# Unit 9K Speeding up

## About the unit

In this unit pupils:
- use the concept of speed
- consider the relationship between forces (including balanced forces) on an object, and its movement
- study the effects of water and air resistance on speed, and how streamlining reduces these effects
- use ideas of balanced and unbalanced forces to explain the movement of falling objects

In scientific enquiry pupils:
- measure and calculate, with appropriate precision, the speed of objects in a range of situations
- consider a range of techniques for measuring time and evaluate their relative accuracy and appropriateness for different situations
- construct and interpret speed–time graphs, describing patterns or relationships

This unit is expected to take approximately 8 hours.

### Where the unit fits in

The unit builds on work in unit 7K ‘Forces and their effects’. It relates to some of the ideas in unit 9J ‘Gravity and space’. There is further work on forces in unit 9L ‘Pressure and moments’.

It links to work on resistant materials in the design and technology scheme of work.

## Expectations

### At the end of this unit

### in terms of scientific enquiry

**most pupils will:** measure the speed of moving objects in the laboratory using a datalogger; describe patterns in data and use these to make predictions and check them; recognise that different degrees of precision are required for measuring speed in different contexts; interpret distance–time graphs of falling objects and relate these to the forces acting on objects; present a report, based on secondary sources, on an aspect of the development of faster vehicles

**some pupils will not have made so much progress and will:** measure the speed of some moving objects and relate these to speed data from secondary sources; identify factors affecting the fall of parachutes; describe an invention which has helped people to travel faster

**some pupils will have progressed further and will:** describe non-linear relationships between speed and distance travelled; justify appropriate levels of precision in measuring speed; interpret speed–time graphs of falling objects; explain how a technological development contributed to faster travel

### in terms of physical processes

**most pupils will:** manipulate and apply the relationship between speed, distance and time; relate forces acting on an object to its movement; describe how streamlining reduces resistance to air and water and how this resistance increases with the speed of the object, and relate this to the particle model; apply ideas of unbalanced and balanced forces to falling objects

**some pupils will not have made so much progress and will:** compare speeds; describe how forces change movement; give examples of streamlined objects; identify the forces acting on an object

**some pupils will have progressed further and will:** use the definition of speed in calculations and conversions from different units; relate change in movement of an object to its mass and the forces acting upon it; explain increased air resistance with the speed of an object, using the particle theory

## Prior learning

It is helpful if pupils:

- can use the concept of speed and describe changes of speed
- know that forces cause a change in movement

## Health and safety

Risk assessments are required for any hazardous activity. In this unit pupils:

- use forcemeters with fast-moving, massive objects

Model risk assessments used by most employers for normal science activities can be found in the publications listed in the *Teacher's guide*. Teachers need to follow these as indicated in the guidance notes for the activities, and consider what modifications are needed for individual classroom situations.

## Language for learning

Through the activities in this unit pupils will be able to understand, use and spell correctly:

- words relating to measurement, *eg accuracy, precision*
- words for describing the relationship between variables, *eg proportional*
- words and phrases relating to movement, *eg constant speed, acceleration*

Through the activities pupils could:

- solve a problem, consider alternatives, structure plans and organise group activity

## Resources

Resources include:

- pictures from local traffic police of speeding cars captured by speed camera
- a video of athletic events, with times or similar data
- a video of movement in space and of a spacecraft re-entering the Earth's atmosphere and of skydivers, including free-fall parachute descents
- stopwatches or datalogging sensors for measuring time and speed
- performance data for different cars, including fuel consumption, mass
- speed–time graphs for parachute descents and other contexts
- secondary sources about vehicle design and safety

## Out-of-school learning

Pupils could:

- observe traffic-speed cameras and speed limits
- collect examples of speed measured during sporting events, *eg athletics, motor racing, tennis*, and note the units and precision of the values expressed
- visit a funfair or theme park to experience changes of movement and think about the forces involved
- look up braking times in the *Highway code*

| Learning objectives<br>Pupils should learn: | Possible teaching activities | Learning outcomes<br>Pupils: | Points to note |
|---|---|---|---|
| **How fast is it moving?** | | | |
| • that speed can be determined by measuring distance travelled and time taken<br>• the units in which speed is measured<br>• to manipulate and apply the quantitative relationship linking distance, time and speed | • Show pupils videos of situations where speed is measured, *eg athletics events, world speed record attempts, cars exceeding speed limits,* and elicit what they know about how speeds can be determined. Discuss speedometers and show one, if possible.<br>• Provide pupils with times for a series of athletic events, *eg men's/women's 100m, 200m, etc; pupils' own times,* and ask them what they can deduce about the speeds in the events and how to explain their answers. If pupils have difficulty with this, establish that distance and time have to be measured and provide practice in this. Help pupils to consolidate their ideas by providing them with a series of statements which they have to classify as true or false, *eg*<br>– *If I travel 30 miles in an hour I'm going at the same speed as someone who travels 60 miles in two hours*<br>– *A car that passes the speed markings in two seconds is going faster than the car that passes them in one second*<br>• Introduce the formal relationship between speed, distance and time and help pupils use it in a variety of contexts. For some pupils, it will be appropriate to compare speeds in different units of measurement. | • recognise that in some contexts, *eg a race of a given length*, comparisons of speed can be made from measurements of time alone<br>• compare speeds from data of distance and time<br>• make measurements of distance and time and use these to calculate speeds<br>• use the quantitative relationship between distance, time and speed in a variety of contexts | • In unit 7K 'Forces and their effects' pupils had some experience of considering speed and how it might be measured.<br>• Some pupils will find it straightforward to relate the measurement of distance and time to the determination of speed; others will need a good deal of practice.<br>• If there are pupils with physical disabilities in the class, ensure that examples are used which enable them to make a positive contribution, *eg records from the Special Olympics for people with disabilities.*<br>• Extension: pupils could be asked to find out about a range of land, water and air speed records, and why distances to stars are given in light years rather than the normal units of length. |
| • to plan and organise a group activity to solve a problem<br>• to make sufficient measurements using ICT<br>• to use ICT-generated graphs<br>• to describe trends or relationships in graphs | • Remind pupils of measurements of speed they made earlier, or work with pupils to make measurements of the time taken for toy cars to roll down a ramp. Discuss with pupils what the values mean and whether the car is travelling at the same speed at each point. Introduce the term 'accelerate', to be used qualitatively.<br>• Demonstrate how a computer-connected light gate can measure the speed of the car. Ask groups of pupils to plan and make measurements of the car's speed at a number of points on the slope, to consider reasons for variations in the readings, to make predictions about how increasing the steepness of the slope or mass of the car would affect the results obtained, and to test these predictions. Use ICT to display pupils' results and ask pupils to describe the pattern and make a generalisation about the relationship shown. | • contribute to a group plan<br>• identify the difference between average speed and speed at a point<br>• collect readings of speed at a point using datalogging equipment<br>• describe the pattern in results, *eg the higher the ramp, the faster the car at the bottom; the car accelerates down the slope* | • An alternative technique is to use a digital video camera to record the movement of the car.<br>• Extension: pupils could measure the speed of sound in air using a suitable method.<br>• Extension: pupils could be asked to find out how the speed of the tennis ball during a service, or the maximum speed of a racing car during a lap, is determined. |
| • to compare and evaluate different ways of making measurements<br>• that measurements for different purposes may not be equally precise | • Ask pupils to describe how times are determined in school athletics activities, and to compare this with the light gate they have just used and with the electronic equipment used in major athletics events. It would be useful to watch a video of a major athletics event and to describe how the system works. Show pupils a sequence of world records for the 100m and ask them to explain why these values need to be more precise than school athletics records. | • suggest reasons, *eg reaction time,* why hand-held timers may be less accurate than electronically triggered timers<br>• give reasons why some specific measurements need to be more precise than others | |

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| **How do forces affect speed?** | | | |
| • that a force produces a change in speed (an acceleration)<br>• that in the absence of force, objects move at a steady speed, or remain stationary<br>• to make generalisations about forces and speed | • Demonstrate that objects can move at uniform speed with no forces acting, *eg friction-free pucks on glass, a trolley on an air track, videos of ice skating, curling.* Draw on pupils' experiences and support with use of ICT simulations.<br>• Show that introducing forces produces changes in speed – accelerations – not steady speeds.<br>• Introduce the idea that the larger the mass that the force acts on, the smaller will be the change in speed. Continue with the athletics and sports context and ask questions, *eg*<br>– *How far can you skate on smooth ice?*<br>– *How does a sprinter get a good start?*<br>– *Why are shot-putters massive and runners slim, but both need to be muscular?*<br>• Laboratory investigations, *eg ask pupils to*<br>– *arrange friction-free movement and show that constant speed needs no force, using the equipment above*<br>– *measure the force needed to get objects of different mass moving*<br>– *try to keep applying constant force and use sensing equipment to observe the change in speed, eg up slopes, on different surfaces*<br>– *use secondary data to compare the performance of cars, eg starting acceleration with engine size or with mass of car* | • give examples of movement without force, *eg skating*<br>• give examples of situations, *eg athletics, cars, classroom objects,* in which forces increase or decrease speed<br>• make simple generalisations, *eg the larger the force, the greater the increase of speed*<br>• make comparisons using information from secondary sources | • Pupils will have met the relationship between force and movement at key stage 2 and in unit 7K 'Forces and their effects', but many will wrongly associate constant force with constant speed.<br>• Consumer advice magazines are a useful source of information on car performance.<br>**Safety** – care is needed with moving massive objects. Ensure forcemeters are matched to masses to avoid damage to springs |
| **Checking progress** | | | |
| • about the forces on moving objects<br>• that objects can continue at steady speeds with no force acting in the direction of movement | • Provide pupils with pictures or diagrams of moving objects, *eg a car, a swimmer, a puck travelling on an ice rink,* and ask them to label forces shown by arrows.<br>• Reinforce the correct associations, and challenge misconceptions by showing video or CD-ROM sequences and discussing these, *eg ball sports, space travel, astronauts on the Moon*. | • identify forces and show their directions, *eg friction, thrust, upthrust, weight*<br>• state that when forces are balanced, objects do not change speed, and apply this to everyday situations, *eg ball sports* | • Take the opportunity to challenge any pupil's association between force and constant speed, *eg after the ice puck has been struck, it has no force on it in the direction it travels.* |
| **How can we increase speed?** | | | |
| • that air resistance and water resistance are forces that oppose motion<br>• how the effects of air resistance and water resistance can be reduced by streamlining | • Ask pupils to suggest why streamlining is important to the shapes of humans and vehicles and, with the class, compile a chart showing examples, *eg body shape of fish, sportswear worn by athletes, wind deflectors on lorries*. Ask pupils to write a radio advertisement for sportswear or a car, emphasising the advantages its streamlining will bring. | • give examples of air and water resistance opposing motion<br>• explain that in order to increase speed without increasing thrust, resistance (or drag) has to be reduced<br>• describe ways in which streamlining is achieved and why streamlining is important | • Streamlining of animals is also covered in unit 7C 'Environment and feeding relationships' in relation to adaptation to an environment. |

| Learning objectives<br>Pupils should learn: | Possible teaching activities | Learning outcomes<br>Pupils: | Points to note |
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| • that air and water resistance increase with increasing speed<br>• that the energy required to keep a moving object moving depends on air resistance | • Establish with pupils that air resistance increases with speed, *eg by reference to experiences of walking and running while carrying a large piece of card or an open umbrella carried horizontally*, and compare data on fuel consumption of cars at different speeds. Remind pupils that fuel consumption (on a horizontal road) relates to overcoming resistive forces, not to keeping cars moving. | • describe differences in the effect of air resistance when walking or running<br>• identify that fuel consumption for a particular vehicle is greater at greater speed and relate this to air resistance | • At key stage 2, pupils are likely to have considered the effects of air resistance on themselves when running, and investigated the effect of shape on movement through a liquid.<br>• Extension: ask pupils to find information on, and draw inferences from, the relative performance of cars in relation to streamlining and fuel consumption. |
| • to apply knowledge of the particle model in explaining air resistance | • Show a video/simulation of a space capsule becoming red-hot as it passes through the atmosphere. Ask pupils to use the particle model to suggest an explanation for the observation. | • explain that increased air resistance leads to a greater heating effect<br>• explain how, at higher speeds, the movement of an object is resisted by more particles | • Pupils could be asked to find out about the properties of materials developed for cladding space capsules, *eg Teflon*, and high-speed planes (metals with high melting points). |
| **How do parachutes work?** | | | |
| • that when the upward force of air resistance balances the downward force of weight, the speed remains constant<br>• to interpret distance–time graphs and relate them to the situation from which data was obtained<br>• to translate data presented in one form into another | • Show pupils video clips of skydivers, including in free fall and landing, and ask them to explain the forces acting as the parachute descends. Provide pupils with graphs that show how the speed of descent changes with height, and ask them to interpret them in terms of changes in the upward force (air resistance), while the downward force (weight) remains constant. For some pupils, extend the activity to the interpretation of speed–time graphs – firstly for parachutes descending and then in other contexts. | • identify the forces of air resistance and weight<br>• state that as the parachute begins to descend, it speeds up and air resistance increases<br>• explain that when air resistance balances weight, the parachute no longer speeds up<br>• identify on a speed–time graph the point at which the upward and downward forces balance<br>• 'tell the story' of a speed–time graph and translate a description of motion into a sketched speed–time graph | • At key stage 2, pupils are likely to have investigated factors affecting the time taken for a parachute to fall. Some pupils could carry out a similar investigation, and use the results to consolidate understanding of some aspects of investigative work, *eg repeating measurements, presenting and interpreting graphs.*<br>• Software simulations, CD-ROMs or videos could illustrate this.<br>• A formal treatment of acceleration and terminal velocity is not required at key stage 3. However, some pupils will be able to describe and interpret speed–time graphs. |

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| **Reviewing work** | | | |
| • to use understanding to evaluate a device or contribution of a scientist/inventor | • Provide groups of pupils each with a question or task relating to making things go more quickly, and ask them to present a report, or to summarise key points based on research from secondary sources. These could include:<br>– how scientists/inventors improved the design of vehicles/invented new vehicles, *eg George Stephenson ('The Rocket'), Christopher Cockerill (hovercraft), George Cayley (aeroplane), Mike Burrows (bicycle)*<br>– the history of cycle design, including clothing and safety features to cope with the dangers of travelling faster | • identify factors that affect the speed of moving objects in terms of developing technology and social contexts | • This work could link with the design and technology scheme of work, *eg unit 9A(ii) 'Selecting materials (resistant materials)'*. |