

Equations of Motion

PH11-8

ORIENTATION

Lesson goal: build accurate physics fluency for equations 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 8:

Galileo showed that constant acceleration turns motion into a mathematical problem. The equations of motion encode that idea in a form that is easy to apply.

LEARNING OBJECTIVES

- State the SUVAT assumptions for constant acceleration.
 - Select the correct equation of motion for a given problem.
 - Solve for unknown kinematic variables with units.
 - Evaluate whether results are physically reasonable.
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CONTENT

Assumptions for SUVAT

The equations apply to **straight-line motion with constant acceleration**. Air resistance and changing forces are neglected unless stated.

SUVAT equations only work when acceleration is constant. If acceleration varies, you must use calculus or graphical methods.

Core equations

The four SUVAT equations are:

$$v = u + at$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

$$s = \frac{(u + v)}{2}t$$

Where:

- s = displacement (m)
- u = initial velocity (m/s)
- v = final velocity (m/s)
- a = acceleration (m/s²)
- t = time (s)

Equation Selection Guide

MISSING VARIABLE	USE EQUATION
s	$v = u + at$
v	$s = ut + \frac{1}{2}at^2$
u	$s = vt - \frac{1}{2}at^2$
a	$s = \frac{(u+v)}{2}t$
t	$v^2 = u^2 + 2as$

Problem-solving strategy

1. List known variables with units.

2. Identify the unknown variable.
3. Choose an equation that includes the knowns and the unknown.
4. Substitute, solve, and check sign conventions.

Interactive: SUVAT Equation Solver

Use this interactive tool to solve kinematics problems. Enter any three known values, and the solver will calculate the remaining two.

1. Enter at least 3 known values (leave unknown fields empty)
2. Click "Solve" to calculate the missing values
3. The tool shows which equation was used

WORKED EXAMPLES

Example 1: Final velocity

A cyclist starts at 3.0 m/s and accelerates at 0.80 m/s² for 5.0 s.

Known: $u = 3.0$ m/s, $a = 0.80$ m/s², $t = 5.0$ s **Unknown:** v

1. Use $v = u + at$
2. $v = 3.0 + (0.80)(5.0) = 3.0 + 4.0$
3. $v = 7.0$ m/s

Velocity increases in the positive direction.

Example 2: Displacement under acceleration

A car travels at 10 m/s and accelerates at 1.5 m/s² for 4.0 s.

Known: $u = 10$ m/s, $a = 1.5$ m/s², $t = 4.0$ s **Unknown:** s

1. Use $s = ut + \frac{1}{2}at^2$
2. $s = (10)(4.0) + \frac{1}{2}(1.5)(4.0)^2$
3. $s = 40 + 12 = 52$ m

Example 3: Stopping distance

A train slows uniformly from 22 m/s to rest over 110 m. Find the acceleration.

Known: $u = 22$ m/s, $v = 0$ m/s, $s = 110$ m **Unknown:** a

1. Use $v^2 = u^2 + 2as$ (no t needed)
2. $0^2 = 22^2 + 2a(110)$
3. $0 = 484 + 220a$
4. $a = -2.2 \text{ m/s}^2$

The negative sign indicates deceleration.

Example 4: Free fall

A ball is dropped from rest. How far does it fall in 3.0 s? (Take $g = 9.8 \text{ m/s}^2$ downward)

Known: $u = 0 \text{ m/s}$, $a = 9.8 \text{ m/s}^2$, $t = 3.0 \text{ s}$ **Unknown:** s

1. Use $s = ut + \frac{1}{2}at^2$
2. $s = 0 + \frac{1}{2}(9.8)(3.0)^2$
3. $s = 44 \text{ m}$

Visualization: Motion Under Constant Acceleration

The graphs below show the relationship between position, velocity, and time for an accelerating object:

Observe:

- The curve is a parabola (characteristic of constant acceleration)
- The gradient increases over time (velocity increases)
- The tangent line at any point gives instantaneous velocity

COMMON MISCONCEPTIONS

- **Misconception:** SUVAT equations apply to any motion. **Correction:** They require constant acceleration.
- **Misconception:** Negative acceleration always means moving backward. **Correction:** It indicates acceleration opposite to the chosen positive direction.
- **Misconception:** Using the wrong equation still gives the correct answer. **Correction:** Each equation depends on the variables included.
- **Misconception:** Time is always required. **Correction:** $v^2 = u^2 + 2as$ doesn't need time.

PRACTICE QUESTIONS

Easy (2 marks)

A runner accelerates from rest at 2.0 m/s^2 for 3.0 s . Find final velocity.

- Correct equation and substitution (1)
- Final velocity with units (1)

Answer: $v = u + at = 0 + (2.0)(3.0) = 6.0 \text{ m/s}$

Medium (4 marks)

A ball is thrown upward at 12 m/s . Ignore air resistance. Find the maximum height.

- Use $v^2 = u^2 + 2as$ with $v = 0$ (2)
- Correct height and units (2)

Answer:

- At maximum height, $v = 0$
- $0^2 = 12^2 + 2(-9.8)s$
- $0 = 144 - 19.6s$
- $s = 7.3 \text{ m}$

Hard (5 marks)

A cart travels 25 m in 5.0 s with constant acceleration and finishes at 12 m/s . Find the initial velocity and acceleration.

- Use two SUVAT equations (2)
- Correct acceleration (2)
- Correct initial velocity (1)

Solution:

From $s = \frac{(u+v)}{2}t$:

- $25 = \frac{(u+12)}{2}(5.0)$
- $25 = 2.5(u + 12)$
- $10 = u + 12$
- $u = -2.0 \text{ m/s}$ (moving backward initially!)

From $v = u + at$:

- $12 = -2.0 + a(5.0)$
- $14 = 5a$
- $a = 2.8 \text{ m/s}^2$

Answers: $u = -2.0 \text{ m/s}$, $a = 2.8 \text{ m/s}^2$

MULTIPLE CHOICE QUESTIONS

Test your understanding with these interactive questions:

QUICK QUIZ: SUVAT PROBLEM SOLVING

Test your kinematics skills with this timed quiz:

SUMMARY

- SUVAT equations model straight-line motion with constant acceleration.
 - Choose equations based on known and unknown variables.
 - Signs encode direction and must stay consistent.
 - Check results against physical expectations.
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SELF-ASSESSMENT

Check your understanding:

After studying this section, you should be able to:

- State the conditions for using SUVAT equations
 - List all four SUVAT equations from memory
 - Select the correct equation for a given problem
 - Solve multi-step kinematics problems
 - Interpret the meaning of negative values in solutions
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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
