Minds•On Physics Activity

AT•14

Reasoning About Relative Motion

Purpose and Expected Outcome

In this activity you will reason about the motion of objects in moving frames. You will learn more about how to relate the position and velocity of an object in one frame to its position and velocity in another frame.

Prior Experience / Knowledge Needed

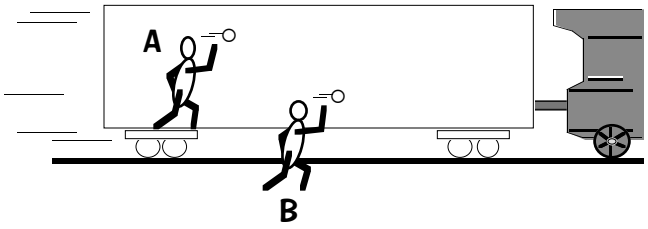
You should have some experience with motion in one and two dimensions. You should be familiar with relative motion in one and two dimensions. Also, you should be familiar with the Impulse–Momentum Theorem and Conservation of Energy, and you should know how to find the work done on an object by a force. Finally, you should be familiar with projectile motion.

Explanation of Activity

In each of the situations described below, you are asked to reason out an answer. Try not to get too bogged down with numerical values.

SITUATION A: Throwing Balls

Two boys throw identical 250g balls horizontally at 10m/s. Boy A is inside a railroad car traveling at a constant speed of 20m/s as seen from the ground, and the other (B) is outside the railroad car standing on the ground.



A1. Which boy exerts the larger average force on the ball while throwing it? Explain.

A2. Which boy delivers the larger impulse to the ball while throwing it? Explain.

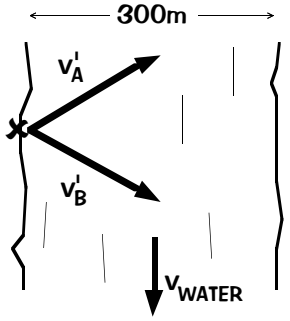
A3. Which ball has more work done on it during the throw? Explain.

A4. Which boy converts more of his internal energy into kinetic energy of the ball? Explain.

A5. Are your answers to A2 and A3 consistent with each other? Are your answers to A3 and A4 consistent with each other? Explain any apparent contradictions.

SITUATION B: Swimming Across a River

Two girls (Arielle and Bebe) are attempting to swim across a slowly flowing river. They both begin at the ✕ and swim at the same speed (relative to the water) but in different directions. Their velocities relative to the water are shown at right. The velocity of the water relative to the ground is also shown.



B1. Which girl reaches the other side first? Explain.

B2. Which girl has the larger speed relative to the ground? Explain.

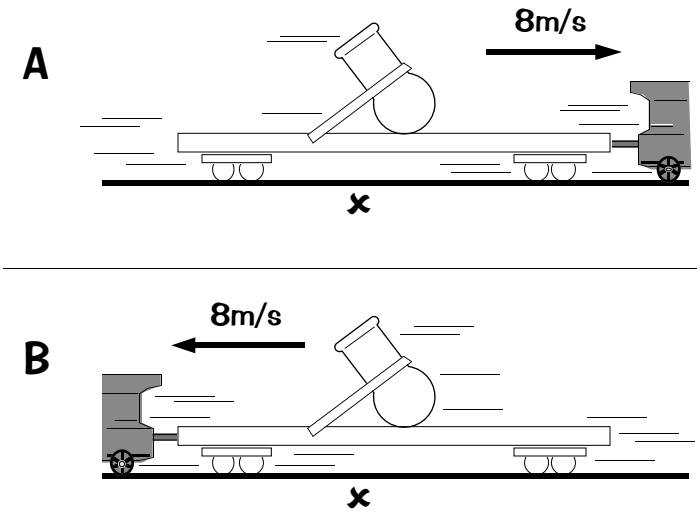
B3. Which girl travels the longer distance before reaching the other side? Explain.

B4. Which girl do you suppose is more tired when she reaches the other side? Explain.

B5. Are your answers to B1 and B2 consistent with each other? Explain any apparent contradictions.

SITUATION C: Firing Cannons Mounted On Railroad Cars

Two identical cannons that fire cannon balls at 35m/s are mounted onto two railroad cars as shown. Railroad car A is pulled at a constant speed of 8m/s to the right, while railroad car B is pulled at a constant speed of 8m/s to the left. Both cannons are fired when they reach the ✘'s in the diagram below.



C1. As measured from the ground, which ball has the larger initial speed, or are they the same? Explain.

C2. Which ball reaches a larger maximum height? Explain.

C3. Which ball lands farther from its ✘? Explain.

C4. Which ball lands farther from its railroad car? Explain.

C5. Which ball has more kinetic energy immediately after being fired? Explain.

C6. Which cannon gives more energy to the ball when it is fired? Explain.

C7. Are your answers to C5 and C6 consistent with each other? Explain any apparent contradictions.

Reflection

R1. Create and describe a situation in which the vertical components of the velocity are different in two different frames, but the horizontal components are the same. What must be true about the relative velocity of the two frames?

R2. (a) Which answers in this activity seem to depend on the frame of reference? For instance, reconsider C5. Does the amount of kinetic energy depend on the frame?

(b) Which answers seem to not depend on the frame?

R3. Are the laws of physics valid on the Earth? Explain. Are the laws valid in a frame moving relative to the Earth? Explain. Under what circumstances do you suppose the laws of physics might not be valid? Explain. Give an example of a situation in which the laws of physics (as you have learned them) do not appear to be valid.

R4. (a) Estimate the speed of the Earth relative to the Sun.

(b) Estimate the speed of a person standing at the equator relative to the center of the Earth.

(c) Estimate the acceleration of a person standing at the equator relative to the center of the Earth.

(d) Comment on the validity of experiments done on the Earth to verify or demonstrate the laws of physics.

R5. (a) Which types of relative motion are hardest for you to visualize? For each type listed below, rate its difficulty from 1–10, where 1 is easiest to visualize and 10 is hardest.

i. someone moving on a boat
ii. something thrown on a boat
iii. someone swimming in a flowing river
iv. someone moving on a bus
v. something moving on a bus
vi. someone moving on a railroad car
vii. something moving on a railroad car
viii. someone moving on an airplane
ix. something moving on an airplane
x. an airplane flying in windy air
xi. a ball fired from a cannon mounted on a railroad car

(b) Why do you suppose the hard ones are hard for you? What makes the easy ones easy for you?