# Chapter 10-10.3

CHAPTER

# 10 Distance, Speed, and Acceleration

## Getting Started

HOW DO YOU KNOW IF YOU ARE MOVING?
This seems like a simple question with an obvious answer. If you are napping on a comfortable sofa or standing at a bus stop, you would say that you are not moving. Perhaps, using physics language, you might say that you are "at rest." You know you are not moving because it does not look as though your fixed surroundings are moving, and you do not feel as though you are moving. In fact, you and everything else on Earth are moving around the Sun at an amazing thirty kilometres per second (30 km/s) (**Figure 1**). Why do we not notice this? There are three main reasons: we cannot see ourselves moving past anything else; we do not feel any movement because we are moving at a fairly constant speed; and the air is moving with us.

Imagine that you are in an elevator (**Figure 2**). If the elevator is travelling at a constant speed in the middle of its trip, you have little

**Figure 1**
We cannot sense Earth's rapid motion through space.


**Figure 2**
You can feel the acceleration when an elevator starts and stops.

sensation of movement. However, if the elevator is speeding up or slowing down, you can feel the effect of this change in speed in your body. If you were carrying a bag of groceries, the effect of a changing speed would be quite noticeable in your arms.

The feeling of rapidly changing speed is something that many people enjoy. Many amusement park rides, such as roller coasters (**Figure 3**), are specifically designed to produce rapid changes in speed and direction. The next time you are enjoying some kind of motion, take a moment to think about the physics behind the movement.

When you start to walk, run, or ride, you must increase your speed and, therefore, you must accelerate (**Figure 4**). The study of acceleration is, in part, the study of increasing and decreasing speed. Not only can you feel the acceleration but you can also measure it. Measuring the acceleration is important to sprinters as they train for their races. One of the most important performance indicators for natural and machine motion is acceleration.

**Figure 3**
Acceleration is very noticeable on a roller coaster.

**Figure 4**
Accelerating up to speed

## Reflect on your Learning

1. Is it possible for you to be somewhere and not be moving? Where would this place be?
2. What is your impression of what happens to the speed of a rock when it is dropped?
3. Is it possible to move an object that is initially at rest from one place to another without accelerating it? Explain your answer.
4. As speed increases, what happens to the distance travelled in each second?
5. Try this "thought experiment": You are in a car that is gradually increasing its speed. You are measuring the time it takes to travel from one telephone pole to the next. Would the time between each pair of poles be the same? If not, how would it change?

Throughout this chapter, note any changes in your ideas as you learn new concepts and develop your skills.

## Try This Activity: Leaving a Trail

Wear all appropriate safety equipment, including a helmet and padding.

You will need a skateboard, in-line skates, or a bicycle, plus the appropriate helmet and pads. (Alternatively, you could just run!) You will also need a bottle that slowly drips water, which you can use to mark equal time intervals. Choose an open, safe place such as a paved area in the school grounds. While speeding up, travelling at constant speed, and slowing down, use the dripping bottle to make marks on the ground at regular time intervals.

(a) Describe the pattern of marks left by the water.

# 10.1 Explore an Issue

**DECISION-MAKING SKILLS MENU**

- ● Defining the Issue
- ○ Identifying Alternatives
- ● Researching
- ● Analyzing the Issue
- ● Defending a Decision
- ○ Evaluating

## Travelling Off-Road

Given the nature of our landscape, it is perhaps natural that many Canadians feel a need to drive vehicles that can travel over a wide variety of terrain (**Figures 1** and **2**). In 1922, Joseph Armand Bombardier, a mechanic from Valcourt, Québec, designed a propeller-driven sled, the first of many snow vehicles that he was to develop. Bombardier made the vehicle more practical by incorporating steering by skis in front of double looped tracks. In the mid-1950s, the introduction of the air-cooled, two-stroke engine made possible the small, powerful sports models common today, such as the Ski-Doo and the Lynx.

Snowmobiles provide transportation into areas previously impassable except on skis, snowshoes, or dogsled. In the north of Canada, snowmobiles are the main means of surface transportation for many months of the year. They deliver mail, aid in search-and-rescue missions, and provide emergency medical help. They also allow people to use cabins and cottages year-round. There are snowmobile trails in many parts of the country, and snowmobile racing is a popular sport. But the explosion in the use of snowmobiles brings serious concerns about noise, environmental damage, and rider safety. Each year, as more and more people take to the backcountry on their snowmobiles, there are more deaths from avalanches or falling through thin ice. While the snowmobile is an extremely useful vehicle, its misuse sometimes involves vandalism, habitat destruction, and poaching. For these reasons, plus the fact that snowmobiles are powerful machines capable of travelling up to 160 km/h, all provinces have passed regulations governing and restricting the use of snowmobiles. Many snowmobile clubs have also set safety rules.

Motorized travel in the backcountry is no longer limited to the winter months as the development of the all-terrain vehicle (ATV) makes off-road areas accessible year-round. Over 20 million ATVs have been sold in North America. While farmers, ranchers, trappers, forestry workers, and environmental scientists use ATVs for work, the tremendous increase in ATV sales is largely due to their recreational use. Like snowmobiles, ATVs can have a serious impact on the environment (**Figure 3**). New, unplanned trails form as riders compete to see who can climb the steepest hill. Soil loses its organic material and becomes compacted, increasing water runoff and leading to serious erosion. Sand dunes are particularly fragile and can be permanently destroyed if ATVs disturb the vegetation that stabilizes the dunes. Even fish can suffer, when their streams are used as trails.

**Figure 1**
Snowmobiling is a popular winter recreation and sport, as well as being an essential means for transportation.

**Figure 2**
ATVs have opened up many backcountry areas. As people travel faster on more powerful machines and seek more challenging routes, accidents increase.

As the numbers of ATVs and snowmobiles increase, so does the number of accidents, most frequently involving young, inexperienced, and untrained riders. Alcohol is often a contributing factor. Riders' associations have established safety courses that teach operators about the safe and proper use of their machines. The public is becoming increasingly concerned about the impact of personal recreational vehicles, leading provincial governments to enact regulations governing their use.

**Figure 3**
Continuous use of ATVs can create considerable environmental damage. Here, repeated use of a trail is causing erosion.

### Work the Web

Visit www.science.nelson.com and follow the links through Science 10 to 10.1. Find some accident statistics on snowmobile and ATV use. Use these in your article to support your position.

### Understanding the Issue

1. In your own words, describe the origin of the snowmobile.
2. List three nonrecreational uses of snowmobiles.
3. List at least three positive and three negative aspects of snowmobile use.
4. Describe the environmental impact of the backcountry use of ATVs.
5. Give four examples of unsafe uses of snowmobiles or ATVs.

## Take a Stand: Should off-road vehicles be more closely regulated?

### Point

*Opinion of environmentalist*
The environmental impact of ATVs is clearly shown by the damage to soil, vegetation, wildlife, and water. We need stricter laws to protect the environment and threatened species' habitat.

*Opinion of police officer*
Many riders involved in snowmobile and ATV accidents are under 16 years old. Mandatory training, testing, and licensing are required to reduce the number of ATV injuries and fatalities.

### Counterpoint

*Opinion of recreation group member*
People who travel in the backcountry should be monitoring these vehicles' use. It would be better for recreation groups to educate the public on outdoor ethics than for governments to bring in laws.

*Opinion of ATV owner*
It is the parents' responsibility to train their children to use ATVs safely. My children only drive on private land and they should be free to enjoy the great outdoors without bureaucratic regulation.

### What do you think?

1. (I) Find out what regulations govern the use of snowmobiles and ATVs in your province. Research licensing requirements, operating regulations, access to public land, and education programs.
2. (R) Produce an information pamphlet for teenagers about the dangers associated with ATVs, or prepare a multi-media presentation about the regulations and issues associated with off-road vehicles.

**SKILLS HANDBOOK:** (I) General Research (R) Writing for Specific Audiences

# 10.2 Activity

# Speed Comparisons

Speed is one of many topics included in the study of motion. However, even within the topic of speed, there are many possible classifications or categories: constant or changing, increasing or decreasing, in a straight line, a circle, or on some other path. Classification is an important part of science. Scientists observe, classify, and organize information. This is all part of the process of trying to find patterns in the world around us. Eventually the aim of science is to explain these patterns. The purpose of this activity is to practise describing, interpreting, and classifying speed in different situations.

## Question

What are some different categories of the speed of an object?

## Design

In **Figures 1** to **4** you can see different examples or categories of speed represented. Study each one carefully so that you can clearly describe each situation, make distinctions among them, and eventually develop your own idea of what each situation represents.

## Evidence

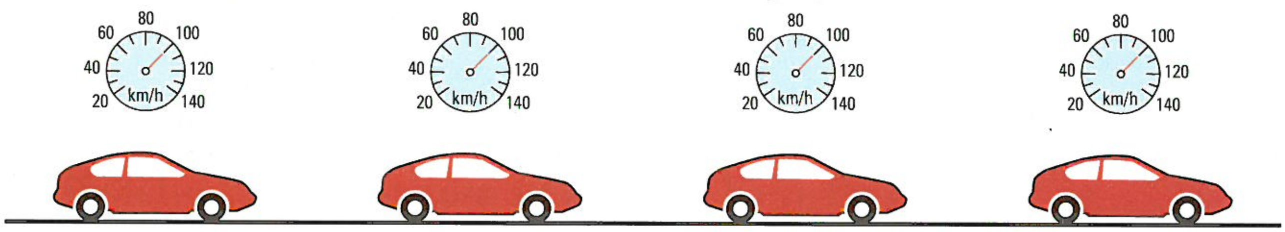


**Figure 1**

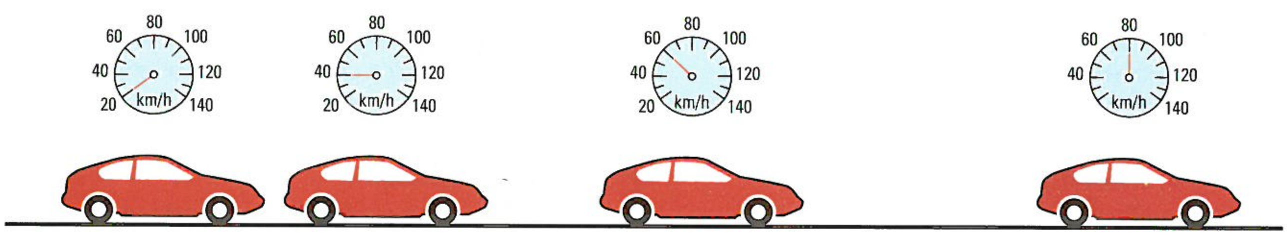


**Figure 2**

## Analysis

(a) Observe and interpret what is happening in **Figures 1 to 4**. Using words, graphs, and any other method of communication, describe as much as you can about the distances travelled, speed, and changes in speed of the four vehicles.

(b) Classify the four situations into categories.

(c) Which categories (from question 2) are easiest to classify? Why?

## Challenge

3 How might you collect speed–time evidence to construct graphs?

### Understanding Concepts

**1.** How would a student demonstrate, on a bicycle, the different categories of speed that you classified in the Analysis?

**2.** What are some limitations of trying to represent speed in drawings, such as **Figures 1** to **4**?

**3. (a)** Write a scientific question in terms of independent (K2) and dependent variables and related to one of the motions represented in **Figures 1** to **4**.

**(b)** Briefly describe an experiment that might answer your question.

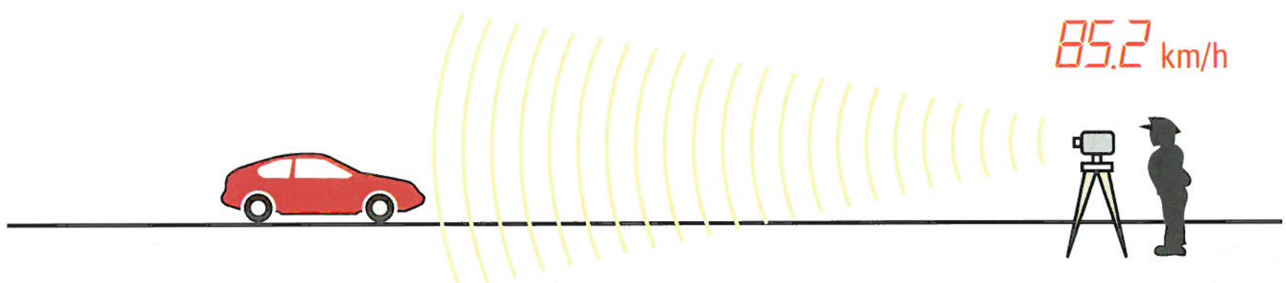


Figure 3

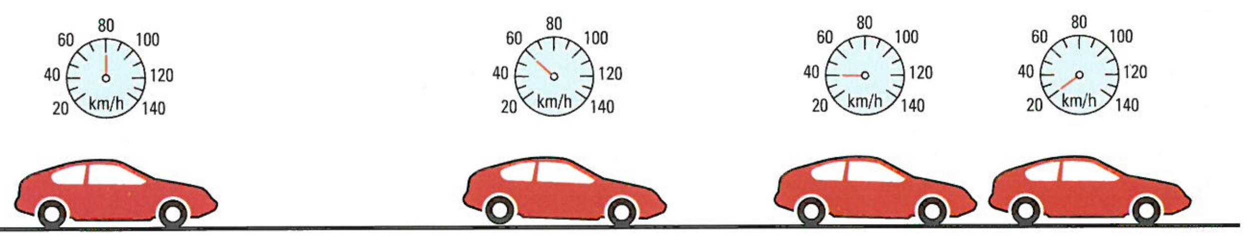


Figure 4

10.3

# Defining Acceleration

**Figure 1**
The bus driver tries to keep the speed as steady as possible but has to change speeds in response to changing conditions.

Suppose you are riding in a bus moving at a constant speed of 100 km/h (**Figure 1**). This means that for every hour on the bus, you travel a distance of 100 km. Of course, this also means that the bus travels 200 km every two hours or 50 km every half-hour. All these ratios of distance to time are the same. However, when the bus starts from rest, its speed increases.

When the speed is not constant, it may be changing slowly or rapidly. It may be increasing or decreasing. One aim of science is to describe these events as precisely and simply as possible. The term acceleration describes all situations in which the speed is changing. **Acceleration** ($a$) is the rate of change in speed and is calculated by the ratio of the change in speed ($\Delta v$) to the time interval ($\Delta t$) during which this change occurred.

$$a = \frac{\Delta v}{\Delta t} \quad \text{or} \quad a_{av} = \frac{\Delta v}{\Delta t}$$

If this ratio remains constant throughout the acceleration, then the acceleration is called constant (or uniform) acceleration. During **constant acceleration**, the same change in speed ($\Delta v$) occurs in each equal interval of time ($\Delta t$).

When acceleration varies over a period of time, we generally describe the object's average acceleration. **Average acceleration** ($a_{av}$) is the average rate of change in speed of an object.

For all calculations in this unit of study, the acceleration is assumed to be constant so either of the equations above can be used correctly.

Suppose you speed up on a motorcycle from rest (0 m/s) to 9.0 m/s in a time of 2.0 s. Your change in speed is 9.0 m/s and your average acceleration is calculated as follows:

$\Delta v = 9.0$ m/s

$\Delta t = 2.0$ s

$a_{av} = ?$

$$a_{av} = \frac{\Delta v}{\Delta t}$$

$$= \frac{9.0 \frac{\text{m}}{\text{s}}}{2.0 \text{ s}}$$

$$= 4.5 \frac{\text{m/s}}{\text{s}}$$

The average acceleration is $4.5 \frac{\text{m/s}}{\text{s}}$. (This answer is read as "four point five metres per second per second.")

In other words, you will increase your speed by an average of 4.5 m/s during every second of travel. Starting from rest, your speed is 4.5 m/s at the end of the 1st second; 9.0 m/s at the end of the 2nd second; and 13.5 m/s at the end of the 3rd second.

**Did You Know?**

Astronauts are launched in a horizontal position because in that position the human body can briefly tolerate acclerations of as much as 120 $m/s^2$. In the vertical position, acclerations of only 30 $m/s^2$ usually result in unconsciousness.

The units for acceleration are the units of the speed divided by the units of time, exactly as specified in the definition of acceleration. For convenience and efficiency the final units are usually simplified from $\frac{\text{m/s}}{\text{s}}$ to m/s².

$$4.5\,\frac{\text{m/s}}{\text{s}} = 4.5\,\frac{\text{m}}{\text{s}^2} \quad \text{or} \quad 4.5\ \text{m/s}^2$$

This is read as "four point five metres per second squared." It means the same as "metres per second per second."

We can use other units for acceleration, as long as they include the ratio of speed units to time units. The most common example is the result of an acceleration road test for cars. It is convenient for the people testing the cars and for the consumers to know the change in speed in kilometres per hour and the time in seconds. A particularly powerful car may accelerate from 0 to 100 km/h in 6.0 s. The average acceleration of this car can be calculated:

$\Delta v = 100$ km/h

$\Delta t = 6.0$ s

$a_{av} = ?$

$$a_{av} = \frac{\Delta v}{\Delta t}$$

$$= \frac{100\,\frac{\text{km}}{\text{h}}}{6.0\ \text{s}}$$

$$= 17\,\frac{\text{km/h}}{\text{s}} \quad \text{or } 17\ \text{(km/h)/s}$$

The average acceleration is 17 $\frac{\text{km/h}}{\text{s}}$. This is read as "seventeen kilometres per hour per second." What does this value mean? It means that, on average, at the end of each second, the car is moving 17 km/h faster than it was at the end of the previous second.

The following examples work through some acceleration questions.

**Sample Problem 1**

Myriam Bédard accelerates at an average 2.5 m/s² for 1.5 s (**Figure 2**). What is her change in speed at the end of 1.5 s?

$a_{av} = 2.5\ \text{m/s}^2$

$\Delta t = 1.5$ s

$\Delta v = ?$

$$a_{av} = \frac{\Delta v}{\Delta t}$$

$$\Delta v = a_{av}\Delta t$$

$$= 2.5\,\frac{\text{m}}{\text{s}^{\not 2}} \times 1.5\,\not\text{s}$$

$$= 3.8\,\frac{\text{m}}{\text{s}}$$

or

$$a_{av} = \frac{\Delta v}{\Delta t}$$

$$2.5\,\frac{\text{m}}{\text{s}^2} = \frac{\Delta v}{1.5\ \text{s}}$$

$$\Delta v = 2.5\,\frac{\text{m}}{\text{s}^{\not 2}} \times 1.5\,\not\text{s}$$

$$= 3.8\,\frac{\text{m}}{\text{s}}$$

Bédard's change in speed is 3.8 m/s.


**Figure 2**
Canadian Myriam Bédard won two gold medals in biathlon in the 1994 Winter Olympics.

The cancellation of units for $a_{av}\Delta t$ can be shown as

$$\Delta v = 2.5\,\frac{\text{m}}{\not\text{s}^2} \times 1.5\,\not\text{s} \quad \text{or}$$

$$\Delta v = 2.5\,\frac{\text{m}}{\not\text{s}^{21}} \times 1.5\,\not\text{s}$$

**Sample Problem 2**

A skateboarder rolls down a hill and changes his speed from rest to 1.9 m/s (**Figure 3**). If the average acceleration down the hill is 0.40 m/s$^2$, for how long was the skateboarder on the hill?

$\Delta v = 1.9 \text{ m/s}$

$a_{av} = 0.40 \text{ m/s}^2$

$\Delta t = ?$

$$a_{av} = \frac{\Delta v}{\Delta t}$$

$$\Delta t = \frac{\Delta v}{a_{av}}$$

$$= \frac{1.9 \frac{\cancel{m}}{\cancel{s}}}{0.40 \frac{\cancel{m}}{s^{\cancel{2}}}}$$

$$= 4.8 \text{ s}$$

or

$$a_{av} = \frac{\Delta v}{\Delta t}$$

$$0.40 \frac{m}{s^2} = \frac{1.9 \frac{m}{s}}{\Delta t}$$

$$0.40 \frac{m}{s^2} \times \Delta t = 1.9 \frac{m}{s}$$

$$\Delta t = \frac{1.9 \frac{\cancel{m}}{\cancel{s}}}{0.40 \frac{\cancel{m}}{s^{\cancel{2}}}}$$

$$= 4.8 \text{ s}$$

The skateboarder had spent 4.8 s on the hill.

**Figure 3**
A skateboard is a mode of transportation.

A quick way to simplify the units in this calculation is to think of the units in the denominator as a fraction and multiply by the reciprocal.

$$\Delta t = \frac{1.9 \frac{m}{s}}{0.40 \frac{m}{s^2}} = 4.8 \frac{\cancel{m}}{\cancel{s}} \bullet \frac{s^{\cancel{2}}}{\cancel{m}} = 4.8 \text{ s}$$

In Sample Problems 1 and 2, the information given in the questions has a certainty of two significant digits. Therefore, the final answer should also have a certainty of two significant digits.

## Refining the Acceleration Equation

In the real world, when you accelerate in a car, you usually know your initial speed. Typically, you would accelerate to some final speed such as the speed limit. Both the initial speed ($v_1$) and the final speed ($v_2$) affect your change in speed.

$$\Delta v = v_2 - v_1$$

The acceleration definition, $a_{av} = \frac{\Delta v}{\Delta t}$, can now be written more specifically as $a_{av} = \frac{v_2 - v_1}{\Delta t}$.

Note that other symbols are sometimes used in place of $v_1$ and $v_2$, such as $v_i$ and $v_f$ or $u$ and $v$, respectively. You may see these in other books or web sites.

**Sample Problem 3**

Kerrin Lee-Gartner is moving at 1.8 m/s near the top of a hill (**Figure 4**). 4.2 s later she is travelling at 8.3 m/s. What is her average acceleration?

$v_1 = 1.8 \text{ m/s}$

$\Delta t = 4.2 \text{ s}$

$v_2 = 8.3 \text{ m/s}$

$a_{av} = ?$

$$a_{av} = \frac{v_2 - v_1}{\Delta t}$$

$$= \frac{(8.3 - 1.8) \frac{m}{s}}{4.2 \text{ s}}$$

$$= 1.5 \frac{m}{s^2}$$

Lee-Gartner's average acceleration is 1.5 m/s$^2$.

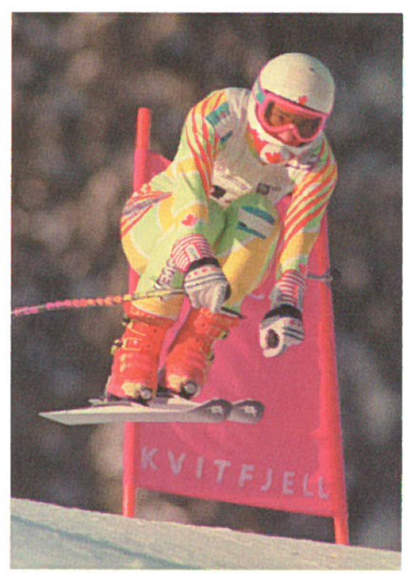


**Figure 4**
Kerrin Lee-Gartner won a gold medal for Canada in the 1992 Olympics downhill race.

Another way of thinking about acceleration is to realize that your final speed is determined by your initial speed plus your change in speed. If you are initially moving at 5.0 m/s and gain 2.0 m/s while accelerating, then your final speed is 7.0 m/s.

$$\begin{aligned} v_2 &= v_1 + \Delta v \\ &= 5.0\,\frac{\text{m}}{\text{s}} + 2.0\,\frac{\text{m}}{\text{s}} \\ &= 7.0 \text{ m/s} \end{aligned}$$

The change in speed, $\Delta v$, is the result of the acceleration and equals $a_{\text{av}}\Delta t$. Substituting $a_{\text{av}}\Delta t$ into the above equation gives a convenient equation for acceleration but in a different format from the above equation.

$$v_2 = v_1 + a_{\text{av}}\Delta t$$

This equation is particularly convenient when you are predicting a final speed (Sample Problem 4) and some people also find it useful for predicting initial speeds (Sample Problem 5).

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**Sample Problem 4**

A bus with an initial speed of 12 m/s accelerates at 0.62 $\text{m/s}^2$ for 15 s (**Figure 5**). What is the final speed of the bus?

$v_1 = 12$ m/s

$a_{\text{av}} = 0.62\ \text{m/s}^2$

$\Delta t = 15$ s

$v_2 = ?$

$$\begin{aligned} v_2 &= v_1 + a_{\text{av}}\Delta t \\ &= 12\,\frac{\text{m}}{\text{s}} + 0.62\,\frac{\text{m}}{\text{s}^{\cancel{2}}} \times 15\ \cancel{\text{s}} \\ &= 21\,\frac{\text{m}}{\text{s}} \end{aligned}$$

The final speed of the bus is 21 m/s.

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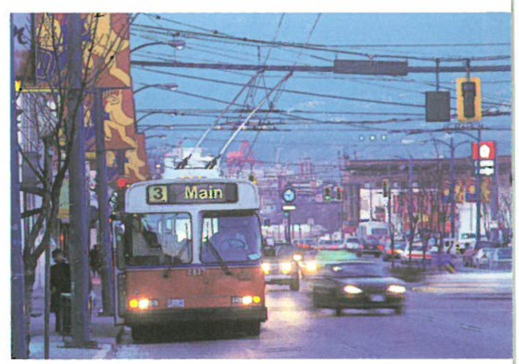


**Figure 5**

The acceleration of buses is usually much less than that of cars.

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**Sample Problem 5**

A snowmobile reaches a final speed of 22.5 m/s after accelerating at 1.2 $\text{m/s}^2$ for 17 s (**Figure 6**). What was the initial speed of the snowmobile?

$v_2 = 22.5$ m/s

$a_{\text{av}} = 1.2\ \text{m/s}^2$

$\Delta t = 17$ s

$v_1 = ?$

$$\begin{aligned} v_2 &= v_1 + a_{\text{av}}\Delta t \\ v_1 &= v_2 - a_{\text{av}}\Delta t \\ v_1 &= 22.5\,\frac{\text{m}}{\text{s}} - 1.2\,\frac{\text{m}}{\text{s}^{\cancel{2}}} \times 17\ \cancel{\text{s}} \\ &= 2.1\,\frac{\text{m}}{\text{s}} \end{aligned}$$

or

$$\begin{aligned} v_2 &= v_1 + a_{\text{av}}\Delta t \\ 22.5\,\frac{\text{m}}{\text{s}} &= v_1 + 1.2\,\frac{\text{m}}{\text{s}^2} \times 17 \text{ s} \\ v_1 &= 22.5\,\frac{\text{m}}{\text{s}} - 1.2\,\frac{\text{m}}{\text{s}^{\cancel{2}}} \times 17\ \cancel{\text{s}} \\ &= 2.1\,\frac{\text{m}}{\text{s}} \end{aligned}$$

The initial speed of the snowmobile was 2.1 m/s.

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**Figure 6**

Snowmobiles are the primary means of motorized transportation in many parts of Canada.

## Acceleration While Slowing Down

All vehicles that speed up eventually have to slow down. How quickly this occurs is an important safety consideration. The definition of acceleration includes a change in speed that can be either an increase or a decrease. There is no difference in the procedure for solving problems if the speed decreases, but the acceleration you obtain or use will have a negative sign.

### Sample Problem 6

In a race, a car travelling at 100 km/h comes to a stop in 5.0 s. What is the average acceleration?

$v_1 = 100$ km/h

$v_2 = 0$

$\Delta t = 5.0$ s

$a_{av} = ?$

$$a_{av} = \frac{v_2 - v_1}{\Delta t}$$

$$= \frac{0 - 100\,\frac{\text{km}}{\text{h}}}{5.0\ \text{s}}$$

$$= -20\,\frac{\text{km/h}}{\text{s}}$$

The average acceleration of the car is –20 (km/h)/s.

### Understanding Concepts

1. In uniform or constant speed, the speed is the same during each time interval. In constant acceleration, what is the same in each time interval?
2. You and your friend are on your bicycles and accelerate from rest. If your average acceleration is double that of your friend, how will your change in speed compare with your friend's after the same time interval?
3. In a road test, car A accelerates from rest (0 km/h) to 100.0 km/h in 16.0 s and car B takes 8.0 s in the same test. Which car has the greater average acceleration? By how many times?
4. A cyclist increases her speed by 5.0 m/s in a time of 4.5 s. What is her acceleration?
5. A roller coaster car accelerates at 8.0 $m/s^2$ for 4.0 s. What is the change in the speed of the roller coaster car?
6. The human heart pumps about 60 mL of blood into the aorta during a single stroke, which lasts about 0.1 s. In a single stroke, a pulse of blood is accelerated from rest to about 50 cm/s. Calculate the average acceleration of the blood in metres per second squared.
7. A downhill skier moving at 2.5 m/s accelerates to 20.0 m/s in a time of 3.8 s.
   (a) Calculate the average acceleration of the skier.
   (b) What does this acceleration mean?
8. An electric car accelerates from rest to 50.0 km/h in 8.20 s.
   (a) What is the average acceleration of the electric car in kilometres per hour per second?
   (b) Assuming constant acceleration, what time would the car take to accelerate from 40 km/h to 60 km/h?

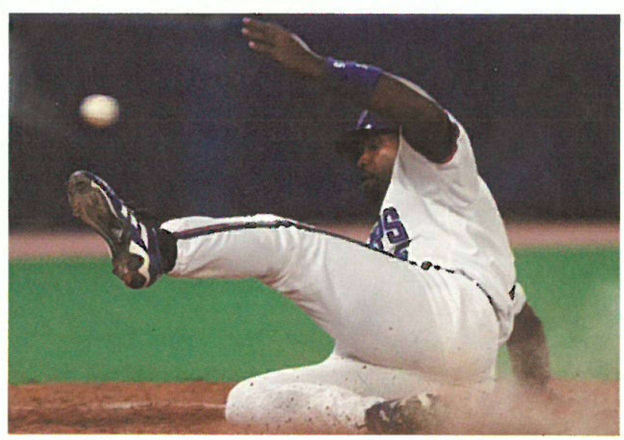

Figure 7

**9.** A baseball player running at 6.0 m/s slides into home plate and stops in 2.5 s (**Figure 7**). What is the average acceleration of the baseball player?

Questions 10–14 require you to rearrange the acceleration equation.

**10.** You are coasting on your skateboard at 1.4 m/s and you decide to speed up. If you accelerate at 0.50 $m/s^2$ for 7.0 s, what is your final speed?

**11.** A train is moving at 5.0 km/h and accelerates at 95 $km/h^2$ for 0.50 h. What is the final speed at the end of the 0.50 h?

**12.** A car travelling at a constant speed approaches the top of a hill. The car rolls down the hill at an acceleration of 2.0 $m/s^2$ for 8.0 s and reaches a final speed of 26 m/s. What was the initial speed of the car before accelerating down the hill?

**13.** An octopus can accelerate rapidly by squirting a stream of water for propulsion. An octopus moving at 0.10 m/s accelerates at 5.5 $m/s^2$ to a final speed of 3.5 m/s. What is the elapsed time during the acceleration?

**14.** The NASA space shuttle touches down on a runway at an initial speed of 95 m/s and accelerates at a rate of −4.40 $m/s^2$ (**Figure 8**). How much time does it take for the shuttle to stop?

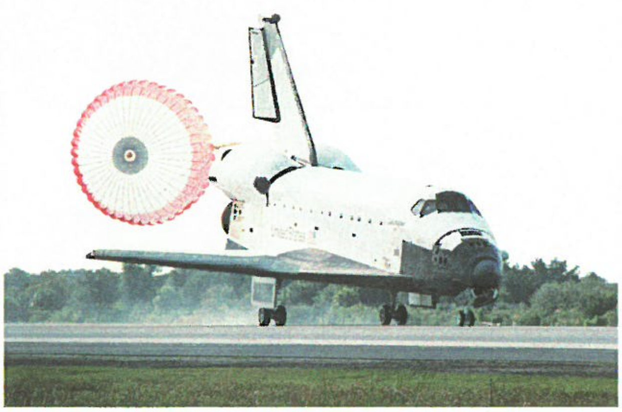

**Figure 8**

## Making Connections

**15.** Complete the analysis for the following investigation.

**Question**

Which minivan has the greatest average acceleration?

**Design**

Tests by *Consumer Report* provide evidence for the time for various minivans to reach 100 km/h from rest. These values are used to determine their average acceleration.

**Table 1** **Time for Minivans to Reach 100 km/h**

| Minivan | Initial speed (km/h) | Final speed (km/h) | Time (s) |
|---|---|---|---|
| Plymouth Grand Voyager | 0 | 100 | 11.2 |
| Ford Windstar | 0 | 100 | 9.5 |
| Pontiac Trans Sport | 0 | 100 | 10.3 |
| Chevrolet Venture | 0 | 100 | 10.0 |

**Analysis**

**(a)** Calculate the average acceleration for each minivan.

**(b)** Which minivan has the greatest average acceleration?

**16.** It is said that nobody is killed by falling, only by the sudden stop at the end of the fall. Interpret this statement in terms of acceleration. How do stunt performers survive their falls?

## Exploring

**17.** Choose one of the following Guinness® World Record questions and provide the answers in metric units.

**(a)** What is the acceleration of the world-record, most-expensive production car?

**(b)** What is the world record for the acceleration of a land vehicle with a driver?

**(c)** Describe the world record for the longest free fall by a stunt person.

## Challenge

3 Braking results in accelerating while slowing down. Use the formula $a = \frac{v_2 - v_1}{\Delta t}$, choose a fixed value for $a$, and find out how much time it takes for a car to stop from a variety of speeds ($v_1$).

## Work the Web

A jet on an aircraft carrier has a limited distance and time to become airborne. Similarly, it has to land and stop very rapidly. What are some typical accelerations of a jet taking off from, and landing on, an aircraft carrier? How are these accelerations achieved? Visit science.nelson.com and link through Science 10 to 10.3 to help you with your research. Illustrate your discoveries with a series of labelled sketches.