

3•2 Velocity and Acceleration

Science Words

velocity
acceleration

Objectives

- Compare and contrast speed, velocity, and acceleration.
- Calculate acceleration.

Velocity and Speed

You turn on the radio and hear the tail end of a news story about a tornado sighting in a storm, such as the one in **Figure 3-7**. The storm, moving at a speed of 60 km/h, has just left a town 10 km north of your location. Should you be worried? Unfortunately, you don't have enough information. Knowing only the speed of the storm isn't much help. Speed only describes how fast something is moving. You also need to know the direction the storm is moving. In other words, you need to know the velocity of the storm. **Velocity** describes both *speed* and *direction* of an object.

Picture a motorcycle racing down the highway at 100 km/h. It meets another motorcycle going 100 km/h in the opposite direction. The speeds of the motorcycles are the same, but their velocities are different because the motorcycles are not moving in the same direction.

You learned earlier that speed isn't always constant. Like speed, velocity may also change. Unlike speed, the velocity of an object can change even if the speed of the object remains constant! For example, if a car goes around a curve in the road, its direction changes. Even if the speed remains constant, the velocity changes because the direction changes.



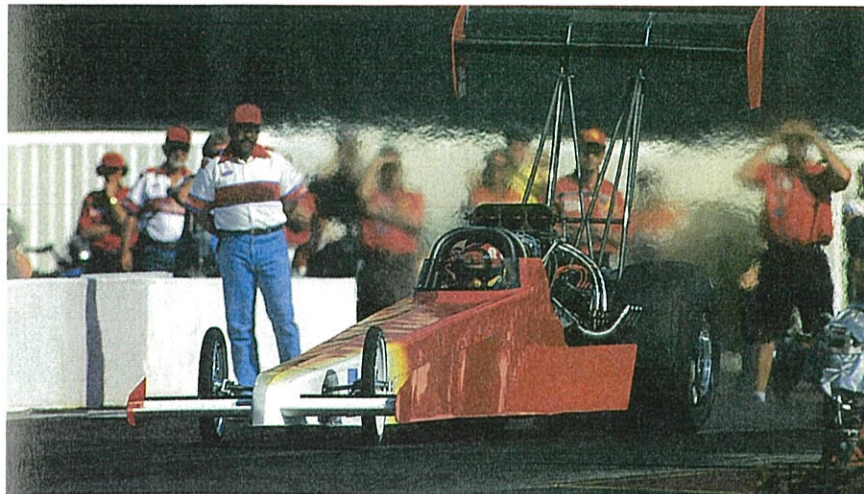
Figure 3-7

Knowing the speed and direction of a tornado can be important for safety.

Acceleration

At the starting line of a drag strip, the driver idles the dragster's engine. When the starting signal flashes, the driver presses the gas pedal.

The car leaps forward, as shown in **Figure 3-8A**, moving faster and faster until it crosses the finish line. Then, in **Figure 3-8B**, the driver releases a drag chute and the car rapidly slows down and comes to a stop. While the car gains speed, it is accelerating. Strange as it may seem, the car is also accelerating as it slows down. How is this possible?



A The dragster accelerates continuously as it races down the track.

B The drag parachute is used to change the direction of the dragster's acceleration.

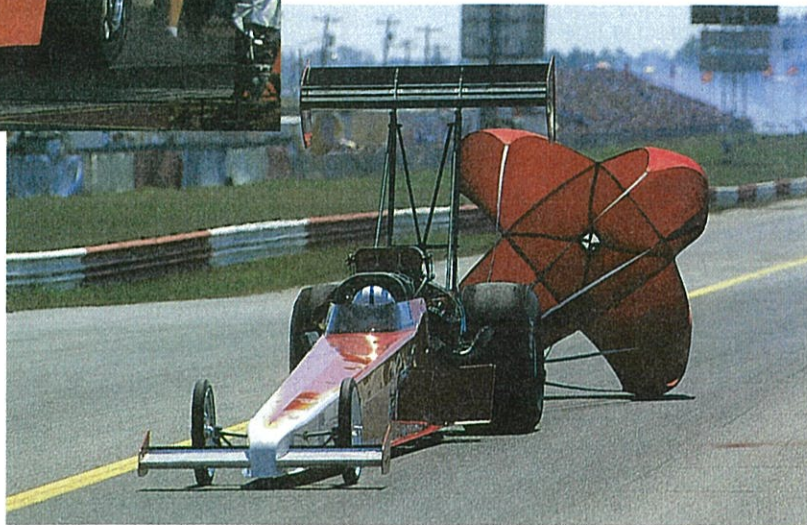


Figure 3-8

The dragster is accelerating in both of these photos.

What is acceleration?

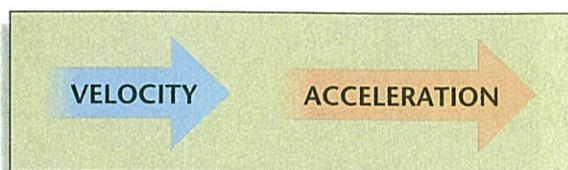
Acceleration is the rate of change of velocity. Because velocity includes both speed and direction, if either one changes, velocity will change. In other words, acceleration can occur through a change in speed or a change in direction.

If an object travels in a straight line and the directions of acceleration and velocity occur along the same line, as with the dragster, then acceleration is just the rate of change of speed. If the acceleration is in the same direction as the velocity, then the dragster *speeds up*. Its acceleration is positive. If they are in opposite directions, then the dragster *slows down*. Its acceleration is negative. These principles are illustrated in **Figure 3-9**.

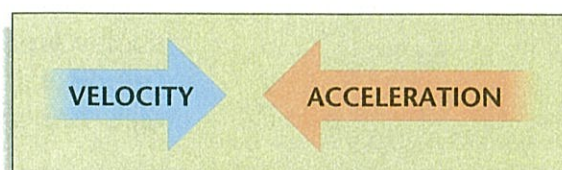
The amount of acceleration depends on both the change in velocity and the time interval. The *time interval* is the amount of time that passed while the change in velocity was taking place. The acceleration will be large if the change in velocity is large; it will also be large if the change in velocity occurs in a small time interval.

Figure 3-9

The diagram indicates how positive and negative acceleration are defined. *Explain these two definitions.*



Positive Acceleration



Negative Acceleration

MiniLAB

How can you describe the motion of a car?

Procedure

1. Select a line or place a pencil on the floor to mark your starting point.
2. Beginning at the starting line, give your car a gentle push forward. At the same time, start your stopwatch.
3. Stop timing exactly when the car comes to a complete stop. Mark the spot at the front of the car with another pencil.
4. Record the time for the entire trip. Measure the distance to the nearest tenth of a centimeter and convert it to meters.

Analysis

1. Calculate the average speed during your car's trip. What was the car's average velocity?
2. How would the velocity reading differ if you repeated your experiment in exactly the same way in the opposite direction?
3. Describe any acceleration you observed the car undergo. How would you cause a greater acceleration?

Calculating Acceleration

To calculate average acceleration, divide the change in velocity by the time interval. To find the *change in velocity*, subtract the initial velocity (starting velocity), v_i , from the final velocity, v_f .

$$a = \frac{v_f - v_i}{t} = \frac{\Delta v}{t}$$

The symbol Δ is the Greek letter *delta* and stands for "change in."

When calculating acceleration, be sure to include all proper units and algebraic signs. The unit for velocity is meters/second (m/s) and the unit for time is seconds (s). Thus, the unit for acceleration is meters/second/second. This unit is usually written as m/s^2 and is read as "meters per second squared" or "meters per second per second."

You can see from the equation that acceleration will be positive if an object is speeding up and negative if an object is slowing down. In a horse race, for example, the outcome is often determined by whether a horse is speeding up or slowing down during the stretch run near the end of the race. When Secretariat set the speed record for the Kentucky Derby, **Figure 3-10**, he ran each quarter mile faster than the previous one. The graph in **Figure 3-10** illustrates Secretariat's motion.

When you work on acceleration problems, be careful to correctly identify the initial velocity and the final velocity. If

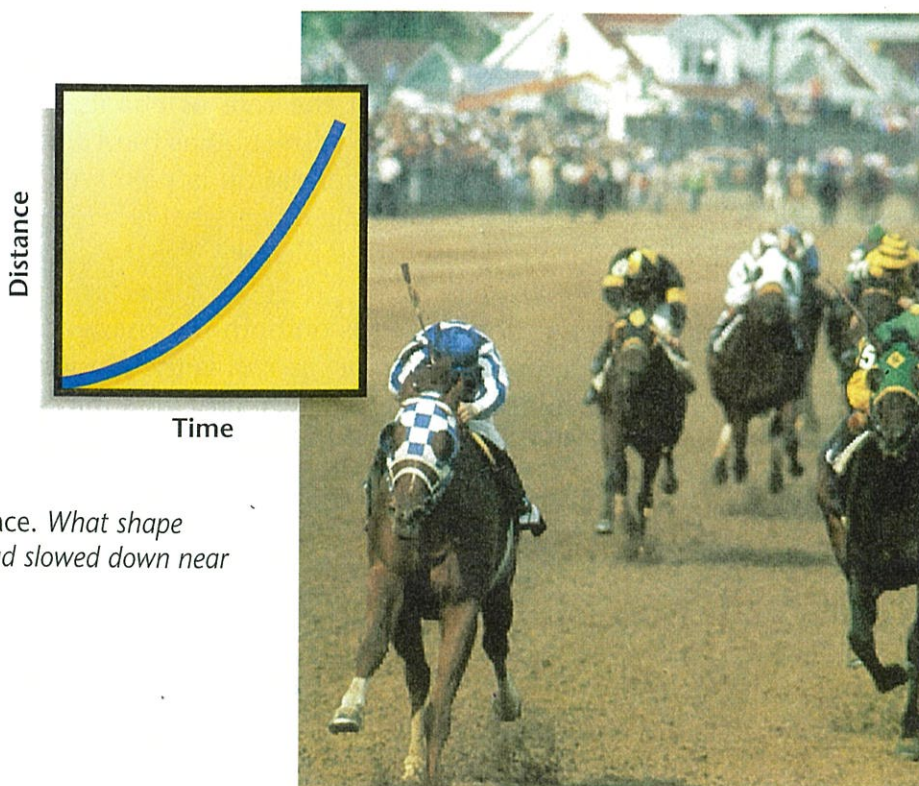


Figure 3-10

Horses often tire near the end of a race. What shape would the graph have if Secretariat had slowed down near the finish line?



you confuse them, the acceleration will have the wrong sign (positive or negative). The problems below provide practice in calculating acceleration.

USING MATH

Calculating Acceleration

Example Problem:

A car's velocity changes from 0 m/s to 30 m/s 10 seconds later. Calculate the car's average acceleration.

1. What is known? initial velocity, $v_i = 0$ m/s; final velocity, $v_f = 30$ m/s; time, $t = 10$ s.

2. Use the equation $a = \frac{v_f - v_i}{t}$.

3. **Solution:** $a = \frac{v_f - v_i}{t}$ $a = \frac{30 \text{ m/s} - 0 \text{ m/s}}{10 \text{ s}} = \frac{30 \text{ m/s}}{10 \text{ s}} = 3 \text{ m/s}^2$

The car's average acceleration is 3 m/s².

Practice Problem

As a roller coaster starts down a hill, its speed is 10 m/s. Three seconds later, its speed is 32 m/s at the bottom of the hill. What is the roller coaster's acceleration?

Strategy Hint: Find the change in velocity by subtracting initial velocity from final velocity.

Section Wrap-up

Review

1. One jet plane is flying east at 880 km/h, and another plane is traveling north at 880 km/h. Do they have the same velocities? The same speeds? Explain.
2. A swimmer speeds up from 1.1 m/s to 1.3 m/s during the last 20 s of the workout. What is the acceleration during this interval?
3. **Think Critically:** Describe three different ways to change your velocity when you're riding a bicycle.



Skill Builder

Making and Using Graphs

Decide on a style of graph to show how velocity changes over time. Explain your choice. Show the graph. If you need help, refer to Making and Using Graphs in the **Skill Handbook**.



Science Journal

In your Science Journal, explain why we have speed limits on streets and highways rather than velocity limits.