The National Strategies
Secondary

Force and motion

Science teaching unit

department for
children, schools and families

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Force and motion

First published in 2008

Ref: 00094-2008DVD-EN

Contents

00094-2008DVD-EN

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Background

This teaching sequence bridges from Key Stage 3 to Key Stage 4. It links to the Secondary National Strategy Framework for science yearly learning objectives and provides coverage of parts of the QCA Programme of Study for science. The overall aim of the sequence is for pupils to review and refine their ideas about forces from Key Stage 3, to develop a meaningful understanding of ways of representing motion (graphically and through calculation) and to make the links between different kinds of motion and forces acting.

It is likely that pupils will come to these lessons having had some teaching on identifying forces and representing them with force arrows. However, our experience has been that the quality of force diagrams, which pupils produce, is often poor with force arrows being used in a non-systematic way. We believe that the scientific habit of producing accurate and carefully labelled diagrams is fundamental to gaining a clear understanding of forces and the ability to analyse situations in terms of forces. We have therefore included a 'Lift-off' lesson at the start of the sequence, which allows the teacher to gauge pupils' abilities in this area and to respond with further tuition as necessary.

The teaching approaches set out here are planned to be interactive in nature as links between subject matter are explored and established through appropriate talk between teacher and pupils, and amongst pupils.

Teaching design principles

The design of this sequence is based upon a number of key principles. These are as follows:

Working on knowledge

The sequence involves:

- probing, and explicitly working from, pupils' existing understanding of force and motion;
- helping pupils understand the scientific point of view based on the concepts of force, speed (and velocity), acceleration, represented both graphically and quantitatively through calculation;
- using these concepts to analyse a wide range of different motions and to relate those motions to the forces acting.

Teaching approach

The sequence involves:

- introducing the basic concepts of forces, speed (velocity), and acceleration;
- introducing how different motions can be represented through distance/time and speed/time graphs;
- making the links between different kinds of motions and the state of the forces acting;
- using all of these concepts to analyse a range of different motions;
- providing explicit opportunities for Assessment for Learning (AfL) through an extensive series of diagnostic questions.

Mode of interaction

The sequence has been designed to maximise pupils' learning by incorporating lots of interaction between the teacher and pupils.
It involves:

- using different modes of interaction between teacher and pupils according to different teaching purposes;
- providing opportunities for pupil–pupil talk in pairs and small groups.

How science works

The sequence involves extensive use of modelling in terms of forces.

Pupils' starting points

The sequence of lessons builds on previous work on forces from which it is assumed that most pupils will:

1. be aware of different kinds of forces, such as pushes, pulls, gravitational force, friction;
2. have some experience of representing forces with force arrows;
3. be familiar with the notions of balanced and unbalanced forces;
4. know of the link between balanced and unbalanced forces acting and the state of motion of an object;
5. be able to carry out simple calculations of speeds.

These ideas are reviewed through the 'Lift-off' activity and Lesson 1 of this sequence.

Force and motion units

This is a full listing of the units used in the lesson sequence.

Variable	Unit	Unit Symbol
Force	newton	N
Distance	metre	m
Time	second	s
Speed	metre/second	m/s
Acceleration	metre/second each second	m/s/s or m/s^2

It is a good idea to be consistent in the use of units to encourage good habits in pupils. Thus:

NOT: 2.5 Newtons or 2.5 n…………..**BUT:** 2.5 newton or 2.5N

NOT: 10 sec or 10 secs………………**BUT:** 10 second or 10s

The rules here are that:

- the unit is expressed in lower case and strictly speaking should be 'singular': 2.5 newton;
- the unit symbol is written in upper case if it refers to a person's name, such as N or V, A.

Overview map

Lift-off activity: Remember forces?: Diagnostic questions

Identifying and representing forces: forces circus

Representing motion - distance/ time/speed: groupwork and accident in Queensway Tunnel

Representing motion - speed and acceleration: diagnostic questions and group activity

Linking force and motion: diagnostic questions and teacher presentation

Investigating motion: Maggots and woodlice and diagnostic questions

Lift-off activity: Remember forces?

Teaching 'story'

The teaching sequence starts with an activity to probe pupils' existing understanding of forces by asking them to talk through and record their ideas about three situations.

It is a good idea for this activity to be completed at the end of the lesson prior to starting the work on forces. This way the teacher has the opportunity to read through and to be ready to respond to the pupils' ideas before beginning the sequence.

Click here to see an example of this

Activity: Remember forces?

In this activity the pupils work in pairs on three diagnostic questions:

1. Falling apple
2. Ball on string
3. Book on table.

Teaching objectives

- To encourage pupils to talk through their ideas about what forces are acting in the three situations.
- To collect assessment for learning (AfL) baseline information about the pupils' existing ideas.

Learning outcomes

By the end of this activity, pupils will be able to:

- identify their own and others' existing ideas about forces.

What to prepare

- Sets of the three diagnostic questions: Falling apple, Ball on string, Book on table.

Mode of interaction

Pairs of pupils discussing and putting forward their ideas about the forces acting in each of the three situations: INTERACTIVE/DIALOGIC

DIALOGIC HOTSPOT

What happens during this activity

The pupils work in pairs on the three worksheets. In each case the pupils are asked to write down the forces which are acting on a particular object: the apple; the ball; the book. The point should be stressed by the teacher that the purpose of this activity is NOT to identify ALL forces which are acting in the particular situation, but to identify the forces acting on the specified object:

'So, in the first example, I want you to focus on the APPLE, to talk through your ideas and to write down what forces are acting on the APPLE'.

If any pair of pupils fails to agree on a particular situation, they can hand in separate sheets with their individual responses.

Pupil responses to the worksheets

The three situations have been carefully chosen to bring to light possible 'alternative conceptions' and other gaps in pupils' knowledge and understanding:

Alternative conception 1: No MOTION no FORCE.

It is common for pupils to argue that in a situation where nothing is moving, no forces can be acting. Thus for 'Book on table', pupils might suggest:

'There are no forces here. Nothing is happening to the book, it's just sitting on the table'

or:

'The ball is just hanging on the string'.

Alternative conception 2: People can exert forces but objects cannot.

Pupils often suggest that inanimate objects cannot exert forces. For example, with 'Book on table', pupils might suggest that:

'The book is just sitting on the table. The table isn't pushing it. The table is just in the way'.

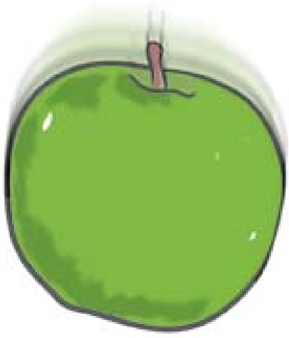
Our experience has shown that pupils are not, however, necessarily consistent with their thinking and might believe that the table is not pushing, whilst for situation 2, they argue that the string (another inanimate object) is pulling:

'The string is pulling up on the ball to stop it from falling'.

Representing forces

In addition to these fundamental alternative conceptions there is likely to be considerable variation in the ways in which pupils represent forces on the three diagrams. All of these issues are addressed in the next lesson.

1. Falling apple



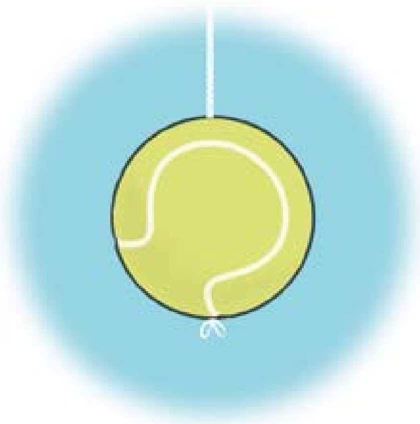
An apple is falling through the air.

1. Write down any FORCES which are acting ON THE APPLE.

2. What can you say about the SIZE of these forces?

3. Carefully DRAW in the forces on the diagram of the falling apple above.

2. Ball on string



A ball is hanging from a length of string.

1. Write down any FORCES which are acting ON THE BALL.

2. What can you say about the SIZE of these forces?

3. Carefully DRAW in the forces on the diagram of the falling ball above.

3. Book on table

A book is left on the table.

1. Write down any FORCES which are acting ON THE BOOK.

2. What can you say about the SIZE of these forces?

3. Carefully DRAW in the forces on the diagram of the table and book above.

Lesson 1: Identifying and representing forces

Teaching 'story'

Having had the opportunity to probe the pupils' existing ideas and understanding about forces, the teacher now takes the three situations as a starting point for establishing the scientific approach to identifying and representing forces, paying special attention to the pupils' alternative conceptions and other difficulties which may have become apparent through the worksheet exercises.

Activity 1.1: Review

In this first activity the teacher and pupils review the three situations of the Lift-off activity.

Teaching objectives

- To review pupils' responses to the Lift-off activity.
- To establish an approach to identifying and representing forces.

Learning outcomes

By the end of this activity, pupils will be able to:

- recognise the importance of specifying the target object when identifying the forces acting:
- represent forces as arrows of specific length (representing the magnitude of the force) and direction;
- recognise that forces act in all real-life situations whether objects are moving or not;
- recognise that an inanimate object (such as a table) can exert forces.

What to prepare

- Three slides of the Lift-off activity worksheets to be used on the interactive white board:
  1. Falling apple
  2. Ball on string
  3. Book on table
- Force arrows of different sizes to be moved over the slides.

Mode of interaction

The teacher works with the pupils through an INTERACTIVE/ AUTHORITATIVE approach, posing questions to check understanding and presenting the scientific approach to identifying and representing forces.

What happens during this activity

Responses to the three diagnostic questions are returned to the pupils and the teacher carries out an interactive review with the class sitting around the white board.

Experience has shown that pupils have little problem accepting that the force of gravity causes objects to fall, but have more problems accepting that inanimate objects, such as a table, can exert an upward force on any object placed at its surface. Rather, the table is mostly seen as being 'in the way' of the object. Students have fewer problems in recognising the tension in a spring or rope which is holding up a hanging object. Taking these points into account it is advisable to take the situations in the order:

1. Falling apple
2. Ball on string
3. Book on table

When analysing situations in terms of forces, we have found it useful to instruct pupils to take the following approach (using the example of the falling apple):

a) What is the target object?

[The apple]

b) What are the forces acting on the target object?

[Gravity: the downward pull of the Earth on the apple; air resistance: the upward push of the air on the apple.]

c) Where do the forces act on the object?

[Gravity from the centre of the apple; air resistance at the leading edge of the falling apple.]

d) In what direction do the forces act?

[Gravity from the centre of the apple acting downwards; air resistance at the leading edge of the falling apple acting in the opposite direction to that of the motion.]

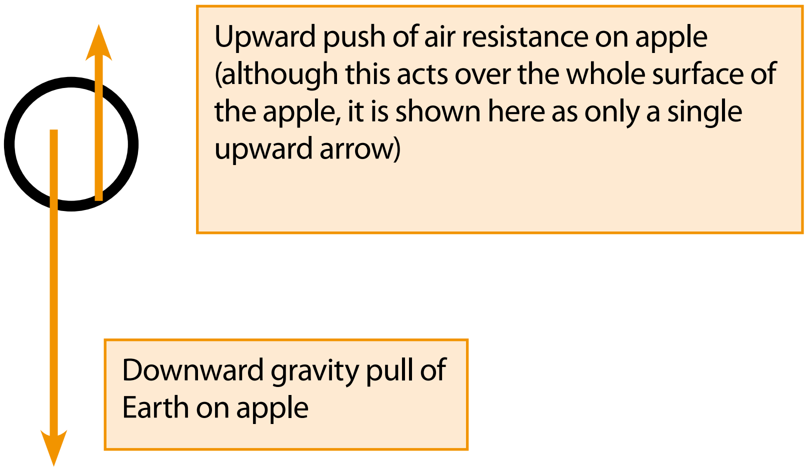
e) How big are the forces acting?

[The pull of gravity is greater than the air resistance force.]

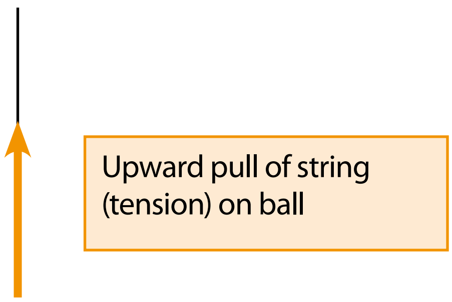
It is important that the teacher is careful to make clear that 'the pull of the earth on the apple' and 'the force of gravity on the apple' are one and the same force, not two different forces. It helps to refer to the 'gravity pull of the Earth'.

Using this general approach, the 'forces picture' for each situation is as follows:

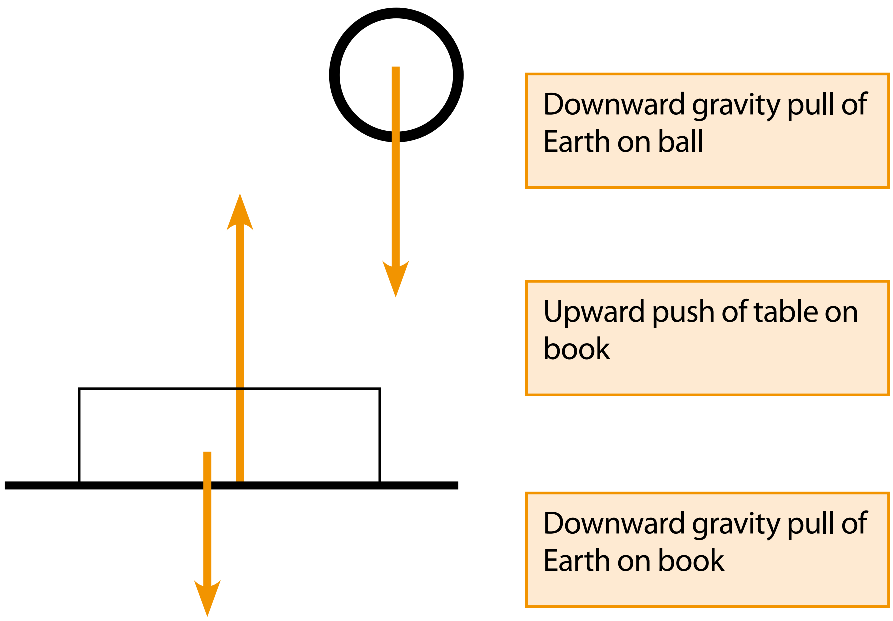
1. Falling apple



2. Ball on string



3. Book on table



Note: Each force arrow should be carefully drawn in such a way that:

1. The direction in which the force is acting is shown by the direction of the arrow.
2. The size of the force is shown by the length of the arrow.
3. Each arrow is drawn so that it starts from the point where the force acts (for example, the upward pull of the string acts at the point of attachment to the ball).

Note: It is a good idea to get the pupils into the habit of writing out the label for each force, stating: the nature of the force; which object is providing the force; and which object the force is acting upon.

Teaching 'story'

The discipline of producing accurate 'force arrow' diagrams is very helpful in developing clear ideas about how, and where, and on what forces are acting. This is an area which often tends to be overlooked and forces diagrams can be very confused (and confusing!). Let's get this right!

Note: How can a table provide an upwards push? It is one matter just telling pupils that 'Yes, the table is pushing up on the book'. It is quite another matter, to support pupils in developing a meaningful understanding of what is, from a common sense point of view, quite a counter-intuitive idea. One way to address this teaching challenge is via the following approach:

1. Get a pupil to hold a balloon between the flat palms of their hands, one hand under the balloon the other on top. The pupil then presses down with one hand and up with the other. What happens to the balloon? It becomes squashed. What provides the forces to squash the balloon? One hand pressing up the other hand pressing down.
2. Now place the balloon on a table. Get the pupil to press down on the balloon with their hand. What happens to the balloon? It becomes squashed. What provides the forces to squash the balloon? One hand pressing down… and what is pushing up? The table must be pushing up.

Click here to see an example of this

This argument leads plausibly to the idea that the table must be pushing up; it does not provide an explanation of how the table is able to provide this force. The key idea here is that the table has a little 'elastic give' in its surface. When the book is placed on the table, the springy bonds between the molecules in the table surface compress a little and provide an upward force. This is similar to the force that you experience when you lie down on the mattress of your bed. You sink a little way before the mattress springs support you. In just the same way, it is the springiness of the table surface which provides the force to support the book.

Activity 1.2: A forces circus

Once the pupils have reviewed these aspects of identifying and representing forces they need to have the opportunity to apply them for themselves in different situations.

Teaching objectives

- To support pupils in identifying and representing the forces acting on specific objects in situations with and without movement.

Learning outcomes

By the end of this activity, pupils will be able to:

- identify the forces acting on specified objects in a range of situations;
- represent the forces acting with an arrow (force vector) notation, indicating force magnitude (length of arrow) and force direction (direction of arrow).

What to prepare

A circus of simple situations which pairs of pupils move around. These might include:

- a **cup** on a table
- a **mass** hanging on a spring
- a **wooden block** floating in water
- a **block of foam** under a heavy book
- a **toy car** rolling down a slope
- a **ball** thrown up into the air.

Mode of interaction

The teacher encourages an INTERACTIVE/AUTHORITATIVE approach as the pairs of students identify and represent forces.

What happens during this activity

Pairs of pupils move around the circus responding to the questions at each station:

1. What are the forces acting on the OBJECT?
2. Use force arrows (with correct position, length and direction) to show the forces acting.
3. Fully label each force arrow.

The pupils make a record of their responses for each station.

One approach to use to emphasise the interest in forces during this activity is to invite the pupils to put on their 'FORCES SPECTACLES':

> *'What we're on the lookout for here are the FORCES acting. We're not looking at objects in terms of their shape or their size or their colour. We're looking at them in terms of the FORCES acting on them. It's as if we're looking at the world through FORCES SPECTACLES which allow you to see the forces acting'.*

The teacher then dons a pair of old safety goggles with a FORCES label stuck across the top and peers at the objects around him!

Some classes might find it helpful to use force arrows made from card in talking through each situation.

Activity 1.3: Plenary

The pupils present their ideas for each situation to the whole class.

Teaching objectives

- To consolidate the pupils' use of vectors to represent forces of different kinds.

Learning outcomes

By the end of this activity, most pupils will be able to:

- use force arrows to represent the position, direction and size of forces.

Mode of interaction

The plenary will involve an INTERACTIVE/DIALOGIC communicative approach as different ideas are presented by pupils. Then the teacher needs to provide the guidance which leads, via an INTERACTIVE/AUTHORITATIVE approach, to the correct scientific view.

DIALOGIC HOTSPOT

What happens during this activity

The class sit around the whiteboard and pupils take turns in presenting their force arrow diagrams, shifting arrows around on the whiteboard. An important job for the teacher here is to make links between apparently different situations: how is the book on the table similar to the floating block of wood? (both have gravity pulling down on them; the table provides an upward push on the book, and the water provides an upward push on the block).

Click here to see an example of this

Lesson 2: Representing motion–distance/time/speed

Teaching 'story'

The focus of this lesson is on representing motion through distance/time graphs. This is addressed through the context of a crime scene investigation (CSI) where the pupils are required to interpret data collected at the scene of a fatal 'hit-and-run' accident to establish 'whodunnit'.

Activity 2.1: An accident in the Queensway Tunnel: setting the scene

An accident has occurred in the Queensway Tunnel leading to the death of a car driver. Various pieces of information are available from the close circuit television (CCTV) cameras and the CSI team now faces the challenge of reconstructing what actually happened in the tunnel.

Teaching objectives

- To provide an overview of the fatal accident in the tunnel.
- To explain how the data the pupils will be working with were collected.
- To specify the aim of the exercise: to find out who was responsible for the accident.

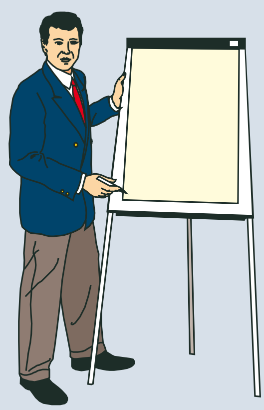
Learning outcomes

By the end of this activity, most pupils will be able to:

- offer an account of the available information relating to the accident.

Mode of interaction

Here the teacher is presenting information with a NON-INTERACTIVE/ AUTHORITATIVE approach.



What to prepare

Copies of:

- the CSI Report: The Queensway Tunnel
- Queensway Tunnel
- full graph data.

What happens during this activity

The first job for the teacher is to build up a vivid picture of the accident, describing what happened and specifying what information is available.

> *'In today's lesson, I want you to imagine that you are part of a CSI team that has been called to a fatal accident which occurred in the Queensway Tunnel in the early hours of the morning. This is what happened'.*

A car broke down inside the tunnel. The driver of the car abandoned his vehicle but in doing so was hit by another car which continued on and left the tunnel without assisting the victim who later died in hospital. In the tunnel there are CCTV cameras every 500 m which keep a record of the cars passing along with the precise time. To investigate the accident the police team has taken the CCTV record of the three cars that entered the tunnel at the same time as the car of the victim. Unfortunately the accident was not recorded directly on camera because it took place in a 'blind spot' between cameras.

At the scene of the accident there were two sets of tyre skid marks on the road. The longer set of skid marks coincided with the position where the body was found on the road.

The challenge for the CSI Team is to use the available data to reconstruct what happened inside the tunnel and to identify the person responsible for the hit-and-run fatality.

Click here to watch a teacher discussing this with their class

Activity 2.2: Distance/time plots for the cars

In this activity the pupils work in small groups with numerical data to construct distance/time graphs for the cars passing through the tunnel at the time of the accident.

Teaching objectives

- Pupils plot and interpret distance/time graphs linked to this 'real-life' incident.

Learning outcomes

By the end of this activity, pupils will be able to:

- recognise some of the key features of distance/time graphs.

What to prepare

- Graph paper, pencils and rulers.

Mode of interaction

The teacher circulates around the groups intervening as necessary with an INTERACTIVE/ AUTHORITATIVE approach focusing on the pupils producing accurate graphs

What happens during this activity

Pupils work in 'CSI teams' of four. Each team has sets of data 'CSI Report: The Queensway Tunnel' for the four cars travelling through the tunnel: the victim's car and three other cars which were passing through at the same time.

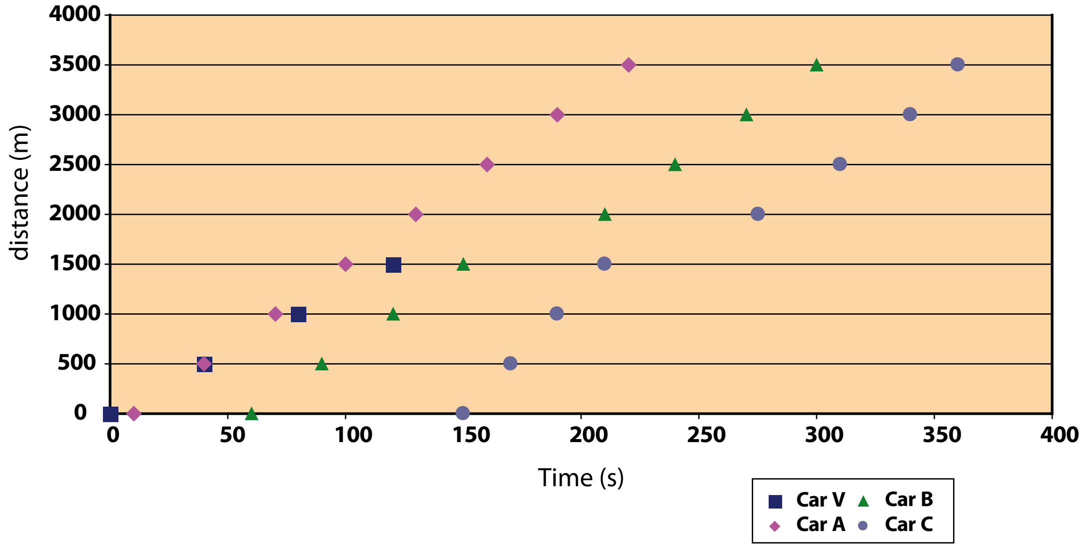
The table records the time at which each of the cars went past each of the 8 cameras in the tunnel. There are 500m between each camera.

	Cam 1	Cam 2	Cam 3	Cam 4	Cam 5	Cam 6	Cam 7	Cam 8
	0 m	500 m	1000 m	1500 m	2000 m	2500 m	3000 m	3500 m
Car V	0	40	80	120				
Car A	10	40	70	100	130	160	190	220
Car B	60	90	120	150	210	240	270	300
Car C	150	170	190	210	275	310	340	360

All of the times are recorded in seconds elapsed after the first car (the car of the victim, Car V) entered the tunnel. Hence Car A entered the tunnel (camera 1) 10s after Car V, and Car C entered the tunnel 150s after Car V.

Within each CSI team, each pupil takes responsibility for plotting a distance/time graph for one of the cars. The team as a whole then compare and contrast the individual graphs trying to come to an understanding of what happened in the tunnel.

When each CSI team has had the chance to examine the individual plots, the teacher provides a single sheet, 'Full Graph Data' for each team with the four distance/time plots superimposed.



At this point the teams are instructed to:

> *'Talk through these plots in your groups and try to make as much sense of them as you can. Build up a picture of what happened in the tunnel and start to develop a case for how the victim was killed and who was responsible'.*

Activity 2.3: Plenary: What happened in the tunnel?

When all of the groups have had the opportunity to talk in some detail about the combined graph of the four plots, the teacher collects the class around the whiteboard with the combined graph displayed.

Teaching objectives

- To review the key features of the four car plots in detail.
- To establish key features of distance/time graphs in general.

Learning outcomes

By the end of this activity most pupils will be able to:

- outline the major events in the tunnel by referring to the 4 graph plots;
- recognise that for distance/time graphs:
  - a straight line plot indicates steady speed;
  - the slope of the distance/time plot indicates the speed: big slope–high speed;
  - zero slope indicates not moving: stationary;
  - a curved line indicates changing speed or acceleration.

Mode of interaction

The teacher conducts the plenary taking pupils' ideas with an INTERACTIVE/DIALOGIC approach at first and then moving to a more AUTHORITATIVE account of the graphs.

DIALOGIC HOTSPOT

What happens during this activity?

The plenary begins with the teacher inviting comments about any aspects of the plots. The first job is to build up a shared understanding of as many features of the graphs as possible. The key features of the plots which help towards an understanding of what happened in the tunnel are:

Step 1: 'Reading' the graphs:

- the plot for the victim's car stops 1500m from the tunnel entrance;
- the plots for both cars B and C have some kind of discontinuity or 'step' at 1500m;
- the plots for all four cars start at a different time on the time axis, indicating that they entered the tunnel at different times (with the victim's car entering at time zero). It is helpful for pupils to see that distance/time plots do not always start at (0,0).

Step 2: Further interpretation of the graphs:

- the plot for car A is linear (see graph). It covers equal distances in equal amounts of time (check figures): it is travelling at a steady speed;
- the plot for car V is linear until 1500m (see graph): the car is moving with a steady speed (check figures);
- the plot for car A rises more steeply than that of car V and crosses it. This indicates that Car A was travelling more quickly than Car V and overtakes it as they pass the 500m camera (before the accident occurred);
- the plot for car V becomes horizontal after 1500m indicating that the car has stopped;
- car B enters the tunnel at a steady speed, then at 1500m slows down, before speeding up again and travelling on at the same steady speed;
- car C enters the tunnel at a steady speed, travelling faster than any of the other cars. At 1500m it slows down and then accelerates away (as indicated by the curved plot).

General points arising from the graphs:

- a straight line plot indicates steady speed;
- the slope of the distance/time plot indicates the speed: big slope–high speed;
- zero slope indicates not moving: stationary;
- a curved line indicates changing speed or acceleration.

So who did it?

After talking through all of these aspects of the graph it becomes apparent that only two cars (B or C) could have been responsible for the fatal accident. Both cars arrived at the 1500m mark after the victim's car had stopped. Both cars slowed down as they passed the victim's car. Neither car stopped. Coincidentally, cars B and C were identical models.

Click here to watch a discussion of this

The key piece of additional evidence concerns the tyre skid marks found at the scene of the accident. The set next to the victim's body were significantly longer than the other set. This indicates heavier braking from a higher initial speed and points to car C being responsible for the death.

The final account from the 'official' CSI team

The victim's car entered the Queensway Tunnel travelling at a steady speed. The victim's car was overtaken by Car A, travelling at a steady higher speed, at the 500 m mark. At the 1500m mark the victim's car came to a halt (later shown to be due to mechanical failure). The victim tried to restart his car and was passed by Car B which slowed down but did not stop. The victim then got out of his car and was hit by Car C which was travelling quickly, slowed down but then accelerated away. The victim was dead on arrival at hospital.

Crime scene investigation (CSI) report: The Queensway Tunnel

Date of incident: Sunday January 20th

Time of incident: 1.30am

Summary

In the early hours of Sunday 20 January a 25-year-old man was killed in the Queensway Tunnel after having been hit by another car. It appears that the victim's car broke down, that he got out of the car and was then hit by another car in a 'hit-and-run' incident. There are CCTV cameras at 500m intervals throughout the tunnel, but the incident took place in a 'blind spot' and was not recorded on camera.

However, pictures are available of the victim's car (V) and three other cars (A,B,C) which were travelling through the tunnel at about the same time. These pictures have been used to produce the following table which records the time at which each of the cars went through each of the 8 cameras in the tunnel.

All times are taken from the moment at which the first car (victim Car V) entered the tunnel. Hence Car A entered the tunnel (camera 1) 10 seconds after Car V, and Car C entered the tunnel 150 seconds after Car V.

	Cam 1	Cam 2	Cam 3	Cam 4	Cam 5	Cam 6	Cam 7	Cam 8
	0 m	500 m	1000 m	1500 m	2000 m	2500 m	3000 m	3500 m
Car V	0	40	80	120				
Car A	10	40	70	100	130	160	190	220
Car B	60	90	120	150	210	240	270	300
Car C	150	170	190	210	275	310	340	360

Further information

Two sets of tyre skid-marks were found in the tunnel alongside the victim's car. One set of skid-marks was significantly longer than the other. By coincidence, cars B and C were the same model.

Brief

To use these recorded times and distances to help reconstruct what happened in the tunnel and to identify which of the cars A, B, C was responsible for the 'hit-and-run' crime. (See graph on page 26)

Queensway Tunnel

The Queensway tunnel is 2 miles long (3240 m). There are CCTV cameras along the tunnel at intervals of 500m (the last camera is situated in the road 260m after the tunnel exit).

Public Domain

©Mersey Tunnels

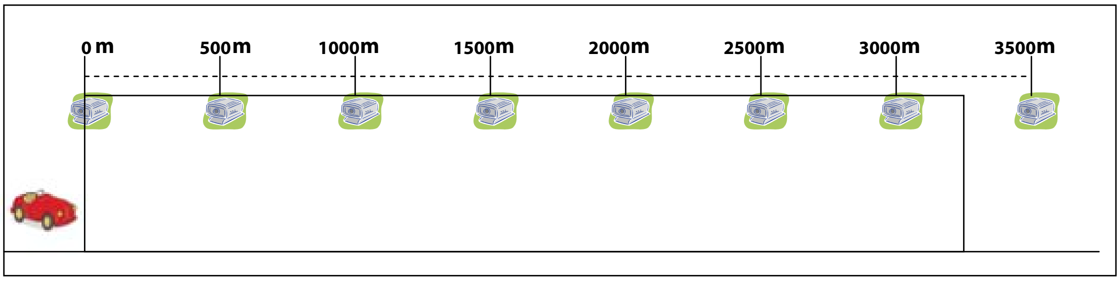
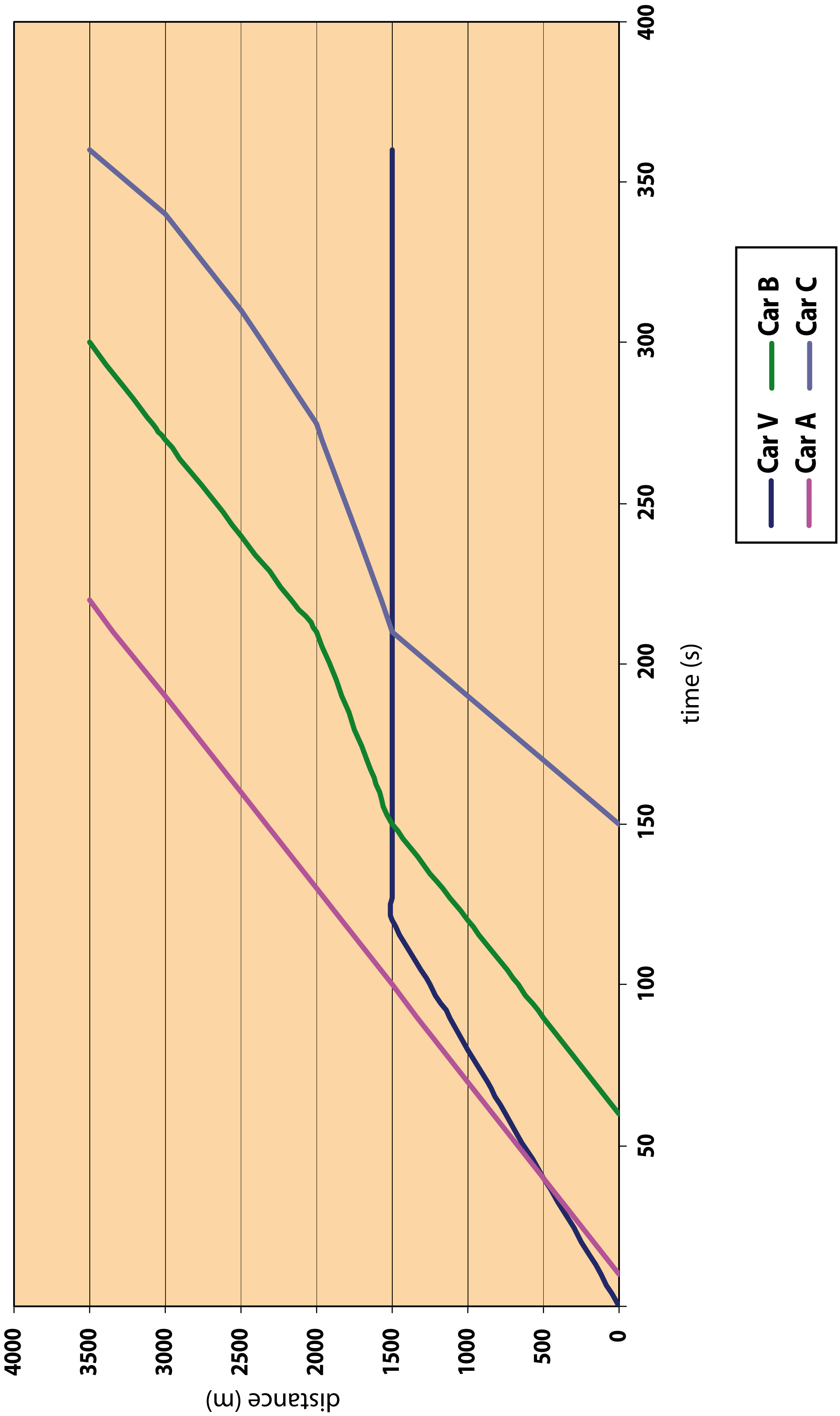


Diagram of the tunnel (not to scale)


distance (m)
0
500
1000
1500
2000
2500
3000
3500
4000
time (s)
50
100
150
200
250
300
350
400
Car V
Car A
Car B
Car C

Lesson 3: Representing motion– speed and acceleration

This lesson starts with a review of distance/time graphs and moves on to speed/time graphs and acceleration.

Activity 3.1: Diagnostic questions on distance/time graphs and speed

A comprehensive set of diagnostic questions is provided which addresses all of the key aspects of distance/time graphs. The diagnostic questions are to be used as a focus for discussion between pupils, enabling the teacher to check their developing understanding.

Teaching objectives

- To engage pupils in talking about a full range of distance/time graphs and to review the key features of distance/time graphs.

Learning outcomes

By the end of this activity the pupils will be able to:

- interpret both linear and curved distance/time graphs;
- relate the slope of a distance/time graph to speed.

What to prepare

The following diagnostic questions are available (see table on following page). Sets of the questions might be produced on card and laminated.

What happens during this activity

The teacher selects the diagnostic questions to be worked on. The activity might be organised in:

a. **Pairs:** pupils work in pairs on the questions and report back in a plenary.

b. **Pairs/fours:** pupils work in pairs and then join with another pair to come up with a joint/agreed response. The groups of four report back to the plenary.

c. **Plenary:** the teacher and class talk through the questions on the whiteboard.

Mode of interaction

Groupwork
Pairs/groups of pupils talk through the questions focusing on the correct scientific point of view: INTERACTIVE/ AUTHORITATIVE.

Whole class plenary
Teacher reviews answers to questions with whole class: INTERACTIVE/AUTHORITATIVE.

	Question	Focus	Answer
1	*Red and blue cars*	*Speed = distance/time*	*a. Red b. Red travelled further in same time*
2	*Passenger*	*Speed = distance/time*	*Speeding up steadily*
3	*Train 1*	*Dist/time graph: not moving*	*Stationary*
4	*Train 2*	*Dist/time graph: uniform speed*	*Constant speed*
5	*Train 3*	*Dist/time graph: accelerating*	*Speed steadily increasing*
6	*Train 4*	*Dist/time graph: decelerating*	*Speed steadily decreasing*
7	*Train 5*	*Dist/time graph: changing speed*	*Constant speed then reduced constant speed*
8	*Cyclist*	*Dist/time graph: changing direction*	*Steady, turned, slower*
9	*Car*	*Dist/time graph: gradient and speed*	*B: slope greatest D: not moving*
10	*What speed?*	*Dist/time graph: speed calculation*	*6 m/s*

Notes for teacher

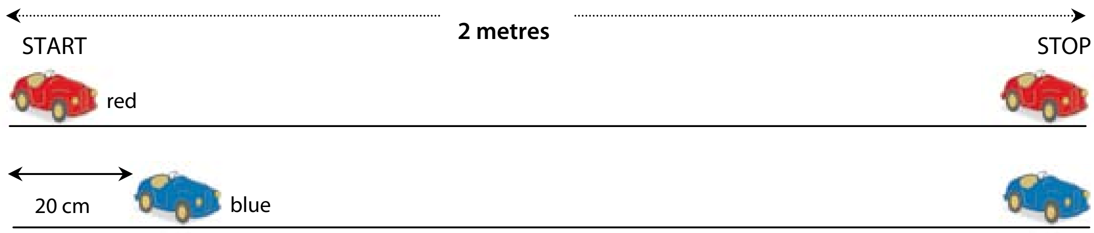
These diagnostic questions cover the key features of distance/time graphs.
Some points to look out for:

- It is quite common for pupils to relate the shape of a graph plot to the physical situation being described, for example: a sloping graph plot may be likened to 'going up a hill' (see the Train questions).
- Question 8 involves a change in direction. The cyclist first travels away from the starting point along the straight road and then moves back in the reverse direction.
- Question 9 involves estimating instantaneous speeds (by considering the slope of the graph plot at specific points) for a situation where the speed of the car is continuously changing.

Diagnostic questions

1. Red and blue cars

Two toy cars, red and blue, travel along a 2 metre track.



The blue car has a 20cm start.

The two cars start at the same time.

The two cars reach the end of the track (the STOP mark) at the same time.

(a) Which car was faster?

*Tick **ONE** box*

☐	The red car.
☐	The blue car.
☐	Both had the same speed.

(b) All of the following statements are correct. But which is the best explanation for the answer above?

*Tick **ONE** box*

☐	Both cars started and stopped at the same time.
☐	The red car travelled further than the blue car in the same time.
☐	The blue car started ahead of the red car.
☐	Another reason:.. ....

2. Passenger

A passenger in a train notes the time on a stopwatch as the train passes posts which are spaced 5 kilometres apart beside the track.

Here are his results:

Distance travelled/kilometres	0	5	10	15	20	25
Reading on stopwatch /seconds	0	200	390	570	740	900

(a) Which of the following was the train doing?

*Tick **ONE** box*

☐	*going at a constant speed*
☐	*speeding up steadily*
☐	*slowing down steadily*
☐	*speeding up then slowing down*
☐	*slowing down then speeding up*

(b) Explain your answer:

....

....

....

....

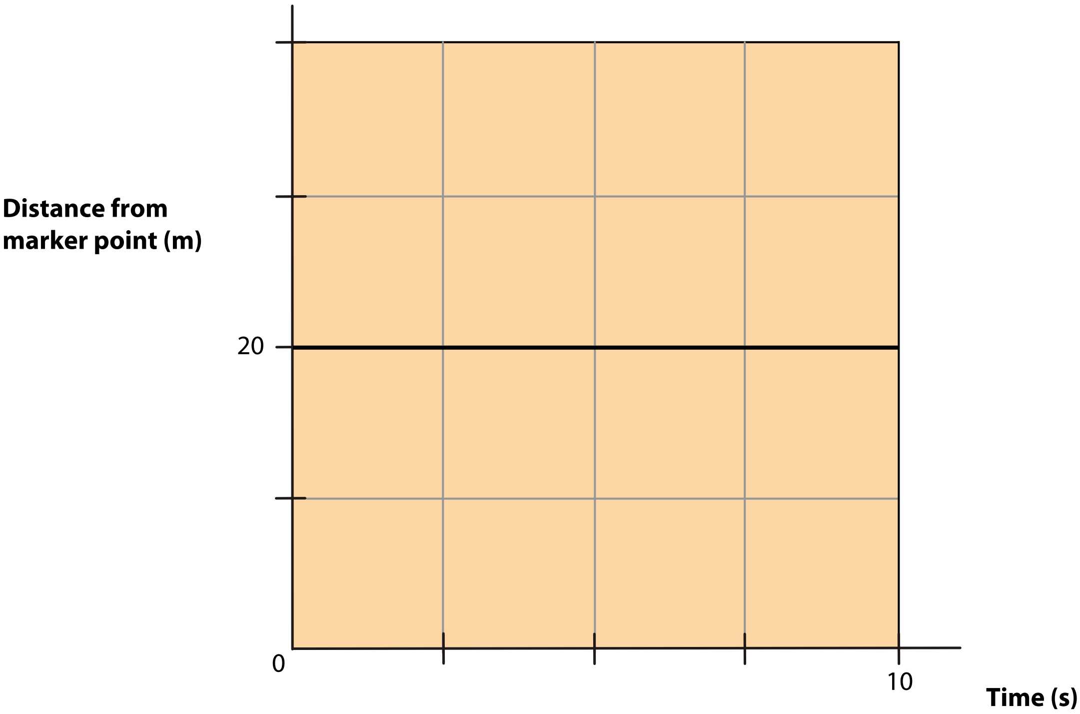
....

....

....

3. Train (i)

A train is on a straight section of track. The graph below shows its distance from a marker point on the track, over a period of 20 seconds.



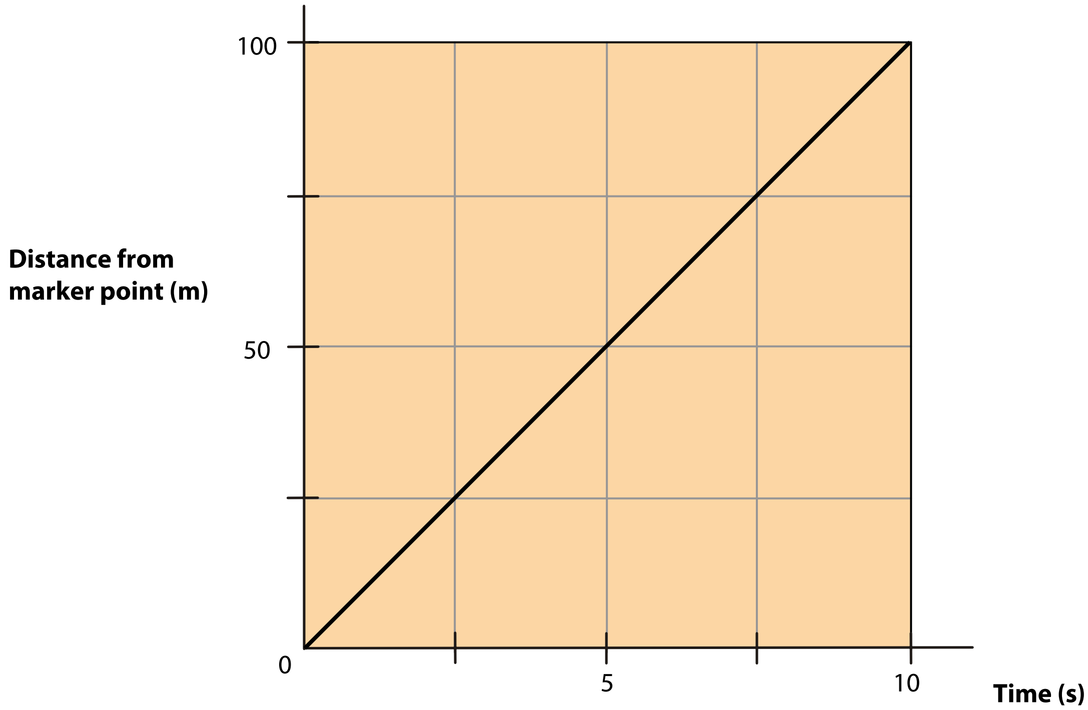
Which of these can you say from the graph?

*Tick **ONE** box*

☐	The train was on a level track.
☐	The train was stationary.
☐	The train travelled at a constant speed.
☐	The speed of the train got steadily greater.

4. Train (ii)

A train is on a straight section of track. The graph below shows its distance from a marker point on the track, over a period of 10 seconds.



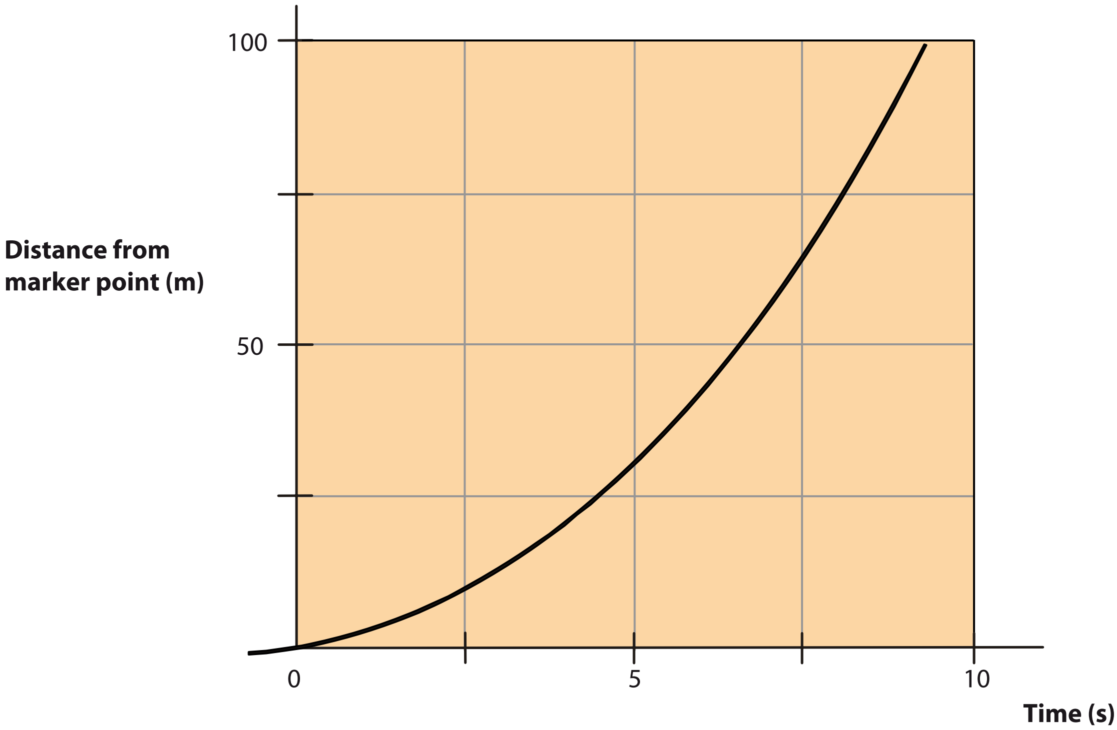
Which of these can you say from the graph?

*Tick **ONE** box*

☐	The train went up a slope.
☐	The train did not move during this time.
☐	The train travelled at a constant speed.
☐	The speed of the train got steadily greater.

5. Train (iii)

A train is on a straight section of track. The graph below shows its distance from a marker point on the track, over a period of 10 seconds.



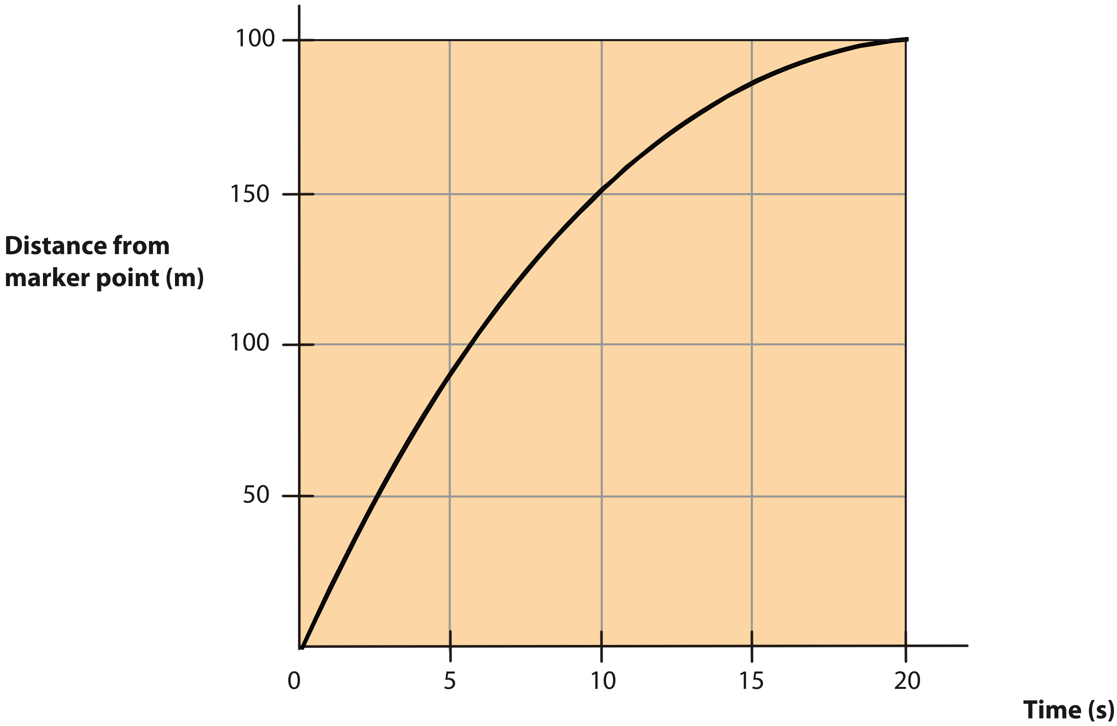
Which of these can you say from the graph?

*Tick **ONE** box*

☐	The train went up a slope that got gradually steeper.
☐	The train travelled at a constant speed.
☐	The speed of the train got steadily greater.
☐	The speed of the train got steadily smaller.

6. Train (iv)

A train is on a straight section of track. The graph below shows its distance from a marker point on the track, over a period of 10 seconds.



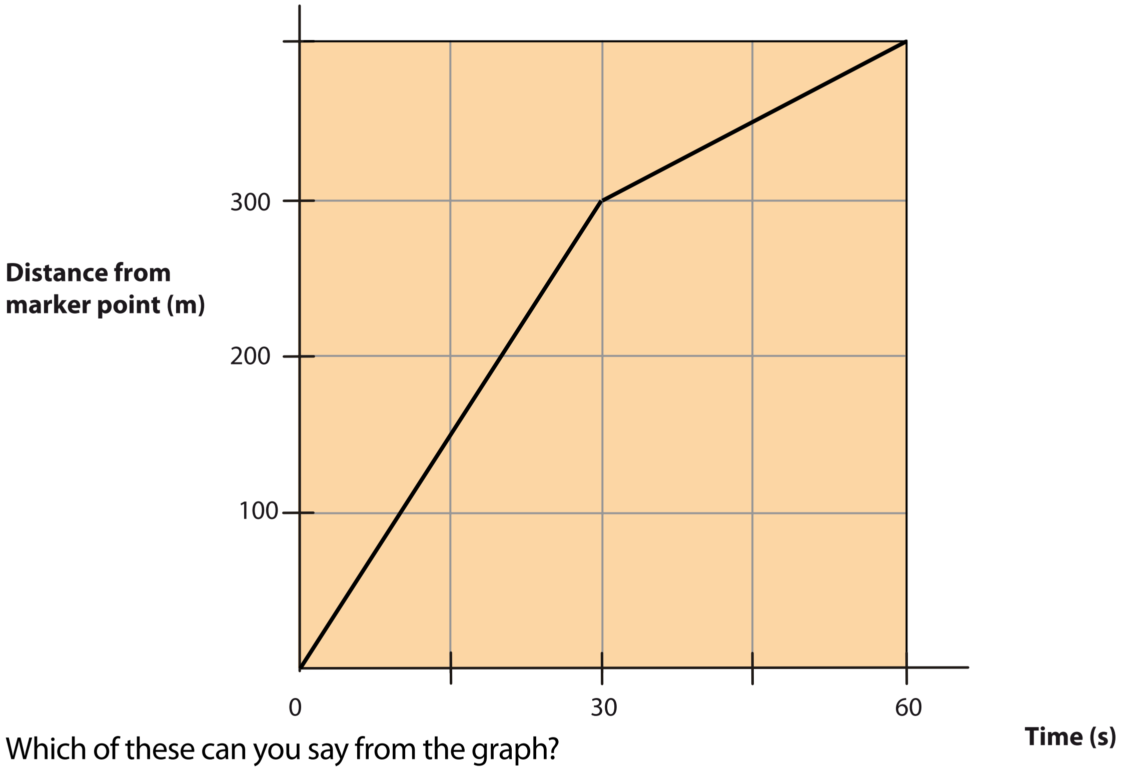
Which of these can you say from the graph?

*Tick **ONE** box*

☐	The train went up a slope that gradually levelled off.
☐	The train travelled at a constant speed.
☐	The speed of the train got steadily smaller.
☐	The speed of the train got steadily greater.

7. Train (v)

A train is on a straight section of track. The graph below shows its distance from a marker point on the track, over a period of 60 seconds (s).



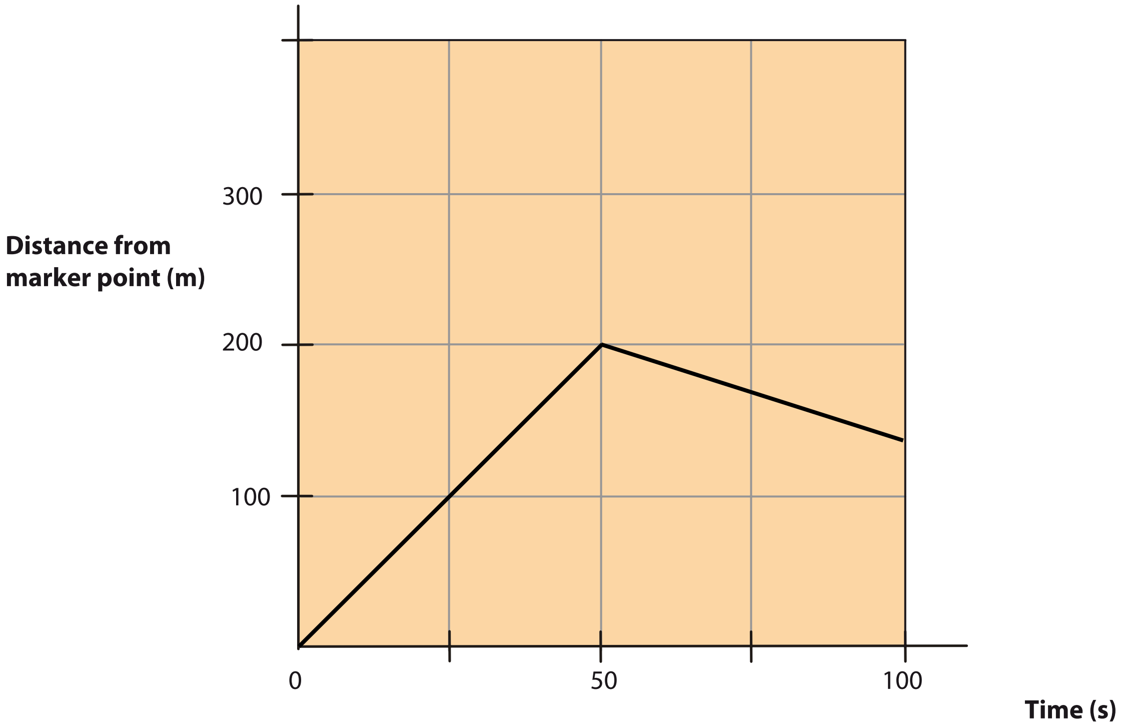
Which of these can you say from the graph?

Tick ***ONE*** *box*

☐	The train went up a steep slope at first, and then a gentler slope.
☐	The train travelled for 30s at a constant speed. It then reduced speed and travelled for the next 30s at a lower constant speed.
☐	The train travelled for 30s at a constant speed. It then increased speed and travelled for the next 30s at a higher constant speed.
☐	The train had a uniform acceleration for the first 30s. It then travelled for the next 30s at a constant speed.
☐	The train had a uniform acceleration for the first 30s. It then had a smaller uniform acceleration for the next 30s.

8. Cyclist

A cyclist goes for a ride along a straight road. The graph below shows his distance from his starting point, over a period of 100 seconds (s).



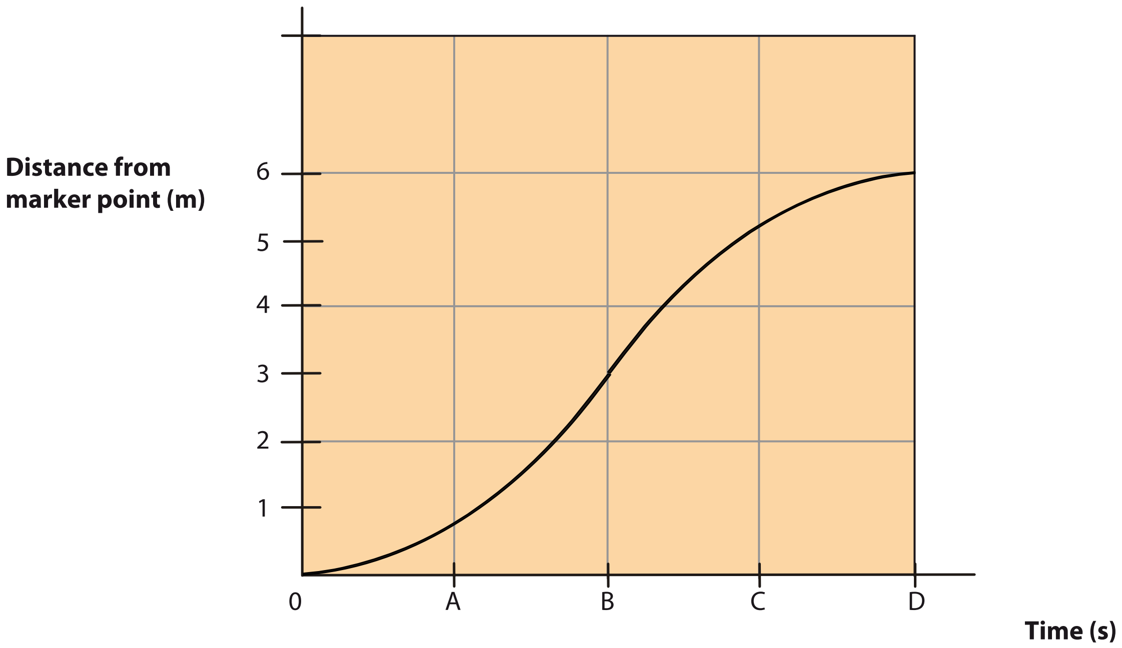
Which of these can you say from the graph?

*Tick **ONE** box*

☐	He went uphill for the first 50s, then downhill after that.
☐	He cycled at a steady speed for 50s, and then continued at a slower steady speed in the same direction.
☐	He cycled at a steady speed for 50s, and then turned round and came back, at a slower steady speed.
☐	He cycled at a steady speed for 50s, and then turned round and came back, at a faster steady speed.
☐	His speed increased for the first 50s, then it began to decrease steadily again.

9. Motorway

A car is travelling along a straight section of motorway. The graph below shows how its distance from its starting point changed with time during a journey.



(a) At what time, A, B, C or D, was the car travelling fastest? ....

Explain your answer: ....

....

....

(b) At what time, A, B, C or D, was the car travelling slowest? ....

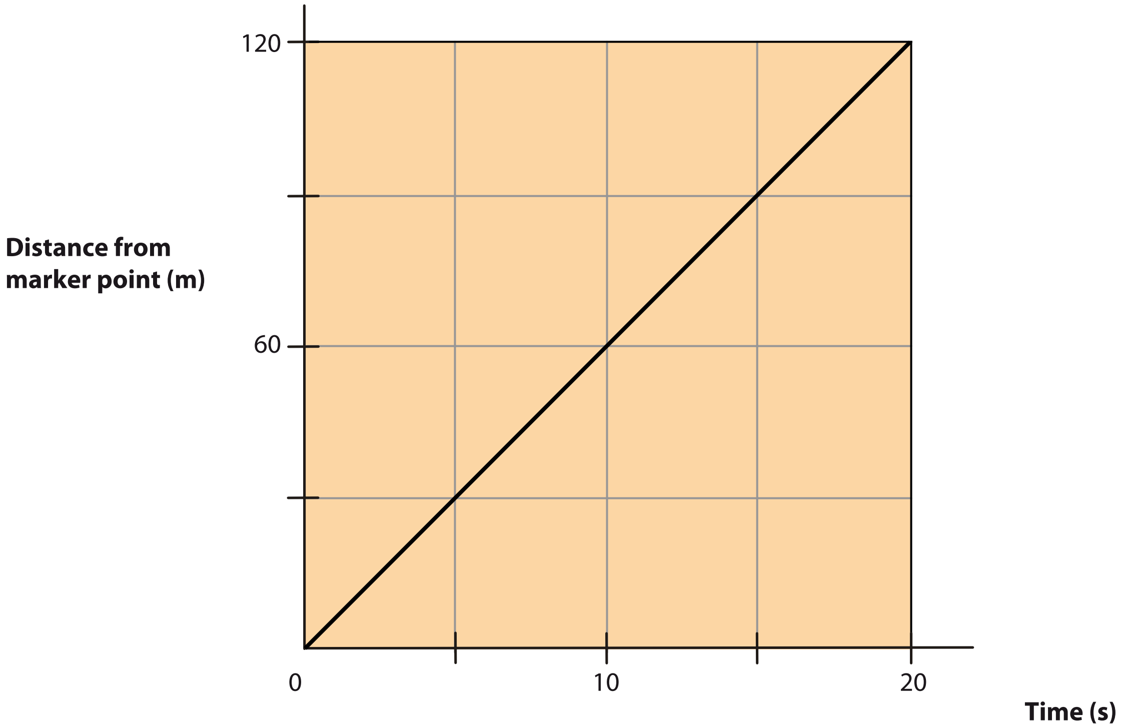
Explain your answer: ....

....

....

10. What speed?

A car travels along a straight road. The graph below shows its distance from a marker point on the road, over a period of 20 seconds.



At what speed was the car travelling?

Tick ***ONE*** *box*

☐	120 m/s
☐	20 m/s
☐	6 m/s
☐	2400 m/s

Activity 3.2: From distance/time to speed/time

This activity makes the step from distance/time graphs to speed/time graphs.

Teaching objectives

- To make the link between distance/time and speed/time graphs.
- To introduce the key features of speed/time plots.

Learning outcomes

By the end of this activity, pupils will be able to recognise that for speed/time graphs:

- zero slope (flat plot) means steady speed;
- straight line plot (positive slope) means constant acceleration: the speed increases by equal amounts in equal intervals of time;
- straight line slope (negative slope) means constant deceleration: the speed decreases by equal amounts in equal intervals of time;
- the slope of the graph line is a measure of acceleration.

What to prepare

- Sets of the worksheets: Exercise 1, 2, 3: Speed/time.

Mode of interaction

Groupwork
Pairs/groups of pupils talk through the questions focusing on the correct scientific point of view: INTERACTIVE/ AUTHORITATIVE.

What happens in this activity

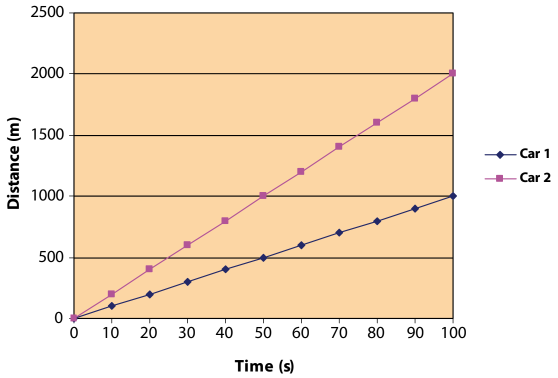
This activity involves three exercises based on three different motions:

- steady speed
- speeding up (accelerating)
- slowing down (decelerating)

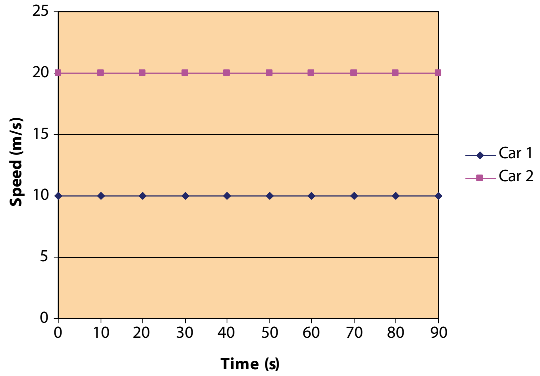
In each case the pupils, working in pairs, are presented with a distance/time graph and are directed first to sketch and then to plot the equivalent speed/time graph (see the worksheets provided).

Exercise 1: Steady speed

Distance/Time Graph

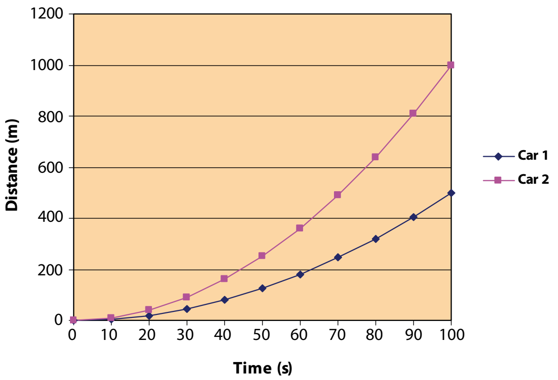


Speed/Time Graph

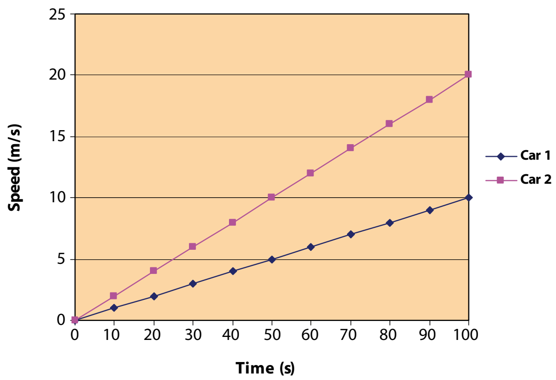


Exercise 2: Speeding up

Distance/Time Graph

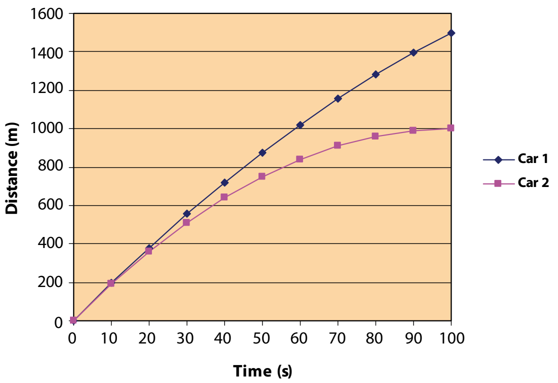


Speed/Time Graph

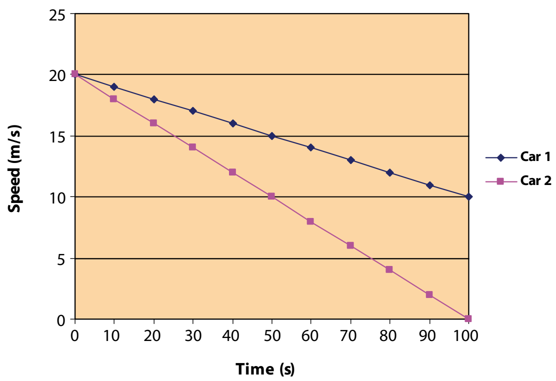


Exercise 3: Slowing down

Distance/Time Graph



Speed/Time Graph



Plenary

The key points to emphasise in relation to speed/time graphs are as follows:

- zero slope (flat plot) means steady speed (Exercise 1);
- straight line plot (positive slope) means constant acceleration: the speed increases by equal amounts in equal intervals of time (Exercise 2);
- straight line slope (negative slope) means constant deceleration: the speed decreases by equal amounts in equal intervals of time (Exercise 3);
- the slope of the graph line is a measure of acceleration/deceleration.

Comparing the graph lines in Exercise 2 leads to the idea that:

> *'Car 2 is speeding up more quickly than Car 1'*

or:

> *The rate at which the speed of Car 2 increases is greater than that for Car 1'*

or:

> *'The acceleration of Car 1 is greater than that for Car 2'.*

The acceleration can actually be calculated from the slope of the graph:

For example, for Car 1:

Acceleration = Change in speed/time taken

= (10 – 0)/100

= 0.1 m/s^2

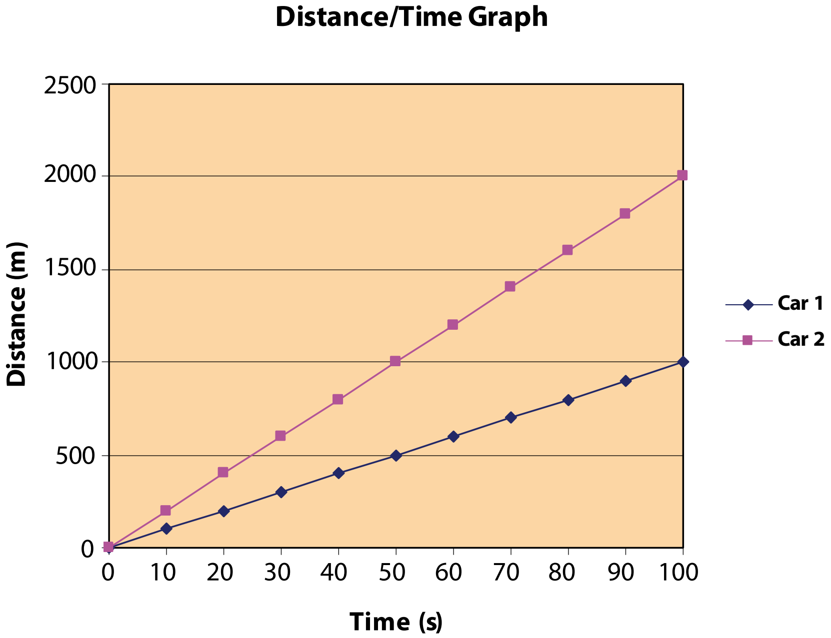
At first, the concept of acceleration can be confusing for pupils. The acceleration is 0.1 m/s^2. What does this mean?

> *'The speed of the car increases by 0.1m/s each second'*

It is worth using this 'long-hand' form when first talking about acceleration.

Exercise 1: Speed/time

These are the distance/time plots for two cars:



Instructions

1. Discuss with your partner:
What is the motion of each car?
Fully describe the motion:

Car 1:

....

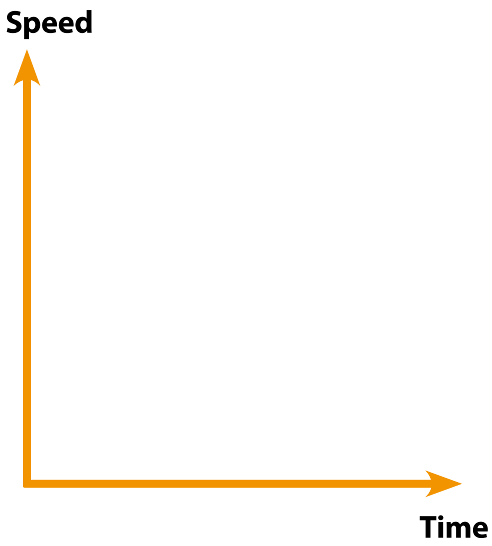
....

Car 2:

....

....

2. Sketch a speed/time plot for each car.

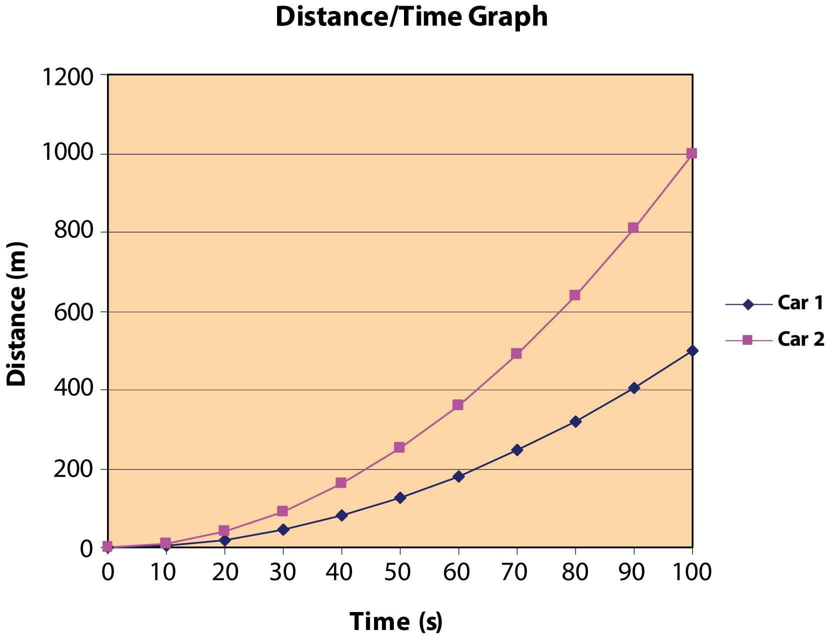


Using the data provided in the table below draw the speed/time graphs for each car. Compare these graphs with the ones you have sketched before, and if there is any difference, try to explain it.

Time (s)	**Speed (m/s)**	
	Car 1	**Car 2**
0	10	20
10	10	20
20	10	20
30	10	20
40	10	20
50	10	20
60	10	20
70	10	20
80	10	20
90	10	20
100	10	20

Exercise 2: Speed/time

These are the distance/time plots for two cars:



Instructions

1. Discuss with your partner:
What is the motion of each car?
Fully describe the motion:

Car 1:

....

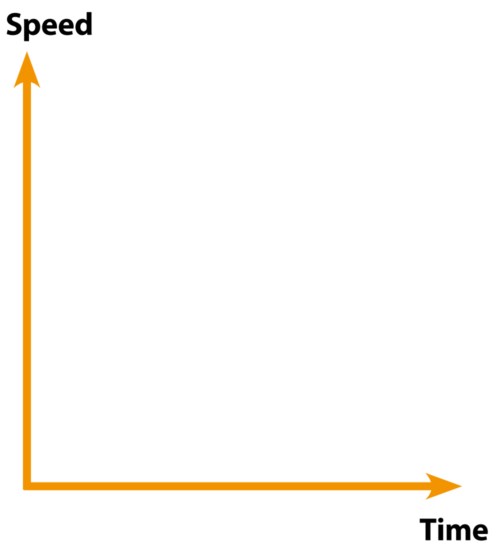
....

Car 2:

....

....

2. Sketch a speed/time plot for each car.

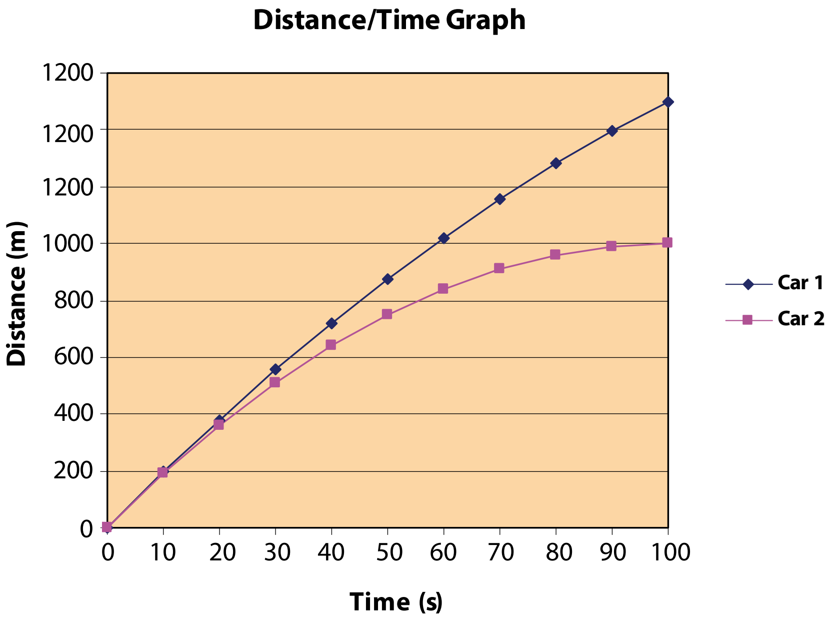


Using the data provided in the table below draw the speed/time lines for each car. Compare these graphs with the ones you have sketched before and if there is any difference try to explain it.

Time (s)	**Speed (m/s)**	
	Car 1	**Car 2**
0	0	0
10	1	2
20	2	4
30	3	6
40	4	8
50	5	10
60	6	12
70	7	14
80	8	16
90	9	18
100	10	20

Exercise 3: Speed/time

These are the distance/time plots for two cars.



Instructions

1. Discuss with your partner:
What is the motion of each car?
Fully describe the motion:

Car 1:

....

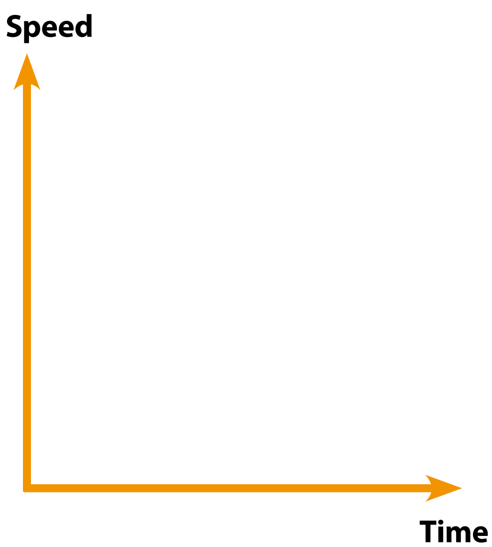
....

Car 2:

....

....

2. Sketch a speed/time plot for each car.



Using the data provided in the table below draw the speed/time lines for each car. Compare these graphs with the ones you have sketched before, and if there is any difference, try to explain it.

Time (s)	**Speed (m/s)**	
	Car 1	**Car 2**
0	20	20
10	19	18
20	18	16
30	17	14
40	16	12
50	15	10
60	14	8
70	13	6
80	12	4
90	11	2
100	10	0

Lesson 4: Linking force and motion

This lesson starts with a review of speed/time graphs and moves on to the relationship between force and motion.

Activity 3.1: Diagnostic questions: speed/time graphs and acceleration

A comprehensive set of diagnostic questions is provided which addresses all of the key aspects of speed/time graphs. The diagnostic questions are to be used as a focus for discussion between pupils, enabling the teacher to check their developing understanding of the subjects.

Teaching objectives

- To enable pupils to use their developing knowledge and understanding to review the key features of distance/time graphs.

Learning outcomes

By the end of this activity the pupils will be able to:

- interpret both linear and curved speed/time graphs;
- relate the slope of a speed/time graph to acceleration.

What to prepare

The following diagnostic questions are available. Sets of the questions might be produced on card and laminated.

	Question	Focus	Answer
1	Acceleration	Defining acceleration	A; NA; NA; A; A; NA (maybe); A; NA (maybe); A
2	Car (i)	Speed/time graph: uniform speed	Constant speed
3	Car (ii)	Speed/time graph: steady acceleration	Speed steadily increasing
4	Car (iii)	Speed/time graph: steady deceleration	Speed steadily decreasing
5	Car (iv)	Speed/time graph: increasing acceleration	Increasing acceleration
6	Car (v)	Speed/time graph: decreasing acceleration	Decreasing acceleration
7	Moving object	Speed/time graph	Tennis ball
8	Calculate acceleration	Speed/time graph	$0.5 m/s^2$

What happens during this activity

The teacher selects the questions to be worked on. The activity might be organised in:

a. **Pairs**: pupils work in pairs on the questions and report back in a plenary.

b. **Pairs/fours:** pupils work in pairs and then join with another pair to come up with a joint/agreed response. The groups of four report back to the plenary.

Plenary: the teacher and class talk through the questions on the whiteboard.

Mode of interaction

Groupwork **Groups of pupils talk through explanations for the graphs focusing on the correct scientific point of view: INTERACTIVE/AUTHORITATIVE.**	
Whole-class plenary **Presentations by pupils with questions from the teacher to establish the correct scientific point of view: INTERACTIVE/ AUTHORITATIVE.**	

Distinguishing between speed and velocity

This would be a good time to introduce the distinction between SPEED and VELOCITY, in such a way that:

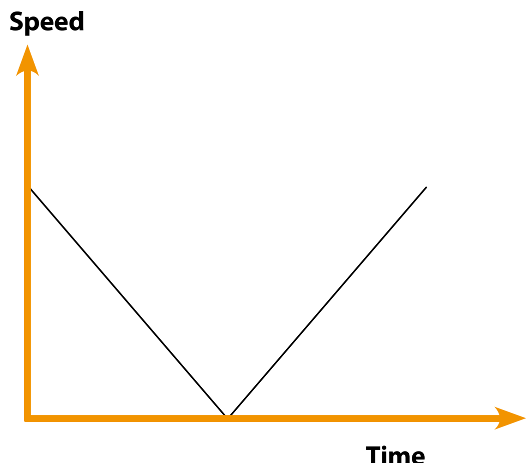
- speed is a SCALAR quantity which is defined in terms of size (how fast?) only;
- velocity is a VECTOR quantity which is defined in terms of size and direction (how fast **and** in which direction?).

For example, two objects A and B might be travelling at 10m/s in opposite directions (one due north the other due south).

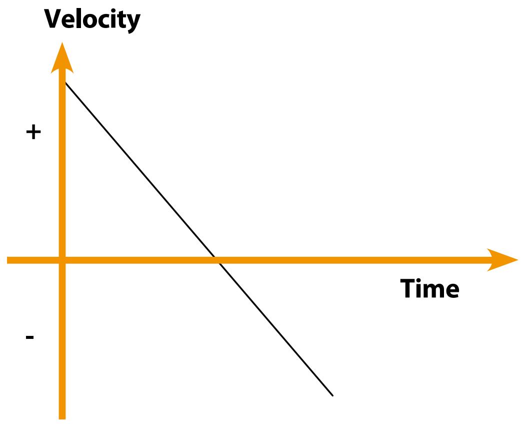
Speed A = 10m/s   Speed B = 10m/s

Velocity A = +10m/s   Velocity B = -10m/s

Note that ALL of the diagnostic questions refer to SPEED/time graphs. Question 7 is interesting in that it involves a change in direction.

<table>
<tr><td>
</td><td>The graph shows speed falling steadily to zero and then increasing at the same rate. It relates to the tennis ball which steadily decelerates as it climbs, comes to a halt for a moment at the top, and steadily accelerates as it falls.</td></tr>
</table>

If the graph is re-plotted as velocity/time, the shape changes:

<table>
<tr><td>
</td><td>As the ball RISES the velocity is shown as positive and it steadily decreases to zero. As the ball FALLS, it is travelling in the opposite direction (downwards) and therefore has a negative velocity which is increasing. In addition, the ball decelerates upwards at the same rate at which it accelerates downwards and so the velocity/time plot is a straight line.</td></tr>
</table>

This graph is particularly challenging to interpret and the teacher will need to go through the explanation step by step.

Activity 4.2: Linking force and motion

In this activity the link is made between the state (balanced or unbalanced) of the forces acting on an object and the motion of that object.

Teaching objectives

- To make the link between the state of the forces acting on an object and the motion of that object.

Learning outcomes

By the end of this activity most pupils will be able to:

- explain that zero or balanced forces on an object lead to a stationary or steady speed motion;
- explain that unbalanced forces on an object lead to an accelerated motion;
- use the equation F = ma.

Mode of interaction

Here the teacher is presenting new ideas with an INTERACTIVE/ AUTHORITATIVE approach.

What happens in this activity

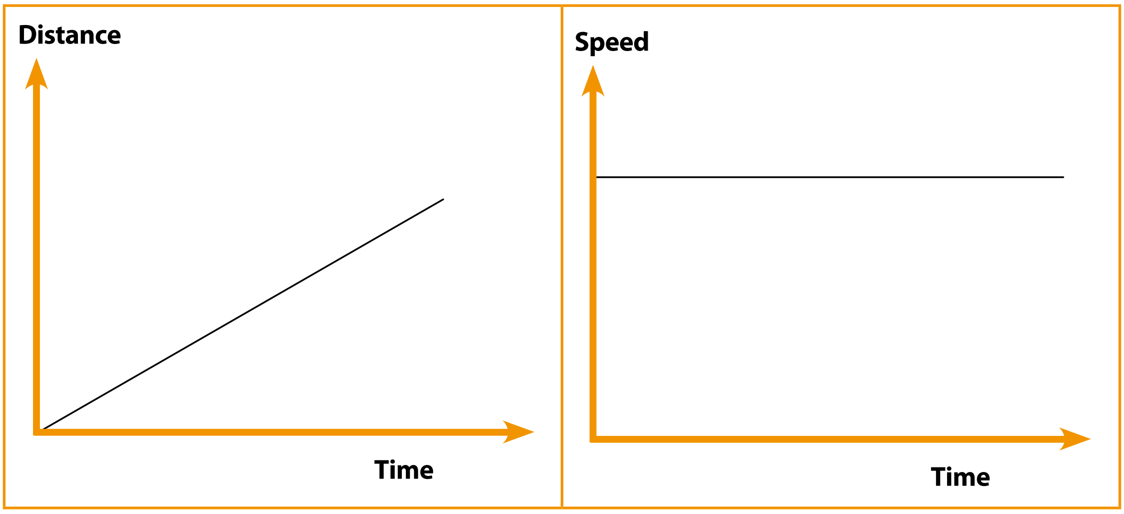
This a teacher-led presentation/demonstration in which the link between force and motion is made. There are two general cases to consider:

1. Object moving **with steady speed** ⟷ Forces acting are **BALANCED**

2. Objects moving with **changing speed** ⟷ Forces acting are **UNBALANCED**

1. Steady speed

The teacher starts by reviewing the graphical representations of steady speed:



What might have this kind of steady motion?

'Can you think of any situations where something moves along with steady speed?'

Pupils are likely to suggest examples such as:

A car travelling along the motorway at a steady 70mph.'

'Me walking at a steady pace.'

Examples which are less likely to come forward relate to situations where the forces acting on the object are minimised:

'A skater gliding across the ice.'

'A space capsule drifting through deepest space.'

These latter examples (such as the space capsule) are of interest because:

'In the furthest corner of space, well away from any planets or stars, there are no forces acting to either speed up or to slow down the space capsule which drifts through space with a graceful, steady motion'.

This kind of steady motion which results from there being NO (or very little) forces acting on an object can be demonstrated with a 'glider' moving along an air track. The general rule which follows from these specific examples is that:

When there are no forces acting on a moving object it continues with no change in motion.

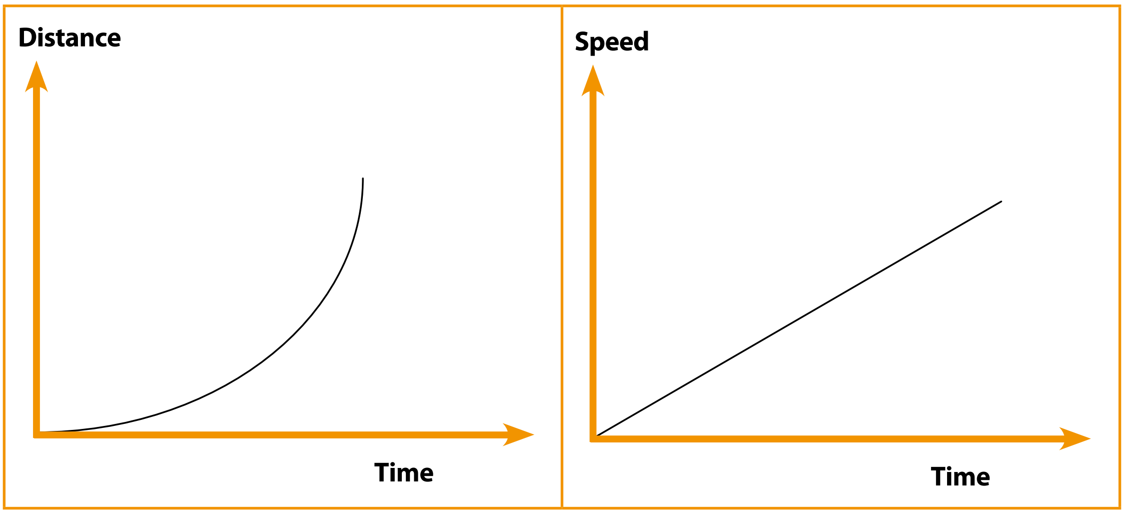
But, how does this fit with the car travelling along the motorway at a steady speed? There are clearly forces acting on the car. The key point here is that the forces acting on the car must be BALANCED and thereby cancel each other out producing NO RESULTANT (or overall) force and this leads to steady motion. In the case of the car, the propelling force produced by the engine is balanced by all of the frictional and air resistance forces acting against the motion of the car.

The general rule is that:

When the forces acting on a moving object are balanced (giving no resultant force) it continues with no change in motion.

2. Changing speed: acceleration

The teacher now turns to situations where the speed is changing:



What might have this kind of motion?

'Can you think of any situations where something moves along with increasing speed?'

Pupils are likely to suggest examples such as:

' Lewis Hamilton's car starting a Grand Prix'

'A sprinter starting a 100m race'

Other objects which have an accelerated motion include: objects falling freely; a trolley running down a slope; a book pushed along a table with a big steady force. Taking this last example:

With a BIG steady push the book speeds up from the rest position:

Push of hand on book

Friction force of table on book

The book accelerates along the table for as long as the pushing force is greater than the friction force. The key point here is that the forces acting on the book must be UNBALANCED, with the push of the hand being greater than the friction force between table and book. This produces a RESULTANT (or overall) force which leads to an accelerated motion.

The general rule is that:

When the forces acting on an object are unbalanced (giving a resultant force) it has an accelerated motion.

The size of the acceleration produced by a resultant force can be calculated using the equation:

F= ma

Where:

- F is the resultant force (in newton, N) acting on the object;
- m is the mass (in kilogram, kg) of the object;
- a is the acceleration (in m/s^2) of the object.

For example, in the case above, supposing:

Push of hand = 20N

Force of friction = 5N

Mass of book = 0.5kg

What is the acceleration of the book?

F = ma

(20 – 5) = 0.5 x a

a = 30m/s²

The relationship F = ma can be explored further with the question 'Force, mass and acceleration' (see worksheet).

Diagnostic questions

1. Acceleration

If something changes its speed, we say that it accelerates – it has an acceleration.

(a) For each of the following, put a tick in one column to show if you think it has an acceleration, or no acceleration.

Situation	Acceleration	No Acceleration
A train leaving a station after picking up some passengers.		
A Formula 1 racing car travelling along a straight line at a steady 200 miles per hour.		
A cyclist riding along at 12 kilometres per hour.		
A snail starting to move after a rest.		
A ball being thrown.		
A parachutist falling after her parachute has opened.		
An apple falling from a tree.		
A person going up on an escalator (moving stairs).		
A football just as it is being kicked.		

(b) A bus is braking to stop at a bus stop. Does it have an acceleration?

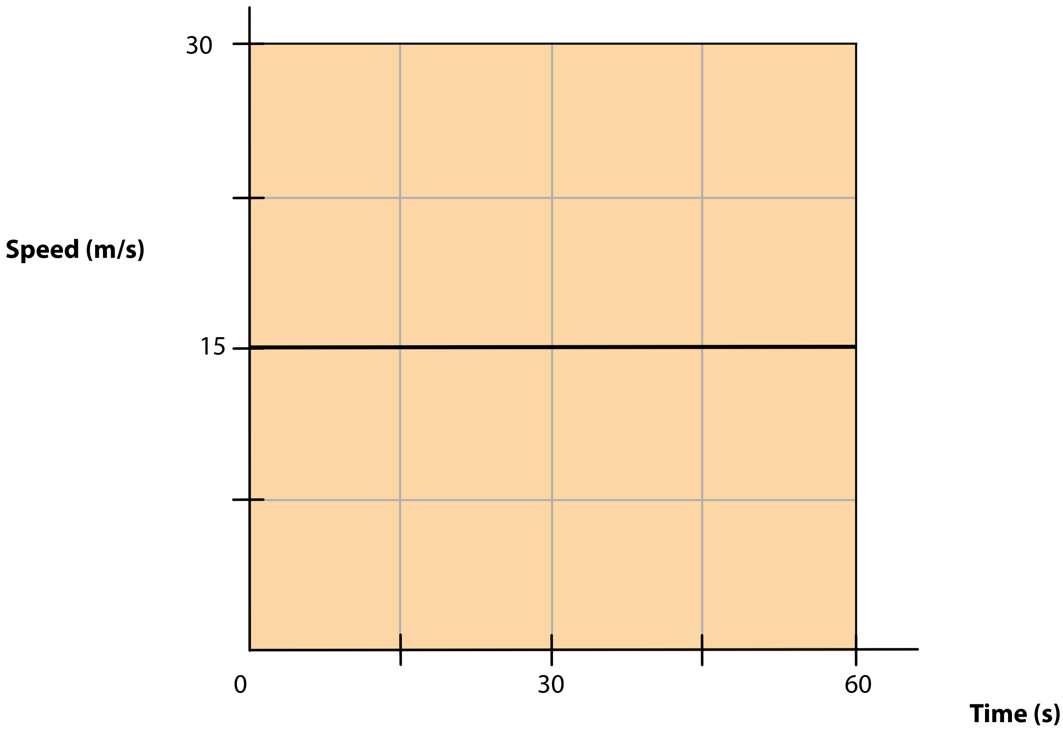
Explain your answer: ....

....

....

2. Car (i)

A car is on a straight road. The graph below shows its speed over a period of 60 seconds.



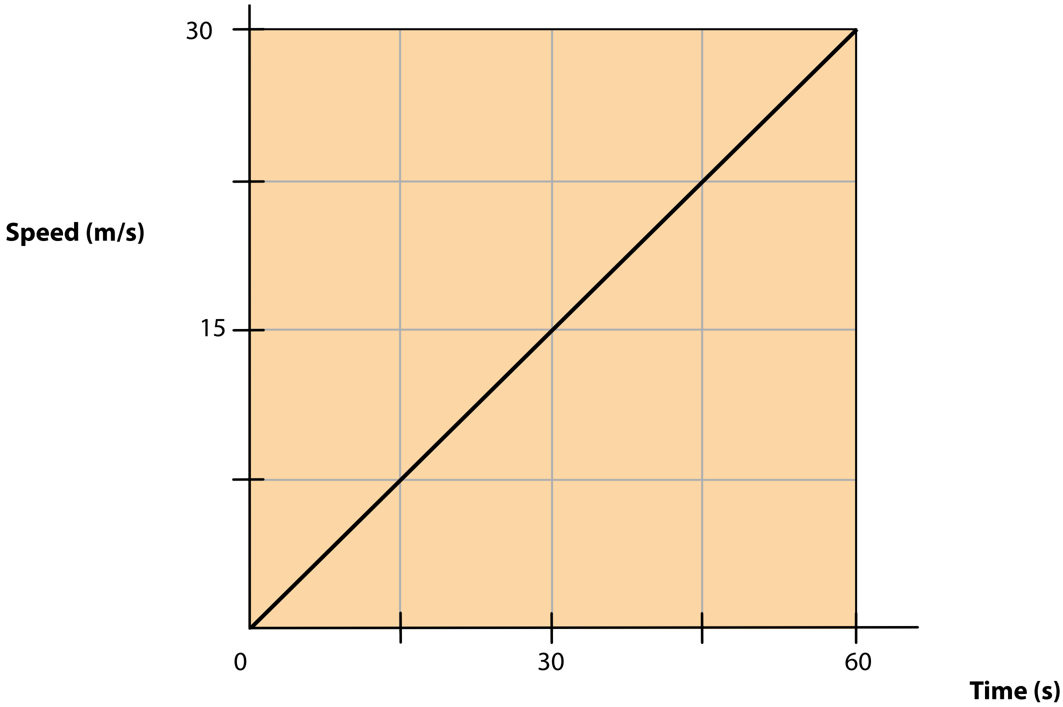
Which of these can you say from the graph?

*Tick **ONE** box*

☐	The car was on a level road.
☐	The car did not move during this time.
☐	The car travelled at a constant speed.
☐	The speed of the car got steadily greater.
☐	The speed of the car got steadily smaller.

3. Car (ii)

A car is on a straight road. The graph below shows its speed over a period of 60 seconds.



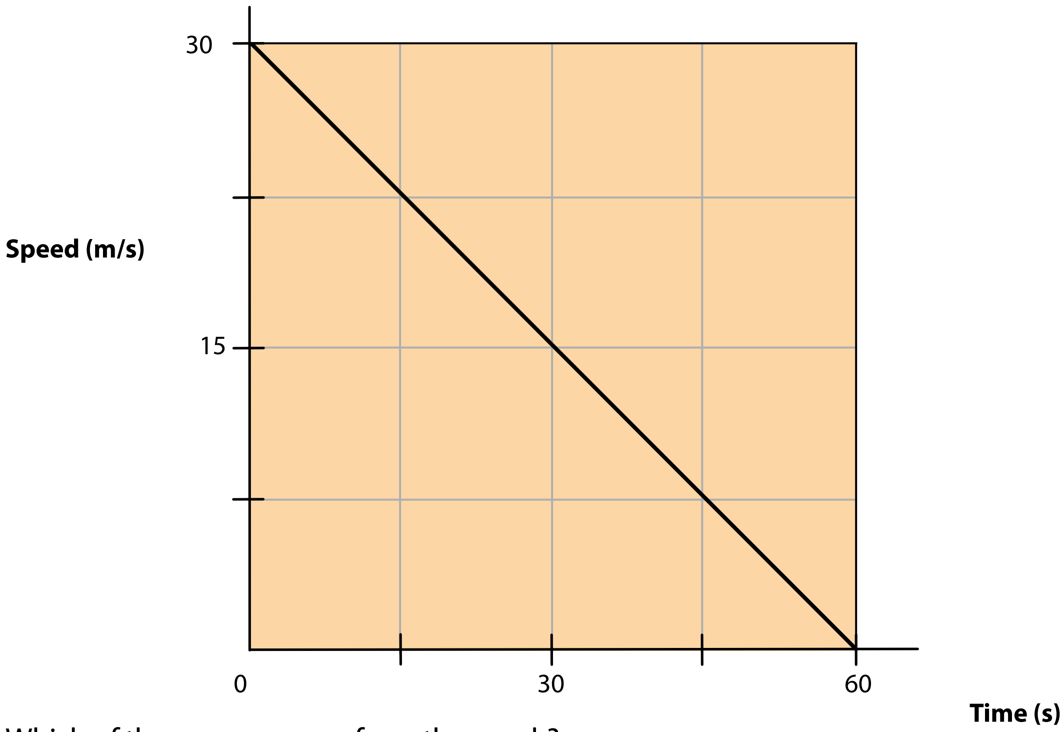
Which of these can you say from the graph?

*Tick **ONE** box*

☐	The car was going up a slope.
☐	The car did not move during this time.
☐	The car travelled at a constant speed.
☐	The speed of the car got steadily greater.
☐	The speed of the car got steadily smaller.

4. Car (iii)

A car is travelling along a straight road. The graph below shows its speed over a period of 60 seconds.



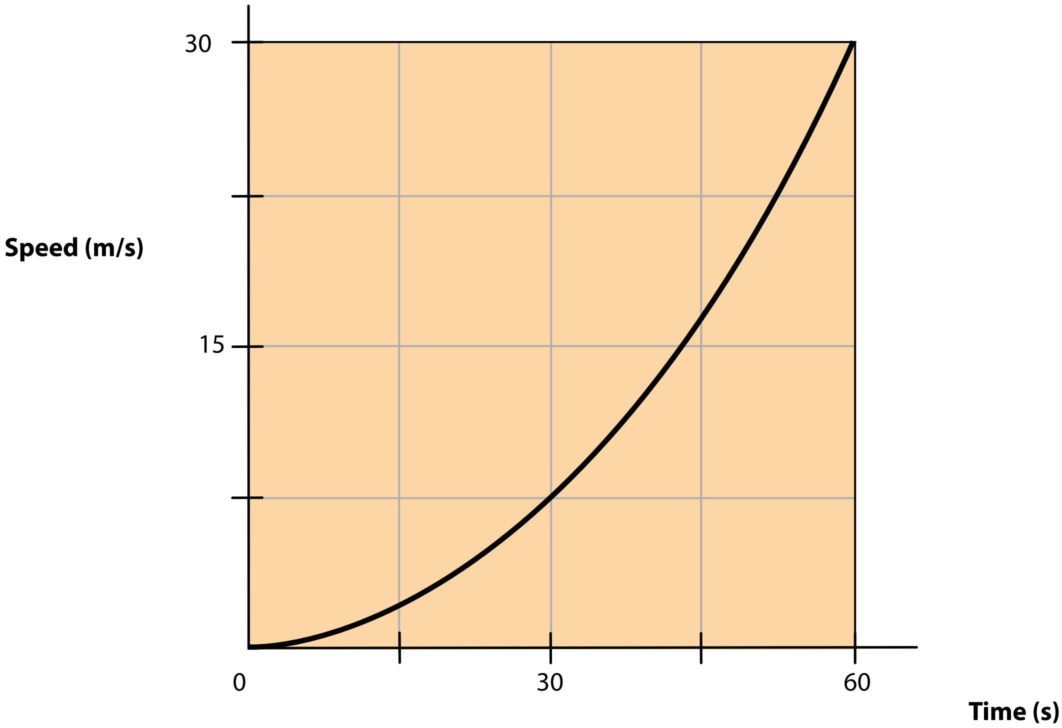
Which of these can you say from the graph?

*Tick **ONE** box*

☐	The car was going down a slope.
☐	The car travelled at a constant speed.
☐	The speed of the car got steadily smaller.
☐	The speed of the car got steadily greater.
☐	The car was going back towards the start.

5. Car (iv)

A car is travelling along a straight road. The graph below shows its speed over a period of 60 seconds.



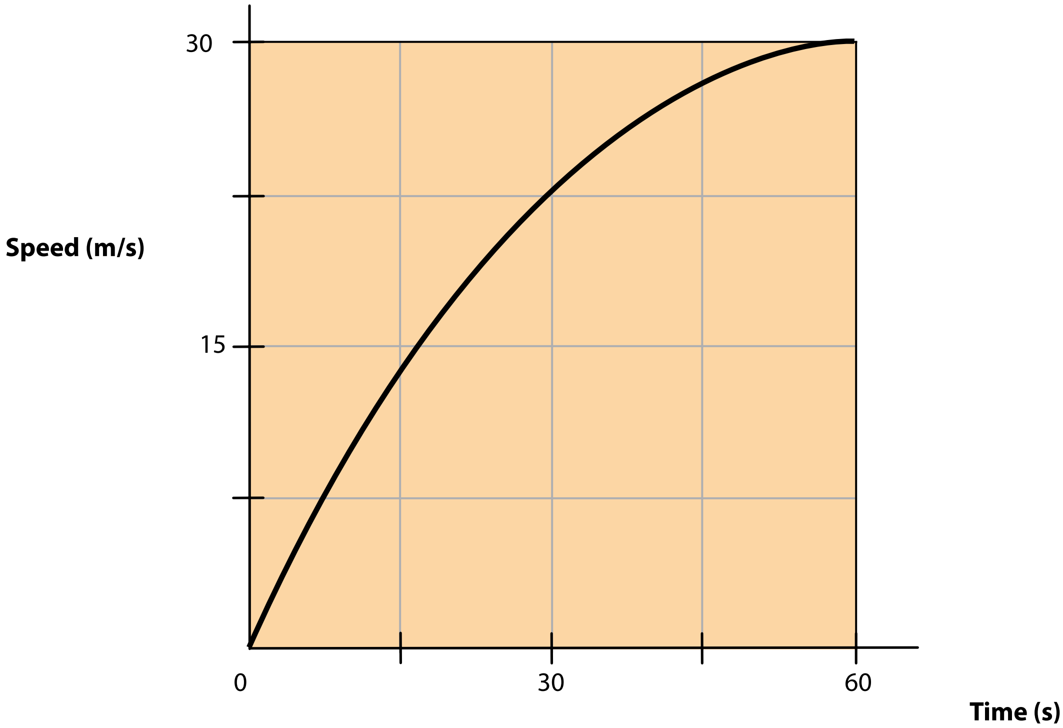
Which of these can you say from the graph?

*Tick **ONE** box*

☐	The car moved at a constant speed.
☐	The car moved with a constant acceleration.
☐	The car moved with an increasing acceleration.
☐	The car moved with a decreasing acceleration.
☐	The car went up a slope that got steadily steeper.

6. Car (v)

A car is travelling along a straight road. The graph below shows its speed over a period of 60 seconds.



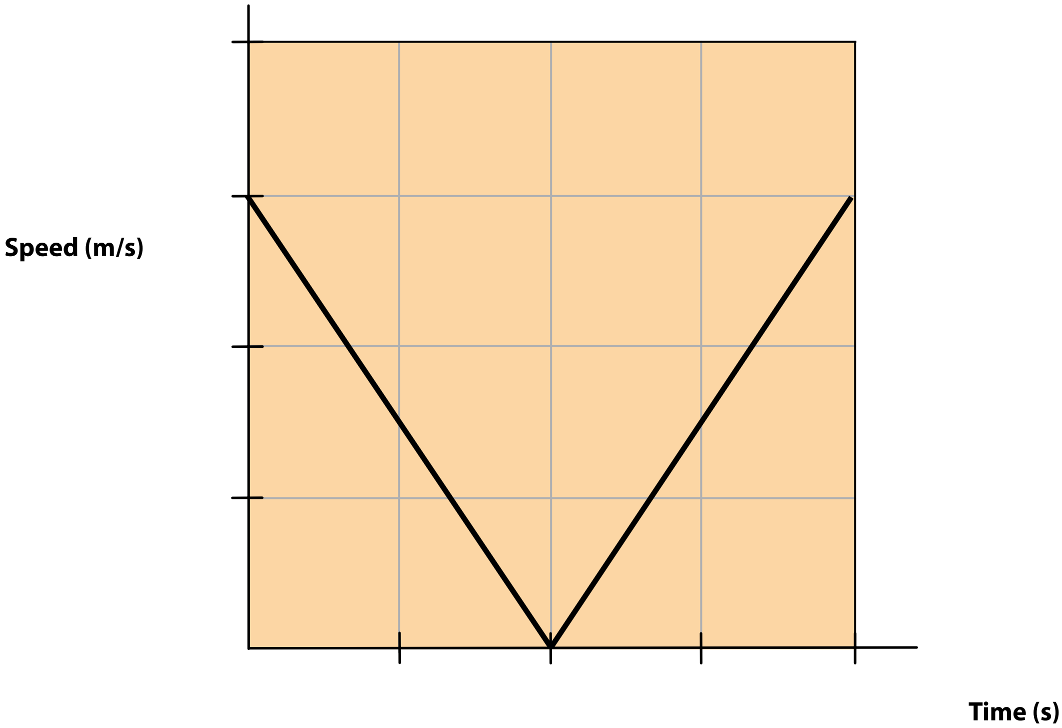
Which of these can you say from the graph?

Tick ***ONE*** *box*

☐	The car moved at a constant speed.
☐	The car moved with a constant acceleration.
☐	The car moved with an increasing acceleration.
☐	The car moved with a decreasing acceleration.
☐	The car went up a slope that got steadily less steep.

7. Moving object

Here is the speed-time graph for a moving object.



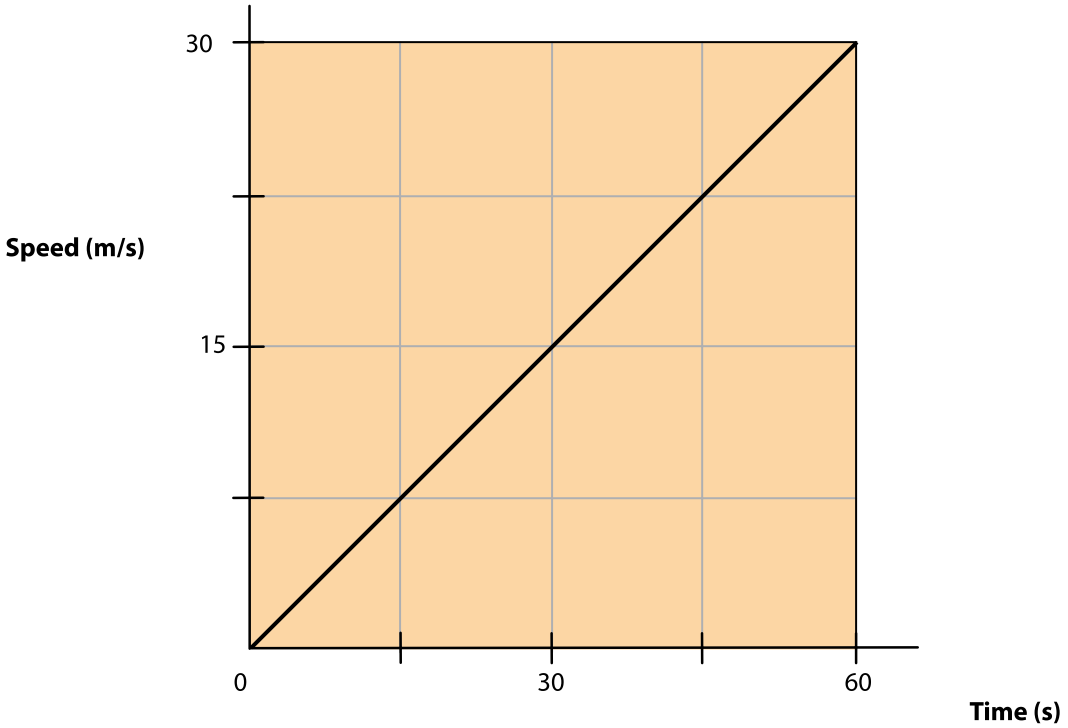
Which of the following situations might this speed-time graph represent?

*Tick **ONE** box*

☐	A snooker ball bouncing off the side cushion.
☐	A tennis ball thrown straight up into the air and coming down again.
☐	A cyclist freewheeling downhill at first, and then uphill.
☐	A car driving along at a steady speed and then accelerating to pass a lorry.

8. Calculate acceleration

A car is travelling along a straight road. The graph below shows its speed over a period of 60 seconds.



What is its acceleration?

*Tick **ONE** box*

☐	0.5 m/s^2
☐	2 m/s^2
☐	30 m/s^2
☐	60 m/s^2

Force, mass and acceleration

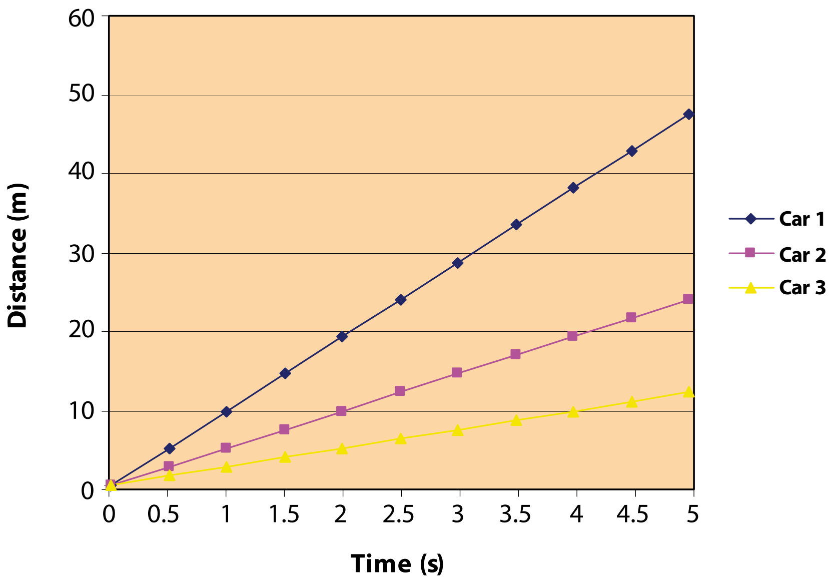
<table>
<tr><td></td><td>M = 1800 Kg
F = 9000 N</td><td rowspan="3">For each of the following cars, we have their mass and the force their engines exert when accelerating.

The graph below shows their motion when using full power.

1. Identify which line corresponds to which car.

2. How would you relate force, mass and acceleration?</td></tr>
<tr><td></td><td>M = 900 Kg
F = 9000 N</td></tr>
<tr><td></td><td>M = 1800 Kg
F = 4500 N</td></tr>
</table>

Distance/Time Graph



Lesson 5: Investigating motion

In this final lesson of the sequence pupils apply the ideas of force and motion to various situations.

Activity 5.1: Maggots and woodlice

In this activity pupils have the opportunity to apply some of the ideas learned in the preceding lessons to a novel context: that of investigating the respective motions of a maggot and a woodlouse!

Teaching objectives

- To enable pupils to plot and interpret distance/time graphs linked to a 'real-life' situation.

Learning outcomes

By the end of this activity, most pupils will be able to:

- collect distance/time data and plot them as a distance/time graph;
- interpret the distance/time plot, identifying the key features of the motion represented.

What to prepare

- Maggots can be bought from most fishing tackle shops.
- 'Race tracks' to set the maggots and woodlice along can be made from strips of paper with metre rules to act as the 'rails'.
- Stopclocks.

Mode of interaction

Pupils work in groups sharing ideas about carrying out the investigation with an INTERACTIVE/DIALOGIC approach.

DIALOGIC HOTSPOT

What happens during this activity

In this activity pupils work in small groups to investigate the motions of a maggot and a woodlouse! The activity can be organised in such a way that:

1. The class is given full and clear directions on how to make measurements and collect data. This would involve:
   - making a paper 'track' down which the maggot moves;
   - marking the track with a pair of metre rules so that the maggot does not wander off the track;
   - setting the maggot moving and marking its position every 20 seconds (with a pencil mark just behind the maggot) until the maggot has completed a full metre;
   - measuring and plotting the total distance travelled in 0, 20, 40 seconds.
2. Each group develops their own approach to making measurements and collecting data.

Either way, each group should be given the challenge of producing as full a report as they can, comparing the motions of the maggot and the woodlouse. This report might include:

- a distance/time plot for each creature produced on the same axes;
- qualitative descriptions of the motions;
- average speed calculations;
- calculations of acceleration (if possible).

Note: The maggots and woodlice are not 'volunteers' for this activity. The teacher needs to emphasise this point and insist that the animals are handled carefully and that all are returned in good health.

Teaching 'story'

This activity is one which pupils enjoy very much and which often leads to insightful and carefully prepared reports. A major strength of the activity is that it allows a link to be made between the motions observed directly 'at the bench' and the distance/time plots and calculations. Thus the image of the maggot wriggling along at a steady speed can be related directly to the distance/time graph rising steadily.

A limitation of the activity is that it does not allow the link to be made between the motion described and the forces acting. If this is the aim of the activity a different situation might be selected for investigation.

Activity 5.2: Diagnostic questions: making connections between graphs

This final set of diagnostic questions focuses on making connections between distance/time and speed/time graphs. The diagnostic questions are to be used as a focus for pupils' discussions, allowing the teacher to check their developing understanding of how the graphs can be interpreted.

Teaching objectives

- To review the key features of distance/time and speed/time graphs and to explore the relationship between the two.

Learning outcomes

By the end of this activity most pupils will be able to:

- interpret distance/time and speed/time graphs and explain how they relate to each other.

What to prepare

The following diagnostic questions are available. Sets of the questions might be made on card and laminated.

	Question	Focus	Answer
1	Car distance	Distance/time to speed/ time	D
2	Moving object	Distance/time to velocity/time	D
3	Five graphs	Distance/time and speed/ time	A and C; B and E

What happens during this activity

The teacher selects the diagnostic questions to be worked on. The activity might be organised in:

a. **Pairs:** pupils work in pairs on the questions and report back in a plenary.

b. **Pairs/fours:** pupils work in pairs and then join with another pair to come up with a joint/agreed response. The groups of four report back to the plenary.

Plenary: the teacher and class talk through the questions on the whiteboard

Mode of interaction

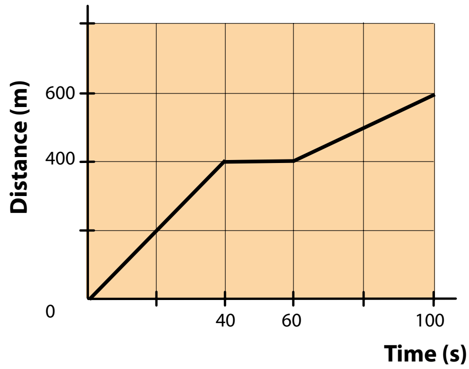
Groupwork
Groups of pupils talk through explanations for the graphs focusing on the correct scientific point of view: INTERACTIVE/AUTHORITATIVE.

Whole-class plenary
Presentation by pupils with questions from teacher to establish the correct science point of view: INTERACTIVE/AUTHORITATIVE.

Diagnostic questions

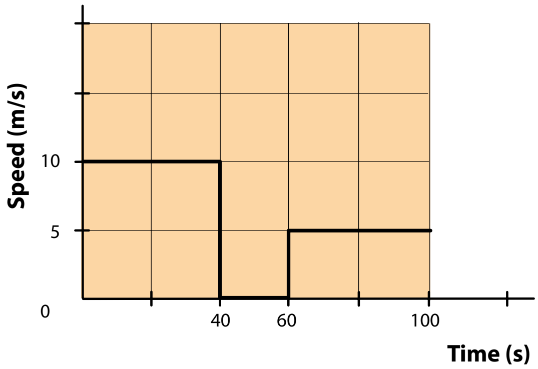
Car distance

A car is travelling along a straight road. This graph shows its distance from its starting point, over a period of 100 seconds.

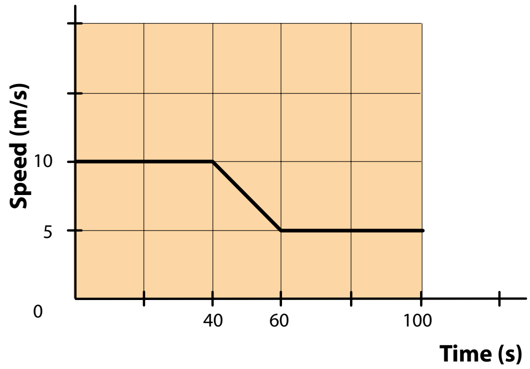


Which of the following graphs correctly shows the speed of the car during this journey?

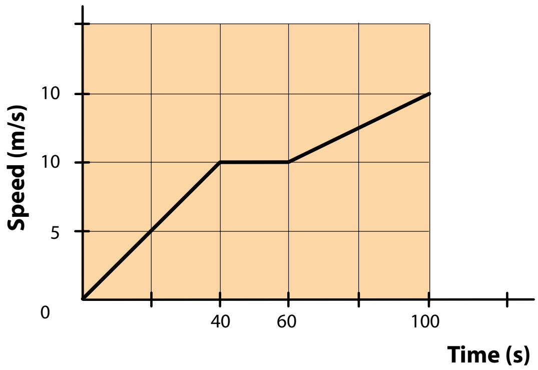
Write one letter (A, B, C or D) in this box to show your answer:



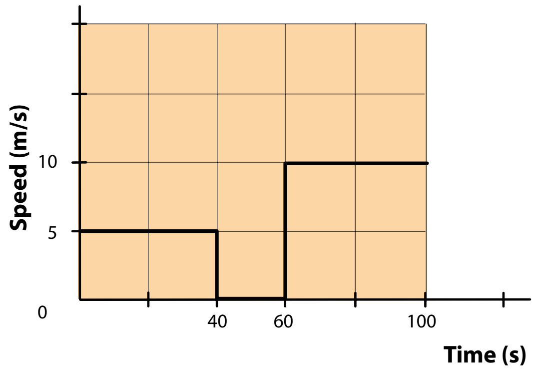
A



B



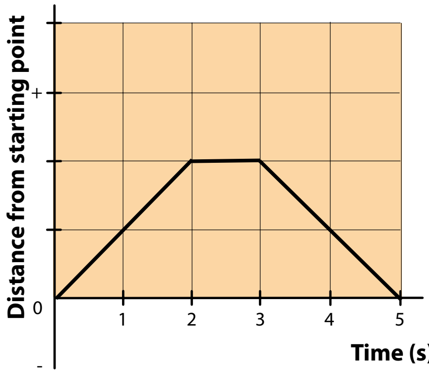
C



D

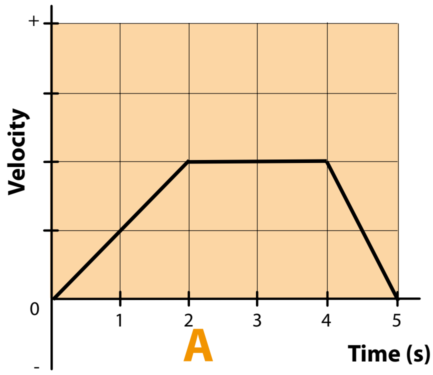
Moving object

An object is moving along in a straight line. This graph shows its distance from its starting point, over a period of 5 seconds.

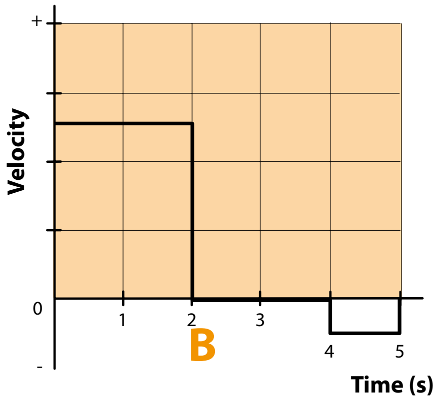


Which of the following graphs correctly shows the velocity of the object during this time?

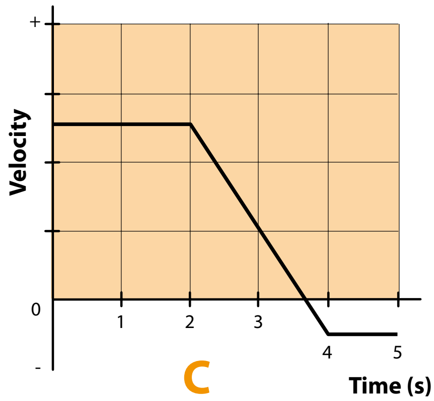
Write one letter (A, B, C or D) in this box to show your answer: ☐



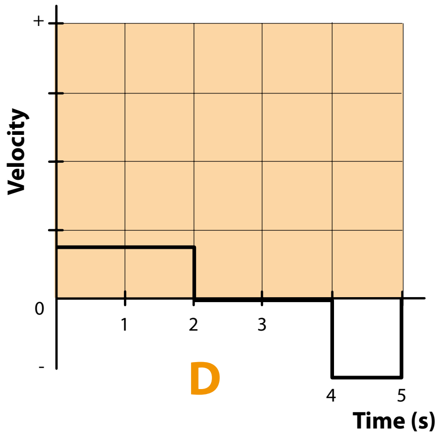
A



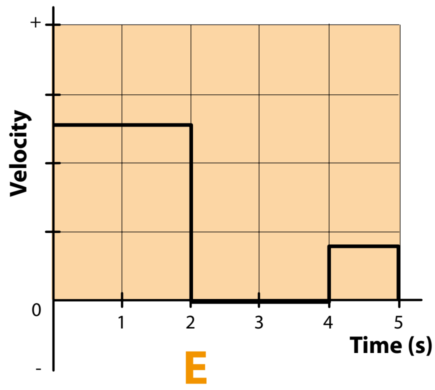
B



C



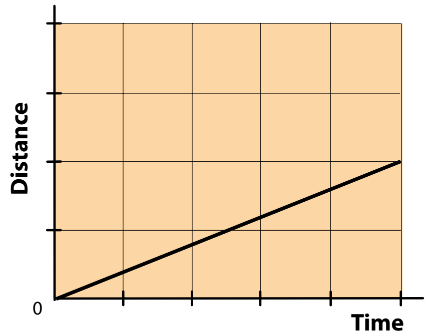
D



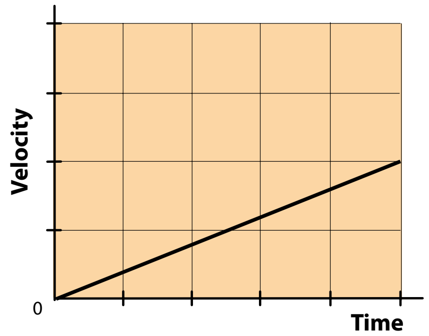
E

Five graphs

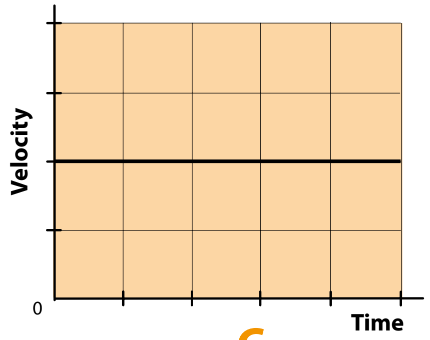
The five graphs below show the motion of a car, travelling along a level straight road. Note that the quantity plotted on the y-axis is **not** the same each time.



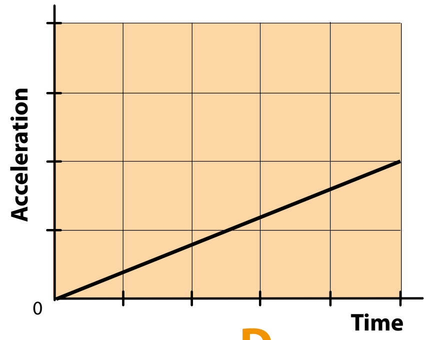
A



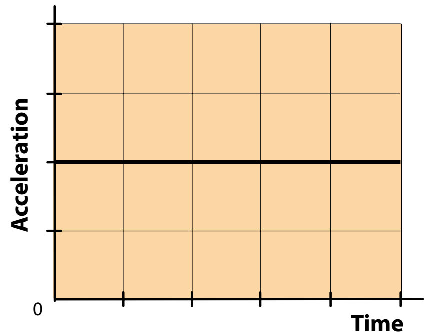
B



C



D



E

(a) Which of these represents motion at a constant velocity?

*Tick **ONE** box*

☐	A, B and D
☐	A and C
☐	B and E
☐	C only
☐	E only

(b) Which of them represents motion at a constant (non-zero) acceleration?

*Tick **ONE** box*

☐	A, B and D
☐	A and C
☐	B and E
☐	D only
☐	E only

Acknowledgements

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Date of issue: 02-2008

Ref: **00094-2008DVD-EN**

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