COLLEGE BOARD CED - COURSE FRAMEWORK V.1

AP Physics 1 -- Unit 1: Kinematics

Topics 1.1-1.5

AP Physics 1 Study Guide

AP Physics 1: Algebra-Based Course and Exam Description (College Board, Course Framework V.1)

Source used: *AP Physics 1: Algebra-Based Course and Exam Description*, Unit 1 "Kinematics" (Topics 1.1–1.5), plus the Science Practices, Required Equations note, and Exam Information sections of the same CED. **Exam weighting:** 10–15% of the multiple-choice section · **Suggested pacing:** ~12–17 class periods (roughly the first three weeks of the course) **A note on scope:** this is the shortest-weighted unit on the exam, but it is load-bearing — every later unit (dynamics, momentum, rotation, oscillations) reuses these equations and this graph vocabulary without re-teaching it. Get sloppy here and it costs you in Units 2 through 8, not just Unit 1.

PART 1 — The Frame

1.1 The core model

Kinematics describes motion. It does not explain *why* something moves the way it does — that's Unit 2 (dynamics, forces). Unit 1 hands you a toolkit for describing position, velocity, and acceleration in four equivalent languages — **diagrams, graphs, equations, and words** — and the entire unit is really about becoming fluent enough to move between those four languages without losing information. That fluency is not a side skill; it's explicitly Science Practice 1 (Creating Representations) and it's the whole premise of FRQ Question 2 on the actual exam, "Translation Between Representations."

Underneath the four representations is one simplifying move: the **object model**. You're allowed to shrink every object to a single point and ignore its size, shape, and internal structure, tracking only properties like mass. That's what makes it legal to draw a car as a dot on a motion diagram. (You lose this simplification later in rotational units, where shape and size suddenly matter — which is a clue that Unit 1's equations are a special case of something bigger, not the whole story.)

1.2 The essential questions the CED itself opens with

College Board frames this unit around four questions worth sitting with, because they're not decorative — they map directly onto the topics:

- How can the idea of frames of reference allow two people to tell the truth yet have conflicting reports? → **Topic 1.4**
- How can we estimate the height of a very tall building with only a small rock and a stopwatch? → **Topics 1.2–1.3** (free fall, kinematic equations)
- Why might it seem like you are moving backwards when a car passes you on the highway? → **Topic 1.4** (relative velocity)
- Why is the rule "double your speed, quadruple your stopping distance" true? → **Topic 1.3** (the v^2 term in the third kinematic equation)

If you can answer all four with an equation *and* a sentence *and* a graph, you've basically mastered the unit.

1.3 Required vs. derived equations — a distinction the CED makes explicit that most students miss

The CED states directly: *"Not all equations in this course framework appear on the equation sheet provided to students... Many of the equations in this document are provided for reference and guidance, or to demonstrate the final results of derivations expected of students."* Equations tagged "Relevant equation" in the essential knowledge are generally the ones handed to you on exam day. Equations tagged **"Derived equation"** are things you're expected to be able to produce yourself from the given ones — they will not be sitting on your reference sheet waiting for you.

For Unit 1, concretely: the three constant-acceleration kinematic equations (below) are given to you. The component form of those equations (subscripting everything with x, for the two-dimensional case) is something you're expected to know how to construct, not something the sheet spells out for you.

1.4 Boundary statements — the exam's fine print, stated plainly

These aren't optional footnotes; they get tested directly.

- **Use $g = 10\ m/s^2$** for any numerical problem unless told otherwise. You will *not* be penalized for using 9.8 or 9.81 m/s^2, but 10 is the College Board default and it's faster under time pressure.
- AP Physics 1 does **not** require you to quantitatively analyze nonuniform (non-constant) acceleration — no calculus, no equations for jerk. You *are* expected to qualitatively describe, sketch, and discuss situations where acceleration isn't constant (e.g., a curving x-t graph whose slope keeps changing).
- Relative-velocity problems (Topic 1.4) are restricted to **one dimension** on this exam. Don't overbuild a 2D relative-motion solution nobody's asking for.
- Unless a problem says otherwise, **assume the reference frame is inertial**.

PART 2 — Topic-by-Topic

TOPIC 1.1 — Scalars and Vectors in One Dimension

What it actually says

A **scalar** is a quantity with magnitude only — distance, speed, mass, time, energy. A **vector** has magnitude *and* direction — position, displacement, velocity, acceleration, force. Vectors get an arrow over the symbol; in one dimension you drop the arrow and let the **sign** carry the direction entirely — that's it, that's the whole notational system for 1D vectors. A vector sum in one dimension is just signed addition: opposite directions get opposite signs, and you add.

Why this matters more than it looks like it should

Almost every kinematics error in Unit 1 traces back to sign confusion, not to not knowing an equation. Getting comfortable treating "negative" as "a direction" rather than "less than" is the actual skill being built here, and it pays off for the rest of the course (forces, momentum, and torque are all signed the same way).

Worked example

A hiker walks 300 m east, then 500 m west. Find (a) the distance traveled and (b) the displacement.

- Distance is a scalar — it's the total path length: 300 + 500 = **800 m**.
- Displacement is a vector — final position minus initial position. Taking east as positive: $\Delta x = -500 + 300 = -200$ m, i.e., **200 m west**.

> ***Trap to avoid:*** *students confuse distance and displacement (or speed and velocity) constantly, especially on round trips. An object that ends up back where it started has a displacement of* ***zero*** *no matter how far it traveled — and a question that asks for "the total distance" versus "the displacement" is not asking the same question twice for redundancy. Read which word is used.*

TOPIC 1.2 — Displacement, Velocity, and Acceleration

What it actually says

- **Displacement**: $\Delta x = x - x_0$ — the change in position, a vector.
- **Average velocity**: $v_{avg} = \Delta x / \Delta t$ — always true, for any motion, constant acceleration or not.
- **Average acceleration**: $a_{avg} = \Delta v / \Delta t$ — same, always true.
- An object is **accelerating** if its velocity's magnitude *and/or direction* is changing. (Direction alone is enough — a car turning a corner at a perfectly constant speed is accelerating. This is a preview of circular motion in Unit 2, and it's worth internalizing now.)
- As the time interval shrinks toward zero, average velocity/acceleration approaches **instantaneous** velocity/acceleration. AP Physics 1 doesn't require calculus notation, but it absolutely requires this intuition — it's the entire justification for "slope of the tangent line = instantaneous rate," which Topic 1.3 leans on hard.

The shortcut that's true sometimes and false often

For **constant acceleration only**, $v_{avg} = (v_0 + v_f) / 2$. This is a genuinely useful shortcut and shows up constantly in worked solutions — but it is not one of the two "always true" definitions above, and it silently breaks the moment acceleration isn't constant.

> ***Trap to avoid:*** *using $(v_0+v_f)/2$ as if it were the universal definition of average velocity. It's a special-case consequence of constant acceleration, not the definition. If a problem doesn't guarantee constant acceleration, fall back to $\Delta x/\Delta t$.*
>
> ***Trap to avoid:*** *"the object stopped, so it's not accelerating." An object with $v = 0$ at one instant (the peak of a vertical throw, the turnaround point of oscillation) still has whatever acceleration is acting on it at that instant — velocity being zero and acceleration being zero are unrelated facts. This exact trap reappears, worded almost identically, in the free-response practice below.*

Quick check

A sprinter's velocity goes from 0 to 10 m/s in 2 s, then holds constant at 10 m/s for 3 s, then drops to 0 over 1 s. What's the average acceleration over the *entire* 6 s, start to finish? *Answer: $a_{avg} = \Delta v/\Delta t = (0-0)/6 = 0$ m/s². The velocity ends where it started, so despite* *three very different-looking acceleration phases, the average over the whole interval is zero. This is a favorite exam trick — "average acceleration over the whole trip" is not the average of the three individual accelerations.*

TOPIC 1.3 — Representing Motion

This is the densest topic in the unit and the one the AP Exam leans on hardest for graph-based reasoning. Budget more study time here than the page count suggests.

The three kinematic equations (constant acceleration only — this condition is doing a lot of work, check for it every time)

1. $v = v_0 + at$
2. $x = x_0 + v_0t + ½at^2$
3. $v^2 = v_0^2 + 2a(x - x_0)$

These three are given on the official AP Physics 1 equation sheet. Motion can also be represented through motion diagrams, graphs, and narrative descriptions — the CED explicitly lists all four as equally valid, and the exam will ask you to produce or interpret any of them.

Graph relationships — memorize this table, don't derive it under time pressure

Graph	What the slope tells you	What the area under the curve tells you
position (x) vs. time	instantaneous velocity	*(not a tested quantity)*
velocity (v) vs. time	instantaneous acceleration	displacement (Δx) — area between the curve and the time axis, signed
acceleration (a) vs. time	*(not tested — this would be "jerk," out of scope)*	change in velocity (Δv)

Two of these are essential-knowledge statements verbatim: instantaneous velocity is the slope of the tangent line on an x-t graph; instantaneous acceleration is the slope of the tangent line on a v-t graph. The displacement-as-area-under-v-t relationship is the one students most often forget exists at all — and it's the one the AP loves to test with a triangle-or-trapezoid v-t graph and no numbers plugged into an equation anywhere.

Speeding up or slowing down? Use signs, not vibes

The single most common Topic 1.3 error: assuming negative acceleration always means "slowing down." It doesn't. What matters is whether velocity and acceleration have the **same sign** (speeding up) or **opposite signs** (slowing down) — regardless of which sign either one actually is.

Sign of v	Sign of a	Relationship	What's happening
+	+	same	speeding up, moving in + direction
+	–	opposite	slowing down
–	+	opposite	slowing down (moving in – direction, but losing speed)
–	–	same	speeding up, moving in – direction
0	nonzero	—	momentarily at rest, about to move in the direction of a

> ***Trap to avoid:*** *"the ball has negative acceleration, so it must be slowing down." A ball thrown downward, still moving downward (negative velocity, negative acceleration due to gravity) — same sign, so it's speeding up, not slowing down. This exact framing shows up in free-response justification prompts, where you're asked to explain a claim, not just calculate a number.*

Worked example — combining the algebra and the graph

A car starts from rest and accelerates uniformly at 4 m/s^2 for 5 s, then travels at constant velocity for 3 s. (a) Find the displacement during the acceleration phase. (b) Find the displacement during the constant-velocity phase. (c) Describe the v-t graph.

- (a) $x = x_0 + v_0t + ½at^2 = 0 + 0 + ½(4)(5^2) = 50$ m.
- (b) First find v at the end of the acceleration phase: $v = v_0+at = 0+4(5) = 20$ m/s. Then constant-velocity displacement is just $v\Delta t = 20(3)$

= 60 m.

- (c) The v-t graph is a straight line from (0,0) to (5, 20) with slope 4 (matching the given acceleration), then a horizontal segment from (5,20) to (8,20). Total displacement (50+60=110 m) is the total area under both segments — a triangle plus a rectangle. This is worth actually computing both ways (kinematic equations vs. graph area) once, so you trust that they agree.

TOPIC 1.4 — Reference Frames and Relative Motion

What it actually says

The reference frame you choose determines the magnitude *and direction* of every measured quantity — this is the formal answer to "how can two people tell the truth and still disagree." An observed velocity is the combination (vector sum) of the object's velocity and the observer's own velocity, and on this exam that combination is restricted to one dimension. The single most important fact in this topic, easy to state and easy to forget under pressure:

> ***Acceleration is the same as measured from all inertial reference frames.*** *Velocity is relative; acceleration is not.*

Why this one fact matters beyond Unit 1

This is the conceptual seed of Newton's laws. If acceleration were frame-dependent, "F = ma" wouldn't mean the same thing to two different inertial observers, and dynamics would fall apart. You don't need to justify Newton's second law yet — just bank the fact that acceleration is frame-invariant, because Unit 2 assumes you already have it.

Worked example

A passenger on a train moving at a constant 15 m/s (relative to the ground, in the +x direction) throws a ball forward at 5 m/s relative to themselves. What is the ball's velocity relative to the ground? v(ball, ground) = v(ball, train) + v(train, ground) = 5 + 15 = 20 m/s.

Now suppose instead the passenger throws it *backward* at 5 m/s relative to themselves: v(ball, ground) = −5+15 = 10 m/s — still moving forward relative to the ground, just more slowly. This is the textbook explanation for "why does a car passing you on the highway seem to move backward relative to you" — you're both moving forward relative to the ground, but your relative velocity (the difference) can look and feel like the other car is retreating.

> ***Trap to avoid:*** *forgetting that acceleration doesn't get this same relative-motion treatment. If the ball in the example above were also accelerating (say, falling under gravity), that acceleration would be identical whether measured by the passenger, a person standing on the platform, or anyone else in an inertial frame — you do* ***not*** *add a frame-velocity correction to acceleration the way you do to velocity.*

TOPIC 1.5 — Vectors and Motion in Two Dimensions

What it actually says

Any vector can be modeled as the resultant of two perpendicular components, resolved using a chosen coordinate system and trigonometry:

$A_x = A\cos\theta$ $A_y = A\sin\theta$ $A = \sqrt{(A_x^2 + A_y^2)}$ $\tan\theta = A_y / A_x$

Two-dimensional motion is then analyzed as **two independent one-dimensional motions**, one along each axis, linked only by a shared time variable. Every equation from Topic 1.3 still applies — you just apply it separately to x and y.

Projectile motion is the named special case: zero acceleration in one dimension (horizontal, assuming no air resistance, so v_x never changes) and constant nonzero acceleration in the other (vertical, a_y = −g).

The independence principle, stated as plainly as possible

Horizontal motion and vertical motion during a projectile's flight don't influence each other **at all**, except that they take the same amount of time. A ball thrown horizontally off a cliff and a ball dropped straight down from the same height at the same instant hit the ground at the exact same time — the horizontal velocity of the first ball has zero effect on how fast it falls.

Worked example

A ball is launched from ground level at 30 m/s, at 37° above the horizontal ($\sin 37° \approx 0.6$, $\cos 37° \approx 0.8$). Use $g = 10\ m/s^2$. Find (a) the time to reach maximum height, (b) the maximum height, (c) the total time of flight, (d) the horizontal range.

- Components: $v_{0x} = 30(0.8) = 24$ m/s (constant throughout flight); $v_{0y} = 30(0.6) = 18$ m/s.
- (a) At the peak, $v_y = 0$: $0 = 18 - 10t \rightarrow t = 1.8$ s.
- (b) $y_{max} = v_{0y}t - \frac{1}{2}gt^2 = 18(1.8) - \frac{1}{2}(10)(1.8^2) = 32.4 - 16.2 = 16.2$ m.
- (c) Symmetric trajectory over level ground → total time is double the time to the peak: $t_{total} = 3.6$ s.
- (d) Range = $v_{0x} \cdot t_{total} = 24(3.6) = 86.4$ m.

> ***Trap to avoid:*** *applying g to the horizontal component, or assuming velocity is zero at the peak. Only $v_y = 0$ at the peak — v_x = 24 m/s the entire flight, including at the very top. "Velocity is zero at the highest point" is only true for a purely vertical throw (Topic 1.3's territory); for an angled projectile, speed at the peak equals v_{0x}, not zero.*
>
> ***Trap to avoid:*** *trying to find a single equation that solves for everything at once. Projectile problems are solved by resolving into components first, solving each 1D sub-problem with Topic 1.3's tools, and using time as the only bridge between them. Reaching for a formula before separating the axes is the single biggest source of projectile-motion errors.*

PART 3 — Cross-Cutting Comparison Tables

Vocabulary and notation — the third column is where the actual understanding lives

Term	Meaning in context	Why it's easy to confuse with something else
Distance	scalar; total path length traveled	Confused with displacement, which is a vector and can be smaller (or zero) even for a long path
Displacement (Δx)	vector; final position minus initial position	Sign matters — "20 m" and "−20 m" are different displacements, not a typo
Speed	scalar; magnitude of velocity	Confused with velocity, which additionally carries direction/sign
Average velocity	$\Delta x/\Delta t$, always valid	Confused with (v₀+v_f)/2, which only equals it under constant acceleration
Instantaneous velocity	slope of the tangent line on an x-t graph	Confused with average velocity when the motion isn't uniform — they're only equal for constant velocity
Acceleration	rate of change of *velocity* (magnitude or direction)	Widely mistaken for "speeding up specifically" — an object turning at constant speed, or slowing down, is still accelerating
Inertial reference frame	a frame in which Newton's first law holds; assumed by default unless stated otherwise	Confused with "the ground" specifically — any frame moving at constant velocity (not just the ground) is inertial
Object model	treating an object as a dimensionless point with mass	Loses validity once size/shape matter (torque, rotational inertia — later units)

Motion-type comparison matrix

	Uniform velocity	Uniform (constant) acceleration	Projectile motion
What's constant	velocity	acceleration	v_x (horiz.) constant; a_y = −g (vert.) constant
Governing equation(s)	$x = x_0 + vt$	the three kinematic equations	the three kinematic equations, applied separately to x and y
x-t graph shape	straight line	parabola	parabola for y-vs-x trajectory itself
v-t graph shape	horizontal line	straight line, nonzero slope	horizontal line (v_x) + straight sloped line (v_y)
Classic trap	assuming acceleration when velocity just looks "fast"	assuming (v₀+v_f)/2 always works	applying g to the wrong axis; assuming v=0 at the peak

PART 4 — Kinematics Toolkit (Which Equation Do I Actually Use?)

The single most useful thing you can build for this unit is the reflex to identify **what's given, what's asked, and what's constant** before touching an equation.

You're given	You need	Use	Condition that must hold
v_0, a, t	v	$v = v_0+at$	constant a
v_0, a, t	x	$x = x_0+v_0t+\frac{1}{2}at^2$	constant a
v_0, a, Δx (not)	v	$v^2 = v_0^2+2a\Delta x$	constant a; watch the ± when taking the square root
any Δx, any Δt	v_avg	v_avg = $\Delta x/\Delta t$	always true — no constant-a requirement
v_0, v (constant a only)	v_avg	v_avg = $(v_0+v)/2$	**constant a only** — do not use otherwise
2D launch angle and speed	anything about the trajectory	resolve into x/y components first, then apply the rows above to each axis independently, linked by shared t	$a_x=0$ (no air resistance), a_y=−g

A practical habit: before selecting an equation, write down which of x_0, x, v_0, v, a, t you actually have numbers for, and which one you're solving for. Four of the five kinematic variables show up in each of the first three equations; picking the equation that's missing the variable you don't have (or don't need) is faster and safer than plugging into whichever equation you remember first.

PART 5 — Practice and Assessment

The College Board's own instructional materials demonstrate that the *same* physical scenario can be tested through completely different skills (1.A–3.C) — a block sliding down a ramp gets asked as a derivation, a calculation, a comparison, a prediction, and a justification, one skill at a time. The set below does the same thing across Unit 1's content, and mixes multiple-choice with a full free-response-style question, matching the real exam's four FRQ types: Mathematical Routines, Translation Between Representations, Experimental Design and Analysis, and Qualitative/Quantitative Translation.

Multiple choice (skill-tagged, mixed topics)

1. (Skill 2.B — Calculation, Topic 1.2) A car starts from rest and accelerates uniformly at 3 m/s^2 for 6 s. What is its displacement? (A) 18 m (B) 27 m (C) 54 m (D) 108 m

2. (Skill 2.C — Comparison, Topic 1.3, graph-based) Object A moves at a constant 4 m/s for 4 s. Object B starts from rest and accelerates uniformly, reaching 8 m/s at the end of the same 4 s. How does object A's displacement compare to object B's? (A) A's is greater (B) B's is greater (C) They're equal (D) Cannot be determined without more information

3. (Skill 2.D — Functional dependence, Topic 1.2) An object undergoes constant acceleration a. If the time interval over which the velocity change is measured is tripled, by what factor does Δv change? (A) one-third (B) unchanged (C) 3 (D) 9

4. (Skill 3.C — Justify a claim, Topic 1.4) A ball is thrown straight up inside a train moving at constant velocity. An observer on the platform and a passenger on the train both measure the ball's motion during its flight. Which statement is correct? (A) The two observers measure different accelerations because their reference frames are moving relative to each other. (B) The two observers measure the same acceleration because both reference frames are inertial. (C) Only the passenger's measurement is valid, since the platform observer is not in the same frame as the ball. (D) The accelerations differ, but only during the upward part of the flight.

5. (Skill 2.A — Derivation, Topic 1.5) A ball is launched horizontally with speed v_0 from height h above level ground. Which expression correctly gives the horizontal distance traveled before landing? (A) $v_0\sqrt{(2h/g)}$ (B) $v_0\sqrt{(h/g)}$ (C) $v_0(2h/g)$ (D) $v_0\sqrt{(2gh)}$

6. (Skill 1.C/2.C — Graph interpretation, Topic 1.1) A hiker walks 300 m east, then 500 m west. Total distance walked and net displacement are, respectively: (A) 200 m, 800 m west (B) 800 m, 200 m west (C) 800 m, 200 m east (D) 200 m, 200 m west

Answer key and reasoning *(try all six on your own before reading — cover this block with a sheet of paper)*

1. **(C)** $x = ½(3)(6^2) = 54$ m.
2. **(C)** — A: x=vt=4(4)=16 m. B: area under v-t graph is a triangle, ½(4)(8)=16 m. Equal, even though B ends up moving twice as fast — a classic area-under-the-curve trap.
3. **(C)** $\Delta v = a\Delta t$; tripling Δt triples Δv for fixed a.
4. **(B)** Acceleration is frame-invariant across inertial frames (Essential Knowledge 1.4.B.2.ii). This holds throughout the flight, not just part of it — eliminate (D) on that basis alone.
5. **(A)** Time to fall: $h=½gt^2 \rightarrow t=\sqrt{(2h/g)}$. Range = $v_0t = v_0\sqrt{(2h/g)}$.
6. **(B)** Distance is scalar total path length (300+500=800 m); displacement is the vector net change, −500+300=−200 m, i.e., 200 m west.

Free-response style question (Mathematical Routines + Translation Between Representations + Qualitative/Quantitative Translation)

A ball is thrown vertically upward from ground level with an initial speed of 20 m/s. Use $g=10$ m/s^2 and neglect air resistance.

(a) Calculate the maximum height reached by the ball.

(b) Calculate the total time the ball is in the air before it returns to the ground.

(c) In words, describe the shape of the ball's v-t graph from launch to landing, including its sign, slope, and any special points.

(d) A student claims: *"The ball's acceleration is zero at the highest point, since the ball isn't moving at that instant."* Using the definition of acceleration, explain whether this claim is correct.

(e) Suppose the same ball were thrown with the same initial speed on a planet where the gravitational acceleration is only 4 m/s^2 (all else unchanged). Without recomputing from scratch, state and justify whether the maximum height would be greater than, less than, or equal to your answer in part (a), and by what factor.

Full solution and reasoning *(work through all five parts before reading — cover this block with a sheet of paper)*

(a) Taking up as positive, at maximum height $v=0$: $v^2=v_0^2-2gh \rightarrow 0 = 400 - 2(10)h \rightarrow h = 20$ m.

(b) By symmetry (level ground, launch and landing at same height), total time is twice the time to the peak. Time to peak: $v=v_0-gt \rightarrow 0=20-10t \rightarrow t=2$ s. Total time = 4 s. (Equivalently: solve $0=v_0t-\frac{1}{2}gt^2$ for the nonzero root.)

(c) The graph is a single straight line (constant slope, since acceleration is constant) starting at $v=+20$ m/s at $t=0$, decreasing linearly, crossing zero exactly at $t=2$ s (the apex), and continuing to decrease linearly to $v=-20$ m/s at $t=4$ s (impact). The slope throughout is -10 m/s² — it does not flatten out or change anywhere, including at the moment $v=0$.

(d) The claim is **incorrect**. Acceleration is the *rate of change* of velocity — the slope of the v-t graph — not the value of velocity itself. At the instant $v=0$, the slope of the (perfectly straight) v-t graph is still -10 m/s², unchanged from every other instant in the flight. Physically: if acceleration really were zero at the peak, the ball would stay there, since nothing would be changing its velocity — but it doesn't stay, it immediately starts moving downward, which is only possible if a nonzero acceleration is acting on it at exactly that instant. Zero velocity and zero acceleration are independent facts, and this scenario is the cleanest possible counterexample to conflating them.

(e) Maximum height is **greater**, since $h=v_0^2/(2g)$ is inversely proportional to g for fixed v_0. Reducing g from 10 to 4 m/s² is a factor of $10/4=2.5$ decrease in g, so h increases by that same factor: new height = $20\times2.5 = 50$ m. (Time of flight scales the same way, since $t_{total}=2v_0/g$ is also inversely proportional to g: new $t = 4\times2.5 = 10$ s.) This kind of proportional-reasoning question — "how does the answer change if one input changes, without redoing the whole calculation" — is exactly what Skill 2.D and the exam's Qualitative/Quantitative Translation question are built to test.

Experimental Design and Analysis prompt

Using only a meterstick and a stopwatch, design a procedure to experimentally determine the local acceleration due to gravity, g. Describe what data you would collect, what you would graph, and how the graph's slope would yield g. Identify the largest source of experimental uncertainty in your procedure and one way to reduce it.

Sample reasoning

Drop an object from a measured height h (starting from rest) and use the stopwatch to record the fall time t; repeat for several different heights, and repeat each height multiple times to average out timing error. Since $h=\frac{1}{2}gt^2$ for an object dropped from rest, plotting h (y-axis) versus t^2 (x-axis) linearizes the relationship into a straight line through the origin with slope $g/2$ — so $g = 2\times$slope. (Plotting h vs. t directly would give a parabola, which is much harder to extract a precise value from than a line — this linearization move, picking what to graph so the relationship becomes linear, is exactly what Skill 1.B is testing.) The dominant uncertainty is human reaction time starting/stopping the stopwatch, which is a roughly constant timing offset that matters proportionally more for short fall times; reduce it by using larger drop heights (longer, more precisely measurable times) or switching to photogates/video frame analysis instead of manual timing.

The One Thing to Remember

Unit 1 is not really "five separate topics." It's one idea — **position, velocity, and acceleration are vectors, and the same motion can always be described in at least four equivalent ways (diagram, graph, equation, words)** — applied to steadily more complicated situations: one object in 1D, then that same object viewed from a different frame, then that same object released into 2D. Every trap in this guide is a version of the same mistake: treating a sign, a slope, or a component as decoration instead of as the actual physics. If you get in the habit of asking "what does this sign/slope/component *mean*, physically" before you calculate anything, Unit 1 stops being a pile of formulas and becomes one coherent skill you'll reuse in every unit after this one.