PHYSICS TALK

Newton's First Law of Motion

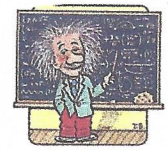
Isaac Newton included Galileo's Principle of Inertia as part of his **First Law of Motion**:

In the absence of an unbalanced force, an object at rest remains at rest, and an object already in motion remains in motion with constant speed in a straight-line path.

Newton also explained that an object's mass is a measure of its inertia, or tendency to resist a change in motion.

Here is an example of how Newton's First Law of Motion works:

Inertia is expressed in kilograms of mass. If an empty grocery cart has a mass of 10 kg and a cart full of groceries has a mass of 100 kg, which cart would be more difficult to move (have a greater tendency to remain at rest)? If both carts already were moving at equal speeds, which cart would be more difficult to stop (would have a greater tendency to keep moving)? Obviously in both cases, the answer is the cart with more mass.

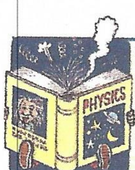


Physics Words

inertia: the natural tendency of an object to remain at rest or to remain moving with constant speed in a straight line.

acceleration: the change in velocity per unit time.

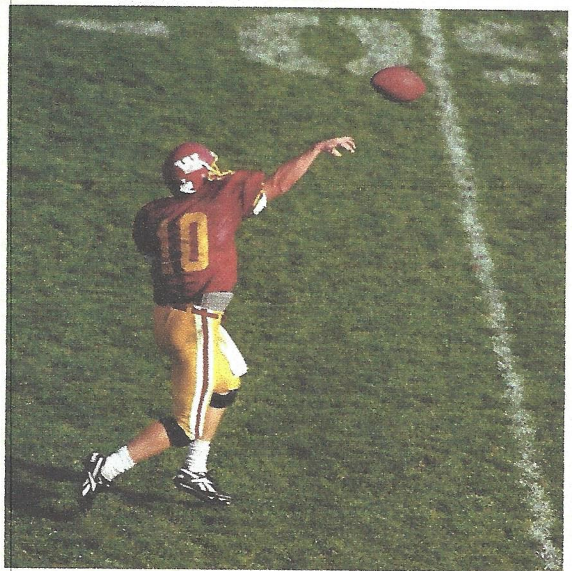
frame of reference: a vantage point with respect to which position and motion may be described.



FOR YOU TO READ

Frames of Reference

In this activity, you investigated Newton's First Law. In the absence of external forces, an object at rest remains at rest and an object in motion remains in motion. If you were challenged to throw a ball as far as possible, you would probably now be sure to ask if you could have a running start. If you run with the ball prior to throwing it, the ball gets your speed before you even try to release it. If you can run at 5 m/s, then the ball will get the additional speed of 5 m/s when you throw it. When you do throw the ball, the ball's speed is the sum of your speed before releasing the ball, 5 m/s, and the speed of the release.



It may be easier to understand this if you think of a toy cannon that could be placed on a skateboard. The toy cannon always shoots a small ball forward at 7 m/s. This can be checked with multiple trials. The toy cannon is then attached to the skateboard. A release mechanism is set up so that the cannon continues to shoot the ball forward at 7 m/s when the skateboard is at rest. When the skateboard is given an initial push, the skateboard is able to travel at 3 m/s. If the cannon releases the ball while the skateboard is moving, the ball's speed is now measured to be 10 m/s. From where did the additional speed come? The ball's speed is the sum of the ball's speed from the cannon plus the speed of the skateboard. 7 m/s + 3 m/s = 10 m/s.

You may be wondering if the ball is moving at 7 m/s or 10 m/s. Both values are correct — it depends on your **frame of reference**. The ball is moving at 7 m/s relative *to* the skateboard. The ball is moving at 10 m/s relative *to* the Earth.

Imagine that you are on a train that is stopped at the platform. You begin to walk toward the front of the train at 3 m/s. Everybody in the train will agree that you are moving at 3 m/s toward the front of the train. This is your speed *relative to* the train. Everybody looking into the train from the platform will also agree that you are moving at 3 m/s toward the front of the train. This is your speed *relative to* the platform.

Imagine that you are on the same train, but now the train is moving past the platform at 9 m/s. You begin to walk toward the front of the train at 3 m/s. Everybody in the train will agree that you are moving at 3 m/s toward the

front of the train. This is your speed *relative to* the train. Everybody looking into the train from the platform will say that you are moving at 12 m/s (3 m/s + 9 m/s) toward the front of the train. This is your speed relative *to* the platform.

Whenever you describe speed, you must always ask, "*Relative to what?*" Often, when the speed is relative to the Earth, this is assumed in the problem. If your frame of reference is the Earth, then it all seems quite obvious. If your frame of reference is the moving train, then different speeds are observed.

In sports where you want to provide the greatest speed to a baseball, a javelin, a football, or a tennis ball, that speed could be increased if you were able to get on a moving platform. That being against the rules and inappropriate for many reasons, an athlete will try to get the body moving with a running start, if allowed. If the running start is not permitted, the athlete tries to move every part of his or her body to get the greatest speed.

Sample Problem 1

A sailboat has a constant velocity of 22 m/s east. Someone on the boat prepares to toss a rock into the water.

a) Before being tossed, what is the speed of the rock with respect to the boat?

b) Before being tossed, what is the speed of the rock with respect to the shore?

c) If the rock is tossed with a velocity of 16 m/s east, what is the rock's velocity with respect to shore?

d) If the rock is tossed with a velocity of 16 m/s west, what is the rock's velocity with respect to shore?

Strategy: Before determining a velocity, it is important to check the frame of reference. The rock's velocity with respect to the boat is different from the velocity with respect to the shore. The direction of the rock also impacts the final answer.

Givens:

v_b = 22 m/s east

v_r = 16 m/s (direction varies)

d) With respect to shore, the rock's velocity is now 6 m/s east.
Since the directions are opposite, the relative velocity is the difference between the two.

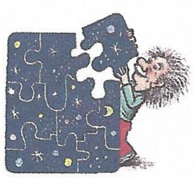
$$v = v_b - v_r$$
$$= 22 \text{ m/s east} - 16 \text{ m/s west}$$
$$= 6 \text{ m/s east}$$

Sample Problem 2

A quarterback on a football team is getting ready to throw a pass. If he is moving backward at 1.5 m/s and he throws the ball forward at 10.0 m/s, what is the velocity of the ball relative to the ground?

Strategy: Use a negative sign to indicate the backward direction. Add the two velocities to find the velocity relative to the ground.

Givens:



Reflecting on the Activity and the Challenge

Running starts can be observed in many sports. Many observers may not realize the important role that inertia plays in preserving the speed already established when an athlete engages in activities such as jumping, throwing, or skating from a running start. "Immovable objects," such as football linemen, illustrate the tendency of highly massive objects to remain at rest and can be observed in many sports. You should have no problem finding a great variety of video segments that illustrate Newton's First Law.