

Graphical Analysis of Motion

PH11-8

ORIENTATION

Lesson goal: build accurate physics fluency for graphical analysis of motion and use that fluency to support clear HSC-style scientific writing.

This page is materialised into the MentorMind course shell from existing teaching, textbook, and eduKG material. Use it as the main lesson surface; use the tutor for targeted repair, worked examples, and concise writing feedback.

SYLLABUS INQUIRY QUESTION

- How is the motion of an object moving in a straight line described and predicted?

From The Feynman Lectures on Physics, Vol I, Chapter 9:

Graphs are compact summaries of motion. A single line can show both the story of an object and the mathematics used to predict it.

LEARNING OBJECTIVES

- Interpret displacement-time, velocity-time, and acceleration-time graphs.
 - Relate gradients and areas to physical quantities.
 - Recognise uniform and non-uniform motion from graph shapes.
 - Use graph features to describe motion in words.
-

CONTENT

Displacement-time graphs

The **gradient** gives velocity. A straight line means constant velocity. A curve means the velocity changes.

Hover over the graph below to see how the gradient at each point relates to instantaneous velocity.

Reading the graph:

FEATURE	PHYSICAL MEANING
Gradient at a point	Instantaneous velocity
Positive gradient	Moving in positive direction
Negative gradient	Moving in negative direction
Zero gradient	Momentarily at rest
Straight line	Constant velocity
Curve	Changing velocity

Velocity-time graphs

The **gradient** gives acceleration. The **area** under the curve gives displacement.

Key relationships:

FEATURE	PHYSICAL MEANING
Gradient	Acceleration
Area above time axis	Positive displacement
Area below time axis	Negative displacement
Total area (signed)	Net displacement
Horizontal line	Constant velocity (zero acceleration)

Acceleration-time graphs

The **area** under the curve gives the change in velocity. A horizontal line indicates constant acceleration.

For constant acceleration, the a-t graph is a horizontal line, and the area equals $\Delta v = a \times t$.

Graph Comparison: Three Types of Motion

The table below summarizes what different graph shapes mean for each type of motion:

MOTION TYPE	S-T GRAPH	V-T GRAPH	A-T GRAPH
At rest	Horizontal line	Line at $v = 0$	Line at $a = 0$
Constant velocity	Straight line (slope $\neq 0$)	Horizontal line	Line at $a = 0$
Constant acceleration	Parabola	Straight line	Horizontal line
Changing acceleration	Complex curve	Curve	Varying line

WORKED EXAMPLES

Example 1: Velocity from an s-t graph

A displacement-time graph is a straight line from $s = 0$ m at $t = 0$ s to $s = 30$ m at $t = 6$ s.

1. Gradient: $v = \frac{\Delta s}{\Delta t} = \frac{30-0}{6-0}$
2. $v = 5.0$ m/s
3. Motion is uniform in the positive direction.

Example 2: Acceleration from a v-t graph

A velocity-time graph rises linearly from 2 m/s to 14 m/s over 4.0 s.

1. $\Delta v = 14 - 2 = 12$ m/s
2. $a = \frac{12}{4.0} = 3.0$ m/s²
3. Acceleration is constant and positive.

Example 3: Displacement from a v-t graph

Velocity increases uniformly from 4 m/s to 10 m/s over 5.0 s.

1. Area is a trapezium: $s = \frac{(v_1+v_2)}{2} \times t$
2. $s = \frac{(4+10)}{2} \times 5.0 = 35 \text{ m}$
3. Displacement equals the area under the curve.

Interactive: Compare Motion Diagrams and Graphs

Below is a motion diagram showing an object decelerating. Compare it with the v-t graph above to see the relationship.

Connection to the v-t graph:

- The velocity arrows in the motion diagram correspond to the v-t graph values
- As dots get closer together, velocity decreases (shown in v-t graph)
- The object reverses direction when $v = 0$ (at $t = 4 \text{ s}$)

COMMON MISCONCEPTIONS

- **Misconception:** The height of a v-t graph gives displacement. **Correction:** Displacement is the *area* under the curve.
- **Misconception:** A flat s-t graph means acceleration is zero. **Correction:** It means velocity is zero.
- **Misconception:** A curved v-t graph always means non-uniform acceleration. **Correction:** Only a *changing gradient* indicates changing acceleration.

PRACTICE QUESTIONS

Easy (2 marks)

A straight-line s-t graph has gradient 3.0 m/s. State the velocity and describe the motion.

- Correct velocity (1)
- Motion description (1)

Answer: Velocity = 3.0 m/s. The object moves at constant velocity in the positive direction.

Medium (4 marks)

A v-t graph is a straight line from 0 m/s at 0 s to 12 m/s at 6 s. Calculate acceleration and displacement.

- Acceleration from gradient (2)
- Displacement from area (2)

Answer:

- $a = 12/6 = 2.0 \text{ m/s}^2$
- $s = \frac{1}{2} \times 6 \times 12 = 36 \text{ m}$ (area of triangle)

Hard (5 marks)

An a-t graph shows 2.0 m/s^2 for 3.0 s , then -1.0 m/s^2 for 2.0 s . The object starts at 5.0 m/s . Find final velocity and total displacement.

- Velocity change from area under a-t (2)
- Final velocity (1)
- Displacement from v-t construction or average velocity (2)

Solution:

Phase 1 (0-3 s):

- $\Delta v_1 = 2.0 \times 3.0 = 6.0 \text{ m/s}$
- v at end of phase 1: $5.0 + 6.0 = 11.0 \text{ m/s}$
- $s_1 = 5.0(3.0) + \frac{1}{2}(2.0)(3.0)^2 = 15 + 9 = 24 \text{ m}$

Phase 2 (3-5 s):

- $\Delta v_2 = -1.0 \times 2.0 = -2.0 \text{ m/s}$
- Final velocity: $11.0 - 2.0 = 9.0 \text{ m/s}$
- $s_2 = 11.0(2.0) + \frac{1}{2}(-1.0)(2.0)^2 = 22 - 2 = 20 \text{ m}$

Answers: Final velocity = 9.0 m/s , Total displacement = 44 m

MULTIPLE CHOICE QUESTIONS

Test your understanding with these interactive questions:

SUMMARY

- Graphs encode motion in gradients and areas.
- Straight lines indicate constant rates of change.
- Areas under v-t and a-t graphs produce displacement and velocity changes.

- Graph interpretation links visual data to equations.
-

SELF-ASSESSMENT

Check your understanding:

After studying this section, you should be able to:

- Calculate velocity from the gradient of an s-t graph
 - Calculate acceleration from the gradient of a v-t graph
 - Calculate displacement from the area under a v-t graph
 - Distinguish between uniform and non-uniform motion on graphs
 - Sketch graphs given a description of motion
-

SCIENTIFIC WRITING AND EXAM SUPPORT

When answering questions from this lesson, separate:

- the physical quantity being discussed,
- the model or law being applied,
- the mathematical relationship, including units,
- the conclusion in words.

For explanation questions, write in the pattern: **claim -> physics reason -> consequence.**

For calculation questions, state the formula, substitute with units, calculate, then interpret the answer.

MAINTENANCE LOOP

One-minute retrieval:

1. State the key law, model, or relationship used in this lesson.
2. Identify one common misconception that would lead to a wrong answer.
3. Write one sentence that links the calculation or evidence back to the physical meaning.

STUDENT WORKING
