Figure 9
High-speed trains such as this one can travel at speeds of about 300 km/h (186 mi/h).

Acceleration has direction and magnitude

Figure 9 shows a high-speed train leaving a station. Imagine that the train is moving to the right so that the displacement and the velocity are positive. The velocity increases in magnitude as the train picks up speed. Therefore, the final velocity will be greater than the initial velocity, and Δv will be positive. When Δv is positive, the acceleration is positive.

On long trips with no stops, the train may travel for a while at a constant velocity. In this situation, because the velocity is not changing, $\Delta v = 0$ m/s. When the velocity is constant, the acceleration is equal to zero.

Imagine that the train, still traveling in the positive direction, slows down as it approaches the next station. In this case, the velocity is still positive, but the initial velocity is larger than the final velocity, so Δv will be negative. When Δv is negative, the acceleration is negative.

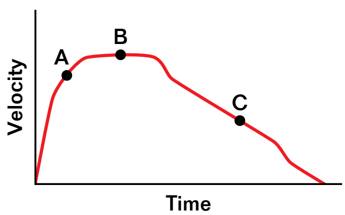

Figure 10
When the velocity in the positive direction is increasing, the acceleration is positive, as at point A. When the velocity is constant, there is no acceleration, as at point B. When the velocity in the positive direction is decreasing, the acceleration is negative, as at point C.

The slope and shape of the graph describe the object's motion

As with all motion graphs, the slope and shape of the velocity-time graph in **Figure 10** allow a detailed analysis of the train's motion over time. When the train leaves the station, its speed is increasing over time. The line on the graph plotting this motion slopes up and to the right, as at point **A** on the graph.

When the train moves with a constant velocity, the line on the graph continues to the right, but it is horizontal, with a slope equal to zero. This indicates that the train's velocity is constant, as at point **B** on the graph.

Finally, as the train approaches the station, its velocity decreases over time. The graph segment representing this motion slopes down to the right, as at point **C** on the graph. This downward slope indicates that the velocity is decreasing over time.

A negative value for the acceleration does not always indicate a decrease in speed. For example, if the train were moving in the negative direction, the acceleration would be negative when the train gained speed to leave a station and positive when the train lost speed to enter a station.

Why it Matters

Conceptual Challenge

1. Fly Ball If a baseball has zero velocity at some instant, is the acceleration of the baseball necessarily zero at that instant? Explain, and give examples.

2. Runaway Train If a passenger train is traveling on a straight track with a negative velocity and a positive acceleration, is it speeding up or slowing down?

3. Hike-and-Bike Trail When Jennifer is out for a ride, she slows down on her bike as she approaches a group of hikers on a trail. Explain how her acceleration can be positive even though her speed is decreasing.