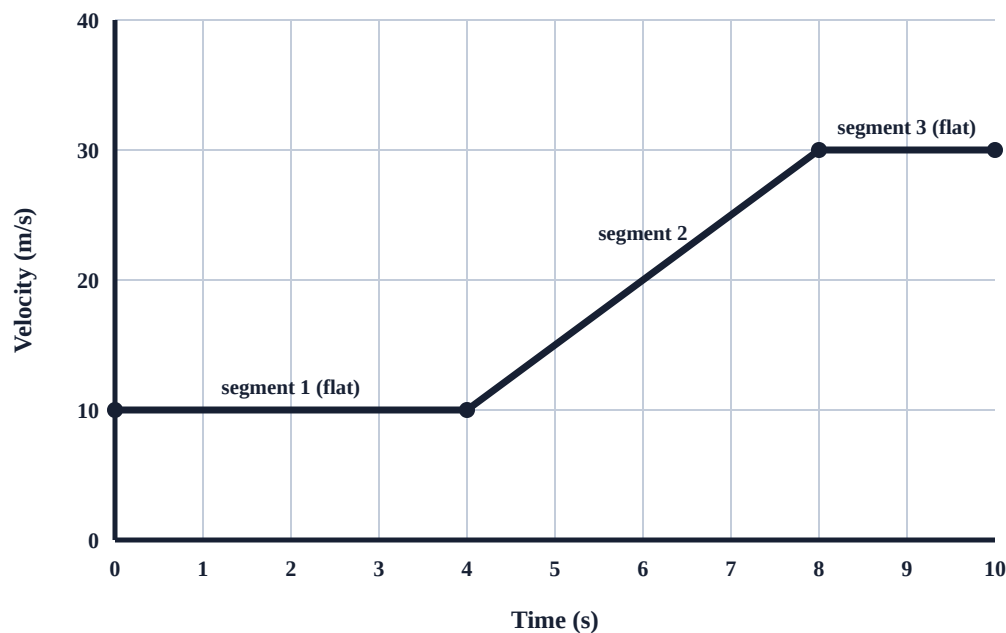
rise $\div$ run — the steepness of a line; equals velocity on a p–t graph and acceleration on a v–t graph.

displacement

the overall change in position (in meters); on a v–t graph it equals the area under the line.



Graph A. A **position–time** graph for **Object A**. Segment 1 (0–4 s) rises from 0 to 40 m; segment 2 (4–7 s) is flat at 40 m; segment 3 (7–10 s) rises from 40 to 100 m. The slope of each segment is the object's velocity there; the labels and gridlines — not color — carry the meaning, so the graph reads clearly in grayscale.



Graph B. A **velocity–time** graph for **Object B**. Segment 1 (0–4 s) is flat at 10 m/s; segment 2 (4–8 s) rises from 10 to 30 m/s; segment 3 (8–10 s) is flat at 30 m/s. On a v–t graph the slope of a segment is the acceleration, and the area under the line is the displacement.

3Using **Graph A**, describe in one sentence what Object A is doing during **segment 2** (from 4 s to 7 s), and say what the slope of that segment equals.

Apply Use the Graphs 20–25 min

Read values straight off the gridlines of Graph A and Graph B. Show your work and keep your **units** in every step. (These are original graphs for this packet.)

4**Read values off Graph A.** Fill in the position of Object A at each time.

- a) At $t = 0$ s, position = _____ m
- b) At $t = 4$ s, position = _____ m
- c) At $t = 7$ s, position = _____ m
- d) At $t = 10$ s, position = _____ m

5**Average velocity from a p–t segment.** Use Graph A, segment 1 (0 s to 4 s). Average velocity = (change in position) $\div$ (change in time). Show the formula, put in the numbers with units, and give the answer in m/s.

6**Compare two slopes on Graph A.** Find the average velocity of **segment 3** (7 s to 10 s) the same way, then state which is faster — segment 1 or segment 3 — and how you can tell from the **steepness** of the line.

7**Acceleration from a v–t segment.** Use Graph B, segment 2 (4 s to 8 s). Acceleration = $\Delta v \div \Delta t$ = (change in velocity) $\div$ (change in time). Show the formula, the numbers with units, and the answer in m/s^2 .

8**Match the motion to the graph.** Read each described motion and write **A** if it matches Graph A (position–time) or **B** if it matches Graph B (velocity–time). One statement is about a single segment; use the graphs to decide.

____ a) "The object is stopped for a while in the middle, then speeds up and covers ground faster than before." (Which graph shows a flat section, then a steeper rise?)

____ b) "The object moves at a steady 10 m/s, then steadily speeds up to 30 m/s, then holds 30 m/s." (Which graph shows velocity itself changing?)

9Error analysis — fix the mistake. A student looked at **Graph A** and wrote: "*During segment 2 (4 s to 7 s) the line is flat and high up on the graph, so the object must be moving very fast and steadily.*" This is wrong. In the box, explain **what the student confused** and give the **correct** interpretation of segment 2, including the velocity value.

Explain Claim–Evidence–Reasoning 7–10 min

Question 10. Using **Graph A**, write a short explanation describing Object A's motion over the full 10 seconds. Write a **claim** that states, in order, what the object does in each of the three segments; support it with **two pieces of evidence** (specific position and time values read from Graph A); then explain your **reasoning** using the idea that the slope of a position–time graph equals velocity.

Sentence stems you may use: "Object A first..., then..., and finally..." · "One piece of evidence is that at $t =$ ____ s the position is ____ m." · "A second piece of evidence is..." · "This shows the velocity because the slope of a position–time graph equals..."

Claim

Evidence (two pieces, with numbers from Graph A)

Reasoning

Close ACE Wrap-Up 5 min

Articulate

In your own words, explain what the **slope** of a line tells you on a position–time graph versus on a velocity–time graph.

Connect

Point to one segment of Graph A or Graph B where the object's velocity is **not changing**, and name the values that show it.

Extend

Describe a **new** real-life trip (walking, biking, driving) in three steps, and say what the shape of its position–time graph would look like for each step.

Continue Early Finisher & Block Extension optional · block ~+30 min

If you finish early (no new materials needed):

Sketch your own motion graph. On the back of this page, invent a short trip and draw its own **position–time** graph with a labeled time axis (seconds) and position axis (meters). Include at least one segment where the object is stopped (a flat line) and one segment that is steeper than another. Then write one sentence naming which segment is fastest and how the slope shows it.

Block-period extension — displacement as area under a v–t graph:

Using **Graph B**, find the **total displacement** of Object B over the full 10 s by calculating the **area under the line**. Break the area into pieces: segment 1 (0–4 s) is a rectangle; segment 2 (4–8 s) is a rectangle plus a triangle (velocity rises from 10 to 30 m/s); segment 3 (8–10 s) is a rectangle. Show the area of each piece with units (area = velocity $\times$ time for a rectangle; area = $\frac{1}{2} \times$ base $\times$ height for a triangle), then add them to get the total displacement in meters. Finally, state why the area under a v–t graph equals the distance the object traveled.

Turn in: Hand in this whole packet with your name, class period, and date filled in. Make sure questions 1–10 and the ACE box are answered. The early-finisher sketch and the block-period area calculation are optional but turn them in too if you did them.

HS_PHYS_MotionGraphs_01 — Interpreting Motion Graphs Student Packet