Name: _____ AP PHYSICS 1 Date: _____

KINEMATICS DAY 11: RELATIVE MOTION

WARMUP **Day 10 Review**

At the highest point of an ideal angled projectile's flight, which statement is correct?

□ **A.** $v_x = 0$, $v_y = 0$, and $a = 0$

□ **B.** v_x is unchanged, $v_y = 0$, and a is downward

□ **C.** $v_x = 0$, v_y is upward, and a is downward

□ **D.** Both velocity components reverse while $a = 0$

Check one → convince your neighbor in one sentence.

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

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

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 8!).

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**

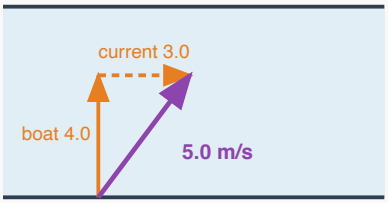
A plane flies at 220 m/s relative to the air. Find its ground speed with **(a)** a 30 m/s tailwind and **(b)** a 30 m/s headwind. Which flight gets there sooner?

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 is it slower than if the same boat aimed straight across and let the current carry it downstream?

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?