KINEMATICS DAY 8: FREE FALL

WARMUP **Day 7 Review**

From rest, a cart accelerates at 4.0 m/s² for 2.0 s, then cruises at constant velocity for 3.0 s. Find the total distance. (Phase table!)

G = 9.8 M/S², DOWN, ALWAYS

While airborne (no air resistance) every object has **a = g = 9.8 m/s² directed downward** — on the way up, at the top, and on the way down. Free fall is Day 5 with a known acceleration.

With up positive, write a = –9.8 m/s² once at the top of your work and let the algebra carry the sign. Most free-fall errors are sign errors.

WE DO **Exercise 1: Straight Drop**

A rock is dropped from rest and falls for 3.0 s. Find **(a)** its speed at that moment — show (9.8 m/s²)(3.0 s) with units — and **(b)** how far it has fallen.

YOU DO **Exercise 2: Up and Over**

A ball is thrown straight up at 19.6 m/s. **(a)** How long does it take to reach the top? **(b)** How high does it go? **(c)** Without new computation, how long is the total flight back to the throwing height, and why?

THE CALCULUS UNDER FREE FALL

YOU DO Exercise 3: Impact Speed

A flowerpot falls from rest off a 45 m balcony. Find its impact speed. *(No time given, none wanted — which Day 5 equation is missing t?)*

CALCULUS CORNER — Y(T) IS A DOUBLE ACCUMULATION

Free fall is the cleanest possible integration chain. Start from the one fact a = –9.8 m/s² (up positive) and accumulate twice:

$$v(t) = v_0 + \int a\,dt = v_0 - 9.8t \quad \rightarrow \quad y(t) = y_0 + \int v\,dt = y_0 + v_0 t - 4.9t^2$$

The **–4.9t²** is not a memorized constant — it is ½g·t², the accumulated triangle under the growing (negative) part of v(t). Units audit: (m/s²)(s) = m/s on the first accumulation, (m/s)(s) = m on the second.

Real fallers aren't ideal: with air resistance, the acceleration itself shrinks as speed builds — a(t) is variable, the constant-a equations die, and only accumulation survives. Try it:

CALC Exercise 4: A Real Skydiver's First Seconds

A skydiver steps out at rest. As speed builds, air resistance grows, and her a-t graph falls in a straight line from 9.8 m/s² down to 0 over the first 4.0 s (a simplified model of approaching a steady speed). **(a)** Accumulate the a-t triangle, with units, to find her speed at t = 4.0 s. **(b)** How much LESS is that than the ideal free-fall speed (9.8 m/s²)(4.0 s)? **(c)** What does the area under her a-t graph after this point accumulate — anything at all?

AP FREE-RESPONSE PRACTICE

FRQ Type — Qualitative/Quantitative Translation: the AP exam asks you to connect words to math. Paragraph parts are graded on claim → evidence → reasoning: state your claim, point to the physics (an equation or definition), and connect them in complete sentences.

AP FRQ

The Top of the Flight

A ball is thrown straight up at 14.7 m/s and caught at the same height it left the hand.

(a) A classmate claims: "At the highest point the velocity is zero, so the acceleration must also be zero." In a short paragraph, explain whether this claim is correct, using the definition a = dv/dt in your reasoning.

(b) Calculate the total flight time and the maximum height above the hand.

(c) Compare the ball's speed when passing a point 5.0 m above the hand on the way up versus on the way down. Justify your answer without computing either speed.

PAPER PRACTICE

PRACTICE PROBLEMS

P1 Drop Time

How long does an object dropped from rest take to fall 20 m?

P2 Height from Impact Speed

An object dropped from rest hits the ground at 21 m/s. From what height did it fall?

P3 Initial Speed from Max Height

A ball thrown straight up reaches a maximum height of 10 m above the hand. How fast was it thrown?

P4 Staggered Drop

Ball A is dropped from a tall cliff; 1.0 s later, ball B is dropped from the same point. **(a)** Find the gap between them 2.0 s after A is released. **(b)** Does the gap grow, shrink, or stay constant as they fall? Explain in one sentence using their speeds.