# Section 11.1: The Special Theory of Relativity

## Mini Investigation: Understanding Frames of Reference, page 576

Answers may vary. Sample answers:

**A.** The speed of the ball is greater when the person tossing the ball walks forward. The speed appears to be the sum of the speed at which the ball is tossed and the speed of the person tossing the ball.

**B.** The speed of the ball was even faster when the student throwing the ball walked forward more quickly. This supports what we inferred in Question A.

**C.** When the student throwing the ball walked slowly backward, the speed decreased. The decrease occurred because the person tossing the ball was moving away from the catcher.

**D.** Yes, if you know the speed of an object in one inertial reference frame, you can determine its speed in another inertial reference frame, at least at the slow speeds used in this investigation. We can determine the speed of the ball if we know the speed in the catcher's inertial frame and the speed of the pitcher relative to the catcher. When we change this relative speed between the two inertial frames, we can determine the speed of the ball in the new inertial frame.

## Section 11.1 Questions, page 579

**1.** Answers may vary. Sample answers:

**(a)** The three most natural reference frames to use would be: 1) a frame moving alongside the skater at the same velocity; 2) a frame fixed on the deck of the boat; and, 3) a frame fixed on the shoreline.

**(b)** For reference frame 1 in part (a), the student on skates would not be moving along, just moving in place. But the boat would be moving at constant speed, as would the shoreline (unless the skater's velocity relative to the boat was equal but opposite to the velocity of the boat relative to the shoreline). For reference frame 2, the skater would be moving along, the shoreline would be moving past, but the boat would appear fixed in place. For reference frame 3, the skater would appear to be moving with velocity equal to the vector sum of the boat's velocity relative to the shoreline and the skater's velocity relative to the boat. In this inertial frame, the boat would appear to be moving past the shoreline, but the shoreline would appear fixed.

**2. (a)** An inertial frame of reference moves at constant velocity, whereas a non-inertial frame accelerates (i.e., its velocity changes).

**(b)** Answers may vary. Sample answer:

Two examples of an inertial frame of reference being at rest on the ground and being in an airplane cruising at constant altitude, with a fixed direction and fixed speed.

Two examples of a non-inertial frame of reference are being in a car accelerating from a traffic light and being on a merry-go-round at a carnival.

**3. (a)** According to special relativity, the astronaut would measure the speed of light to be $c$.

**(b)** The speed of the light measured by a person on Earth would equal $c$.

**4. (a)** Lutaaq would see Gabor's ball follow a parabolic arc and Gabor moving along underneath the ball. The ball would be seen to fall directly into Gabor's hand.

**(b)** Gabor would see the same thing that Lutaaq had seen, that is, Lutaaq's ball following a parabolic arc and Lutaaq moving along underneath the ball, having the ball land in her hand.

**5.** The feature of Einstein's coil and magnet thought experiment that Einstein found troubling was that in the inertial frame of the coil, an electric field causes a current, but in the inertial frame of the magnet, a magnetic field produces a current. The explanation depended on the inertial frame of the explainer.
**6.** The two postulates of the special theory of relativity are
1. The laws of physics are the same in all inertial reference frames.
2. For an observer in at least one inertial reference frame, the speed of light in a vacuum is independent of the motion of the light source.
**7.** The conclusion that results from the combination of Einstein's two postulates is that all inertial observers, regardless of their motion, will measure the same speed of light in a vacuum, regardless of the motion of the light source.
**8.** A thought experiment is an imagined experiment that may be possible to do but impractical. The experiments are generally used to test an hypothesis or show a problem with an idea. As an example of the former, if one wonders if a laser beam from Earth could be used to deflect an incoming comet, then one could imagine the experiment, using current knowledge about lasers and comets. The hypothesis might be that the vaporized material causes the comet to change course. In Einstein's thought experiment concerning the magnet and coil, he was demonstrating a problem with the then-current ideas of electrodynamics.
**9.** To determine whether your ship is in an inertial frame of reference, you must show that the ship is not accelerating. Qualitatively, if you were fixed to your seat, you would feel any acceleration in your body. For a quantitative measure, the simplest experiment would be to hold a ball out in front of you such that it is not moving relative to you or the ship. Then, carefully let go of the ball without giving it any push or pull. Does the ball move? If so, your frame is non-inertial and you can measure the acceleration. (Unless your spacecraft is as massive as a small planet and you are not at its centre, then the ball should float, free of the influence of gravity.)
**10. (a)** The ball rolls forward but then suddenly slows down when the train car suddenly accelerates forward. You would have felt this acceleration too. It means your reference frame suddenly became non-inertial.
**(b)** You pushed the ball straight ahead (forward), but it curved to the right because your train car is accelerating to the left. You would sense this acceleration too. It means that your reference frame is non-inertial.