

KINEMATICS DAY 6: FREE FALL

WARMUP Day 5 Review

A trip has two phases: first accelerating, then cruising. What must connect the two phase calculations?

- ☐ **A.** The acceleration must stay the same ☐ **B.** The position must reset to zero
- ☐ **C.** Phase 1 final velocity becomes Phase 2 initial velocity ☐ **D.** Phase 2 must start from rest

Check one → convince your neighbor in one sentence.

Physics in the Wild — Hang Time Is a Lie We Tell Ourselves: A great vertical leap is about 1.0 m. Time to rise: $t = \sqrt{2h/g} = \sqrt{2 \times 1.0 \text{ m} \div 9.8 \text{ m/s}^2} \approx 0.45 \text{ s}$ — so total "hang time" is under a second, even for elite athletes. It *feels* longer because speed is smallest near the top, so that's where the jumper spends most of the time. Free fall is just Day 4 with a known acceleration.

FREE FALL

While airborne (no air resistance), every object has $a = g = 9.8 \text{ m/s}^2$, directed downward — always.

- Taking up as positive: $a = -9.8 \text{ m/s}^2$ the entire flight — rising, at the top, and falling
- At the very top: $v = 0$ but a is still -9.8 m/s^2
- Symmetry: time up = time down; speed at a given height is the same going up and coming down

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 $(9.8 \text{ m/s}^2)(3.0 \text{ s}) = 29.4 \text{ m/s}$ — and **(b)** how far it has fallen.

THROWN UPWARD

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?

Keep the sign of g honest. With up positive, write $a = -9.8 \text{ m/s}^2$ *once* at the top of your work and let the algebra carry it. Most free-fall errors are sign errors — a dropped negative quietly turns "slowing down" into "speeding up."

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 equation?*)

FRQ Type 2 of 4 — 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 · QUALITATIVE/QUANTITATIVE **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 $a = \Delta v / \Delta t$ 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.