5 Road science

Planning page

Getting started

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- Investigate 12 Investigating motion
- Animation Motion graphs

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Essential Learnings for Chapter 5

Essential Learnings	References		
	Student book (page number)	Workbook (page number)	Teacher Edition CD (Assessment task)
Knowledge and understanding *Energy and change* An unbalanced force acting on a body results in a change in motion	pp. 101–116		Assessment task 5 Vehicle collisions
Objects remain stationary or in constant motion under the influence of balanced forces	pp. 117–122	Exercise 5 pp. 36–37	
Ways of working Select and use scientific equipment and technologies to enhance the reliability and accuracy of data collected in investigations	Investigate 12 pp. 105–107		
Evaluate data, information and evidence to identify connections, construct arguments and link results to theory.	Investigate 12 pp. 105–107 Activity p. 117	pp. 33–35	
Research and analyse data, information and evidence	Activities pp. 101, 114 Investigate 12 pp. 105–107 Investigate 13 pp. 118–119 Experiment p. 112	pp. 32–35 pp. 37–38 p. 40	
Plan investigations guided by scientific concepts and design and carry out fair tests	Experiment p. 112 Investigate 13 pp. 118–119		Assessment task 5 Vehicle collisions

QSA Science Essential Learnings by the end of Year 9

Vocabulary

acceleration
accelerometer
accident
average
collision
crumple zone
deceleration
inertia
instantaneous
inversely
kilometres
momentum
occupants
proportional
speedometer
velocity

Focus for learning

Check their knowledge of motion (eg speed) and car safety features (page 100).

Equipment and chemicals (per group)

Activity page 101 radio-controlled cars (optional)

Investigate 12 pages 105–107
Part A: ticker timer complete with carbon disc, ticker tape, AC power supply and connecting wires, dynamics trolley, G-clamp, pair of scissors, adhesive tape, board for ramp approx 1.5 m long and 30 cm wide (eg old table top)
Part B: datalogger and motion detector, computer or graphing calculator
Try this*: bricks or wooden blocks (for ramp), piece of cardboard, ball, pendulum, radio-controlled car

Experiment page 112* bicycle, stopwatch, dynamics trolley, ramp plus bricks or wooden blocks, ticker timer and tape, datalogger and motion detector (optional), tape measure or metre rule

Activity page 114 block of wood with hook, newton spring balance

Activity page 117 drinking glass, piece of cardboard, 20-cent coin

Investigate 13 pages 118–119
Parts A and B: wooden ramp, bricks or wooden blocks, wooden block to act as a barrier, two dynamics trolleys, plasticine or playdough, piece of chalk, metre rule, masking tape, talcum or graphite powder, graph paper
Try this*: paper cylinder (or egg carton, straws, bubble wrap), masking tape, dynamics trolley with spring (optional)

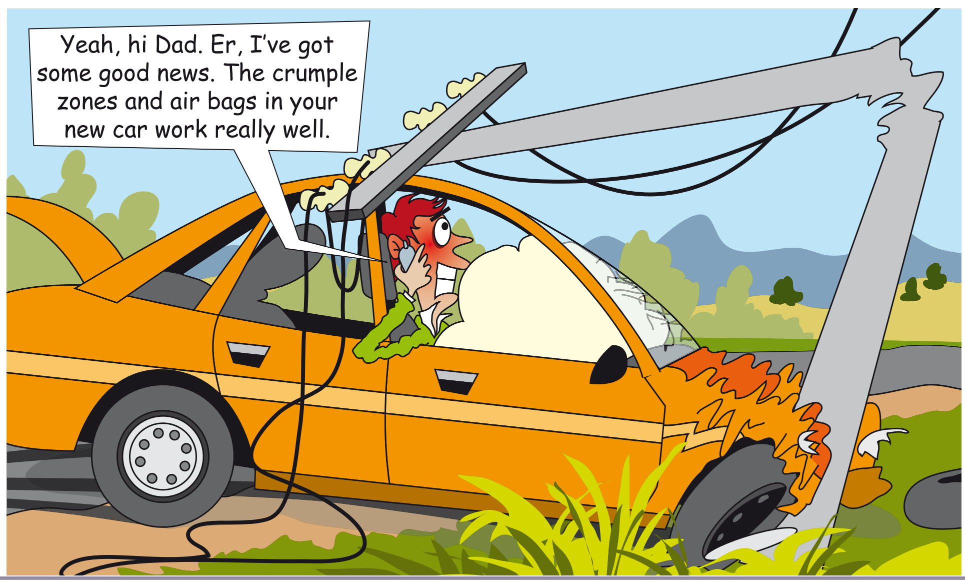
* Students to list the equipment they will need, which may be different from what is listed here.

5 Road science

Getting Started

In a small group, decide on answers for each of the questions below. This should give you some idea of how much you already know about the science involved in driving a car.

1 How do you calculate your average speed for a trip?
2 What is deceleration?
3 When you have to stop in an emergency, what is meant by the term ‘reaction time’?
4 When you brake hard you sometimes lose control of the car. Why is this?
5 Why do you fall forward when a car brakes suddenly?
6 What are the crumple zones in a car, and how do they work?



Starting point

1 Planning for learning and teaching is essential at the beginning of any new topic. A key to good teaching is to be prepared. Make sure you have identified the following issues, particularly if you are not a physics teacher:
   - *Teaching focus:* What do the students already know, what would they like to know, and what do they need to know?
   - *Learning activities:* What do the students need to do to learn the knowledge or develop the required thinking skills?
   - *Resources:* What resources will be used in order to clarify and/or reinforce concepts and facilitate learning?
   - *Real-world applications:* What are some real-world applications of this learning that the students may find interesting?

2 Because students at this level are getting close to the age at which they will be able to obtain their driver’s licence, this chapter is important, as it explores the physics of driving. If educated well, they will be alerted to possible road dangers and understand the need to be safe and responsible road users.

3 Ensure that all learning experiences are meaningful and connected to the real world. The scientific investigations use physics to tackle road safety issues and it is vital that the facts and information you present are current, otherwise you will lose their interest and the topic will have less impact. Mathematical ideas and techniques are often used for practical purposes. However, make sure that students explain their reasoning and conclusions.

4 Everything we do involves motion, whether it is getting up in the morning, riding to school in a car or walking from classroom to classroom. The trees outside sway in the breeze, vibrating air molecules make heat or sound, and even the flow of electrons creates electricity, but what *is* motion? Get the students to brainstorm and come up with a definition to share with the class.

5 After each group of students has finished answering the questions in Getting Started, allow them time to view other groups’ responses. Consider giving an initial time limit to answer the questions before sharing answers around the groups in an orderly fashion.

5.1 Speed and acceleration

Activity

Three radio-controlled cars, A, B and C, were being raced against each other. They all crossed the starting line together. The motion of the three cars was recorded using a motion detector and datalogger. The graphs show the position of each car, measured from the starting line, for the first 10 seconds of the race. Use the graphs to answer these questions.

1 Which variable is measured on the horizontal axis of each graph?

2 What is measured on the vertical axis?

3 Which car moved at a constant speed throughout the 10 seconds? How do you know?

4 Which car stopped during the race? How do you know?

5 How far did each car travel in 10 seconds?

6 Which car was winning the race after 10 seconds? Explain your answer.

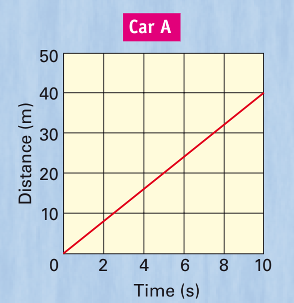
7 Which car was travelling the fastest:

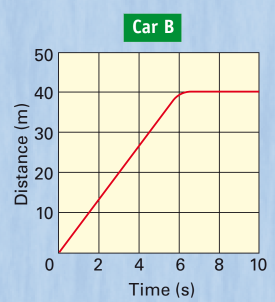
  a at 4 seconds?

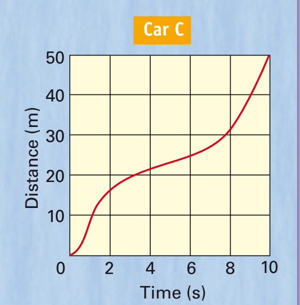
  b at 10 seconds?

  Give reasons for your answers.

8 At what speed did car A travel during the first 10 seconds?







Hints and tips

- This topic requires the students to have a firm understanding of algebra (particularly transposition and substitution) and graphs. Try to identify as early as possible those who are capable and those who will require extra assistance. It would be worth checking with the students' maths teacher(s) so allowances can be made if necessary. However, don't be tempted to make mathematics the key focus of this chapter—understanding the science should be the focus.

Activity notes

Here are the answers to the questions.

1 time (s)

2 distance (m)

3 Car A—it travelled the same distance each second.

4 Car B—it stopped from t = 6 to t = 10 seconds.

5 Car A travelled 40 m.
  Car B travelled 40 m.
  Car C travelled 50 m.

6 Car C

7 a Car B—it has the steepest gradient (instantaneous speed) at 4 s.

7 b Car C—it has the steepest gradient (instantaneous speed) at 10 s.

8 4 m/s

Learning experience

What are SI units? Ask the class to find out the origin of the abbreviation, what it means and why SI units are used. (SI units are the International System of Units used by scientists throughout the world. They are based on the metric system used in Australia and most countries. The USA does not use metric units.) Either get the students to compile a list of some SI units or give them a table, for example:

Quantity	Unit	Symbol
Distance	metre	m
Time	second	s
Mass	kilogram	kg
Force	newton	N
Energy	joule	J
Temperature	kelvin	K

It is good for the students to be familiar with common SI units, particularly if they plan to study senior chemistry and physics.

Learning experience

If there are any students in the class who have radio-controlled cars, organise for them to bring them to this lesson and try an activity similar to the one outlined here. Ensure the girls participate and encourage them to have a go at racing. You could divide the class into boys and girls and have a competition. The cars could be used as a theme throughout this chapter (ticker tape experiments analysing graphs, friction and wheel types, crash dummy tests and so).

Speed

Look at the graph for car A. It travelled 40 metres in 10 seconds. To calculate its **average speed** you divide the distance travelled by the time it takes to travel that distance. The speed is usually measured in kilometres per hour (km/h) or, in this case, metres per second (m/s).

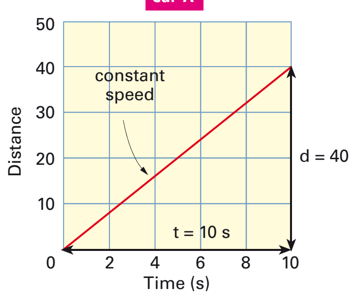
$$\text{average speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

$$v_{av} = \frac{d}{t} = \frac{40\ \text{m}}{10\ \text{s}} = 4\ \text{m/s}$$

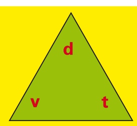
You can also find the average speed by calculating the slope of the distance–time graph.

$$v_{av} = \frac{d}{t} = \text{slope of graph}$$

Car A



You can rearrange the equation using the triangle rule:



$$d = vt \qquad t = \frac{d}{v}$$

You can also calculate the average speed in the same way you calculate any average:

$$v_{av} = \frac{v + u}{2}$$

where v is the final speed and u the initial speed.

Notes

1 To convert m/s to km/h you multiply by 3.6.

$$1\ \text{m/s} = \frac{1}{1000}\ \text{km/s} = \frac{60 \times 60}{1000}\ \text{km/h} = 3.6\ \text{km/h}$$

To convert km/h to m/s you divide by 3.6.

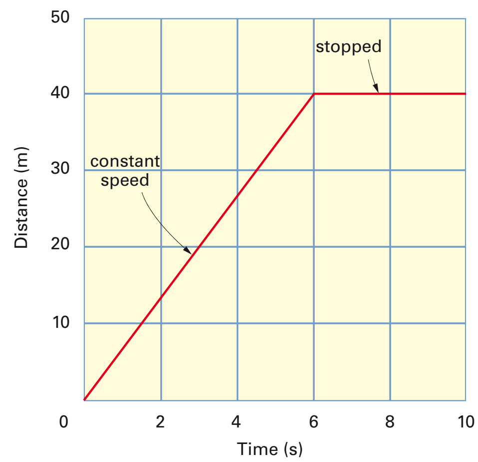
2 The symbol v is used for speed because v stands for *velocity*. Velocity is the same as speed except it includes a direction; for example, an aeroplane might have a velocity of 400 km/h *north*.

Now look at the graph for car B. For the first 6 seconds car B also travelled at a constant speed. You know this because the graph is a straight line. The graph is steeper than for car A, which means that for the first 6 seconds it travelled faster than car A. You can calculate the speed as before:

$$v = \frac{d}{t} = \frac{40\ \text{m}}{6\ \text{s}} = 6.7\ \text{m/s}$$

From 6 seconds to 10 seconds the graph is flat (zero slope). This means that the speed was zero, or the car had stopped.

Car B



Hints and tips

- A calculator will most likely be needed by most students for this chapter, so remind them to bring one each lesson. Graphics calculators are ideal if students know how to use the statistics function/application. They can enter data into a list and then draw graphs. Able students can determine the lines of best fit. The data can be downloaded from the calculator to a computer and used in programs such as Microsoft Excel. An advantage of this is that the students can manipulate data, print graphs and submit electronic practical reports.
- Senior physics teachers will be really pleased if you explain to the class the difference between distance and displacement, and speed and velocity. It often helps the students to remember the motion equations used in this chapter. Consider using the symbols u = initial 'velocity' and v = final 'velocity' (instead of 'speed').
  - — *Distance*: a measure of how much length an object has travelled—a scalar quantity (magnitude only). Distance is the length travelled for the entire circuit of a racetrack if a car completed one lap.
  - — *Displacement*: a measure of the object's change in position—a vector quantity (magnitude and direction). Displacement is the change in position of the car from its starting position to its finishing position—probably zero in this case if the car completes one lap of the race circuit.
  - — *Speed*: a measure of the rate at which an object moves over a distance—a scalar quantity. We say that speed is a rate. A rate is a quantity divided by time.
  - — *Velocity*: a speed with a direction (a measure of the rate of displacement)—a vector quantity.

  Therefore speed is a description of how fast something moves, while velocity is how fast it moves in a certain direction.
- Don't assume the students will remember from their maths classes how to interpret graphs. A quick maths lesson would be of real benefit. This way they will have a better understanding of how the equations were derived and why the unit for speed is m/s. Check that students:
  - — can differentiate between the *rise* and *run*
  - — understand that *slope* and *gradient* have the same meaning here
  - — realise that sections of graphs can be analysed separately, especially if the gradients are different.

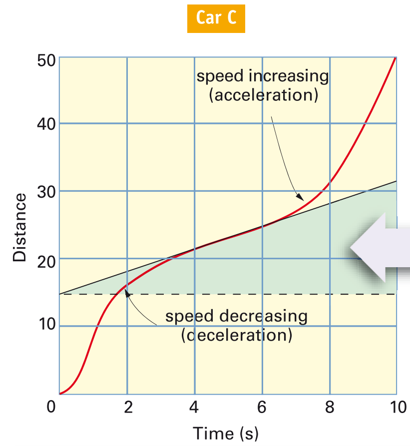
Learning experience

To identify any misconceptions or preconceived ideas, and to find out what students already know, give them a pre-test. A concept map works very well for this topic and can be given as a pre- and post-test. Each student is given a piece of poster paper—they use one side for the initial concept map and the other side for the final map. When the students construct their second concept map at the end of the chapter, they will be able to evaluate their learning. Ask them to write a self-reflection for this topic at the same time as the post-test.

Finally, look at the graph for car C. The average speed can be calculated as usual:

$$v = \frac{50\text{ m}}{10\text{ s}} = 5\text{ m/s}$$

From the slope of the graph, however, you can tell that the speed varied over the 10 seconds. After 1 second the car was moving very quickly (steep slope). Around 5 seconds it had slowed down (not so steep), and finally it sped up again.



$$\text{slope of tangent at 5 seconds} = \frac{32\text{ m} - 15\text{ m}}{10\text{ s}} = \frac{17\text{ m}}{10\text{ s}} = 1.7\text{ m/s}$$

Fig 6 The slope of the distance–time graph gives the instantaneous speed at a particular time.

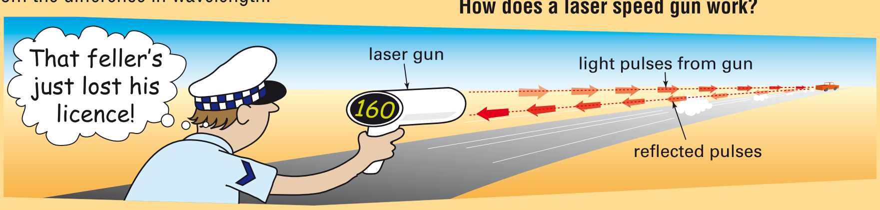
You can find the speed at any particular time by drawing a tangent to the curve and calculating its slope. This is called the *instantaneous speed*. For example, at 5 seconds the slope (and the instantaneous speed) is about 1.7 m/s, and at 10 seconds it is about 11.1 m/s. (Check it yourself.)

The speedometer on a car measures your instantaneous speed. Suppose you go on a trip to the beach and it takes you an hour to travel 60 km. This means your average speed is 60 km/h, even though there were times when your instantaneous speed was greater than 60 km/h, and there were times when you were going slower than this or were even stopped.

Radar and laser guns

Police use radar and laser guns to find the instantaneous speed of cars. A radar gun emits high-frequency radio waves, which are reflected by the car. If the car is coming towards the gun, the reflected waves have a shorter wavelength than those sent out. If the car is moving away from the gun, the reflected waves are longer. The gun picks up the reflected waves and calculates the speed from the difference in wavelength.

A laser gun emits a very short pulse of infra-red light in a narrow beam. This beam is reflected back to the gun, which measures the time for the round trip. Multiplying this time by the speed of light and dividing by two (because of the round trip) gives the distance to the car. The gun measures the distance many times during an interval of about half a second, and from this the computer in the gun can calculate the speed. For more information go to www.scienceworld.net.au and follow the links to **How does a laser speed gun work?**



Hints and tips

- Sometimes the unit of speed is written as m s^{-1}. Revise index laws to show the class why, for example:

$$\frac{1}{x} = x^{-1} \therefore \frac{1}{s} = s^{-1} \Rightarrow \frac{m}{s} = m\ s^{-1}$$

- Explain to the students that 60 km/h means that if you travelled for one hour you would have gone 60 km. For some students, this is not obvious, and it is worth reinforcing.

Research

- Ask students to research laser speed guns. How do they work? How accurate are they, and in what conditions can they be used? What conditions give false readings? What are some interesting points about the laser speed guns? Students should respond to these questions using the appropriate language outlined in this chapter. A PMI (Pluses, Minuses, Interesting) chart could be used as a starting tool to help them with their research. Allow students to choose the format of their final presentation.
- An alternative research task is investigating the history of the motor car. What impact has it had on our society? How has it changed their lives? What are some advantages and disadvantages of using cars? Again, a PMI chart is a good starting tool.

Learning experience

Moving objects don't always travel with changing speeds. They can move at a steady rate and this is at a constant speed. This means that the object will cover the same distance every second for its journey. Ask students where motorists are likely to travel at a constant speed (on a freeway) and to explain. Choose some students to demonstrate to the class walking at a constant speed and then at a changing speed. Students who prefer a kinaesthetic learning style will probably volunteer for this.

Learning experience

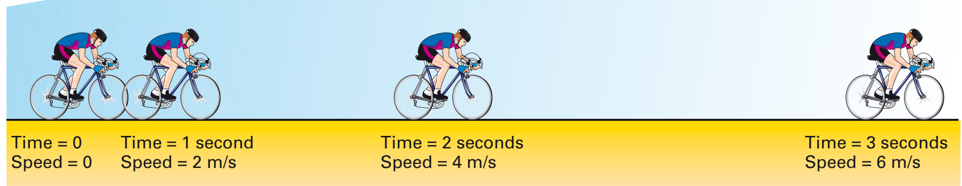
A good way for students to make better connections between science and the real world, and to understand key points, is by doing an activity before explaining the theory. A fun activity is to get the class to measure the speeds of cars on a section of road. (You might need to fill out a risk management form if you have to leave the school grounds.) Discuss with the class what measurements are needed and how they would do this investigation. Come up with a common procedure for the class to try. One of the aims could be to observe if motorists travel within the given speed limit. Be sure to warn students not to stand close to the road and to follow any necessary safety precautions. Avoid any stretches of road near traffic lights or other traffic obstacles. Questions to discuss here are:

- What type of speed was measured (average speed or instantaneous)?
- How do you convert the measurements from m/s to km/h?
- Which unit of measurement (m/s or km/h) is more meaningful to them, and why?
- Would their measurements of speed from this investigation be a true reflection of all motorists travelling on this section of road?

Hints and tips

- Review the concepts covered so far in this chapter. Ask each student to write down about five questions with answers on a piece of paper for you to collect. Allow only a few minutes to do this. Once you have collected the papers, run a short quiz. You may need to be selective with your questions. Spend no more than about 15 minutes on this activity.
- To explain acceleration as a physicist would, we say that it is the rate at which an object changes its *velocity*, not its speed. An object accelerates by changing its velocity by either speeding up or slowing down (changing its speed), keeping its speed the same but changing its direction, or doing both. It is not such a difficult concept for students to understand, and if it is taught this way it will please the senior physics teachers.
- Consider modelling acceleration for the class. Choose a student to walk from the front of the room to the back at a constant speed but in a straight line. Have they accelerated? (No.) Now get them to walk to the front of the room but with increasing speed and still in a straight line. Have they accelerated this time? (Yes.) Without telling the student how, ask them to walk in such a way that their speed remains constant but they are accelerating. Give them a hint and ask them what else needs to be considered other than speed when describing velocity (ie direction). They could walk in a circle at a constant speed. Their velocity is changing because their direction is changing and thus they are accelerating. At the end of the lesson ask the students to accelerate out the door but keep their speed constant.
- Racing-car commentators will sometimes say that a car is accelerating if it is moving very fast. However acceleration has nothing to do with going fast. A car can be moving very fast, and still not be accelerating. Acceleration is to do with *changing* how fast something is moving. If the car is not changing its velocity, then the car is not accelerating.

Acceleration



When an object gets faster we say that it accelerates. The diagram above shows the position of a cyclist each second, and his speed. The speed is increasing steadily, and we say that there is a constant **acceleration**. Acceleration is the rate at which the speed increases. In this case it is increasing at 2 metres per second each second. We write this as 2 m/s/s or 2 m/s^2.

Acceleration is important when considering the performance of cars. For example, Kartika wants to compare a Holden Astra with a Mazda RX-8 Turbo. She has found the following performance figures in a car magazine. The Astra takes 5.0 seconds to reach 60 km/h, whereas the RX-8 takes only 3.1 seconds.

Performance	Holden Astra	Mazda RX-8 Turbo
Standing start to ...		
60 km/h	5.0 s	3.1 s
80 km/h	8.0 s	4.4 s
100 km/h	11.4 s	5.7 s
120 km/h	16.0 s	7.5 s

from *Wheels*, September 2005

To calculate the acceleration of each car, Kartika used this equation:

$$\text{average acceleration} = \frac{\text{change in speed}}{\text{time taken}}$$

$$= \frac{\text{final speed} - \text{initial speed}}{\text{time taken}}$$

$$\text{or} \quad a_{av} = \frac{v - u}{t}$$

Fig 9 A dragster decelerating

For the Astra the speed increases from 0 to 60 km/h in 5.0 s (60 km/h = 60/3.6 = 16.7 m/s). So:

$$\text{acceleration} = \frac{16.7 - 0 \text{ m/s}}{5.0 \text{ s}} = 3.3 \text{ m/s}^2$$

For the RX-8:

$$\text{acceleration} = \frac{16.7 - 0 \text{ m/s}}{3.1 \text{ s}} = 5.4 \text{ m/s}^2$$

So the RX-8 accelerates much more quickly than the Astra.

When a car slows down it is said to *decelerate*; for example, a dragster at the end of its run (Fig 9). Deceleration is the rate at which the speed *decreases*. It is negative acceleration.

Look at the distance–time graph for radio-controlled Car C on the previous page. From 1 to 4 seconds the graph is curving downwards. This means the car is decelerating. From 6 to 10 seconds the graph is curving upwards—the car is now accelerating.

Learning experience

Often students have the preconceived idea that physics is 'too hard or boring'. Physics is exciting and a way to make it more appealing is to involve the students in as many hands-on activities as possible. Students could be enthused by getting them to find out what cars celebrities drive, and then listing any interesting cars and driving facts about them. They could construct a 'Celebrity car gossip page' and put their findings on the school intranet or on posters to be displayed around the room. They could do a similar task for racing-car drivers.

Investigate 12 Investigating motion

Aim

To use a ticker timer or a motion detector and datalogger to measure the distance, speed and acceleration of various objects and analyse this motion.

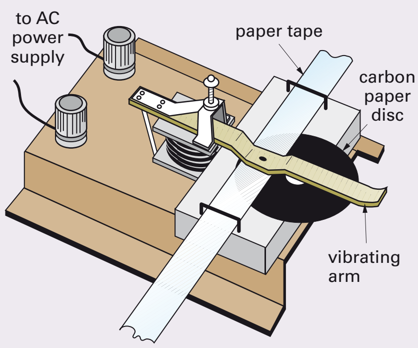
Planning and Safety Check

Discuss with your teacher how you will do this experiment. You will need to be able to work as a team, with different people doing different things.

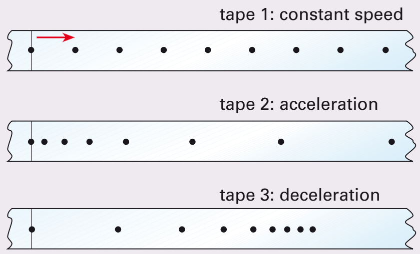
Teacher note: Depending on your school situation you can do this experiment using ticker timers or a datalogger (Part B).

PART A
Using a ticker timer

The diagram below shows how a ticker timer works. The vibrating arm strikes the carbon paper and leaves dark marks on the paper tape. If the tape is attached to a moving object, a series of dots is left on the tape. Because the ticker timer vibrates 50 times per second, the dots are made $^1/_{50}$ of a second apart.



The further apart the dots are, the faster the object is moving. The closer the dots, the slower the object. If the dots are evenly spaced, then the object has a constant speed (tape 1). If the distance between the dots is increasing, the object is accelerating (tape 2). And if the dots are getting closer together, the object is decelerating (tape 3).



Materials

- ticker timer, complete with carbon disc
- ticker tape
- AC power supply and connecting wires
- dynamics trolley
- G-clamp
- pair of scissors
- adhesive tape
- board for ramp approx. 1.5 m long and 30 cm wide (eg old table top)

Method

1 Set up the ticker timer as shown on the left. Clamp it to the bench. Cut off several 1 m lengths of ticker tape.

2 Start the timer and pull a piece of tape through at a *constant speed* until about 60 cm of tape has gone through. Label the tape and show the direction of movement.

3 Repeat Step 2 for several different tapes, with a new piece of tape each time.

4 Examine the tapes.

What do you notice about the spacing between the dots on each tape?

Explain the differences between the tapes.

Hints and tips

In science classes, students often do a lot of cooperative learning, especially when they are performing a practical experiment or investigation. For most tasks, small groups are better to ensure all members contribute. Make sure each student has a chance to use the ticker timer and datalogging equipment such as the motion detector.

Lab notes

Part A

- Although ticker timers are a bit old-fashioned, they still work well and students can use the strips to make meaningful graphs.
- Check that the timers all work before the lesson, and do not allow students to fiddle with them.
- Using ticker timers is very noisy. Check that they are not left on unnecessarily.
- What often works well is to stand at the teacher's desk with a 1 metre ruler on it and cut lengths of tape for the students. This minimises tape wastage and you can scan the room to see which groups need assistance.
- The most common errors with this activity are:
  - — The ticker timers are connected to DC instead of AC.
  - — Students put the tape and the carbon paper the wrong way around and it does not make a mark.

Learning experience

Find out what science is at work when new cars are taken for test drives and rated according to performance and safety. What are the test conditions? How are they tested and who gets to test them? What are the Australian standards for cars driven here? How are the performance figures (such as those shown on this page) measured? Find some other performance figures for different cars. How do magazines such as *Wheels* or *Road Ahead* (RACQ) review cars?

The students could answer these questions individually or in small groups.

A learning tool which could be used here is Placemat. Divide students into groups of about five or six. For each group, divide a large sheet of paper into sections so that each group member has a section to write in, and a square or circle is drawn in the middle of the sheet to record the group response. Each group is given a different question to investigate. Each student in the group first investigates the question on their own before sharing and helping to formulate a group response. Allow sufficient research and preparation time. Once group responses are recorded, get each group to share their findings with the rest of the class.

Lab notes

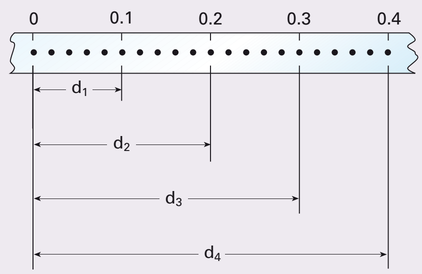
Part A (cont.)

- Remind the students when plotting their distance versus time graph that the horizontal axis (independent variable) is for the time and the vertical axis (dependent variable) is for the distance.
- You might need to show the class how to do some ticker tape calculations. Stop the class and make sure everyone is listening before attempting to explain.
- For more advanced students, it can be explained that the reason five dots represent a time interval of $\frac{1}{10}$ of a second is that AC frequency is 50 Hz (50 dots represents one second).
- Use small glue sticks for the paper strips to make the graphs.

Part B

- Graphics calculators are ideal here, especially if students know how to use the statistics function. The data entered into the lists (from the datalogger application) can be used to plot and compare graphs. Refer students to the Skillbuilder and Animation on page 11. The entered data can be downloaded from the calculator to the computer and used in programs such as Microsoft Excel. An advantage of this is that students can manipulate data, print graphs and submit electronic practical reports. If computers are used you may need to give a refresher lesson on how to use the graphing program.
- The motion detector is quite sensitive and any large disturbance in the air near the detector is likely to cause incorrect readings. Emphasise this with the students.

5 Select one of the tapes and mark a starting point. Count along the tape from the first dot, marking off every fifth dot, as shown below. Five dots represent 0.1 second.

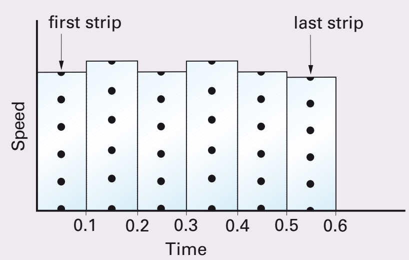


6 Measure the distances d_1, d_2, d_3, d_4, etc and record them in a data table.

7 Plot a graph of distance versus time and draw a line of best fit.

Calculate the slope of the graph, which gives you the average speed of the trolley for this tape. (Give your answer in cm/s.)

8 Cut the tape at each 0.1 second mark. Then stick the strips onto graph paper in the correct order, as shown. (It is a good idea to number them.) Each strip represents the distance travelled in 0.1 seconds, so you have made a graph of speed against time.



Describe in your own words what you can infer from this graph.

If the speed is not constant, suggest a reason for this.

Estimate the average speed. Does this agree with what you calculated in Step 7?

9 If you have time, analyse the other tapes as well.

10 Repeat the experiment, but this time pull the tape through at *increasing* speed. (Give it a quick pull.) To get a steadily increasing speed you can attach the tape to a trolley that can run down a steep ramp. Another way is to set up the ticker timer vertically, attach the tape to a mass and let it fall.

11 Analyse the tape and draw a distance–time graph. Then cut up the tape to make a speed–time graph.

How does this graph compare with those for constant speed?

How do you know there was an acceleration? Was it constant?

12 Estimate the acceleration. This is the average increase in speed in each 0.1 second interval. Give your answer in cm/s^2.

PART B
Using a datalogger

A motion detector is similar to a police radar or laser gun (page 103), but it sends out ultrasound waves which are reflected back to it from the moving object. From these reflected waves the

detector can calculate the distance of the object every tenth of a second, or other chosen time interval.

The data from the motion detector is sent either directly or via a datalogger to a computer or graphing calculator. The data can then be displayed in a table or as a graph, eg distance versus time or velocity versus time.

Materials

- datalogger and motion detector
- computer or graphing calculator

Working with technology

For information on using dataloggers, open the ICT skillsheet on the CD.
Detailed instructions on how to set up and operate dataloggers, as well as suggested experiments, are available from the suppliers. The output of the datalogger can be displayed on an overhead projector or computer screen.

Method

1 Set up the motion detector with a clear space in front of it so that you can walk backwards and forwards. You can get as close as 0.5 m and as far away as 6 m.

2 Carefully connect the motion detector to the datalogger and computer or graphing calculator. Set up the datalogger to show a distance–time graph.

3 Move slowly away from the detector.

4 Look at the distance–time graph. Print it out and put it in your notebook.
How can you explain the shape of the graph?

5 Repeat Step 3 to collect a new set of data, but move in a different way, eg slowly or quickly, away or towards the detector, speed up or slow down, stop. It is probably best to try only one or two things at a time and then see if you can make sense of each graph.
Print out the graphs and label them, eg moving away, moving fast, slowing down, stopped.

6 To check that you understand what the graphs mean, you can record a distance–time graph and ask someone who didn't see how you moved to try to match it by moving in the same way.

7 Now that you understand the distance–time graphs, look at the velocity–time graphs.
How can you explain the shapes of the graphs?

To help you understand how the motion of an object can be represented by graphs, open the Motion graphs animation on the CD.

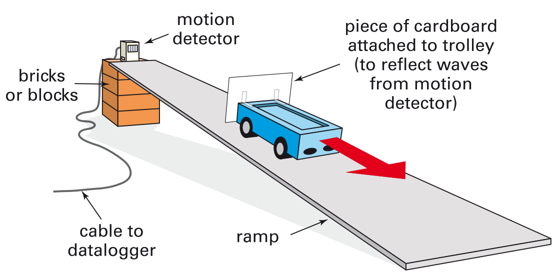
Working with technology

try this

Choose a moving object to investigate using a datalogger. You could try:

- a trolley rolling down a ramp (see diagram)
- a falling object
- a bouncing ball
- a pendulum
- someone starting a sprint
- a radio-controlled car.

Analyse the distance, velocity and acceleration graphs, and write a report of your investigation.



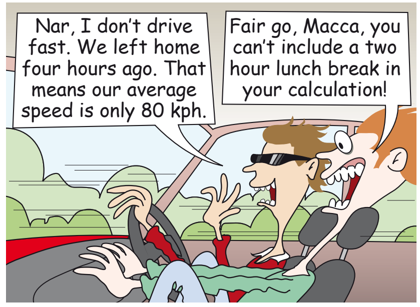
Hint: stop the trolley before it reaches the bottom of the ramp.

Lab notes

If the ticker timer is used for a falling object in Try this, it needs to be held or clamped firmly so that there is little friction between the tape and the ticker timer.

Check!

1 Use what you have learnt in this section to explain the cartoon below.



2 Find the average speed of a jet that flies 2700 km from Melbourne to Perth in 3.5 hours.

3 If the average speed of a spaceship is 32 000 km/h, how long would it take to travel the 80 million kilometres from Earth to Mars? (Give your answer in days.)

4 If you can run at an average speed of 7 m/s, how far can you run in 30 seconds?

5 A car started from rest and reached a speed of 30 m/s in 10 seconds.
- **a** What was its average speed?
- **b** How far did it travel in this time?

6 A train travelling at 10 m/s accelerates to 20 m/s in 5 seconds.
- **a** What is its acceleration?
- **b** What will its speed be after another three seconds if it continues to accelerate at the same rate?

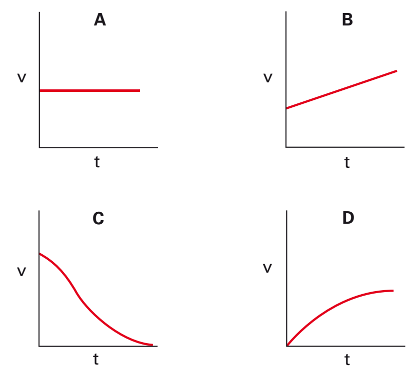
7 A bike coasts down a hill. Its acceleration is 3 m/s². How long does it take to accelerate from 5 m/s to 16 m/s?

8 At the bottom of a waterslide Stacey is travelling at 10 m/s. She skids across the pool, coming to a stop after 2.5 seconds. What is her deceleration?

9 Draw a distance versus time graph for a car that stops at lights, then accelerates away.

10 Draw a velocity versus time graph for a person who is walking, stops briefly, then starts to run. (You could check your answers for **9** and **10** using a motion detector.)

11 Which of the speed–time graphs below could possibly represent the motion of:
- **a** a car coming to a stop?
- **b** a car travelling at constant speed?
- **c** a car moving from a stop at traffic lights?
- **d** a car accelerating?



challenge

1 Two cars make the same trip, a distance of 160 kilometres. Both cars travel at a constant speed, but one averages 50 km/h, and the other 100 km/h. Represent these two trips on a single distance–time graph.

2 After 6 seconds of accelerating at 2.5 m/s², a car is moving at 50 m/s. What was the initial speed of the car if the acceleration was:
- **a** positive?
- **b** negative?

3 Use the internet to find answers to these questions about police radar and laser guns.
- **a** What is the Doppler effect?
- **b** What advantages do laser guns have over radar guns?
- **c** What is the range of laser guns?
- **d** How do speed cameras work?

Check! solutions

1 The average speed is calculated by dividing the total distance travelled by the total time taken. If the time taken included lunch, then the average speed would be considerably greater than 80 km/h. This would explain why the passenger is so scared.

2 The formula you use is:

$$v_{av} = \frac{\text{distance}}{\text{time}} = \frac{2700\text{ km}}{3.5\text{ h}} = 771\text{ km/h}$$

3 The formula you use is:

$$t = \frac{d}{v} = \frac{80\,000\,000\text{ km}}{32\,000\text{ km/h}} = 2500\text{ h} = \frac{2500}{24} = 104\text{ days}$$

4 The formula you use is:

$$d = vt = 7\text{ m/s} \times 30\text{ s} = 210\text{ m}$$

5 a $v_{av} = \frac{1}{2}(v + u) = \frac{1}{2}(0 + 30) = 15\text{ m/s}$

b Distance = average speed × time = 15 m/s × 10 s = 150 m

6 a $a = \frac{v-u}{t} = \frac{20-10}{5} = \frac{10}{5} = 2\text{ m/s}^2$

b The train increases its speed by 2 m/s every second. So, after another second its speed is 22 m/s and after 3 s its speed is 26 m/s.

7 The formula you use is:

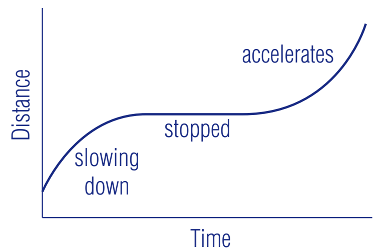
$$t = \frac{v-u}{a} = \frac{16-5}{3} = \frac{11}{3} = 3.7\text{ s}$$

8 The formula you use is:

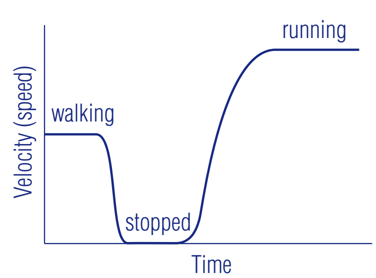
$$a = \frac{v-u}{t} = \frac{0-10}{2.5} = \frac{-10}{2.5} = -4\text{ m/s}^2$$

She comes to a stop, so her final speed is zero.

9 A distance–time graph for the car would look like this:



10



11 a A car coming to a stop could be represented by graph C.

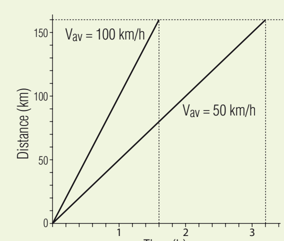
b A car travelling at constant speed could be represented by graph A.

c A car moving from a stop at traffic lights could be represented by graph D.

d A car accelerating could be represented by graphs B and D. In graph A the speed is constant so the acceleration is zero.

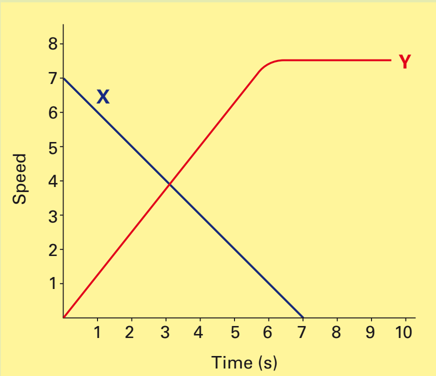
Challenge solutions

1

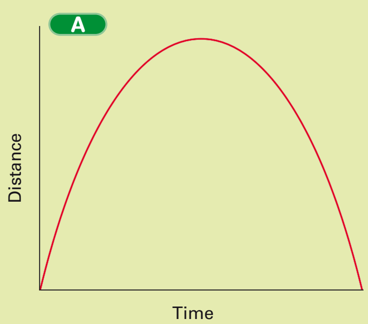


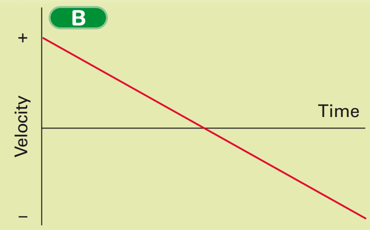
4 The graph below shows the motion of two objects, X and Y. Use the graphs to answer these questions.

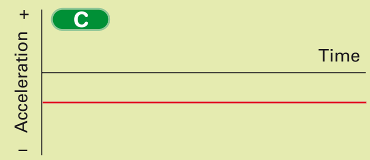
a What was the speed of X after 4 seconds?
b What was the maximum speed of Y?
c What happened to X at 7 seconds?
d When did X and Y have the same speed?
e Calculate the acceleration of X.
f What was the acceleration of Y between 6 seconds and 10 seconds?
g At which time was Y travelling twice as fast as X?



5 Hannah and Kirralee investigated the motion of a ball tossed into the air above a motion detector. They obtained these graphs from their datalogger. Explain the shape of each of the three graphs.



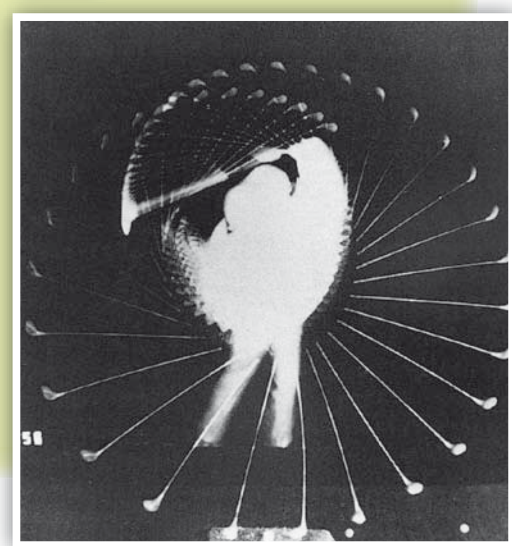




6 Look at the special photograph below of a golfer's swing. It was taken using a stroboscopic light that flashed 50 times per second (so that the time between flashes is 0.02 s).

a What was the speed of the golf club just before and just after it struck the ball?
b Suggest why these speeds are different.
c What was the speed of the ball in the first 0.02 s and the second 0.02 s? What does this tell you about the motion of the ball?

Fig 21 Analyse the golfer's swing (scale = 1/30).



Note that the speed would not remain constant throughout and the graphs would actually be wavy because gears are changed and the road surface changes.

2 The formula you use is v = u + at and therefore u = v − at.

a If a = +2.5 m/s then u = 50 – 6(+2.5) = 50 – 15 = 35 m/s.

b If a = –2.5 m/s then u = 50 – 6(–2.5) = 50 + 15 = 65 m/s.

3 a The Doppler effect: if a moving object is producing any waves, a change in wavelength will be observed. A simple example is a train approaching and then leaving as you stand at a station. As the train approaches, there is an apparent higher pitched sound and, as it goes away, there is a lower pitch. A similar thing occurs with light emitted from moving stars.

b Laser guns are generally better and more reliable than radar guns because they emit short and highly accurate pulses that give a very accurate reading. Radar waves can give false readings if the pulses reflect off hubcaps or certain other parts of the car. The frequency can also be changed by reflecting off different surfaces.

c Laser guns need a line of sight and are generally used up to a range of approximately 600 m.

d If laser or radar guns are connected to a camera, it can be programmed to take a photo of the vehicle if the speed limit has been exceeded and this can then be used as evidence in court.

4 a After 4 s the speed of X is about 3.6 m/s.

b The maximum speed of Y is 7.5 m/s.

c After 7 s, X stopped moving.

d The two objects had the same speed after about 3.2 s.

e $a = \frac{v - u}{t} = \frac{0 - 7}{7} = -1\ m/s^2$.

f The speed does not change in this time so the acceleration is 0 m/s^2.

g Y is travelling about twice as fast as X after 4.7 s.

5
- Graph A shows the vertical distance travelled. Initially, the ball travels fast but then slows down, stops and then speeds up again during the descent.
- Graph B shows a steady change in velocity of the ball from positive (going up) to negative (coming down).
- Graph C shows the ball is accelerating at a constant rate due to the constant force of gravity.

6 a Using the diagram, the golf club's head travelled 15 mm in 0.02 s just before impact. Because the diagram is 1:30 scale, the actual distance is 450 mm or 0.45 m.

$v = \frac{d}{t}$ = 0.45 m/0.02 s = 22.5 m/s.

Again, using the diagram the golf club's head travelled 11 mm in 0.02 s just after impact. Because the diagram is 1:30 scale, the actual distance is 330 mm or 0.33 m.

$v = \frac{d}{t}$ = 0.33 m/0.02 s = 16.5 m/s

b It is reasonable to infer that the club's head travels more slowly after impact because some of its kinetic energy has been transferred to the ball.

c In the first 0.02 s the ball travelled 15 mm. Because the diagram is 1:30 scale, the actual distance is 450 mm or 0.45 m.

$v = \frac{d}{t}$ = 0.45 m/0.02 s = 22.5 m/s

In the second time interval the distance is 21 mm. Because the diagram is 1:30 scale, the actual distance is 630 mm or 0.63 m.

$v = \frac{d}{t}$ = 0.63 m/0.02 s = 31.5 m/s

This tells you that the ball is accelerating, even though the golf club's head is no longer in contact with it.

Hints and tips

- Before this lesson, remind the students to bring their calculators.
- For this exercise, pair mathematically able students with those who need extra assistance.
- Since the motion considered here is linear, using d for distance instead of displacement is acceptable.
- Remind students that deceleration is negative acceleration.

Extra for experts solutions

1 a $u = 0$, $a = 3\ \text{m/s}^2$, $t = 6$ s
The initial speed of the car was 0 m/s.

b $v = u + at$
$= 0 + (3 \times 6)$
$= 18\ \text{m/s} = 65\ \text{km/h}$

2 $u = 250$ m/s, $t = 6$ s, $a = -10\ \text{m/s}^2$, $v = ?$
$v = u + at$
$= 250 + (-10 \times 6)$
$= 250 - 60$
$v = 190$ m/s

3 $t = 12$ s, $a = 9.8\ \text{m/s}^2$, $u = 0$, $d = ?$
$d = ut + \frac{1}{2}at^2$
$= 0 + (\frac{1}{2} \times 9.8 \times 12^2)$
$= 706$ m
(This assumes that there is no friction with the air and that the acceleration is uniform.)

4 $u = 0$, $a = 9\ \text{m/s}^2$, $t = 7$ s, $v = ?$, $d = ?$
a $v = u + at$
$= 0 + (9 \times 7) = 63$ m/s

b $d = ut + \frac{1}{2}at^2 = 0 + (\frac{1}{2} \times 9 \times 7^2)$
$= \frac{1}{2} \times 9 \times 49 = 221$ m

5 $u = 70\ \text{km/h} = \frac{70}{3.6}\ \text{m/s} = 19.4\ \text{m/s}$,
$a = -4\ \text{m/s}^2$, $v = 0$
Using the formula: $v = u + at$
$t = \frac{v - u}{a} = \frac{0 - 19.4}{-4}$
$= \frac{19.4}{4} = 4.85$ s
$v_{av} = \frac{19.4 + 0}{2} = 9.7$ m/s
Therefore, the distance travelled is $d = v_{av} \times t = 9.7\ \text{m/s} \times 4.85\ \text{s} = 47$ m. Using these data you can say that he will be able to stop a few metres from the passing train.

extra for experts

Using maths equations

In this section you have used several mathematical equations. For example:

$$a = \frac{v - u}{t}$$

Using algebra, this equation can be rearranged to give:

$$v = u + at$$

where **v** is the final speed,
u is the initial speed,
a is the acceleration, and
t is the time.

From this equation you can obtain a second equation:

$$d = ut + \tfrac{1}{2}at^2$$

where **d** is the distance travelled.

You can use these two equations to solve various problems.

Sample problem 1

A car was travelling at 15 m/s. It then accelerated at 2 m/s² for 4 seconds. What was its final speed?

Step 1 List the things you know and what you want to find.

u = 15 m/s
a = 2 m/s²
t = 4 s
v = ?

Step 2 Write down the appropriate equation and substitute the values into it.

$v = u + at$
$= 15 + (2 \times 4)$
$= 15 + 8$
$= 23$ m/s

Sample problem 2

A car and a semitrailer are travelling at 90 km/h (25 m/s). To overtake the semitrailer the car accelerates at 1.6 m/s² for 5 seconds. How far does the car travel in this time?

u = 25 m/s
a = 1.6 m/s²
t = 5 s
d = ?

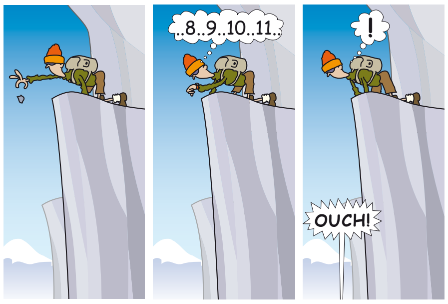
$d = ut + \frac{1}{2}at^2$
$= (25 \times 5) + \frac{1}{2}(1.6 \times 25)$
$= 125 + 20$
$= 145$ m

Questions

1 A car was stopped at traffic lights. When the lights changed it accelerated at 3 m/s² for 6 seconds.
a What was the car's initial speed?
b What was its speed after 6 seconds (in km/h)?

2 A spacecraft is moving at 250 m/s when it fires its retro-rockets for 6 seconds to slow it down. This causes it to decelerate at 10 m/s². What is the spacecraft's speed after the 6 seconds?

3 Owen drops a stone from the top of a mountain pass. If it takes 12 seconds to reach the valley below, how high is the pass? (Hint: the acceleration due to gravity is 9.8 m/s².)



4 A dragster accelerates at 9 m/s² from a stationary start for 7 seconds.
a What speed does the dragster reach?
b How far does it travel in 7 seconds?

5 A motorist is travelling at 70 km/h along a road which crosses a railway line. He notices a train approaching and applies the brakes 55 m from the crossing. The brakes cause the car to decelerate at 4 m/s². Will the car stop before the crossing?

Learning experience

Develop sets of application cards with the class. Have them put a question on the front of the card and the worked solution on the reverse. You will probably need to supply them with extra questions to try. The cards will be a handy revision tool that can be used at the start of any lesson or when they are revising for a topic test.

Learning experience

Consider giving the students the other commonly used equations for straight-line motion. Write up an application worksheet for them to try. Gifted and talented students, particularly those who enjoy maths, will like the challenge.

$v^2 = u^2 + 2ad$

$d = \frac{1}{2}(u + v)t$

$d = vt - \frac{1}{2}at^2$

5.2 Stopping

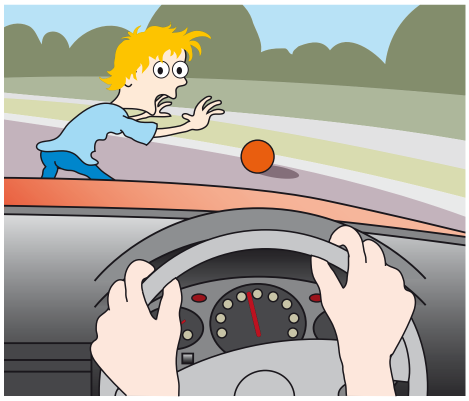
Imagine you are driving along a road and a child suddenly runs onto the road in front of you. You apply the brakes, and the car stops just in time.

Here is an action replay. The child runs onto the road. Your eyes record the scene. This information passes to your brain, which sends a signal to your right leg to push hard on the brake pedal. All this takes about a second. This time is called your **reaction time**. The distance the car travels in this time is called the *reaction distance*.

Under test conditions, reaction time is usually about 0.75 seconds. In real driving situations it is about one second, but may be much longer, depending on the individual and their alertness. The faster you are going, the further the car travels during this reaction time. For example, at 60 km/h (16.7 m/s):

reaction distance = vt = 16.7 m/s × 1 s = 16.7 m

When you put your foot on the brake pedal the car takes a certain distance to stop. This is called the *braking distance*. Good brakes and good tyres can slow a car about 23 km/h every second (about -6 m/s^2) on a good road. If you double your speed, the braking distance is four times as far! And on gravel or wet bitumen, the braking distance is even longer.



The distance it takes your car to stop is made up of the reaction distance plus the braking distance. This is called the *stopping distance*. The chart below shows the stopping distances when travelling at various speeds in a car.

In the experiment on the next page you can investigate the variables that affect stopping distance.

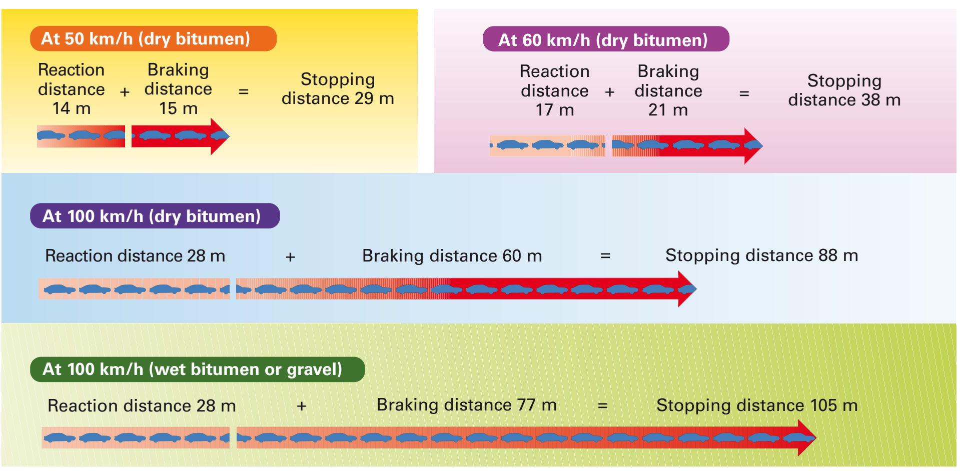


Fig 24 Stopping distance = reaction distance + braking distance

Hints and tips

- Before starting any new material, have the students document and prepare a list of the key points from the last few lessons. How much they can recall will determine how much time you need to spend on review before moving on to more advanced concepts.
- Be sensitive to the needs of any student who has experienced trauma from a road accident. Check student records prior to teaching this section to see if there are any students who may be particularly vulnerable. Ask students if they know anyone who has experienced a road trauma/accident. How do they feel about what happened? How have the people involved coped? What advice would students give to other road users? Has the road accident changed their way of thinking about driving? Encourage a sensitive and caring environment so that any students who share their stories feel supported and safe.

Homework

Children are often unaware of possible road dangers. Ask students to draw a cartoon strip for children to show what they should do before stepping onto a road. Some students might want to show what could happen if they ran onto the road *before* looking.

Learning experience

If drivers are fatigued, under the influence of alcohol or drugs, distracted by passengers or using their mobile phone, how do you think their reaction time will be affected and what are some possible consequences? Pose this question to students and allow a little time for discussion.

Then, to enable students to gain a better appreciation of the actual distances travelled before coming to a stop, measure out some reaction distances and then add the braking distance to give the stopping distance. The stopping distance will be much longer than the classroom and may shock some students. How many house blocks do these distances equate to?

Position some students at different points along the measured reaction distance. For each position, ask the class to describe the likely scenario if they stepped in front of a car travelling at the given speed. Has the car slowed down yet? What type of injuries might the student sustain in these positions? Ask some more students to stand along the measured braking distance and ask them the same questions. Where wouldn't you get struck by the car along the measured length? (at the very end) Students will now be more informed and will be able to answer the original question.

Learning experience

Design a task for the students to alert others about the need to be safe, responsible drivers. Get them to make their own advertisement about the hazards of using mobile phones while driving, driving under the influence of alcohol or drugs, tailgating vehicles, running an amber light, and so on. Their advertisement needs to be aimed at P-plate drivers and should include information relevant to this chapter. They could present their information in poster form or as a video for TV, *YouTube*, or the school intranet.

Lab notes

- It is a good idea to use old desktops and bricks for the ramps, and to do the experiment outdoors or in corridors where there is room and minimal risk of damage.
- If you use bicycles, insist on helmets and do the experiment in the car park or somewhere away from traffic. Before the lesson, organise which student will bring their bike to school for the experiment.

Experiment

STOPPING DISTANCES

Problem to be solved

What is the relationship between speed and stopping distance?

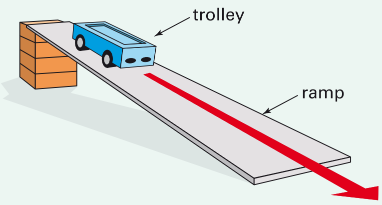
Planning the experiment

In a group, use the questions below to help you design an experiment to solve the problem above. Then carry out your experiment and write a report.

- How are you going to do the experiment? If you work outside you could use a bicycle. If you work in the laboratory you could let a trolley run down a ramp and vary the slope of the ramp.

Whichever method you use you will need to answer these questions:

- How will you measure the speed of the bicycle or trolley?



- What variables will you need to control?
- How can you make your measurements more reliable?

Processing the data

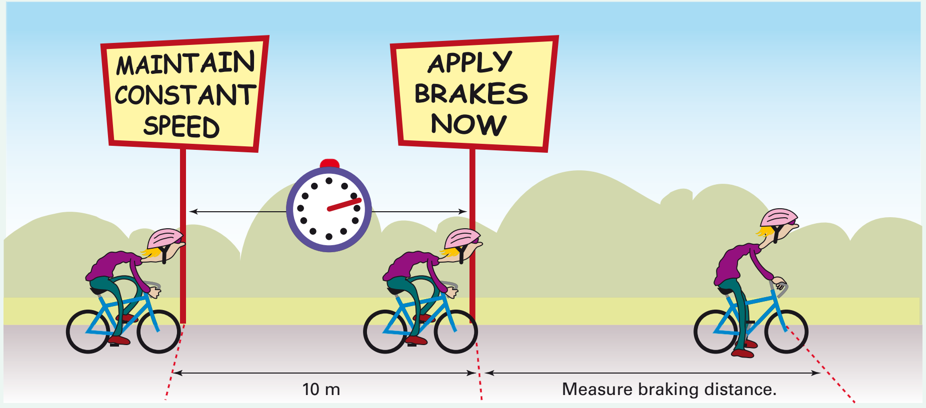
- How will you record your data? For example, can you put them into a spreadsheet such as *Excel*?
- How will you work out the relationship between stopping distance and speed? Will you need to draw a graph? Will the spreadsheet do this for you?

Evaluating the experiment

- How well did your method work?
- Do you think your results are reliable?
- Is your conclusion valid?

try this

What other variables affect the stopping distance? Choose one of these variables and then investigate how it affects the stopping distance.



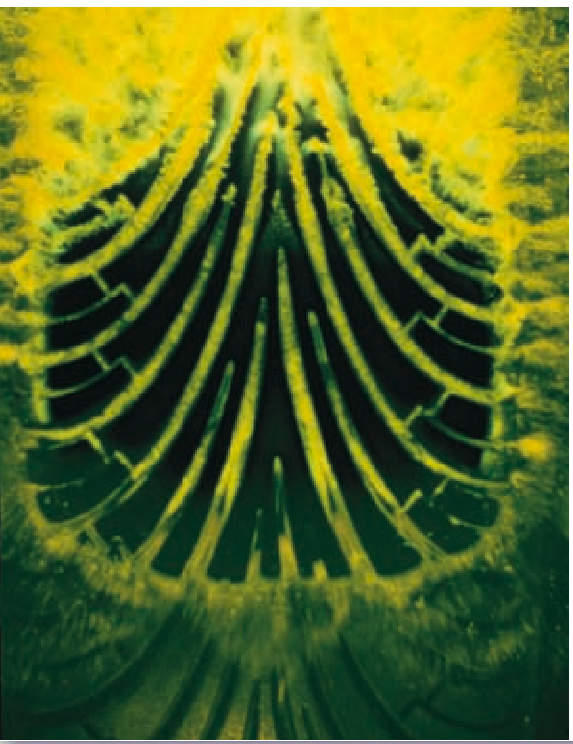
Friction

After the accident Teresa said: *When I saw the other car coming I slammed on the brakes, but I didn't seem to have control. The car just kept skidding until it hit the pole.* What happened here was that Teresa had put the brakes on too hard, stopping the wheels from turning. The brakes had 'locked'.

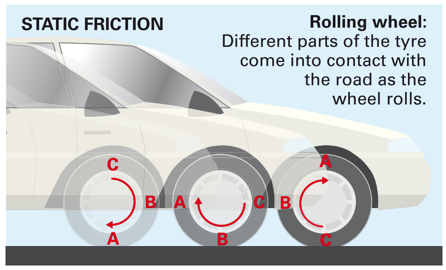
Tyres grip the road by **friction**, and this is what allows a driver to control the car. There has to be enough friction between the tyres and the road to enable the tyres to grip the road. Then, when the engine turns the wheels, the car will go forward. When you turn the steering wheel, the car will turn. And when you put on the brakes, the car will stop.

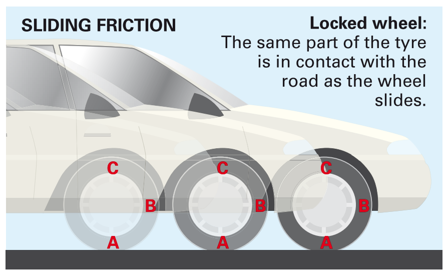
If the friction between the tyres and the road is reduced, driving can become dangerous. That is why you have to take extra care driving on wet roads. The water acts as a lubricant between the tyres and the road, reducing the friction and increasing the braking distance considerably.

Fig 27 A tyre photographed at high speed through a wet glass roadway



There are two types of friction—**static friction** and **sliding friction**. Static friction holds the tyre on the road. As the wheel rolls, another part of the tread comes into contact with a different part of the road, as shown below. The wheel does not slide.





When a wheel locks or slides sideways, the same part of the tyre tread slides along the road. The gripping force in this case is sliding friction, which is less than static friction (see the activity on the next page). Hence the tyres have considerably less grip on the road in a skid than when the wheels are rolling.

A skilled driver knows just how hard to brake without locking the wheels. However, most new cars are equipped with an antilock braking system (ABS). It senses that a wheel is about to lock up or skid and pumps the brake off and on rapidly. When the brakes are released the wheels start rolling again, and when the brakes are reapplied the larger static friction forces help stop the car. The 'brains' behind ABS is a computer chip, which can detect whether one wheel is turning more slowly than the others.

Hints and tips

Briefly revise the concept of forces. Forces can be divided into two categories: contact and non-contact. For cars the main contact forces include friction, drag and thrust. Friction acts between two surfaces and is a force that opposes motion. It occurs mainly between the surface of the road and the tyres. Drag (air resistance) can be considered a frictional force between the air and the body of the car. Thrust is created when the engine drives the wheels of the car.

Learning experience

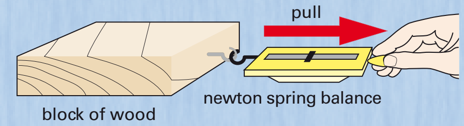
If students constructed a concept map for this chapter (Learning experience, page 102), revise the meanings of the words in it that you have taught so far. Ask students to give not only the word's meaning but an example of how it is applied. Alternatively, they could be given a 'match the word and meaning' worksheet.

Learning experience

Keen students could investigate the aerodynamics of a car, explore some new car designs, or find out the reason why drag racers need a parachute to stop.

Activity

Use the set-up below to investigate the difference between static friction and sliding friction.



1 Pull gently on the spring balance, without moving the block.
Which type of friction is operating?

2 Gradually increase the pull until the block starts to slide. Watch carefully the reading on the spring balance.
What happens to the frictional force when the block slides?
Which type of friction is operating now?

Science in action

Crash tests

Crash testing is designed to collect data on what happens to cars and their occupants during a crash. This data can then be used to make cars safer. Each vehicle that is tested is given a rating to indicate how safe it is.

A crash-test dummy is designed to simulate a person and is built from materials that mimic the physiology of the human body. For example, it has a spine made from alternating layers of metal discs and rubber pads. The dummy has accelerometers all over it to measure the acceleration in all directions. For example, the sudden deceleration of the driver's head during the crash is measured. There are load sensors to measure the amount of force on different parts of the body. For example, the force on the thigh bone is measured to determine the probability of it breaking. There are also movement sensors in the dummy's chest to measure how much it is pushed in during a crash. The dummy's knees, face and parts of the head are painted different colours. In the photo you can see that blue paint from the dummy's face is smeared on the airbag and that its left knee (painted red) hit the steering column. Each crash-test dummy costs about $250 000.

Ballast is added to the car to give it the correct weight. There are calibration marks on the car to help the testers analyse the slow-motion replays. The area is well lit and there are 15 or so high-speed cameras. The car is mounted on a track and propelled into a solid concrete barrier at about 60 km/h. A huge amount of data is temporarily stored in the dummy's chest and then downloaded to a computer. Side-impact tests are also carried out, in which a trolley is crashed into the side of the car.

WEBwatch

For more information on crash tests go to www.scienceworld.net.au and follow the links to **How crash testing works**. This site has an excellent video of a crash test.

Activity notes

This activity can also be carried out with a force measurer attached to a datalogger. If done over several repetitions, more accurate results can be obtained than with a spring balance.

Hints and tips

Ask a representative from the local police to give a presentation to the class about driver safety.

Homework

The Science in action and Webwatch activities are good homework activities. When the students do their own research, make sure to tell them to include an internet bibliography. To do this they should list: author name/s (if appropriate), title of site or web page (in italics/underlined), URL of site, date last updated.

Learning experience

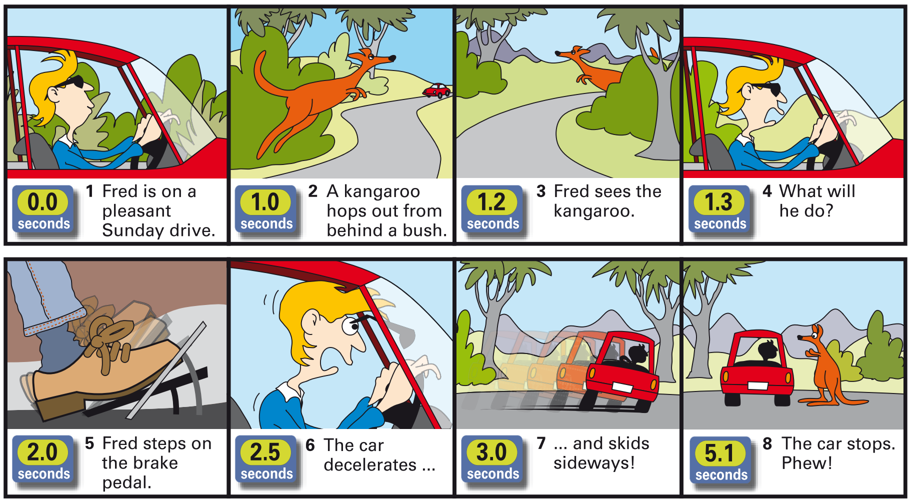
Many students will have part-time work and may be saving for their first car. How do they know what would be a safe choice? Get them to check out websites such as the RACQ, TAC or RTA. Go to the *ScienceWorld 3* Webwatch and follow the links to 'How safe is your car?'

Ask students to select three cars of their choice for under $15 000. Two cars should be selected and recommended for purchase based on their safety rating, while the third car should be selected and not recommended because of its safety rating. The students should be prepared to explain their recommendations to the class and justify their choices. They should do the same for cars under $30 000 and then choose a car of their dreams and outline its safety features.

The class information can be summarised on poster paper and displayed in the room so that all students are able to view the information. Data needs to be clearly identified as 'recommended' or 'not recommended'. Students can search the internet or look through newspapers and magazines to find car prices.

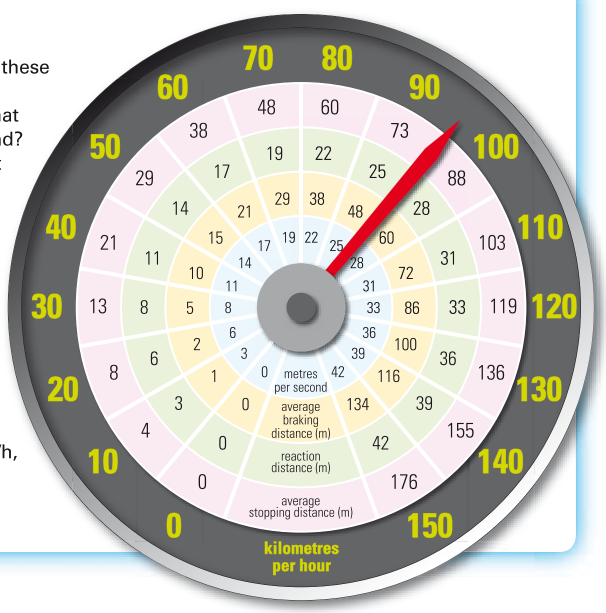
As an extension to this activity, students could add an environmentally friendly or fuel efficiency rating. This would tie in well with Chapter 6.

Check!



1 The cartoon strip above shows what happened to Fred while driving in the country.
- **a** What is Fred's reaction time?
- **b** What is his braking time?
- **c** What is his stopping time?

2 Use the chart on the right to answer these questions.
- **a** You are travelling at 50 km/h. What speed is this in metres per second?
- **b** What is your reaction distance at this speed?
- **c** What happens to the braking distance and stopping distance when the speed doubles from 40 km/h to 80 km/h?
- **d** The chart assumes a reaction time. What is it? How do you know?
- **e** Two identical cars side by side on the freeway brake at the same time. If one is travelling at 80 km/h and the other at 100 km/h, how far apart will they be when they stop?
- **f** You are 50 m from a pedestrian crossing when an elderly person starts to cross. If you are travelling at 60 km/h, will you stop in time? What if the road is wet?



Check! solutions

1
- a Fred's reaction time is the difference between frames 5 and 3, which is 0.8 s.
- b Fred's braking time is the difference between frames 8 and 5, which is 3.1 s.
- c Fred's stopping time is the difference between frames 8 and 3, which is 3.9 s. This is reaction time plus braking time.

2 Using the chart provided:
- a 50 km/h is equal to 14 m/s.
- b At this speed your reaction distance is 14 m.
- c The braking distance increases from 10 m to 38 m, which is about four times greater. The stopping distance increases from 21 m to 60 m, which is about three times greater.
- d The chart assumes a reaction time of 1 s. You know this because at 3 m/s the reaction distance is 3 m.
- e For the car travelling at 80 km/h the stopping distance is 60 m. For the car travelling at 100 km/h the stopping distance is 88 m. So, the cars will be 28 m apart when they stop.
- f If you are travelling at 60 km/h you should be able to stop in 38 m. However, if the road is wet the tyres may lose their grip and you could skid, in which case you may not stop in time.

3 Why is the braking distance greater on a wet road than on a dry one?

4 The stopping distances on the chart on the previous page are for an alert driver in a car with good brakes and tyres, on a dry road. What difference would each of the following make to the stopping distance?
a rain **c** drunk driver
b tired driver **d** fog

5 Gayle wants to move a heavy cupboard. She pushes harder and harder, then suddenly it moves with a jerk. Try to explain why this happens.

6 What is ABS in a car and how does it work?

7 Why is it that the reaction distance increases with speed while the reaction time stays the same?

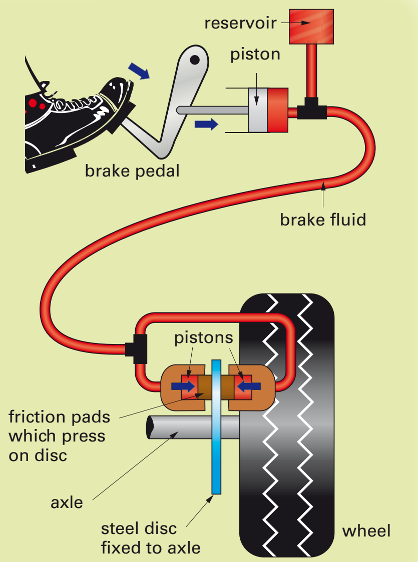
challenge

1 It is often recommended that, under good conditions, you should drive at least two seconds behind the car in front. (This means that it should take your car at least 2 seconds to reach the present position of the car in front.)
a How far behind should you be when travelling at 60 km/h? At 100 km/h?
b Try to explain why a time of 2 seconds is recommended.

2 **a** Use the chart on the previous page to draw a graph of average braking distance versus speed. Plot reaction distance versus speed on the same graph.
b Use your graph to find the reaction distance, braking distance and stopping distance at 65 km/h.

3 **a** Use the diagram on the right to write a paragraph explaining how disc brakes work.
b If you drive through water over the road, the brakes become wet and they do not work as well. Suggest a reason for this.
c Suggest what you could do to get the brakes working properly again.

4 **a** A car is travelling at 60 km/h. If its brakes can decelerate the car at 6 m/s², what is its braking distance? Use the formula $v^2 = u^2 + 2ad$, where v is the final speed, u the initial speed, a the acceleration and d the distance travelled.
b If the driver has a reaction time of 0.8 seconds, what is the reaction distance?
c What will the stopping distance be?



try this

1 Design and carry out an experiment to test whether wider tyres give you better grip than narrow ones.

2 Does it make any difference whether the front wheels, the back wheels or all four wheels are locked up during braking? Design and carry out an experiment to test this.

Check! solutions

3 The breaking distance is greater because the water between the road and the tyres acts as a lubricant and reduces friction, thus increasing the braking distance.

4 a Rain will increase the stopping distance for the reason described in question 3.
b A tired driver will have a slower reaction time and this will increase the stopping distance.
c A drunk driver will also have a slower reaction time and this will increase the stopping distance.
d Fog will reduce visibility and this will also increase the stopping distance.

5 Before the cupboard moves, static friction operates. Once the cupboard moves, sliding friction operates. Because the sliding friction is less than the static friction, the cupboard now slides much more easily.

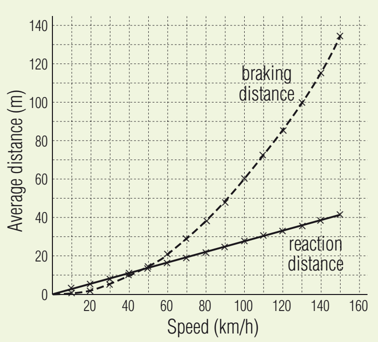
6 ABS stands for 'Antilock Braking System', which senses whether one wheel is turning slower than the others and is about to lock. It then pumps the brake of that wheel on and off so that the tyre does not skid.

7 This is simply because at a greater speed you will travel further in the same amount of time. Your reaction time, however, does not depend on how fast you are going.

Challenge solutions

1 a At 60 km/h (16.6 m/s) you should be about 33 m (16.6 × 2) behind. At 100 km/h you should be about 55 m behind.
b Two seconds is recommended for safety because if the driver is alert it will take at least 1 s to start braking.

2 a



b At 65 km/h the reaction distance would be about 18 m, the braking distance would be about 25 m and the stopping distance about 43 m.

3 a When the driver of the car pushes down on the brake pedal, brake fluid is pumped through the brake line. This fluid moves pistons, which push friction pads against a disc that is attached to the rotating axle and wheel. This increases the friction and slows down the wheel.
b Brakes do not work as well when they are wet because the water acts as a lubricant and reduces the friction between the pads and the disc.
c One way would be to lightly apply the brakes while travelling slowly. This will produce friction in the brakes that will cause them to heat up and dry out so they work properly again.

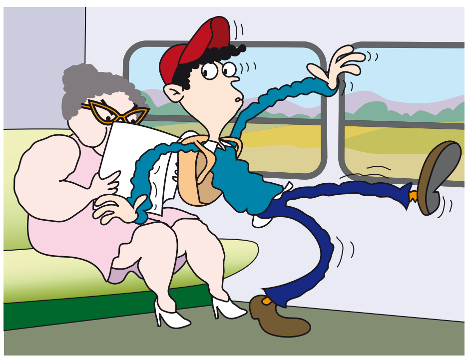
4 a Using the given formula:
$0 = 16.6^2 + 2(-6)d$
$12d = 276$
$d = \frac{276}{12} = 23$ m
b If the driver has a reaction time of 0.8 s, the car will travel a further 0.8 × 16.6 = 13.3 m, which is the reaction distance.
c The stopping distance will be the sum of **a** and **b**, which is 36.3 m.

5.3 Collisions

Inertia

Suppose you are in a car travelling at 60 km/h. Your body is also moving at 60 km/h. If the driver brakes suddenly the car slows down, but because your body is not attached to the car it tends to keep moving at the same speed of 60 km/h. This is why you feel as though you are falling forwards. A seatbelt holds you so that you do not crash into the dashboard, windscreen or front seats.

Similarly, if you are standing in a bus or a train you may be thrown off balance when it starts to move. Your body tends to stay at rest as the bus begins to move. If the bus suddenly speeds up, you may fall backwards. And if the bus turns a sharp corner you may be thrown to the other side.



The train's sudden acceleration was about to cause Mikie a few embarrassing moments.

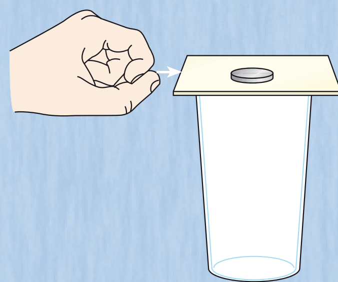
An object will stay at rest, or will not change its speed or direction, unless acted on by a force. The object is said to have **inertia** (in-ER-sha). This inertia depends on the mass of the object—the greater the mass, the greater the inertia. For example, a bus has more mass than a car. Therefore it has more inertia. A bus is harder to start or stop than a car. That is, it takes a larger force to change its motion.

To sum up, if an object is at rest, it tends to remain at rest; and if it is moving, it tends to keep on moving at the same speed and in the same direction. This is called *Newton's first law of motion*, even though it was first proposed by the Italian Galileo in 1612. The Englishman Sir Isaac Newton was born in the year Galileo died, and he used Galileo's idea and developed it further.

Activity

Here is a fun way to illustrate inertia. Place a 20 cent coin on a piece of cardboard on top of a glass as shown. Then flick the card.

Explain what happens in terms of inertia.



Momentum

A heavy truck is harder to stop than a car travelling at the same speed. This is because the truck has more momentum. The **momentum** of an object depends on its mass and its speed. It can be calculated using the formula:

$$M = m v$$

where **M** is the momentum, **m** is the mass in kilograms and **v** is the speed of the object in m/s

Momentum increases as either the mass or the speed increases. A truck has more momentum than a car moving at the same speed. The larger mass of the truck gives it more momentum. For this reason it will do more damage if it collides with something. Also, a fast-moving car has more momentum than a slow-moving one. Its greater speed gives it more momentum.

In Investigate 13 you can investigate the effects of inertia and momentum in car accidents.

Hints and tips

- Inertia can be described as the 'laziness' of an object. That is, if an object is at rest or an object is in motion then it wants to stay in that state of motion. To change the object's state of motion, a force needs to be exerted on it. This is Newton's first law of motion.
- It might be worth telling the students about conservation of momentum. If you are explaining this, be sure to explain to the students that momentum is never lost, rather it is transferred from one object to another. Consider a car and a truck travelling at the same speed but in opposite directions. Which has the greater momentum? (The truck, because it has more mass.) If they collide and come to rest, what is their total momentum? Because they are no longer moving they do not have momentum—what happened to it? The momentum was simply transferred to the earth and the surroundings.
- If the department has a set of momentum balls, take them into class to demonstrate conservation of momentum. You might like to set up the air-track and by using gliders show how momentum is conserved. Students may be able to perform some practical investigations with the air-track.

Activity notes

Consider setting a table with a tablecloth and large jug of water. Amaze the students by pulling the tablecloth from under the jug of water. The trick here is to make sure the table is smooth and the cloth is not too long but just covers the table's surface area. A quick whipping action is required to move it from under the jug.

Learning experience

A fun demonstration of inertia (but recommended for outside) is with a dynamics trolley and a raw egg. Place the egg on the trolley with a length of string attached to the trolley's rear. Hold the string and give the trolley a big push to move it quite fast. When the trolley suddenly stops because the length of string has run out, what happens to the egg? This demonstration can form the basis of a discussion about head injuries and the importance of wearing seatbelts. Get the class to suggest a way to 'seatbelt' the egg, then repeat the procedure with a new egg.

Lab notes

Part A

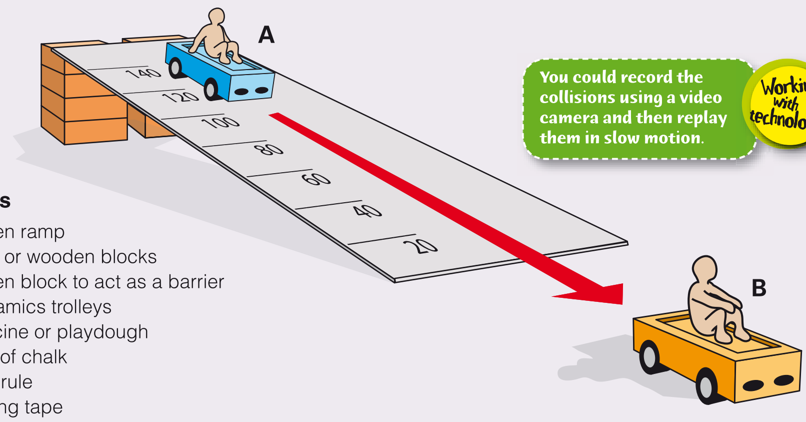
- This is a great investigation but some students will need to be reminded about respecting property and not making the collisions too violent.
- To smooth the edge between the bottom of the ramp and the floor, a strip of moulded plasticine could be used.

Investigate

13 CAR ACCIDENTS

Aim

To use trolleys and dummies as a model for car accidents.



You could record the collisions using a video camera and then replay them in slow motion. Working with technology

Materials

- wooden ramp
- bricks or wooden blocks
- wooden block to act as a barrier
- 2 dynamics trolleys
- plasticine or playdough
- piece of chalk
- metre rule
- masking tape
- talcum or graphite powder
- graph paper

Planning and Safety Check

Read both parts of the investigation carefully.

- What is the aim of each part?
- Design a data table for Part B.

PART A

Method

1 Make two plasticine dummies to represent people in car accidents.

2 Put a dummy on the front of each trolley. (You should powder the bottoms of the dummies to reduce their stickiness.)

3 Mark 20 cm intervals on the ramp, starting from the bottom, as shown.

4 Place trolley B about 40 centimetres in front of the ramp. Place trolley A at the top of the ramp, directly in line with trolley B.

5 Release trolley A so that it collides with trolley B.

Observe carefully what happens to the dummies in the collision.

6 Repeat Step 5 two or three times.

Discussion

1 What happened to the dummy on trolley A during the collision? Explain *why* this happened.

2 What happens to the occupants of a moving car when it collides with a stationary car?

3 What design features of cars reduce the risk of injury in this type of collision?

4 What happened to the dummy on trolley B? Explain why this happened.

5 What happens to the occupants of a stationary car hit from behind by another car?

6 What design features reduce the risk of injury in this type of collision?

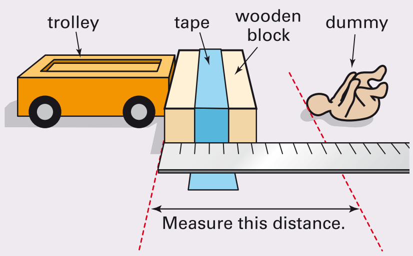
PART B

Method

1 Tape a wooden block firmly to the bench or floor 30 to 40 cm in front of the ramp.

2 Put the plasticine dummy on the trolley and line it up on the 20 cm mark. Release it so that it crashes into the wooden block and observe what happens to the dummy.

Measure the distance from the dummy to the impact side of the wooden block. Measure to the nearest centimetre, and record the result in a data table.



3 Repeat Step 2 at least three times, exactly the same way each time. You will probably get a different result each time. This is because there are variables that are difficult to control. For instance, the trolley may hit the block differently because of small changes in the way it rolls down the ramp.

Find the average of the measurements.

4 Repeat Steps 2 and 3 by placing the trolley at higher positions on the ramp. Record all results.

5 Plot your results on a graph. Try to draw a line of best fit.

Discussion

1 What happens to the impact speed of the trolley as it is released from higher up the ramp?

2 What is the relationship between the impact speed and the distance that the dummy was thrown?

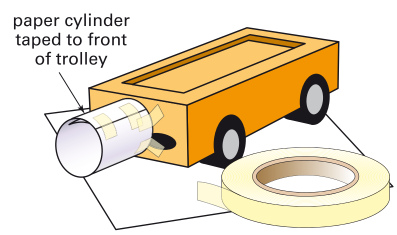
3 Use your graph to predict how far the dummy would be thrown if you released the trolley from one of the marks you have not used. Try it and check your prediction.

4 Could you modify the experiment to get more reliable results? How?

try this

1 Redesign Part A to model what happens in a head-on collision.

2 Experiment with a crumple zone for the trolley, eg a cylinder of paper as shown below. You could also experiment with a seatbelt or airbag for the dummy.



The second and third collisions

How can one person walk away from a major collision and another person die in a minor collision? The following true story will help you answer this.

A farmer loaded his truck with eggs and headed for the markets. On the way he lost control of the truck and crashed into a tree beside the road. The truck was travelling at 60 km/h when it was stopped by the tree. However, due to inertia, the farmer's body continued moving until it collided with the steering wheel and windscreen. There was also a third collision when the farmer's internal organs were slammed against each other and against his skeleton. It was these second and third collisions that seriously injured the farmer.

The eggs in the back of the truck were packed in soft cardboard cartons and stacked in crates.

Lab notes

Part B

- Masking tape seatbelts work better than rubber bands as the rubber bands tend to dismember the dummies.
- For this part of the investigation, you could use old trolleys with springs, or crumple zones made from cardboard egg cartons, straws or bubble-wrap.

Hints and tips

Revise the chapter so far by giving students the crossword puzzle on the CD to complete, or challenge them to make their own crossword.

Hints and tips

Did you know that a decomposition reaction takes place inside an airbag when it is released? Sodium azide decomposes explosively into sodium and nitrogen when the airbag is triggered, and the nitrogen inflates the bag. The chemical reaction is:

$$2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$$

Research

What does the inside of a racing car look like? What types of racing cars are there (eg touring cars, Formula One, V8 Supercars, drag racers, etc)? What surfaces are they raced on? How are they fitted out to ensure there is minimal injury to the driver in the event of a crash? Ask students to do some research into these questions and present the information as a booklet designed for racing-car enthusiasts. Include diagrams to help with explanations. The information presented should be relevant to this chapter.

Homework

Ask students to reflect on what they have learned so far in this chapter, and write down their self-reflection. They could begin with what they have learned, how they have learned it, and how they have helped others. They should write at least 10 sentences. Next lesson, call on students to select one thing they have learned and share it with the class. They will soon realise just how much they have learned.

The crates were also tied down. Some of the crates were thrown from the truck and the eggs smashed, but most of the crates remained in the truck and the eggs were undamaged!

Why was the farmer injured while most of the eggs were safe? Obviously the eggs were carefully packaged, but the farmer was not. Because he was not wearing a seatbelt he smashed into the steering wheel and was seriously injured. At 60 km/h, the impact of the second collision is like landing face first on the ground after falling from the fifth floor of a building. Worse, it is like falling on a steering wheel sticking up from the ground, or on a glass windscreen or a dashboard!

Inertia and car design

Seatbelts hold car occupants securely in place during a crash and reduce the chance of serious injury and death by about 60%. This is why the wearing of seatbelts is law. Also, babies and young children who are too small for seatbelts must have specially designed child restraints.

Some deaths and serious injuries have been caused when car occupants, whether wearing seatbelts or not, have been struck by loose objects flying forward from the rear seat or parcel shelf. If you and the car come to a complete stop from even a moderate speed, say 40 km/h, loose items will continue travelling at that speed. Imagine being struck in the back of the head by a portable radio or something similar travelling at 40 km/h! Even small light objects can kill at that speed.

Head restraints help to prevent neck damage to occupants, particularly in rear-end collisions. Look at the top part of Fig 39, where there is no head restraint. When the car is struck from behind, the person's body is moved forward by the seat, but the head is left behind because of its inertia. The effect is like that of cracking a whip, and the person can suffer a serious neck injury called whiplash. If the head is supported by a head restraint, both body and head move together.

Modern cars are designed to help you survive serious crashes. In a head-on collision, the engine compartment is designed to crumple and absorb as much energy as possible. The engine is forced

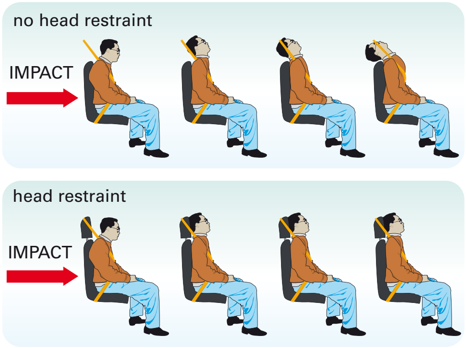


Fig 39 How head restraints work

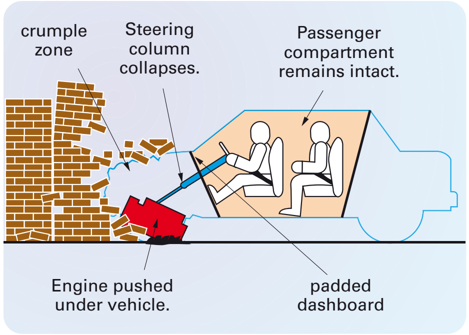


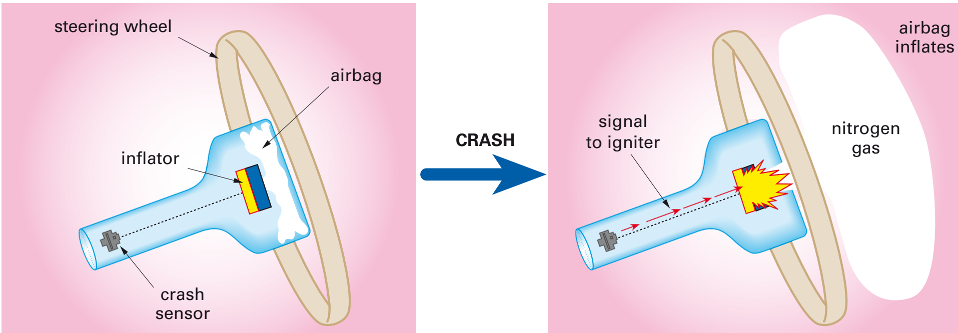
Fig 40 Safety features in a car

under the rigid passenger compartment, and the steering column collapses so that the driver is not speared.

Many new cars are now fitted with *airbags*. These do not replace seatbelts, but are an additional safety device. In a serious crash, belted front occupants may still move forward enough to hit the steering wheel or windscreen. Airbags are designed to inflate in frontal collisions that are comparable to hitting a solid wall at about 25 km/h. Most sensors contain a micromachined accelerometer which produces an electronic signal when jolted. This sends an electric current to the igniter in the inflator. This causes the chemical

Learning experience

There are some good commercial DVDs available on collisions and road safety. Consider showing the class one of these to break up the theory components and make the topic feel more real. You could also search the internet for interactive applications for the class to try.



propellant (usually sodium azide) that is sealed in the module to undergo a rapid chemical reaction which produces nitrogen gas that inflates the bag in about 0.3 seconds. A second later the gas quickly escapes through tiny holes, thus deflating the bag so you can move.

WEBwatch

To find out more about airbags go to www.scienceworld.net.au and follow the links to **How air bags work.**

Force, mass and acceleration

We know that force causes acceleration, but Sir Isaac Newton was the first to work out the relationship between the size of a force and the acceleration it causes.

Firstly, the larger the force, the larger the acceleration it causes. For example, if you push an empty shopping trolley very gently it only moves slowly. If you apply a large force by pushing hard it moves rapidly. This means that the force and the acceleration produced by the force are directly proportional. To double the acceleration of the trolley you need twice the force. And half the force will produce only half the acceleration.

Secondly, a force will give a greater acceleration to an object with a small mass than it will to an object with a large mass. If you push an empty shopping trolley with a large force, it will accelerate rapidly. But when you use the same force to push the same trolley filled with groceries, the acceleration is less. What this means is that for a constant force the acceleration is inversely proportional to the mass of the object being accelerated. In other words, if you double the mass, you halve the acceleration. And if you halve the mass you double the acceleration.

Fig 42 A small push gives an empty shopping trolley a small acceleration. A bigger push gives the empty trolley a large acceleration. But this same push gives a full trolley only a small acceleration.

Hints and tips

- Simply stated, a force causes an object to accelerate. Whenever an object is accelerating there must be a force acting on it because, as stated in Newton's first law, an object won't change its state of motion unless acted on by a force. This is summarised as F = ma and is Newton's second law of motion.
- When students investigate how airbags work, ask them to draw a simple flow diagram to explain the physics and chemistry involved.

Issues

- Should *all* cars driven on Australian roads have airbags? Investigate the issues surrounding this question.
- An issues map can help students to identify the different dimensions of, or perspectives on, a particular event or issue. It is often helpful to phrase the issue as a question so it can be explored differently, depending on the diverse viewpoints held by students. Students then brainstorm the issue using the map. The responses can be categorised as positive or negative. An example map template for the issue of airbags is shown.

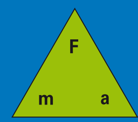
	Science	
Social and community	**Should all cars have airbags?**	Health
	Economics	

These two relationships between acceleration, force and mass can be combined as a single mathematical equation:

$$a = \frac{F}{m}$$

where **a** is the acceleration in m/s^2, **F** is the force in newtons and **m** is the mass in kilograms.

The equation can then be rearranged as shown:



$$F = m\,a$$

This equation is known as Newton's second law of motion.

Crumple zones

Newton's second law of motion is useful in analysing collisions. Using the equation for acceleration you can rearrange the equation F = ma as follows:

$$F = m\,a = m\left(\frac{v-u}{t}\right) = \frac{mv - mu}{t}$$

The quantity mv is the momentum of the object, so you can rewrite F = ma as:

$$\text{force} = \frac{\text{final momentum} - \text{initial momentum}}{\text{time taken}} = \frac{\text{change in momentum}}{\text{time taken}}$$

Suppose a car has a mass of 600 kg. It is travelling at 90 km/h (25 m/s) when it collides with a tree and comes to a stop in 0.1 seconds. We can calculate the force exerted on the car as follows. Because the car comes to a stop its final speed is zero.

$$F = \frac{mv - mu}{t} = \frac{(600 \times 0) - (600 \times 25)}{0.1} = \frac{-15\,000}{0.1} = -150\,000\ \text{N}$$

The negative sign means that the force is decelerating the car. Because it is such a large force, the occupants are likely to be seriously injured.

How can the forces during a collision be reduced? Apart from driving more slowly, the most practical method is to lengthen the time from impact to when the car comes to a stop. This can be done by building crumple zones into a vehicle. In a head-on collision it takes some time for the front end to crumple. Although the car is badly damaged, the occupants are less likely to be hurt. Of course, the occupants must be protected in a rigid passenger compartment (see Fig 40) so that they are not crushed. And they must wear seatbelts to stop them colliding with the interior of the car.

Suppose the car in the previous example had a crumple zone so that it stopped in 0.3 seconds instead of 0.1 seconds. The force now would be 50 000 N, only a third of what it was without the crumple zone. If the car had hit a pile of hay bales it would have stopped in about 1 second. In this case the force on the car would have been only 15 000 N, a tenth of the force when it hit the tree. This is why some roads have energy-absorbing barriers, to increase the collision time and decrease the force on the car.

Fig 43 These energy-absorbing wire ropes prevent vehicles crossing the median strip into the path of oncoming vehicles.

Hints and tips

When students use the formula for the force in a collision (crumple zones), an error commonly occurs: they incorrectly divide only the last part of the numerator by the time. To avoid this happening, get the students to calculate the numerator first and then divide it by the time, or to put double brackets around the numerator and then divide it by the time.

Learning experience

Get the students to add the equations F = ma and $F = \frac{mv - mu}{t}$ to the set of cards they developed in the Learning experience on page 110. They should come up with their own problem that they need each formula to solve, with the worked solution on the back of the card. Ask the students to test themselves or the person next to them using their full set of cards. How much can they remember? Do they need to spend more time practising and writing more cards with new questions on them? If so, give them time to do this.

Learning experience

Give the class some extra questions to try that require them to use each formula. See if they can write their own questions with meaningful figures for others in the class to try. How realistic are their questions and answers?

Learning experience

Ask the students to explain the formulas F = ma and $F = \frac{mv - mu}{t}$ by writing their meaning in sentences.

Learning experience

How does road science link with other areas of science? The students could brainstorm to come up with a two-column list: one column for the science and the other for the object/mechanism. Suggest they flick through the textbook to help them with their brainstorming. Start them off with the following

Science	Object/mechanism
Light	Reflecting mirrors on side of road, radar and laser guns
Sound	Sound barriers along freeways
Energy	Fuel-efficient transport
Chemistry	Car airbag reaction
Aerodynamics	Streamlined designs
Responding (physiology)	Reaction time

Drink driving

It is illegal to drive a motor vehicle if your blood alcohol concentration is more than 0.05, or zero if you are a learner driver or P-plater. *Blood alcohol concentration* is the amount of alcohol per 100 mL of blood in your body at a particular time. It is measured in g/100 mL. So 0.05% means that there is 0.05 g of alcohol in each 100 mL of blood.

On average, a person reaches a blood alcohol concentration of 0.05 after consuming three *standard drinks* in an hour (Fig 44). However, this can vary considerably from person to person. It depends on your weight, whether you are male or female, and whether or not you eat food with the alcohol. As part of its normal functions, the body processes alcohol and gets rid of it. Each hour, blood alcohol concentration falls by about 0.015, equivalent to one standard drink.

Drinking and driving are a deadly combination. The alcohol slows down your reaction time and therefore increases braking distance. As well, your powers of judgment and decision-making are reduced, and you take foolish risks. The more alcohol you consume, the greater the risk of having an accident, as shown in Fig 45. In fact, with a level of 0.05 you are more than twice as likely to have an accident as normal.

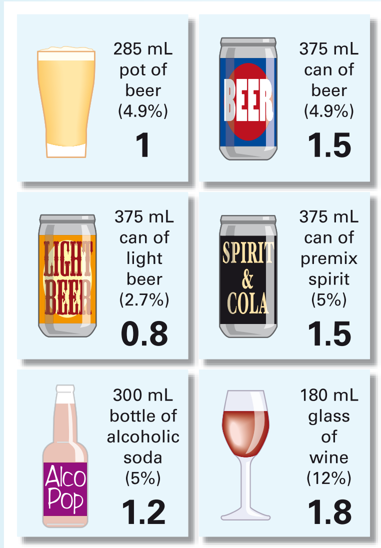


Fig 44 How many standard drinks?

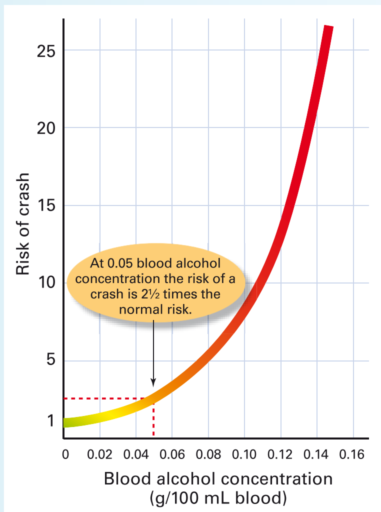


Fig 45 Relative probability of crashing at various blood alcohol concentrations

Questions

1 What does a blood alcohol concentration of 0.05 mean?

2 Use the graph to calculate the risk of having a crash when the driver has a blood alcohol concentration of 0.08, 0.10 and 0.14.

3 How many 375 mL cans of full-strength beer could an average person drink in an hour before reaching the 0.05 limit? How many cans of light beer?

4 Andrew drank three 375 mL cans of beer. How long will it be before all the alcohol is removed from his body?

5 Lauren, Ben, Stephanie and Michael got together for a few drinks one evening. This is what they drank in three hours.

Lauren: 4 glasses of beer and a vodka and tonic
Ben: a can of light beer and a rum and coke
Stephanie: a glass of wine and 3 glasses of orange juice
Michael: 5 pots of beer

a How many standard drinks did each have?
b Who is legally fit to drive home? (All have full licences.)

Hints and tips

Find out what other factors can affect your body's blood alcohol level: for example, fatigue and prescribed medication.

Homework

Ask students to write 10 questions, with answers, related to this chapter. The questions can be collected and used as a class revision tool, or selected questions could be put on a topic test.

Learning experiences

1 A good extension here is to explain that one of the effects of alcohol is to increase reaction time. Students could to do some written exercises on how this will affect stopping distance (refer back to page 111).

2 There are a number of websites where students can measure their reaction time online. Go to *ScienceWorld 3* Webwatch and follow the link to 'Test your reaction time'.

Learning experience

Hand back the pre-test concept map (Learning experience, page 102) to the students so they can complete a post-test concept map. In addition, ask them to write a self-evaluation for the topic.

Learning experience

What do you think is a suitable punishment for people caught drink driving? How might the punishment be enforced? Are we making too much of a fuss about drinking and driving, or not enough fuss? Ask the students to discuss these questions with a partner and present their work as an interview between a police officer and a member of the public. Musically minded students could turn their work into a song. Likewise, those who prefer a kinaesthetic style could role play it.

Check!

1 A sports car and a semitrailer are both stationary. Which one has more inertia?

2 Most small trucks have a sturdy wall behind the driver's cabin. Why is this?

3 List at least five design features that have increased the safety of cars.

4 a Two cars have the same mass but one has an engine three times as powerful as the other. How would the acceleration of the two cars compare?

b Two cars have the same engine but one has a mass one-quarter of the other. How would the acceleration of the two cars compare?

5 Why does a slowly-moving train have more momentum than a speeding bullet?

6 Use what you have learnt in this chapter to explain what is likely to happen to a standing train traveller when the train:

a accelerates rapidly

b stops suddenly.

7 Copy and complete the following table.

Force acting	Mass of vehicle	Acceleration
?	1000 kg	2 m/s^2
2000 N	500 kg	?
5000 N	?	5 m/s^2
10 N	?	26 m/s^2
?	1500 g	3.5 m/s^2
5 N	200 g	?

8 Put these four objects in order, starting with the one with the most momentum.

- a 600 kg car travelling at 100 km/h
- a 5 tonne truck travelling at 15 km/h
- a 45 gram golfball in flight at 100 km/h
- a 100 kg person cycling at 40 km/h

9 Suppose you are travelling at 60 km/h. Which of the following accidents is likely to be most serious? Least serious? Explain your answers.

a hitting a wooden fence

b hitting a large tree

c hitting an oncoming vehicle

challenge

1 When the Space Shuttle takes off, its acceleration increases as it rises. Suggest why this happens.

2 Four-wheel drive vehicles are often fitted with bullbars. What is the purpose of bullbars? Do they protect the occupants of the vehicle in a head-on collision? Explain.

3 How fast would a 25 kg rocket be going if it started from rest and accelerated under the influence of a 350 N force for 6.5 seconds?

4 A spacecraft of mass 2000 kg is moving away from a space station with a speed of 100 m/s. It fires its main engines for 20 seconds. Its speed when it stops accelerating is 400 m/s.

a What is its acceleration?

b What is the force of the rocket engines?

5 What force must your seat belt be able to withstand if you hit a tree at 60 km/h and stop in 0.08 seconds? (Assume your mass is 70 kg.)

6 A football of mass 0.5 kg reaches a speed of 25 m/s as a result of a kick with an impact time of 0.22 seconds. Find:

a the final momentum of the ball

b the average force on the ball

c the acceleration of the ball

7 A 5 kg trolley rests on a table. A horizontal force of 10 N acts on the trolley for 5 seconds. (Hint: use the equations in Extra for Experts on page 110, and assume there is no friction.)

a What is the speed at the end of the 5 seconds?

b How far does the trolley move in the 5 seconds?

c If the force ceased to act after 5 seconds, how fast would the trolley be moving after 6 seconds?

8 A 30 tonne semitrailer travelling at 70 km/h brakes suddenly to avoid a collision. What force must the brakes of the semitrailer exert to stop it in 150 m?

Check! solutions

1 A semitrailer has more inertia than a sports car because it has a greater mass.

2 The sturdy wall is to protect the driver and passenger in case of a collision, which may cause objects in the back of the truck to continue moving forward.

3 Some safety features are:

- padded interiors
- seatbelts
- airbags
- better braking systems
- head restraints
- crumple zones
- collapsing steering column.

There are many others.

4 a The car with the more powerful engine is likely to have three times the acceleration. This is because it is able to apply three times the force to the same mass according to the formula a = F/m.

b The car with the smaller mass will have four times the acceleration. This is because it is able to apply the same force to the smaller mass according to the formula a = F/m.

5 Even though the bullet may be travelling much faster (eg 1000 m/s compared to 5 m/s), the train has a much, much greater mass (eg 50 g compared to 200 tonnes). The momentum (M) is the product of the mass (m) and the speed (v) of an object. Therefore, the momentum of the train will be much greater than the bullet.

6 a As the train accelerates, the passenger tends to stay stationary and will lurch backwards compared to the train.

b As the train suddenly stops, the opposite occurs and the passenger tends to keep moving in the same direction as the train and will lurch forward.

7

Force acting	*Mass of vehicle*	*Acceleration*
2000 N	1000 kg	2 m/s^2
2000 N	500 kg	4 m/s^2
5000 N	1000 kg	5 m/s^2
10 N	385 kg	26 m/s^2
5.25 N	1500 g	3.5 m/s^2
5 N	200 g	25 m/s^2

8 In order, they are the:

- truck (5 × 1000 × 15 = 75 000 kg km/h)
- car (600 × 100 = 60 000 kg km/h)
- person (100 × 40 = 4000 kg km/h)
- golf ball (45/1000 × 100 = 4.5 kg km/h)

9 a When a car crashes into it, a wooden fence will break and the car will not slow down as quickly as if it had hit a solid object such as a large tree; hence, the forces will not be as great and damage and injuries to the car will not usually be as serious.

b When a car crashes into a large, immovable object like a tree, its momentum changes rapidly and large forces are exerted on the car and its occupants, often causing injuries or death.

c When a car crashes into an oncoming vehicle, its momentum changes even more rapidly and huge forces are exerted on the car and its occupants, usually causing serious injuries or death.

MAIN IDEAS

Copy and complete these statements to make a summary of this chapter. The missing words are on the right.

acceleration
airbags
divide
force
equation
inertia
inversely
mass
reaction time
skid
slope
speed

1 To find average speed, ______ the distance travelled by the time taken:

$$\text{average speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

2 The ______ of a distance–time graph gives the instantaneous speed.

3 Acceleration occurs when an object changes ______.

$$\text{average acceleration} = \frac{\text{change in speed}}{\text{time taken}}$$

4 Stopping distance depends on your ______, the speed of your vehicle, and the condition of the brakes, tyres and road surface.

5 Tyres grip the road by friction. When the wheels ______ the friction is less.

6 Inertia is the tendency of an object to stay at rest or continue its present motion, unless acted on by a ______. The inertia of an object depends on its ______.

7 The momentum of an object depends on its mass (m) and its speed (v). Momentum (M) can be calculated by using the ______ M = mv.

8 In a collision a car stops but the occupants have ______ and continue moving until they collide with some solid object. Seat belts, head restraints and ______ are designed to protect people in collisions.

9 The ______ of an object is directly proportional to the force acting on it, and ______ proportional to its mass.

$$a = \frac{F}{m} \quad \text{or} \quad F = ma$$

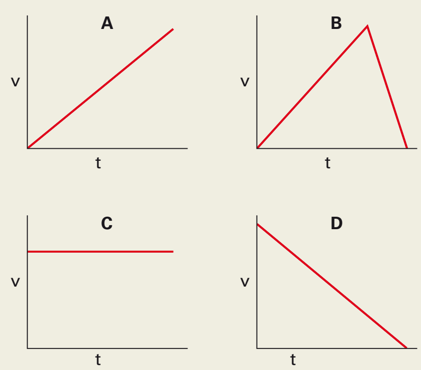
Try doing the Chapter 5 crossword on the CD. Working with technology

REVIEW

1 The acceleration of a car moving at a constant speed of 30 m/s is:
A 30 m **C** 15 m/s²
B 30 m/s **D** 0

2 A bus driver has a trip of 280 km to complete. If the average speed of the bus is 80 km/h, how long will the trip take?

3 Study the velocity–time graphs on the right. Which was made by an object:
a travelling at constant speed?
b accelerating?
c slowing down?
d speeding up and then slowing down?



Main ideas solutions

1 divide
2 slope
3 speed
4 reaction time
5 skid
6 force, mass
7 equation
8 inertia, airbags
9 acceleration, inversely

Challenge solutions

1 The acceleration of the Space Shuttle increases as it rises because the friction with the air and the force of gravity is decreasing as it rises.

2 The original purpose of bullbars was to reduce damage to vehicles in collisions with animals such as bulls. Although they may reduce the damage to vehicles in minor collisions, they may actually increase the risk of injury to people in other cars and to the passengers because they will not crumple and absorb the shock, and 'the second collision' will be more violent.

3 Using the formula $a = \frac{F}{m}$

$a = \frac{350\text{ N}}{25\text{ kg}} = 14\text{ m/s}^2$

The formula to use is: $a = \frac{v - u}{t}$

From this, $v = u + at = 0 + (14 \times 6.5)$
$= 91$ m/s

4 a Acceleration $= \frac{\text{change in speed}}{\text{time}} = \frac{(400 - 100)\text{ m/s}}{20\text{ s}} = \frac{300\text{ m/s}}{20\text{ s}} = 15\text{ m/s}^2$

b The force of the rocket engines = ma
$= 2000\text{ kg} \times 15\text{m/s} = 30\,000\text{N}$

5 v = 0 km/h, u = 60 km/h = 16.7 m/s
Momentum before impact = mu
= 70 × 16.7 = 1169 kg m/s
Momentum after impact = 0 N
Change in momentum = 1169 kg m/s

Force $= \frac{1169\text{ kg m/s}}{0.08\text{ s}} = 14\,613\text{ N}$

6 a The final momentum of the ball
$= mv = 25\text{ kg} \times 0.5\text{ s}$
$= 12.5$ kg m/s

b The average force on the ball is
$= \frac{12.5\text{ kg m/s}}{0.22\text{ s}} = 57\text{ N}$

c The acceleration of the ball
$= \frac{(v - u)}{t} = \frac{25\text{ m/s}}{0.22\text{ s}} = 114\text{ m/s}^2$

7 a Using the formula $a = \frac{F}{m}$
$= \frac{10\text{ N}}{5\text{ kg}} = 2\text{ m/s}^2$

After 5s, v = u + at
$= 0 + (2\text{ m/s}^2 \times 5\text{ s}) = 10\text{ m/s}$

b Using the formula $d = ut + \frac{1}{2}at^2$
$= 0 + (\frac{1}{2} \times 2 \times 25) = 25\text{ m}$

c Assuming no friction, the trolley would still be moving at 10 m/s after 6 s.

8 The first step is to find the time it took to stop in 150 m: $v_{av} = \frac{(v + u)}{2}$
$= \frac{(19.4\text{ m/s} + 0\text{ m/s})}{2}$
$= 9.7$ m/s

$v_{av} = \frac{d}{t}$ and therefore $t = \frac{d}{v_{av}}$
$= \frac{150}{9.7} = 15.5$ s

The next step is to find the acceleration:
$a = \frac{(v - u)}{t} = \frac{(0 - 19.4)}{15.5} = -1.25\text{ m/s}^2$

The final step is to calculate the force required:
$F = ma = 30\,000\text{ kg} \times (-1.25\text{ m/s}^2)$
$= -37\,500$ N

This is the force that must be applied by the brakes if the vehicle is to avoid a collision. It is negative because it is in the opposite direction to the movement of the truck.

4 A sports car and a furniture van are both travelling at a speed of 60 kilometres per hour. Which vehicle would require more force to stop it? Why?

5 Scott was driving to the golf course. He braked to avoid a cat. Explain why the golf clubs hit Scott on the head.

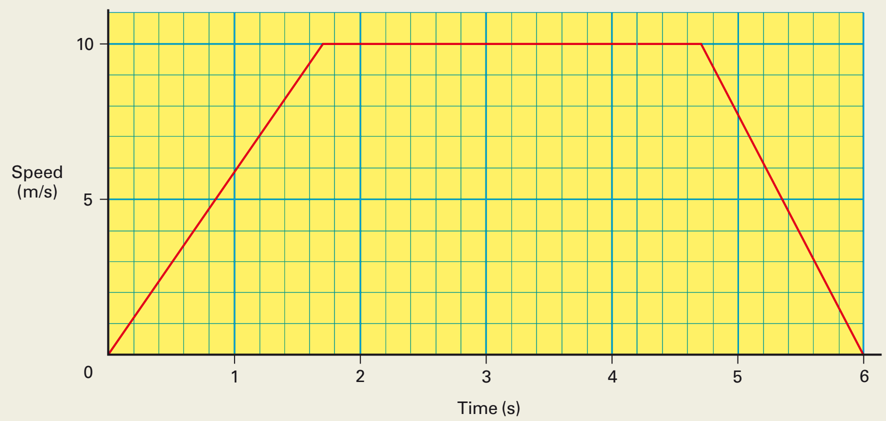
6 The same person drives a motorbike, a car and a semitrailer at 100 km/h. Compare his reaction distances and braking distances for the three vehicles if he has to stop suddenly.

7 A car stopped at traffic lights is hit from behind by another car. Describe what happens to the people in:
  a the stationary car
  b the car that hit the stationary car.

8 a What is meant when we say 'the car's brakes locked'?
  b What happens to the car when this occurs?
  c What have car designers done to solve the problem of brakes locking?

9 Tim is riding his bicycle at a uniform speed of 15 m/s. He brakes and comes to a stop in 3 seconds. If he and the bike have a total mass of 80 kg, what force did the brakes apply?

10 The graph below shows the change in speed of a lift as it travels from the ground to the top floor.
  a Explain the shape of the graph.
  b At what rate does the lift accelerate?
  c At what rate does it decelerate?



Check your answers on pages 333–334.

Review solutions

1 D

2 $v_{av} = \frac{d}{t}$ so $t = \frac{d}{v_{av}}$

$= \frac{280\text{ km}}{80\text{ km/h}}$

$= 3.5\text{ h}$

3 a C
  b A or the first part of B
  c D or the second part of B
  d B

4 The furniture van would require more force to stop it because its mass is greater.

5 Before Scott braked, the golf clubs were moving with the car—at the same speed as it. When he braked, the seatbelt held him in his seat, but there was nothing to stop the clubs continuing to move forward, due to inertia.

6 Reaction distance depends on the driver and on the speed, so it would be the same for the motorbike, car and semitrailer. Braking distance, however, depends on the vehicle, especially its mass. So the braking distance would be shortest for the motorbike and longest for the semitrailer.

7 a When a stationary car is hit from behind by another car, the inertia of the people in the car causes them to move backwards into their seats. If they do not have head restraints they may suffer whiplash injury.
  b The car that hit the stationary car will stop suddenly, so inertia will cause the people in it to continue moving forwards. If they are not wearing seatbelts they may be injured when they hit objects in front of them, eg the dashboard or the steering wheel.

8 a When a car's brakes 'lock', the wheels stop turning and slide (skid) across the road surface.
  b The car may skid and you may lose control of it. It will also take longer to stop because the sliding friction is less than the static friction that exists when the wheels are rolling.
  c Car designers have developed an antilock braking system (ABS) which senses when a wheel is about to lock up and pumps the brake off and on rapidly.

9 You need two different equations to solve this problem.

$a_{av} = \frac{v - u}{t} = \frac{0 - 15\text{ m/s}}{3\text{ s}} = -5\text{ m/s}^2$

$F = ma$

$= 80\text{ kg} \times -5\text{ m/s}^2$

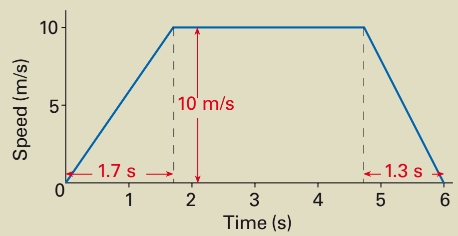
$= -400\text{ newtons}$

(The force is negative because it is a braking force.)

10 a Initially the lift accelerates (upwards slope); it then continues to move at a constant speed (flat part of graph); finally the lift decelerates (downwards slope) and stops.
  b To find the acceleration you calculate the slope of the graph.

$a_{av} = \frac{10 - 0\text{ m/s}}{1.7\text{ s}}$

$= 5.9\text{ m/s}^2$



  c Deceleration $= \frac{0 - 10\text{ m/s}}{1.3\text{ s}} = -7.7\text{ m/s}^2$