Relative Motion Student Lab

AP Physics 1 | Core investigation 45 to 50 minutes | Optional extension on pages 5 and 6

Name _____ Partner _____ Date _____

Investigate how observers can describe the same motion differently. By the end, use signed measurements and graphs to explain relative velocity and identify what agrees between inertial frames.

Prepare and predict

Materials: Relative Motion Lab simulation, this packet, pencil and calculator. Work in pairs; swap operator and recorder roles for Part C. Keep first predictions and add revisions beside them.

Conventions: East/right is positive in every frame. Position x is a coordinate; displacement $d = x_f - x_i$. Average velocity $\bar{v} = d / \Delta t$, where Δt is the elapsed time called t in the reference tables. A/B means A relative to B; v_i and v_f name initial and final velocity.

1. Choose two frames and locate each origin. Can one boat move east in one frame and west in another at the same instant? State a prediction and name both frames.

Part A Motion on the river

2. Select **02 Traveling downstream**, then **03 Traveling upstream**. Use Shore and Water views. Save a first prediction or acknowledge a paper prediction, then choose **Begin observation** and play. Read the worked relationship only after recording evidence and saving your explanation.

Scenario	Boat / water v (m/s)	Water / shore v (m/s)	Predicted boat / shore v (m/s)	Observed boat / shore v (m/s)
02 Downstream	+5	+2		
03 Upstream	-5	+2		

3. Write a signed addition equation for the upstream trial. State its speed and direction. Explain why a negative velocity is not a negative speed.

Part B Walking on a moving deck

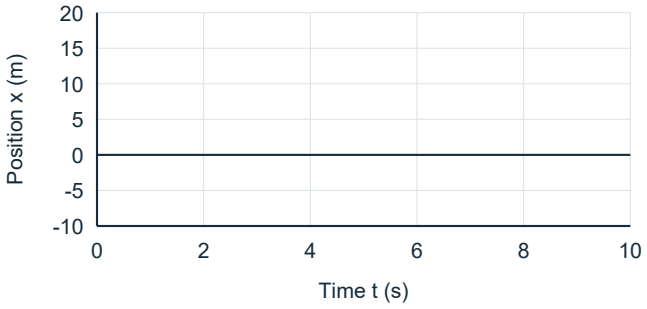
12 minutes | Analyze Passenger | View A Shore | View B Barge

4. Use scenarios 08 and 09 below. Read each preset's conditions anew. Predict both shore velocities and complete question 5 before beginning observation.

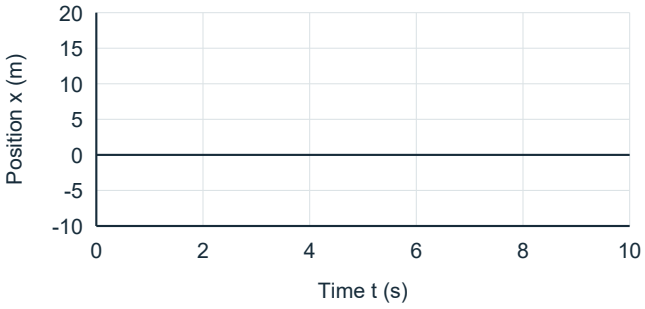
Scenario	Water / shore v (m/s)	Barge / water v (m/s)	Passenger / barge v (m/s)	Predicted passenger / shore v (m/s)	Observed passenger / shore v (m/s)
08 Walking backward	+1	+2	-1		
09 Beside a shore marker	+1	+1	-2		

5. For scenario 09, sketch passenger position from 0 to 10 s in both frames **before beginning observation**. It starts at +15 m in each frame. Then run each trial and record observed velocities above. Preserve your sketches; add observed curves with a different line style and key.

Passenger in shore frame



Passenger in barge frame



6. Build one signed velocity equation connecting passenger, barge, water and shore for scenario 08. Use it to explain how the passenger walks west on deck while moving east relative to shore.

7. For scenario 09, use one slope from each graph to explain how "walking" and "remaining at rest" can both describe this passenger. Name the frame each time.

Part C Design a frame comparison

15 minutes | Change one quantity | Measure position before reading velocity

8. Load **05 Matching the motorboat**. Keep boat / water velocity +2 m/s, current +1 m/s, boat initial shore x = 0 m and observer initial shore x = +20 m. Set View A to Shore and View B to Bank observer. Analyze Motorboat. Use **Change conditions** and apply a new trial for each observer velocity.

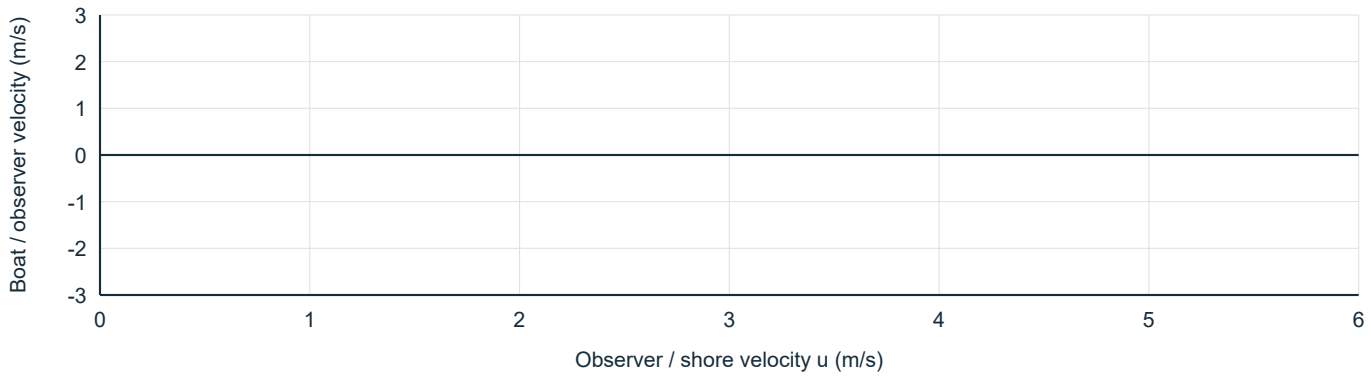
Choose three observer / shore velocities u between 0 and +6 m/s: one below, one equal to and one above the boat's shore velocity. Change only the observer velocity. Use 0 to 5 s for every trial. Explain your choices and predict the relationship between u and boat / observer velocity.

9. Save each first prediction, then begin observation. Use **Reset time** and **Go to exact time** to read the boat's position in the **Bank observer** view at 0 and 5 s. Record each instant. Calculate $\bar{v} = (x_5 - x_0) / 5$ s. Use position change as your measurement method.

Observer / shore u (m/s)	Predicted boat / observer v (m/s)	Boat x at 0 s (m)	Boat x at 5 s (m)	Calculated boat / observer $\bar{v}$ (m/s)

10. Plot calculated boat / observer velocity against u. Draw a line through the trend. Label its slope and vertical intercept; explain what each means. If a graph is inaccessible, describe the ordered pairs, trend, slope and intercept in words.

Relative velocity as observer velocity changes



Part D Explain and transfer

8 minutes | Keep your first prediction visible | Complete the exit response individually

11. State your relationship from Part C using named frames. Support it with two trials and your graph's slope. Explain which condition makes the boat stationary relative to the observer.

12. When boat and observer have equal velocity in scenario 05, must they have equal position? Use the initial positions and one later measurement as evidence.

13. Brief teacher demonstration: load **10 Standing on an accelerating barge**, analyze Passenger, and compare **Shore and Water** views. These two frames are inertial because their relative velocity is constant. Predict whether their passenger acceleration readings agree, then observe. Does an inertial frame require every object in it to have zero acceleration?

14. Explain one limitation of this idealized model and one source of reading uncertainty. Would repeating an identical trial create new independent experimental data? Explain.

15. Individual exit response. A cart moves at +4 m/s relative to the floor. Observer A walks at +1 m/s and observer B at +6 m/s relative to the floor. Predict the cart velocity in each observer's frame. Explain why the descriptions are compatible.

Reference: NYSED Physics Reference Tables, 2025 edition, page 2. Relative-frame subscripts are additional notation for this lab. Return pages 1 to 4 for teacher review.

Extension A An accelerating reference frame

Optional 10 to 15 minutes | Scenario 10 Standing on an accelerating barge

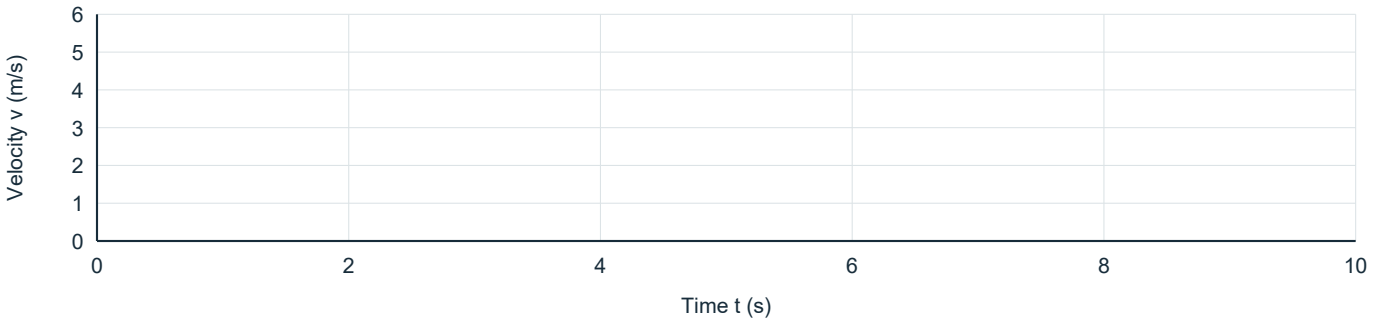
Use Passenger as the analyzed object. The current is +1 m/s; the barge begins at +2 m/s relative to water and has acceleration +0.30 m/s². The passenger stays at the center of the deck: passenger / barge velocity and acceleration are both zero.

E1. Predict passenger velocity and acceleration in the Shore and Barge frames at 0 and 5 s. Record predictions in parentheses; add observed values after playing.

Frame	v at 0 s (m/s)	v at 5 s (m/s)	a at 0 s (m/s²)	a at 5 s (m/s²)
Shore				
Barge				

E2. Sketch a velocity-time graph for the passenger in each frame. Label each line. Explain how one passenger can have different acceleration readings without a contradiction.

Passenger velocity in two frames



E3. Identify which frame is accelerating relative to shore. Why does the statement “all inertial frames agree on acceleration” not require the two readings in this trial to agree?

Model boundary: the simulation prescribes kinematics. A standing passenger is assumed to be carried by deck contact. It does not calculate friction, motor power or forces. Do not infer zero net force from zero coordinate acceleration in the accelerating barge frame.

Extension B When accelerations cancel

Optional 10 to 15 minutes | Scenario 11 Accelerations cancel

Load scenario 11. Current = +1 m/s; initial barge / water velocity = +2 m/s; barge acceleration = +0.40 m/s². Initial passenger / barge velocity = +2 m/s and passenger / barge acceleration = -0.40 m/s². Passenger initial deck position = -10 m; deck length = 60 m.

E4. Before playing, predict the passenger's shore acceleration. Predict when their walking velocity relative to the deck becomes zero. Use $v_f = v_i + at$ in each named frame.

E5. Record predictions in parentheses, then check the values at 0, 5 and 10 s. Use the passenger's deck position to check that the whole interval is valid.

t (s)	Passenger / barge v (m/s)	Passenger / shore v (m/s)	Passenger deck x (m)
0			
5			
10			

E6. At 5 s, is the passenger stationary relative to shore, relative to the barge, both, or neither? Explain the sign of their deck velocity immediately afterward.

E7. Is the passenger frame inertial in this trial? Support your answer with an acceleration relationship and explain why being on an accelerating barge does not determine the answer.

E8. Write a condition under which acceleration measurements agree between two translating, nonrotating frames. Then identify a conclusion about forces that this simulation alone cannot establish.