2.4 Acceleration

Many times in the last section, you read that an object s velocity was increasing, decreasing, or that it was changing direction. Once again, physicists have a precise way of stating the changes in velocity. Acceleration is a vector quantity that describes the rate of change of velocity.

ACCELERATION

Acceleration is the quotient of the change in velocity and the time interval over which the change takes place.

$$\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$$

Quantity	Symbol	SI unit
acceleration	$\vec{a}$	$\frac{m}{s^2}$ (metres per second squared)
change in velocity	$\Delta\vec{v}$	$\frac{m}{s}$ (metres per second)
time interval	Δt	s (seconds)

Unit Analysis

$$\frac{\frac{\text{metres}}{\text{second}}}{\text{second}} = \frac{\frac{m}{s}}{s} = \frac{m}{s^2}$$

The units of acceleration metres per second squared do not have an obvious meaning. If you think about the basic de nition of acceleration, however, the meaning becomes clear. The velocity of an object changes by a certain number of metres per second every second. For example, analyze the statement, A truck is travelling at a constant velocity of 20 m/s[E], then accelerates at 1.5 m/s^2[E]. This acceleration means that the truck s velocity increases by 1.5 m/s[E] every second. One second after it starts accelerating, it will be travelling at 21.5 m/s[E]. One second later, it will be travelling at 23 m/s[E]. The truck s velocity increases by 1.5 m/s[E] every second, as long as it is accelerating.

Direction of Acceleration Vectors

The direction of the acceleration vector is the direction of the change in the velocity and not the direction of the velocity itself. To determine the direction of the acceleration vector, it is helpful to visualize the direction in which you would have to push on an object to cause a particular change in velocity.

SECTION OUTCOMES

- Use vectors to represent position, displacement, velocity, and acceleration.
- Identify and investigate questions that arise from practical problems involvig motion.
- Analyze word problems, solve algebraically for unknowns, and interpret patterns in data.

KEY TERMS

- acceleration
- constant (uniform) acceleration
- non-uniform acceleration
- average acceleration
- instantaneous acceleration

ELECTRONIC LEARNING PARTNER

To enhance your understanding of the language of acceleration go to your Electronic Learning Partner for an interactive activity.

Figure 2.19 shows the motion of a van that starts from rest, speeds up, travels at a constant velocity, slows down, and then stops. The frame of reference shows the origin at the left, with the x-axis pointing in a positive direction to the right. When the van is speeding up, the average velocity vectors and the average acceleration vector point in the same direction (+). When the van is travelling at a constant speed, the average acceleration is zero. When the van is slowing down, the average velocity vectors (+) and the average acceleration vector (–) are in opposite directions.

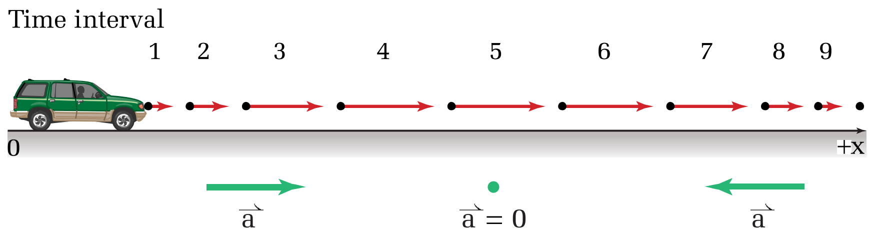


Figure 2.19 When the van is moving in a positive direction but slowing down, the direction of the acceleration is negative.

MISCONCEPTION

They Don't Mean the Same Thing!

Many people think that negative acceleration and deceleration mean the same thing — that an object is slowing down. "Deceleration" is not a scientific term but a common term that people use for slowing down. "Negative acceleration" is a scientific term meaning that the acceleration vector is pointing in the negative direction. However, an object with a negative acceleration might be speeding up.

Consider the directions that the average velocity and average acceleration vectors point if the van turns around and travels back to its starting point. As shown in Figure 2.20, when the van is speeding up in a negative direction, both the average velocity vectors and the acceleration vector point in the negative direction. While the van travels at constant velocity, the average velocity vectors are negative and the acceleration vector is zero. As the van slows down to stop, the average velocity vectors are pointing in the negative direction and the average acceleration vector is pointing in the positive direction.

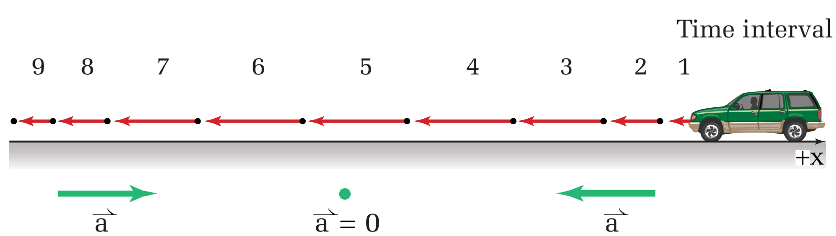


Figure 2.20 When the van is moving in a negative direction and slowing down, the direction of acceleration is positive.

An object can accelerate without either speeding up or slowing down. If the magnitude of the velocity does not change but the direction does change, the object is accelerating. To visualize the direction of the acceleration vector in such cases, study Figure 2.21. Imagine the direction that you would have to push on the tip of the initial velocity vector to make it overlap with the nal velocity vector. The direction of the acceleration vector is from the tip of the initial velocity vector toward the tip of the nal velocity vector.

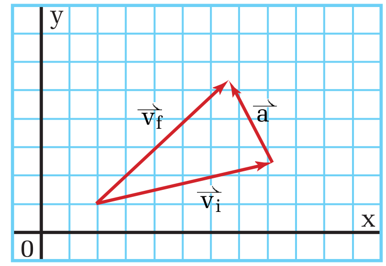


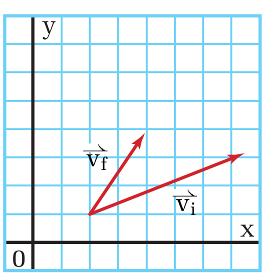
Figure 2.21 Envision pushing on the tip of $\vec{v}_i$, until it overlaps with $\vec{v}_f$.

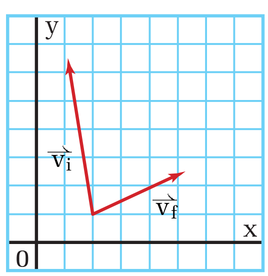
Conceptual Problems

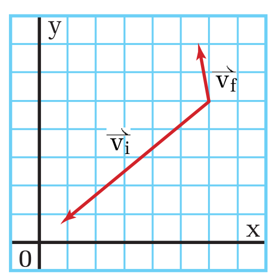
The following charts refer to the van s journeys in Figures 2.19 and 2.20. Redraw the charts below and, using as examples the two rows that have been completed, ll in the remaining rows.

Images in figure	Direction of velocity vector	Direction of acceleration vector	Description of motion
Figure 2.19 Van is moving in the positive direction.			
1-2-3	positive	positive	speeding up in positive direction
4-5-6			
7-8-9			
Figure 2.20 Van is moving in the negative direction			
1-2-3			
4-5-6			
7-8-9	negative	positive	slowing down in negative direction

Sketch each of the combinations of initial and nal velocity vectors, and add to your sketch another vector showing the direction of the acceleration vector.







PHYSICS FILE

Physicists often use the term uniform motion to apply to motion with a constant velocity, and uniformly accelerated motion to apply to motion with a constant acceleration.

Uniform and Non-Uniform Acceleration

Have you noticed the similarity in the mathematical expressions for velocity and acceleration?

$$\vec{v} = \frac{\Delta \vec{d}}{\Delta t} = \frac{\vec{d}_2 - \vec{d}_1}{t_2 - t_1} \qquad \vec{a} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_2 - \vec{v}_1}{t_2 - t_1}$$

The mathematical operations you performed on position vectors to find velocity are nearly the same as those you will perform on velocity vectors to find acceleration. The similarity applies to both equations and graphs. For example, the slope of a velocity-time graph is the acceleration. If the velocity graph is curved, the slope of the tangent to the velocity-time graph at a specific time is the acceleration of the object at that time. The terms applied to velocity also apply to acceleration. Constant or uniform acceleration means that the acceleration does not change throughout specified time intervals. As well, non-uniform acceleration means that the acceleration is changing with time.

The terms, average, constant, and instantaneous apply to acceleration in the very same way that they apply to velocity. Average acceleration is an acceleration calculated from initial and final velocities and the time interval. Constant acceleration means that the acceleration is not changing over a certain interval of time. The velocity-time graph for the time interval is a straight line. Instantaneous acceleration is the acceleration found at one moment in time, and is equal to the slope of the tangent to velocity-time graph at that point in time.

To see the connections among time, position, velocity, and acceleration of a moving object, consider the example of a ball that is thrown straight up in the air with an initial velocity of 20.0 m/s. The position-time data are listed in Table 2.5 and the graphs of position, velocity, and acceleration are shown in Figure 2.22.

The data for the velocity-time graph were determined by the slope of the position-time graph. (Only four tangent lines are shown.) The velocity-time graph of data taken from the slopes of the position-time graph is a straight line with a negative slope that is the same everywhere. Since the slope of the velocity-time graph is the acceleration, the acceleration has the same negative value throughout the motion. (The value is -9.81 m/s^2.)

Table 2.5 Position-Time Data

t (s)	$\vec{d}$ (m)
0.0	0.0
0.5	8.8
1.0	15.1
1.5	19.0
2.0	20.4
2.5	19.4
3.0	15.9
3.5	10.0
4.0	1.6

Note: Since the motion is in one dimension, direction is indicated by plus (+) or minus (–).

Figure 2.22 Position, velocity, and acceleration graphs for Table 2.5