Relative Motion

Unit: Kinematics (Motion) in One Dimension

NGSS Standards/MA Curriculum Frameworks (2016): N/A

AP® Physics 1 Learning Objectives/Essential Knowledge (2024): 1.4.A, 1.4.A.1, 1.4.B, 1.4.B.1

Mastery Objective(s): (Students will be able to…)

- Describe how a situation appears differently in different reference frames.

Success Criteria:

- Explanations account for observed behavior.

Language Objectives:

- Describe a situation when you thought you were moving but you weren't (or *vice versa*).

Tier 2 Vocabulary: relative, reference frame

Vocabulary:

relativity: the concept that motion can be described only with respect to an observer, who may be moving or not moving relative to the object under consideration.

reference frame: the position and velocity of an observer watching an object that is moving relative to himself/herself.

inertial reference frame: a reference frame that is either at rest or moving at a constant velocity.

Use this space for summary and/or additional notes:

Notes:

Consider the following picture, taken from a moving streetcar in New Orleans:

"New Orleans Streetcar." Photo by Don Chamblee.

If the streetcar is moving at a constant velocity and the track is smooth, the passengers may not notice that they are moving until they look out of the window.

In the reference frame of a person standing on the ground, the trolley and the passengers on it are moving at approximately 30 miles per hour.

In the reference frame of the trolley, the passengers sitting in the seats are stationary (not moving), and the ground is moving past the trolley at approximately 30 miles per hour.

Of course, you might want to say that the person on the ground has the "correct" reference frame. However, despite what you might prefer, neither answer is more correct than the other. Both are *inertial reference frames*, which means it is just as correct to say that the ground is moving as it is to say that the trolley is moving.

Use this space for summary and/or additional notes:

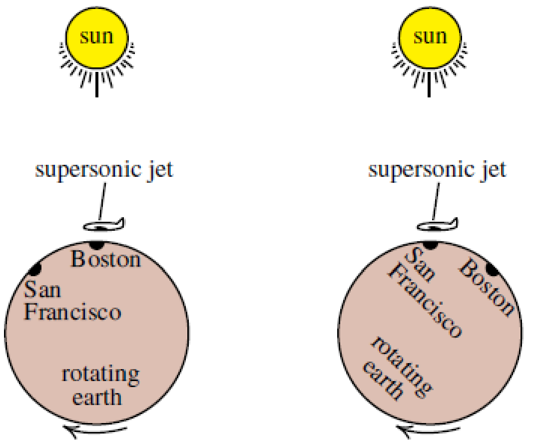
Principle of Relativity

There is no experiment you can do that would allow you to determine conclusively whether or not you are moving uniformly.

Recall that an inertial reference frame is moving with constant velocity (which might be zero or nonzero). If velocity is constant, there is no acceleration, which means there is no net force. (This concept will be discussed further in the *Newton's Second Law* topic, starting on page 293.) If you do not feel any force, you cannot tell whether or not you are moving.

You may have experienced this on a train that is arriving at a station. If you are watching a train on the next track that starts moving just as the train you are on is stopping, you may think that you are still moving until the other train is gone and you suddenly notice that the platform out the window is stationary!

An example of different reference frames is a fast airplane (such as a supersonic jet) flying from Boston to San Francisco. Imagine that the plane takes exactly three hours to fly to San Francisco, which is exactly the same as the time difference between the two locations. Seen from a reference frame outside the Earth, the situation might look like this:



Supersonic jet over Boston just after takeoff.

Supersonic jet three hours later over San Francisco.

You could argue that either:

1. The jet was moving from the airspace over Boston to the airspace over San Francisco.
2. The jet was stationary and the Earth rotated underneath it. (The jet needed to burn fuel to overcome the drag from the Earth's atmosphere as the Earth rotated, pulling its atmosphere and the jet with it.)

Use this space for summary and/or additional notes:

Of course, there are other reference frames you might consider as well.

3. Both the supersonic jet and the Earth are moving, because the Earth is revolving around the Sun at a speed of about $30\,000\,\frac{\text{m}}{\text{s}}$ *.
4. The jet, the Earth and the Sun are all moving, because the sun is revolving around the Milky Way galaxy at a speed of about $220\,000\,\frac{\text{m}}{\text{s}}$.
5. The jet, the Earth, the Sun, and the entire Milky Way galaxy are all moving through space toward the Great Attractor (a massive region of visible and dark matter about 150 million light-years away from us) at a speed of approximately $1\,000\,000\,\frac{\text{m}}{\text{s}}$.
6. It is possible that there might be multiple Great Attractors. If so, they are likely moving relative to each other, or relative to some yet-to-be-discovered larger entity.

Regardless of which objects are moving with which velocities, if you are on the airplane and you drop a ball, you would observe that it falls straight down. In relativistic terms, we would say "In the reference frame of the moving airplane, the ball has no initial velocity, so it falls straight down."

* $30\,000\,\frac{\text{m}}{\text{s}}$ is is about $67\,000\,\frac{\text{mi.}}{\text{hr.}}$. When a meteoroid enters Earth's atmosphere, the relative velocity between the meteoroid and the Earth is usually in the range of $27\,000-90\,000\,\frac{\text{mi.}}{\text{hr.}}$. Unless the meteor is very large, the heat generated by the drag force as it passes through the Earth's atmosphere is enough to burn it up. "Shooting stars" are meteors, usually about the size of a grain of rice, that glow white-hot for a fraction of a second as they burn up in the atmosphere.

Use this space for summary and/or additional notes: