KINEMATICS DAY 13: RELATIVE MOTION

WARMUP **Day 12 Review**

A projectile is launched on level ground with components v_{0x} = 12 m/s and v_{0y} = 9.8 m/s. Find the flight time and the range.

Physics in the Wild — "Velocity Relative to What?": You're "sitting still" reading this — while moving ~460 m/s with Earth's spin and ~30,000 m/s around the Sun. Every velocity is measured *relative to something*. Pilots, ferry captains, and air-traffic controllers do today's math on every single trip.

CHAINING VELOCITIES

$$v_{\text{A relative to C}} = v_{\text{A relative to B}} + v_{\text{B relative to C}}$$

Read the subscripts like dominoes: A→B then B→C gives A→C. In 1D this is just signed addition; in 2D, add components (Day 10!).

Example: walker relative to ground = walker relative to walkway + walkway relative to ground.

WE DO **Exercise 1: The Moving Walkway**

An airport walkway moves at 1.0 m/s. You walk at 1.5 m/s relative to the walkway. Find your speed relative to the ground when walking **(a)** with the walkway and **(b)** against it.

YOU DO **Exercise 2: Headwind, Tailwind**

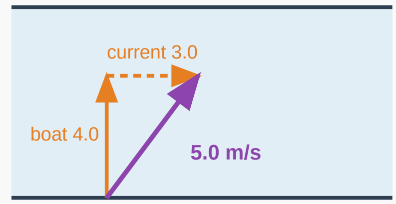
A plane flies at 220 m/s relative to the air. Find its ground speed with **(a)** a 30 m/s tailwind and **(b)** a 30 m/s headwind. Which flight gets there sooner?

TWO DIMENSIONS: THE RIVER PROBLEM

CROSSING A RIVER

Boat velocity (relative to water) and current velocity are perpendicular components of the boat's velocity relative to the ground.

- **Crossing time** depends only on the *across* component
- **Drift** downstream = current × crossing time
- Same independence idea as projectiles!



WE DO **Exercise 3: Crossing with Drift**

A boat aims straight across an 80 m wide river at 4.0 m/s; the current flows at 3.0 m/s. Find **(a)** the boat's speed and direction relative to the ground, **(b)** the crossing time, and **(c)** how far downstream it lands.

The current does not slow the crossing. Crossing time uses only the across-the-river component. The current decides *where* you land, not *when*. (This is the same independence idea from projectile motion — the across-river and downstream directions are separate.)

CORRECTING YOUR COURSE

YOU DO Exercise 4: Crosswind Numbers

A plane flies at 200 m/s relative to the air, pointed due north, with a 15 m/s crosswind blowing due east. Find **(a)** the plane's ground speed and **(b)** the angle its ground track makes with north.

CHALLENGE Exercise 5: Aim Upstream

A boat moves at 5.0 m/s relative to the water and wants to land *directly across* an 80 m river with a 3.0 m/s current. **(a)** At what angle upstream must it aim? *(Hint: the upstream component must cancel the current — a 3-4-5 triangle.)* **(b)** What is its across-river speed? **(c)** How long does the crossing take, and why does aiming upstream make the crossing slower than Exercise 3's straight-across crossing?

PAPER PRACTICE

PRACTICE PROBLEMS

P1 Escalator

An escalator moves up at 1.0 m/s. A passenger walks up it at 0.5 m/s relative to the steps. Find the passenger's speed relative to the building — and relative to a passenger standing still on the adjacent down escalator (also 1.0 m/s).

P2 Downstream Drift

A swimmer crosses a 60 m river swimming 2.0 m/s straight across while the current runs 1.5 m/s. Find the crossing time and the downstream drift.

P3 Angled Crossing

A ferry aims partly upstream so that its across-river velocity component is 3.0 m/s. The river is 45 m wide. How long does the crossing take?

P4 Head-On

Two cars drive toward each other at 25 m/s and 20 m/s, starting 900 m apart. How long until they meet, and how far does the faster car travel?