9I
Forces and motion

This unit starts by revising some aspects of forces and their effects, energy stores and transfers. It then looks at calculations of speed and relative speed, and representing journeys on distance–time graphs. The final topics look at simple machines (levers, ramps and pulleys).

Recommended teaching time for unit: 7.5–10 hours

There is an opportunity for focused development of Literacy & Communication skills in Topic 9Ib. A similar opportunity for focused development of Working Scientifically skills is found in Topic 9Ic. You may wish to spend additional time on these topics should you feel that your students would benefit from these skills-development opportunities.

From previous work, most students will be able to:

- identify forces on stationary and moving objects, and describe the effects of balanced and unbalanced forces on objects (7K)
- recall ways in which energy can be stored and transferred, and identify energy stores and transfers in different situations (7I).

Topic 9Ia revises work from Unit 7K on different forces, and the effects of balanced and unbalanced forces on stationary and moving objects.

Topic 9Ib revises work from Unit 7I on ways in which energy can be stored and transferred. The Literacy & Communication pages look at how a piece of writing needs to be suited to its purpose, audience and format.

Topic 9Ic introduces the formula relating speed, distance and time, and shows how journeys can be represented on a distance–time graph. The Working Scientifically pages look at how simple formulae can be rearranged and how to calculate the gradient of a line on a graph.

Topic 9Id looks at levers and their uses. The page introduces the ideas of moments and of things being balanced when the moments are the same in each direction.

Topic 9Ie introduces ramps and pulleys as further examples of simple machines, and looks at the idea that an increase in force also results in the increase in the distance moved by the effort force. This is quantified by introducing the formula relating work, force and distance.

National Curriculum coverage

This unit covers the following statements from the UK National Curriculum for Science (2013):

- speed and the quantitative relationship between average speed, distance and time (speed = distance/time)
- the representation of a journey on a distance–time graph
- relative motion: trains and cars passing one another
- simple machines give bigger force but at the expense of smaller movement (and vice versa): product of force and displacement unchanged
- work done and energy changes on deformation
- *non-contact forces: gravity forces acting at a distance on Earth and in space, forces between magnets* and forces due to static electricity
- *forces as pushes or pulls, arising from the interaction between two objects*
- *using force arrows in diagrams, adding forces in one dimension, balanced and unbalanced forces*
- *forces: associated with deforming objects; stretching and squashing – springs; with rubbing and friction between surfaces, with pushing things out of the way; resistance to motion of air and water*
- *forces measured in newtons, measurements of stretch or compression as force is changed*
- *other processes that involve energy transfer: changing motion, dropping an object, completing an electrical circuit, stretching a spring, metabolism of food, burning fuels*
- *energy as a quantity that can be quantified and calculated; the total energy has the same value before and after a change*
- *comparing the starting with the final conditions of a system and describing increases and decreases in the amounts of energy associated with movements, temperatures*, changes in positions in a field, in elastic distortions and in chemical compositions
- *using physical processes and mechanisms, rather than energy, to explain the intermediate steps that bring about such changes.*

N.B. Statements in italics cover revision from other units.

In addition to covering a variety of Working Scientifically statements, this unit has a focus on:

- apply mathematical concepts and calculate results.

Literacy & Communication skills

- identify features of writing produced for different purposes and audiences.
- write material in different styles depending on the purpose, audience and format.

Maths skills

- apply mathematical concepts and calculate results
- draw and interpret distance–time graphs
- calculate average (mean) speed from a distance–time graph
- substitute into formulae
- Exceeding: change subject of a simple formula
- Exceeding: calculate gradient of line on graph.

Cross-curricular opportunities

9Ia, 9Ib – History – development of technology

9Id – D&T – use of levers

9Ie – D&T – design of 'mousetrap cars'; mechanisms

9I Background information

9Ia Forces and movement

Refer to the Background information in Unit 7K.

9Ib Energy for movement

Refer to the Background information in Unit 7I for details about energy.

9Ic Speed

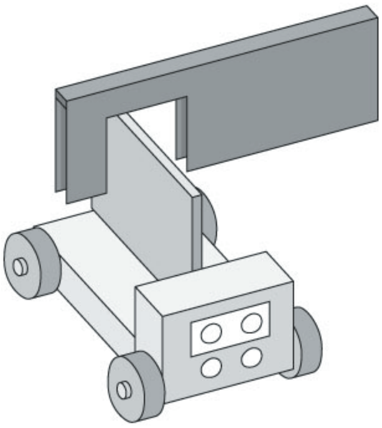
Students tend to grasp the basic concept of speed fairly easily. The main problem is likely to be how the various units (m/s, km/h, mph) relate to each other. Students will be familiar with mph but should be encouraged to look at speed in terms of m/s and km/h.

Measuring speed in the laboratory

Stop clocks can be used to time movement that is fairly slow, or takes place over a long distance (e.g. students measuring their own walking speed). However, datalogging equipment will provide a more accurate way of measuring speed.

Light gates contain a source of light and a sensor, both linked to a computer that can detect when the beam of light has been broken. Two light gates can be set up at the ends of a ramp or track to measure the time taken for an object to go from one to the other.

Most computer programs that come with light gates also calculate speed. A card of known length is attached to the moving object and the computer measures the time for which the light beam is broken. The length of the card is entered into the program, which can then work out the speed the object was moving.



Range sensors are also available with some datalogging equipment. They time reflections of ultrasonics to measure the distance to an object. If they are set up at one end of a ramp or track they can continuously measure the distance to the object and the computer program can be set up to convert distance and time information into speed.

Ticker timers have long been used for speed measurements, although the use of electronic datalogging equipment is preferable as ticker tape is messy and can be difficult to use to calculate speeds. A ticker timer consists of a vibrating needle that puts dots onto a paper tape at regular intervals – typically 50 dots per second. The tape can be cut into 10-dot strips, which are stuck onto graph paper to form a distance–time graph (with each strip representing 0.2 s). The gradient of a line joining the tops of the strips is the speed.

Scalar and vector quantities

The national curriculum mentions displacement–time graphs. Displacement is a vector quantity, which means it has a direction as well as a magnitude. Distance is a scalar quantity, meaning it only has a magnitude.

- You walk 1 km due north in a straight line. Your displacement is 1 km north and the distance covered is also 1 km.
- You walk 0.5 km north and then turn round and walk 0.5 km south. You have covered a distance of 1 km, but your displacement is 0 because you are back where you have started from.
- You walk for 5 km along winding paths, but your destination is only 3 km west of your home. Your displacement is 3 km west.

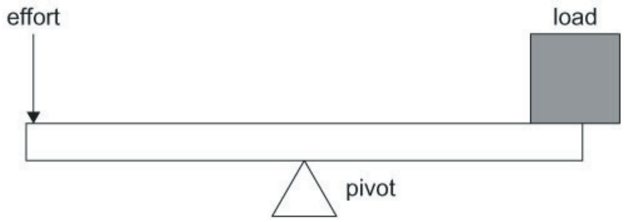
Another commonly encountered vector quantity is velocity. Speed is how fast you are moving and is a scalar quantity. Velocity is how fast you are moving in a particular direction. A car driving around a roundabout may have a steady speed of 20 km/h, but its velocity will be continuously changing because its direction is continuously changing.

9Id Turning forces

Classes of lever

A lever is a simple machine involving a rigid bar and a pivot (or fulcrum). There are three classes of lever.

- Class 1 lever: The pivot is always between the effort and load.



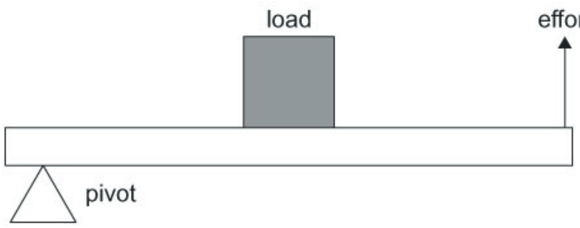
If the load is closer to the pivot than the effort, then the lever acts as a force multiplier – the effort is smaller than the load, but it moves further.

Examples: crowbar, pliers, scissors, seesaw.

If the load is further away from the pivot than the effort, the lever acts as a distance multiplier – the effort is greater than the load, but the load moves further.

Example: large scissors, if the object being cut is near the tips.

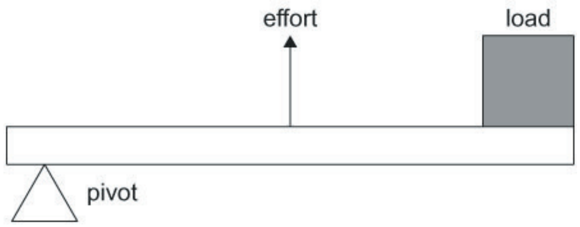
- Class 2 lever: The effort and load are both on the same side of the pivot and the effort is always furthest from the pivot.



The effort is less than the load and always moves more than the load. The lever acts as a force multiplier.

Examples: wheelbarrow, bottle opener.

- Class 3 lever: The effort and load are on the same side of the pivot and the load is furthest from the pivot.



The effort is greater than the load and the load moves more than the effort. The lever acts as a distance multiplier.

Examples: fishing rod, arm lifting a weight.

Oars as Class 2 levers

Oars are levers. An oar is a long piece of wood or metal with a blade on one end and rests in a rowlock on the edge of the boat. The rowlock acts like a pivot – and herein lies the source of confusion.

If you are sitting in a stationary boat and use the oar to flick water (rather than to propel the boat) then the oar is a Class 1 lever with the pivot at the rowlock. However oars are intended to be used to move the boat along, in which case they are acting as Class 2 levers. Considered from the boat, the oar is pivoting about the rowlock, but if you consider a wider frame of reference, the part of the lever that remains stationary (and so can be thought of as the pivot) is the oar blade in the water. In this case the effort is still the rower pulling on the opposite end of the oar and the load is the point at which the oar presses against the rowlocks – this is the force that is propelling the boat along. The effort distance is longer than the load distance and so the oar is acting as a force multiplier.

If students still need convincing of this, ask them to think about the load and effort distances if oars are Class 1 levers. The distance between the oar blade and the rowlocks (the load distance, in the Class 1 scenario) is normally much greater than the distance between the rowlocks and the end of the oar that the rower is pulling on (the effort distance, if it is a Class 1 lever). This would make the oar a distance multiplier – which is not what is wanted when a large force is needed to move the boat.

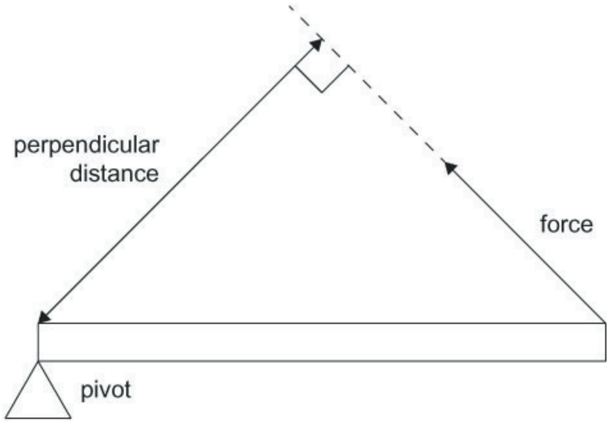
Note that the gearing on bicycles (see following) acts as a distance multiplier – but the two cases are not the same. There are much greater resistance forces to be overcome in propelling a boat than in propelling a bicycle and the top speed of a human-powered boat is much smaller than the top speed of a bicycle. This means a force multiplier is needed for a boat and a distance multiplier for a bicycle.

Moments

The moment is the turning effect of a force. It is calculated by measuring the force, and the perpendicular distance between the force and the pivot:

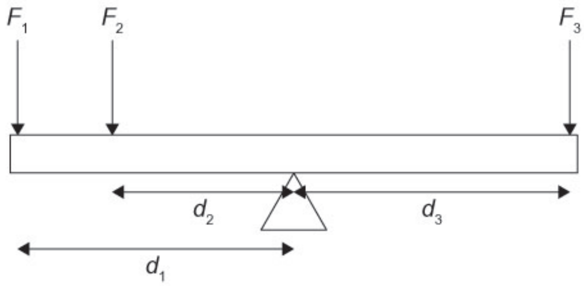
$$\text{moment} = \text{force} \times \text{perpendicular distance}$$

When the force acts at right angles to the lever, the perpendicular distance is just the distance between the pivot and the force. However, if the force is acting at an angle the distance used must be perpendicular to the direction in which the force is acting.



Balancing

When a body is balanced, the sum of the clockwise moments is equal to the sum of the anticlockwise moments. If more than one turning force acts in a particular direction, the moments of all forces are added.



$$(F_1 \times d_1) + (F_2 \times d_2) = F_3 \times d_3$$

The position of the centre of gravity (or centre of mass) of an object is important when considering balancing. Briefly, all the weight on different parts of an object can be considered to act at one particular point. If the centre of gravity is over the base of the object, it will balance. If not, the object will topple over.

Gears

Gear ratios are normally given in terms of the number of teeth on the gear wheels (or sprockets, the name for toothed wheels that are connected with a chain, as on a bicycle). Explanations in terms of the radii of the different sprockets are effectively the same: all the teeth are spaced to fit the links in the chain, so the number of teeth will be proportional to the radius.

9Ie More machines

Ramps and pulleys are further examples of simple machines. Here, they both act as force multipliers only.

9Ia
Forces and movement

This grid shows the basic concepts met in this topic, together with a scheme of cognitive progression for each concept. Opportunities to cover learning and progression are given. Working Scientifically concepts are integrated throughout the materials.

Conceptual statement	Cognitive progress					
	Remembering (a)	Understanding (b)	Applying (c)	Analysing (d)	Evaluating (e)	Synthesising & creating (f)
Moving objects have a top speed.	Recall that drag changes with speed.	Describe how drag changes with speed.	Explain why drag changes with speed, i.e. more particles hitting the object per second, more fluid to be pushed out of the way per second. Explain how the resultant force on a moving object can change with speed.	Explain why vehicles or other moving objects have a top speed. Explain why a falling object reaches terminal velocity. Interpret a speed–time graph for objects reaching maximum speeds. Use and interpret the equation linking drag, density, speed and frontal area.		Measure the speed of a falling object and produce a speed–time graph.
How an object behaves will depend on the interaction of the different forces upon it.	Identify the forces acting on a [moving, stationary] object and the directions in which they act. State what is meant by: resultant force.	Interpret and draw a free-body force diagram.	Calculate the resultant of forces acting in one dimension.		Use scale drawings to find the resultant of forces in two dimensions. Use the idea that a force can be represented by two orthogonal forces.	
Resistive forces have a variety of effects.	Recall some effects of frictional forces. Describe some ways in which friction can be changed.	Explain some ways in which friction can be changed.	Identify simple situations in which friction is [helpful, not helpful]. Apply a knowledge of friction to road safety.	Suggest how and why friction has been [reduced, increased] in unfamiliar situations.	Evaluate the ways in which friction has been [reduced, increased] in unfamiliar situations.	Find out about and use the coefficient of drag in calculations.

Conceptual statement	Cognitive progress					
	Remembering (a)	Understanding (b)	Applying (c)	Analysing (d)	Evaluating (e)	Synthesising & creating (f)
Upthrust is a force that acts in liquids and gases.	State what is meant by: upthrust.	Explain why an object floats.	Recall the factors that affect the amount of upthrust on an object. Explain how the upthrust depends on the weight of fluid displaced.	Work out if something will float.		Use ideas about density changes to explain how a hot air balloon flies/how the depth of a submarine is controlled. Use ideas about displacement to explain phenomena connected with floating and sinking.
Weight and mass are not the same.	State what is meant by: mass, weight. Recall the direction in which gravity acts.	Describe the difference between mass and weight.	Use the formula relating mass, weight and gravitational field strength.	Compare the way in which force meters and balances that compare masses work.		
Forces can be balanced or unbalanced.	State what is meant by: balanced forces, unbalanced forces.	Explain the effects of [balanced, unbalanced] forces in simple situations.	Explain the effects of [balanced, unbalanced] forces in unfamiliar situations. Explain why a vehicle needs a force from the engine to keep moving at a constant speed.	Work out the [resultant, overall effect] of two forces acting along the same line. Explain why the forces on a falling object change.		
There are different types of forces that resist motion.	Recall the different types of resistive forces. State what is meant by: friction, air resistance, water resistance, drag.	Describe how friction forces affect movement.	Describe the ways in which drag forces can be [increased, reduced].	Describe the causes of [air, water] resistance (i.e. in terms of skin friction and 'pushing the air/water out of the way').		
There are many different types of forces, including magnetism, static electricity, gravity, friction.	Recall the names of simple forces.	Identify [situations, places] where different forces are likely to be found.	Describe the effects of different forces on objects.	Identify different types of forces acting on objects.		

Objectives

Developing:

1. Name different forces, such as weight, friction, upthrust, drag.
2. Identify the forces acting on moving and stationary objects, and the directions in which they act.
3. Explain the effects of balanced and unbalanced forces in a range of situations.
4. Describe how drag changes with speed.

Securing:

5. Calculate the resultant of forces acting along the same line.
6. Explain why vehicles or other moving objects have a top speed.

Exceeding:

7. Use scale drawings to find the resultant of forces in two dimensions.

Student materials

Be prepared
Exploring 1 requires materials to make model sleds or travois and rollers. Wheels from a modelling kit may also be needed.

STARTERS

1: Quick Quiz

Developing/Securing/Exceeding

BA

Use the 9I Quick Quiz for baseline assessment. Students can use the 9I Quick Quiz Answer Sheet to record their answers. You could use the Quick Quiz to review the relevant prior learning for the whole unit and then use this information to plan relevant actions depending on students' confidence. Returning to the Quick Quiz at the end of the unit could monitor development of understanding. Alternatively, just use the first four questions, which relate to this topic, to provide information on students' prior learning for your planning. These questions could be revisited formatively in a plenary for this topic. This topic revises material that was originally covered in Unit 7K (mainly Topics 7Ka, 7Kc and 7Kd) and in Unit 8I (mainly Topics 8Id and 8Ie). The Quick Quiz questions for these units could also be used to help assess prior learning. For example, use the Year 7 questions in a competitive class quiz with small group teams.

See the ASP for more information about Quick Quizzes.

Course resources
ASP: 9I Quick Quiz; 9I Quick Quiz Answer Sheet. Optional: 7K Quick Quiz (Year 7); 7K Quick Quiz Answer Sheet (Year 7); 8I Quick Quiz (Year 8); 8I Quick Quiz Answer Sheet (Year 8).

2: Name the forces

Developing

BA

The **AT** presentation *Forces and transport* provides images of different forms of transport. Show students the photos and ask them to jot down the names of the different forces on each vehicle and what the forces are doing. Encourage them to identify any pairs of forces that are balanced or unbalanced.

For the first two or three images, you could get pairs or groups to come to the front of the class to present the forces they have agreed exist. Class comments and discussion will identify any problems or misconceptions before allowing the groups to work through the remaining vehicles independently.

The **AT** video *Using forces* provides images of various uses of forces and simple machines. This can be used in place of the **AT** presentation *Forces and transport*, or in addition to it. The video is best used with the sound off at this stage, as the commentary discusses machines that are not covered until Topics 9Id and 9Ie.

If this task is to be revisited as a plenary (Plenary 4), select the part of the slideshow that does not give the answers.

Exceeding: The last four slides in the presentation ask students to identify forces that will be larger or smaller in the modern form of transport than in the old version. For example, modern trains go much faster than early ones, so the forces of air resistance on them will be greater.

Course resources
AT: Presentation *Forces and transport*. Video *Using forces*.

3: True or false

Developing/Securing

BA **FA**

Students work in pairs or threes to write out five statements about forces: three should be correct statements and two deliberately incorrect. Give students a few minutes to work, then ask each group to read out one of their statements. The rest of the class should show a 'thumbs up' for true statements, and a 'thumbs down' for false ones. If a significant number of students classify a statement incorrectly, ask them to explain their reasoning. Misconceptions can be dealt with at this point, or kept until the end of the lesson when this activity can be revisited as a plenary. In this case, keep your own note of any questions that indicated significant misunderstandings. Students should note down any areas that they were unsure of, along with any correct explanations needed.

EXPLORING TASKS

1: The transport challenge

Developing/Securing/Exceeding

Prac **WS**

Students investigate different ways of moving a load. This can be a very open-ended investigation, or you can restrict students to comparing just two methods. Worksheet 9Ia-2 provides hints for planning an investigation, drawing conclusions and evaluating the investigation. The sheet mentions rollers, a sled and a travois as alternatives to wheels. Wheels could also be investigated; it is much easier to use wheels from a modelling kit than to ask students to build their own.

Ideally, students should be able to test the models on different surfaces, as travoises were in use long after wheels were invented because they were more practical over rough ground. If sleds are investigated, a tray of sand can be used to model snow.

Check that students recall how to calculate means.

Developing: Students follow the instructions on Worksheet 9Ia-2 and compare the force needed to pull a mass, such as a small house brick or 1 kg mass, along a surface with and without rollers. Using rollers will require some teamwork: one student should feed rollers in at the front of the brick and collect them as they emerge from the rear, while another pulls and reads the force meter. Students can then plan their own investigation to compare the use of rollers on different surfaces, or to compare rollers with a travois. When modelling a travois, the horse could be modelled by fastening a loop of string to the front of the travois to hold it up, while a second loop is used to pull the travois using a force meter. This could be a useful point to discuss during evaluation.

Securing: Students plan their own investigation using the hints on Worksheet 9Ia-3. Have a range of apparatus for students to look at for ideas.

Exceeding: Encourage students to expand their investigation to find out which of their methods is best on each of several different surfaces, or to investigate questions such as whether or not the number of rollers makes any difference.

⚠ Ensure adequate supervision if students are working outside the classroom.

Course resources
AP: Worksheets 9Ia-2; 9Ia-3.

Equipment (per group)
Small house brick or 1 kg mass, force meter, 10 pieces of wood to be used as rollers (lengths of dowel or round-section pencils will do), lengths of dowel to be used for travois (strong enough to support the mass provided), model sled (wood, with two runners glued on, which is large enough to take the mass provided), string, access to different surfaces including grass, gravel and rough concrete/tarmac if possible.

2: Calculating resultants

Developing/Securing

Worksheet 9Ia-6 provides questions to give students practice in calculating the resultant of several forces and on working out the effect on movement.

Course resources
AP: Worksheet 9Ia-6.

3: Safer roads

Developing/Securing

This task is best carried out after Explaining 4. Ask students to make a road safety poster or computer presentation. The presentation should describe the forces on a moving car, how these forces can be changed (e.g. extra friction from applying brakes, less friction on wet or icy roads, etc.) and how the balance of these forces affects its movement. The main road safety point that should be emphasised is that it takes longer in both distance and time to stop if you are travelling faster, so a safe driving speed depends on the surroundings, traffic and road conditions.

These presentations could be revisited when students have studied the Literacy material in Topic 9Ib and rewritten for different audiences, such as drivers, pedestrians and cyclists (who should be aware that cars will take longer to stop in certain conditions).

Equipment
Internet access.
Optional: poster paper, scissors, glue, coloured pencils.

EXPLAINING TASKS

1: 9Ia Moving things (Student Book)
Developing/Securing/Exceeding
BA
This page introduces the theme of moving things and provides some questions on forces and energy that can be used as an initial baseline assessment.

The **AT** video *Using forces* (which may already have been used in Starter 2) shows some uses of simple machines in historical and modern times. Students can make a note of any machines they identify. This video will be revisited in Topic 9Ie.

Course resources
AT: Video *Using forces.*

2: 9Ia Forces and movement (Student Book)
Developing/Securing/Exceeding
FA
These pages revise ideas about forces and their effects that were first studied in Units 7K and 8I. Diagram C refers to the force from the sails. You may wish to discuss the fact that this force is caused by air resistance – the resistance of the sail to the wind, as opposed to the type of air resistance that students have looked at before, which is due to the movement of an object through the air.

Questions 2 and 7 can be used for formative assessment. Worksheet 9Ia-1 is the Access Sheet.

Course resources
AP: Worksheet 9Ia-1.

3: Air track demonstration
Developing/Securing
Prac
Demonstrate the effects of friction on movement using a linear air track. Show students that with the air off the gliders do not keep moving unless a force is continually applied to them and show how movement continues after the initial force is removed when the air is on.

The demonstration can be extended by fixing a sheet of card to the gliders at right angles to the track, to model the effect of a sail. A fan can be used to make the glider 'sail' and show that higher fan speeds will produce faster glider movement.

Equipment
Linear air track and blower, desk fan, card, sticky tape.

4: Stopping distances
Developing
The **AT** presentation *Stopping distances* explains how a total stopping distance is made up of a thinking distance and a braking distance, and describes some factors that affect these distances. The presentation includes questions to relate balanced and unbalanced forces to changes in movement. Students are not expected to recall stopping distances at different speeds.

This task can be followed up by Exploring 3.

Course resources
AT: Presentation *Stopping distances.*

PLENARIES

Most plenaries can be used for formative assessment. Suggested assessment, feedback and action strands of formative assessment can all be modified. See the ASP for further information and ideas on formative assessment.

1: Quick Check
Developing/Securing/Exceeding
FA
Assessment: The 9Ia Quick Check sheet provides a set of sentence starters for students to complete using the conjunctions given on the sheet. Students work alone or in pairs to complete the sentences. They should be encouraged to write more than one ending for each, if they can.

Feedback: Ask for volunteers to read out their completed sentences, and ask others to comment on whether or not they are correct or how they could be improved. Students could also show their confidence in their verdicts using 'thumbs up' (confident), 'thumbs level' (not sure) or 'thumbs down' (very unsure).

Action: If there are areas of common difficulty, briefly revisit these, and also note them for further revisiting and clarification throughout the unit.

Course resources
ASP: 9Ia Quick Check.

2: Thinking about forces
Developing/Securing
FA
Assessment:
Consider All Possibilities: A ship is speeding up. (Possible answers: the wind is coming from behind and has got stronger; the crew have put more sails up/increased the force from the engine; the wind is coming from ahead and has got weaker; it has cast off a boat/barge that it was towing.)

Consider All Possibilities: Car A has a higher top speed than car B. (Possible answers: car A has a more powerful engine/can produce a bigger force from its engine; car A has less friction in its wheels, etc.; car A has a more streamlined shape so its air resistance is less.)

Odd One Out: magnetism, upthrust, air resistance. (Possible answers: magnetism is the only non-contact force; magnetism is the only one that can push or pull; upthrust is the only one that always acts vertically upwards; air resistance is the only one that depends on the object being in a state of motion/the speed of movement/the shape of the object.)

Feedback: Give students a few minutes to think of their responses, then ask for volunteers to provide answers. Ask the class to choose the best answers to each question and suggest why they are the best.

Action: Get students to categorise the features of a 'good' answer and to link to areas in which they need to improve, for example, they do not understand the science ideas, poor recall, not reading the task properly, etc. Group together students with similar issues and get them to revise together one area identified for improvement for their group. They could do this by working on a combined 'good response', using the features discussed in class.

The **AT** presentation *9Ia Thinking skills* can be used for this activity.

Course resources
AT: Presentation *9Ia Thinking skills.*

3: Forces on a journey

Developing/Securing

FA

Worksheet 9Ia-4 provides a story about a journey and students are asked to note places in the story where forces would be balanced, and places where they would be unbalanced.

At the end of the activity get students to note two or three points that they have learnt during it and write one question about an area they are still unsure about. Collect in the questions and make sure these are dealt with over the next few lessons.

Developing: Blank out the questions before copying the sheet. Students can circle sections of text and label them with B or U to show whether they think the forces are balanced or unbalanced. Alternatively, read the text to students, then read it again, but ask students to put their hands up when they notice a situation where they can describe the forces. Each situation can be discussed before moving on to the next.

Securing: Students number places in the text, and write separate sentences to state what the forces are and which force of a pair is the biggest.

Exceeding: Students should be encouraged to consider all forces on the objects at different times, including weight and the upwards force from the ground, or upthrust, and say what the single resultant force would be in each situation. If necessary, discuss the fact that objects moving vertically at a constant speed (such as boxes being lowered or hauled up) do not have a resultant force on them. This is normally harder to grasp than the fact that objects moving horizontally at a constant speed have no resultant horizontal force.

Course resources
AP: Worksheet 9Ia-4.

4: Name the forces

Developing

FA

Return to the AT presentation *Forces and transport* used in Starter 2. Show students the images of different forms of transport and ask them to name the different forces on each vehicle and say what the forces are doing. Encourage them to identify pairs of forces that are balanced or unbalanced.

Course resources
AT: Presentation *Forces and transport*.

HOMEWORK TASKS

1: Grand Prix race 1

Developing

Worksheet 9Ia-5 provides simple questions about balanced and unbalanced forces.

Course resources
AP: Worksheet 9Ia-5.

2: Grand Prix race 2

Developing/Securing

Worksheet 9Ia-7 provides questions about balanced and unbalanced forces.

Course resources
AP: Worksheet 9Ia-7.

3: Forces in two dimensions

Developing/Securing/Exceeding

Worksheet 9Ia-8 explains how the resultant of two forces at an angle to each other can be worked out graphically.

Course resources
AP: Worksheet 9Ia-8.

ActiveLearn

Three ActiveLearn exercises are available for this topic: Forces and movement 1; Forces and movement 2; Forces and movement 3.

9Ib
Energy for movement

This grid shows the basic concepts met in this topic, together with a scheme of cognitive progression for each concept. Opportunities to cover learning and progression are given. Working Scientifically concepts are integrated throughout the materials.

Conceptual statement	Cognitive progress					
	Remembering (a)	Understanding (b)	Applying (c)	Analysing (d)	Evaluating (e)	Synthesising & creating (f)
There are different types of forces that resist motion.	Recall the different types of resistive forces. State what is meant by: friction, air resistance, water resistance, drag.	Describe how friction forces affect movement.	Describe the ways in which drag forces can be [increased, reduced].	Describe the causes of [air, water] resistance (i.e. in terms of skin friction and 'pushing the air/water out of the way').		
There are formulae to work out kinetic and gravitational potential energies.	Recall that there is a formula to work out [kinetic, gravitational potential] energy. Recognise the term [KE, GPE].	Describe the factors that affect an object's [kinetic, gravitational potential] energy.	Use the formula KE = $1/2 \times m \times v^2$ Use the formula GPE = $m \times g \times h$		Carry out calculations on work done to show the dependence of braking distance for a vehicle on initial velocity squared (work done to bring a vehicle to rest equals its initial kinetic energy).	
Energy cannot be created or destroyed, but in most energy transfers some energy is lost in a form that is not useful.	State the meaning of: efficiency. Recall the law of conservation of energy. Recall some advantages of low-energy appliances.	Identify useful and wasted energies. Describe whether a machine is more efficient than another.	Calculate energy efficiencies. Use data to consider cost efficiency by calculating payback times.	Explain why the efficiency can never be greater than 1 or greater than 100%.	Use data to evaluate [processes, objects, energy-saving devices].	
Renewable or non-renewable energy resources have advantages and disadvantages.	State the meaning of: hydroelectricity, geothermal, biomass/biofuel, solar energy, wind energy, tidal power.	Describe advantages and disadvantages of different [renewable, non-renewable] energy resources.	Suggest ways in which our use of fossil fuels/non-renewable fuels can be reduced.	Explain the idea of a 'carbon-neutral' fuel. Explain why biofuels are not necessarily carbon-neutral.	Defend or oppose a decision in favour of using an energy resource in a certain area. Evaluate ways of reducing consumption of fossil fuels.	Decide and explain the best energy resources to use in an area.

Conceptual statement	Cognitive progress					
	Remembering (a)	Understanding (b)	Applying (c)	Analysing (d)	Evaluating (e)	Synthesising & creating (f)
Fuels are used to release energy, usually by combustion.	Recall examples of renewable and non-renewable fuels and their sources.		Explain the source of the energy in [food, fuels].	Explain how the Sun is the ultimate source of the energy used in [hydroelectric, wind, wave] power.		
Energy can be transferred into different forms.	Recall the different ways in which energy can be stored. Recall the different ways in which energy can be transferred.	Identify situations in which energy is stored. Identify situations in which an energy transfer is taking place.				

Objectives
Developing:

1. Recall the different ways in which energy can be transferred and stored.
2. Identify situations in which energy is stored or in which an energy transfer is taking place.
3. Recall examples of renewable and non-renewable energy resources.
4. Identify useful and wasted energies.
5. Recall the law of conservation of energy.

Securing:

6. State the meaning of efficiency.
7. Describe the factors that affect an object's kinetic energy and gravitational potential energy.

Exceeding:

8. Apply ideas about energy stores and transfers to complex situations.

Focused Literacy & Communication Objectives
This topic provides an opportunity to focus on key Literacy & Communication skills.

1. Identify features of writing produced for different purposes and audiences.
2. Write material in different styles depending on the purpose, audience and format.

Student materials

STARTERS

1: Alphabet words
Developing
BA **FA**
Assessment: Ask students to write out the alphabet vertically on a sheet of scrap paper and then to work in small groups to write one or more words for each letter that are connected with energy stores, transfers and resources.

Feedback: Give them a few minutes for this task and then ask for suggestions. Ask for someone to explain the meaning of each word suggested. Ask the rest of the class to say if each definition is correct, or if they can improve on the definitions given. If you wish to introduce a competition, a group gets a point for a word only if no other groups have suggested that word.

Action: Make a note of any words that students have difficulty defining and keep the list to revisit at the end of the lesson. Get students to add any keywords that were not suggested (see the Word Sheets for this unit) and ask for suggested definitions for these as well. Students should keep their own list of words and definitions that includes their own and other groups' suggestions.

Course resources
ASP: 9I Word Sheets.

2: Spot the energies
Developing
FA
The **AT** presentation *Energy and transport* provides images of different forms of transport (similar to those in **AT** presentation *Forces and transport* used in 9Ia Starter 2). Show students the photos and ask them to jot down the energy resources used by each one, and to suggest some of the ways in which energy is transferred by each vehicle. Encourage them to consider useful and wasted energy transfers. They could do this first individually then compare answers with a partner. If

this task is to be revisited as a plenary (Plenary 4), select the part of the slideshow that does not give the answers.

Exceeding: Ask students to draw Sankey diagrams to represent the energy transfers in one or two machines.

Course resources
AT: Presentation *Energy and transport*.

3: Quick Quiz
Developing/Securing/Exceeding
BA

This topic revises material first covered in Unit 7I. The Quick Quiz from that unit could be used here as a way of assessing prior learning concerned with energy and energy transfers, and to help you to plan learning in this topic. If not already used, the four relevant questions from the 9I Quick Quiz can also be used here. Students can use the Unit 7I and 9I Quick Quiz answer sheets to record their answers. Students should note any areas from Unit 7I that they feel unsure about and revisit the relevant questions at the end of this topic.

Course resources
ASP: 7I Quick Quiz (Year 7); 7I Quick Quiz Answer Sheet (Year 7); 9I Quick Quiz; 9I Quick Quiz Answer Sheet.

EXPLORING TASKS

1: Circus of energy transfers
Developing
Prac

Set up a circus of energy transfer devices and ask students to identify the initial energy and final energy stores for each one, including which of the final energy stores is useful and which is wasted. Worksheet 9Ib-2 provides some questions to go with each set of apparatus that can be given to students, or cut up and used as cards placed with the equipment. Hold a mini-plenary session during this activity to discuss the answers when students have had time to visit all the stations. If time is short, students could consider only one or two pieces of apparatus and report back in the plenary session. The **AT** interactive *Energy circus* provides a matching exercise for students to link energy stores and transfers to some of the suggested practical activities. This can be used after the practical to help students to summarise what they have found. Explaining 3 provides an alternative activity.

Developing: Students answer only questions 1–4 on the worksheet.

⚠ Ensure that any items of domestic equipment used have been PAT-inspected and appear on the school's inventory or are known about by the school's Health and Safety manager. Any heating apparatus should be set to get warm, not hot, to the touch. Ensure students appreciate health and safety considerations for each activity, as they will be handling the equipment. It may be helpful to have a technician to support the class.

Course resources
AP: Worksheet 9Ib-2.
AT: Interactive *Energy circus.*

Equipment (as circus)
Battery-operated moving toy, mains-operated fan, manually operated fan, low-voltage electric bell or buzzer, low-voltage heater, Bunsen burner, wind-up torch, clockwork moving toy.

2: Investigating pendulums
Developing/Securing/Exceeding
Prac **WS**

Students investigate the factors that affect the swing of a pendulum.

Developing: Students can investigate the effect of the length, mass or initial amplitude of swing on the period (time per swing). Worksheet 9Ib-3 provides questions to help students with planning. Discuss the questions with students and help them to write a plan for their investigation. Note that only the length of the pendulum should have an effect. Some students may need to be reassured that finding no link between factors is a valid result.

Securing: Students work in pairs to plan their own investigation into factors affecting the time for one swing, using Worksheet 9Ib-3.

Exceeding: Worksheet 9Ib-4 asks questions that help students to predict which factors will affect the time for which a pendulum will swing before it comes to a stop. This could take some time, so groups could be encouraged to test only one factor each and share their results.

⚠ Ensure that any clamps and stands used as supports for pendulums are secure, particularly if larger masses are being used for the bobs. Use G-clamps to secure the bases of the stands to the bench.

Course resources
AP: Worksheets 9Ib-3; 9Ib-4.

Equipment
String, small mass to act as pendulum bob, scissors, clamps and stands, G-clamps, metre rule, stop clock.

3: Finding out about steam
Developing/Securing
Ask students to find out about the history of steam engines and other ways of powering transport. Students could:

- find information to produce a timeline of significant developments; such as first engine demonstrated, first one used successfully commercially, first one used for a locomotive, first used for passenger services, first steamship, etc.
- find out about individual inventions and note their significant points; engines to research could include Hero's aeolipile, Savery engine, Newcomen's atmospheric engine, Watt's engines, etc.
- find out about funicular railways and explain how they work (they usually include a counterbalance system and some, such as the Bridgnorth Cliff Railway, originally used water as ballast to provide the energy).

Students could present their findings as posters or computer presentations, or could use the information as part of a Literacy activity (see Exploring 4).

Exceeding: Students could be asked to produce brief explanations of how the different engines worked, including their advantages compared with previous designs.

Equipment
Internet access.

4: Writing for different audiences
Developing
Lit
This task develops work done in Explaining 2. Worksheet 9Ib-5 provides some information about the *Ra* expeditions carried out by Thor Heyerdahl. Students are asked to pick one format (aimed at a particular audience) in which to present information on the *Kon-Tiki* and/or *Ra* expeditions and to work on these in pairs. If possible, computer access should be provided so that students can use a word-processing package to help them to edit and develop their ideas. Individuals or pairs should then swap their texts with others who have written to a different format, and comment on how well the text matches its intended audience and purpose.

Developing: Ask students to read the text on the worksheet, and then discuss with them the differences in content and style needed between the different formats suggested on the sheet.

Securing: Students follow the instructions on the worksheet.

Exceeding: Students can be asked to find out about other experimental archaeology projects on the Internet and to produce two pieces of text aimed at different audiences on a project of their choice.

When the texts have been completed, they can be posted up around the room. Encourage students to look at the texts, and note one good point and one piece of constructive criticism about each one. Share these comments in a plenary session.

Course resources
AP: Worksheet 9Ib-5.

Equipment
Internet access, access to computers with word-processing software.

EXPLAINING TASKS

1: 9Ib Energy for movement (Student Book)
Developing/Securing/Exceeding
FA
These pages revise ideas about energy stores and transfers that were first studied in Unit 7I. Question 8 can be used for formative assessment. Worksheet 9Ib-1 is the Access Sheet.

Course resources
AP: Worksheet 9Ib-1.

2: 9Ib Purpose and audience (Student Book)
Developing/Securing/Exceeding
FA Lit
These pages look at ways in which writing is adapted to its purpose and audience, and to the format used. The emphasis on this page is for students to evaluate the differences between different formats.

The Literacy activity in Unit 8K looked at choosing language appropriate to the audience and it may be useful to revise this work here. Other Literacy work that may be relevant includes sentences (7C) and paragraphs (7D), adding 'weight' to writing (8A), information and explanation text (8E), giving a presentation (8J) and making a scientific argument (8L).

3: Energy transfers and stores

Developing

Prac

This practical can supplement or replace Exploring 1.

Motor lifting a weight: Set up an electric motor connected to a cell, driving a pulley that can be used to lift a weight. Remind students that we can think of energy as being stored (in hot or moving objects, in high up or stretched things, or in chemical substances) and that energy can be transferred between stores in different ways. Ask students to suggest the energy stores and transfers involved when the motor is used to lift the weight, including wasted energy transfers. The energy transfer here is from energy stored in the chemical substances in the cell, to gravitational potential energy stored in the lifted weight and thermal (internal) energy in the surroundings (transferred by heating from the wires, motor and pulley (from friction), and by sound from the motor).

Linear air track: Set up a linear air track with elastic bands at the ends and set a glider moving gently. Ask students to count how many times it goes up and down the track before it stops. Point out that you have given the glider a store of kinetic energy when you set it moving.

Developing: Ask students what happens to the energy as the glider bounces off the elastic bands. Elicit the idea that the model of energy transfers between different stores can explain why the glider keeps moving. Ask students why the glider eventually comes to a stop, if necessary reminding them that the moving glider has to push air out of the way and that some energy is therefore transferred to the surroundings by heating.

Securing: Extend this by giving the glider a harder push and asking students to explain why it travels further this time before stopping (there is more energy to be dissipated).

Pendulum: Set up a pendulum using a clamp and stand. Set it swinging and ask students to observe it carefully, eliciting the information that the bob stops moving momentarily at the end of each swing. Ask students what has happened to the kinetic energy stored in the bob at these points and get them to describe the transfer of energy between kinetic and gravitational potential energy stores. As before, ask them to explain why the pendulum will eventually stop swinging. Point out that, in addition to transferring energy to the air, some movement is transferred to the clamp and stand, and (depending on how you have fastened the string to the clamp) that there may also be some friction between the string and the clamp.

⚠ Ensure that there is a clear area to carry out each demonstration.

Equipment
Motor and weight: cell in holder, motor, connecting wires, pulley and clamp, belt, string, small mass.
Linear air track: linear air track with elastic bands at the ends, glider.
Pendulum: string with weight attached for a pendulum, clamp, stand.

PLENARIES

Most plenaries can be used for formative assessment. Suggested assessment, feedback and action strands of formative assessment can all be modified. See the ASP for further information and ideas on formative assessment.

1: Quick Check

Developing/Securing/Exceeding

FA

Assessment: The 9Ib Quick Check sheet provides a set of statements that summarise what students should know or understand following the first two topics in this unit. Students are asked to draw lines from each statement to a set of traffic lights to describe how confident they are about the material described by that statement.

Developing: Students can omit sentence d.

Feedback: Go through the statements one by one, asking for a show of hands for students who have linked it to red, then to amber, then to green. Carry out a spot check by asking students who have selected green one or two questions related to the statement. Make a note of any of the statements that have a significant number of amber or red responses.

The second question on the sheet asks students to suggest what they need to do to be able to link all the statements to the green light. Ask for volunteers to describe some of their ideas.

Action: Implement some of the students' suggestions and/or briefly revise areas of difficulty. Make a note of these areas, as some aspects of these two revision topics are built on in the following topics and so further reinforcement can be carried out then.

Course resources
ASP: 9Ib Quick Check.

2: Quick Check Literacy
Developing/Securing/Exceeding
FA **Lit**
Assessment: The 9Ib Quick Check Literacy sheet provides two samples of text that students are asked to allocate to different purposes and audiences. Students are then asked to rewrite one of the texts for a different purpose and audience.

Feedback: Give students a few minutes to work on their answers in pairs or small groups, then ask for volunteers to read out their answers. Invite constructive comments on these.

Action: Go over the key points of writing for different purposes again.

Course resources
ASP: 9Ib Quick Check Literacy.

3: Thinking about energy
Developing
FA
Assessment:

Consider All Possibilities: The temperature inside a room is rising. (Possible answers: the outside temperature is warmer/the Sun is shining on it and energy is being transferred by heating; there is a fire burning in the room; there is an electric heater on in the room; there is an inefficient appliance switched on in the room, which is wasting energy by heating the room.)

Odd One Out: solar energy, coal, tidal power. (Possible answers: coal is the only non-renewable resource; coal is the only resource that can easily be stored; tidal power is the only one that can be used only to generate electricity (solar can provide heating or electricity, as can coal).)

What Was The Question: elastic potential energy. (Possible questions: How is energy stored just before an archer fires an arrow? How is energy stored in a clockwork toy? How is energy stored when a bungee jumper is at the bottom of the jump? Name one way in which energy is temporarily stored for a pendulum/gymnast on a trampoline.)

Feedback: Ask students to volunteer their answers for each of the questions and to explain these. Use a smiley face on the board to indicate good answers (that show correct understanding of the science) or a sad face for answers that indicate misconceptions.

Action: Get students to help you identify any misconceptions or areas of poor recall during the discussion. Use this information to plan further reinforcement of these ideas. Get students to select an answer to improve, then use what they learnt in the discussion to do this, working in pairs.

The **AT** presentation *9Ib Thinking skills* can be used for this activity.

Course resources
AT: Presentation *9Ib Thinking skills.*

4: Spot the energies revisited
Developing
FA
Assessment: The **AT** presentation *Energy and transport* provides images of different forms of transport. Show students the photos and ask them to jot down the energy resources used by each one, and to suggest some of the ways in which energy is transferred by each vehicle. Students may have used this presentation in Starter 2 – in this case, ask them to amend any notes they made at the time.

Exceeding: The final slides challenge students to represent energy transfers as Sankey diagrams.

Feedback: Show the part of the presentation that provides answers. When each answer screen is shown, ask for a thumbs up/horizontal/down to show who had all, some or no correct answers. Discuss any wrong answers as you go through the presentation.

Action: Ask students to describe what they find difficult about this exercise. Make a note of any areas of difficulty. Some aspects of energy transfers can be revisited in Topics 9Id and 9Ie when discussing simple machines. Help students to write a brief set of revision notes to cover any areas of particular difficulty, for example by agreeing some summaries of the key ideas.

Course resources
AT: Presentation *Energy and transport*.

HOMEWORK TASKS

1: Energy transfers and stores 1
Developing
Worksheet 9Ib-6 provides simple questions about energy stores and transfers.

Course resources
AP: Worksheet 9Ib-6.

2: Energy transfers and stores 2

Developing/Securing

Worksheet 9Ib-7 provides questions about the energy transfers in a glider on a linear air track and in a pendulum.

Course resources
AP: Worksheet 9Ib-7.

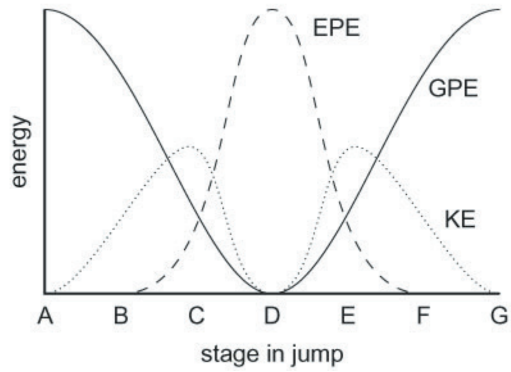
3: Bungee jumping

Exceeding

Worksheet 9Ib-8 asks students to explain the energy transfers and the forces during a bungee jump. This is a relatively complex example as, unlike a pendulum, elastic potential energy has to be taken into account as well as gravitational potential energy and kinetic energy. Students may have looked at the forces and their effects in Unit 7K – you may wish to give them a copy of Worksheet 7Ke-5 to help them to work out how the forces change, which could help them to work out the energy changes.

Showing students the **AT** animation *Forces during a bungee jump* (originally seen in Year 7) will also be helpful.

Students could also be challenged to sketch a line graph to show the energy changes through one bounce, ignoring any energy transfers due to heating or air resistance, and putting GPE, EPE and KE on one set of axes. It will be helpful to discuss this with students before they attempt the homework. On the graph, GPE should vary between the original value and zero. EPE is zero until part-way through the jump. Maximum EPE is equal to maximum GPE. KE increases and then decreases to zero when GPE is zero, then increases and decreases to zero again by the time GPE is at a maximum again. The total of all three energy stores should be constant.



Course resources
AP: Worksheet 9Ib-8.
Optional: Worksheet 7Ke-5 (Year 7).
AT: Animation *Forces during a bungee jump.*

ActiveLearn

Five ActiveLearn exercises are available for this topic: Energy for movement 1; Energy for movement 2; Energy for movement 3; Purpose and audience 1; Purpose and audience 2.

9Ic
Speed

This grid shows the basic concepts met in this topic, together with a scheme of cognitive progression for each concept. Opportunities to cover learning and progression are given. Working Scientifically concepts are integrated throughout the materials.

Conceptual statement	Cognitive progress					
	Remembering (a)	Understanding (b)	Applying (c)	Analysing (d)	Evaluating (e)	Synthesising & creating (f)
There are different methods of measuring speeds.	Recall the measurements needed to calculate a speed.	Explain how the distance travelled and the time taken affects the speed.	Represent simple journeys on a distance–time graph Describe changes of speed shown on a distance–time graph. Explain what relative speed means. Explain how Gatso speed cameras work (refers to the photographs, not to the radar part).	Calculate speeds from the gradient of a distance–time graph. Calculate the relative speed between two objects moving along the same line.	Measure speed in various ways. Evaluate different ways of measuring speed. Work out the direction of relative motion for two objects moving in the same plane, but not in parallel.	
Speed is how far an object moves during a set period of time.	Recall some units for measuring speed.	Describe what a speed is. Describe the meaning of 'average speed'.	Use the formula relating speed, distance and time.			

Objectives
Developing:

1. Describe the meaning of speed and mean speed.
2. Explain how the distance travelled and the time taken affects the speed.
3. Use the formula relating speed, distance and time.
4. Represent simple journeys on a distance–time graph.
5. Describe changes of speed shown on a distance–time graph.
6. Explain what relative speed means.

Securing:

7. Explain why the maximum speed on a journey is usually greater than the mean speed.
8. Calculate speeds from the gradient of a distance–time graph.
9. Calculate the relative speed between two objects moving along the same line.

Exceeding:

10. Work out the direction of relative motion for objects not moving along the same line.

Focused Working Scientifically Objectives
This topic provides an opportunity to focus on key Working Scientifically skills.

1. Change the subject of a simple mathematical formula.
2. Calculate the gradient of a line on a graph.

Student materials

Be prepared
Exploring 2 and 3 and Explaining 3 require the use of light gates or a digital video camera with a stop clock.

STARTER TASKS

1: Brainstorm speed

Developing

Ask students to jot down their ideas about speed, what it means, its units of measurement and some examples of fast- and slow-moving objects. They can then be asked to contribute ideas to a class brainstorm.

It may help to make notes on the board that can be referred to later in the topic. This is particularly useful if any misconceptions are apparent in students' answers – you may wish to leave them initially and revisit the results of the brainstorm later in the topic, when students may be able to correct their own misconceptions.

2: Match the speeds

Developing

FA

Worksheet 9Ic-4 provides a set of cards with descriptions of moving objects and their speeds given in three different units. Ask students to cut out the cards and match them up. This activity is intended to familiarise students with the three common units for measuring speed and to give them a feel for how speeds in the three different units compare. At its simplest, the speed cards could be kept together and students just match the speeds with the descriptions. If all the cards are separated, students could match up the speeds in different units (working in pairs or small groups) by putting the cards for each unit into rank order. The fastest animals quoted are the cheetah, sailfish and peregrine falcon (in a dive).

The **AT** interactive *Comparing speeds* provides an alternative form of this activity.

Course resources
AP: Worksheet 9Ic-4.
AT: Interactive *Comparing speeds.*

Equipment
Scissors.

3: Relative speeds

Securing

FA

The **AT** video *Relative speeds* provides some clips of people or objects moving at different speeds and poses some questions for discussion. It is suggested that only the first couple of clips, showing escalators and motorway traffic, are used here as a starter, to get students thinking about the concept of relative speed. The rest of the clips can be used as part of Explaining 5 or Plenary 5.

Ask students to write a short paragraph explaining the idea of relative speed – then check one or two paragraphs as a class.

Course resources
AT: Video *Relative speeds.*

EXPLORING TASKS

1: Walking speed

Developing/Securing

Prac **WS**

Ask students to measure their speed when walking at a normal pace and when walking as fast as possible.

Developing: Instructions are provided on Worksheet 9Ic-2.

Securing: Students should be asked to write their own method and ask for any apparatus they need.

If computers are available, class results could be entered into a spreadsheet and a mean value for the class calculated. Students could also be sorted into order of walking speed, or they could use their data to answer specific questions, such as 'Do taller people walk faster?', 'Do boys walk faster than girls?', etc.

⚠ Ensure the area to be used is free of obstacles.

Course resources
AP: Worksheet 9Ic-2.

Equipment
10 m or 20 m measuring tape, stop clock.

2: Speed targets

Securing

Prac **WS**

Show students how to use light gates and datalogging equipment to measure the speed of moving objects, then challenge students to move their hands (holding a piece of card of the size the light gates have been calibrated for) through the gate at particular speeds. If a distance ranger is available, students can also be challenged to walk towards or away from the ranger at various speeds. You could also sketch a distance–time graph (reminding students that steeper slopes represent faster movement) and ask students to move to build up a similar graph using the distance ranger.

Exceeding: Ticker timers can also be used for this activity (see Background information). Students can be introduced to the idea that cutting the tape into strips representing equal times and pasting these next to each other effectively builds up a distance–time graph.

Equipment
Light gates or distance ranger, datalogger.
Optional: ticker timer, power supply, ticker tape, scissors, glue, graph paper.

3: Investigating speed
Developing/Securing/Exceeding
Prac **WS**
Students investigate the variables that affect the speed of toy cars running down a ramp. Trolleys can be used in place of cars if they are more readily available. Factors that could be investigated include the steepness of the slope, the mass of the cars/trolleys, the type of car, and different surfaces for the ramp.

The mean speed of the car could be measured using stop clocks, but a better method is to use light gates and datalogging equipment, or to record the movement of the car using a digital video camera with a stop clock in the frame. If these methods are to be used, it will be helpful if students have seen them demonstrated (in Explaining 3) before planning their own investigation. Students should be encouraged to discuss the relative accuracies of the different methods before planning their investigations. These methods may have to be used as a teacher demonstration if there is not enough equipment available for individual group work. Worksheet 9Ic-3 provides questions to help students to plan their investigation.

Developing: Ask students to predict how changing the slope of the ramp will affect the speed of the car. Discuss the questions on the worksheet with students and help them to write their own plans. Check that students recall how to calculate means.

Securing: Ask students to work in groups to discuss the different variables that could affect the speed of the car and to plan their own investigations with the help of Worksheet 9Ic-3.

Exceeding: Students work in pairs to plan and carry out their own investigation, including any preliminary work they think necessary and a risk assessment.

⚠ Especially with heavier toys or trolleys, there should be a 'catching' device to stop heavy masses hurtling off the end of the ramp – cushions are good for this.

Course resources
AP: Worksheet 9Ic-3.

Equipment
Metre ruler/tape measure, toy car or trolley, ramp, blocks, masses, stop clock, cushions or something similar to 'catch' toys or trolleys.
Optional: light gates and datalogger.

4: Distance–time graphs 1
Developing/Securing
Worksheet 9Ic-5 provides a distance–time graph and asks students to match statements to different points on the graph.

Developing: Students answer the questions on the worksheet, omitting questions 3 and 4. Question 3 could be worked through as a class.

Securing: Students answer the questions on the worksheet.

Exceeding: Remove the graph from the worksheet before giving it to students. Ignore the questions and ask students to work in pairs to arrange the cards in any order they choose and note the order. Then ask them to draw a distance–time graph to represent the journey. They will need to calculate the distance travelled on card F and can also be asked to calculate the speeds for all sections of the journey. Students can then give their graph to another group and challenge them to work out the order of the cards.

Course resources
AP: Worksheet 9Ic-5.

Equipment
A4 paper, graph paper (for students working at *Exceeding*).

5: Relative speed calculations
Securing
Worksheet 9Ic-7 provides questions on relative speed calculations.

Developing: Students work in pairs as far as questions 1 and 2.

Securing: Students work as far as question 4, singly or in pairs.

Exceeding: Students use the whole sheet.

Course resources
AP: Worksheet 9Ic-7.

6: How is speed measured?
Developing/Securing
Students research how speed is measured for road vehicles, ships and aircraft, and present their findings. Students could find out about one or more of the following methods:

- cycle speedometers (magnet attached to spoke, speed calculated from number of revolutions of the wheel and the wheel circumference)
- car speedometers (a magnetic sensor detects the speed of a toothed wheel attached to a wheel axle)
- satnav/GPS systems (location and time data are used to calculate speed)
- speed cameras (radar detects the speed of a car, or a camera takes two photos a set time apart and distance is measured from the photos via a grid painted on the road)
- aircraft (speed through the air (airspeed) is measured by detecting the pressure drop as air flows through a narrow pitot tube sticking into the airflow; speed over the ground (groundspeed) can only be measured by GPS or other radio/satellite system)
- ships (speed through the water is measured by measuring the speed of a small propeller sticking into the water, or by using ultrasonics to detect how fast particles in the water are moving past; in the past, a 'log' was thrown overboard and the amount of rope it pulled out in a set time gave a measure of speed – the rope was knotted at regular intervals, hence the unit for speed 'knots' used for ships).

Developing: Students could limit their research to cycle speedometers (as these may be familiar to them) and satnav/GPS systems (which will help to reinforce the idea that a distance and a time need to be measured). They can write a few sentences to explain how they work.

Securing: Students should only be asked to produce a brief outline of how the different methods work. They can present their findings via annotated diagrams, bullet points or paragraphs of text.

Exceeding: Students could provide some detail about how some of the methods work, possibly including worked examples for things like the cycle speedometer or photographic speed traps, or could discuss factors that could reduce the accuracy of the methods (such as underinflated tyres changing the effective circumference of a wheel).

Students could provide two versions of their presentations for different named audiences, to build on the Literacy material in Topic 9Ib.

Equipment
Internet access or reference books.

EXPLAINING TASKS

1: 9Ic Speed (Student Book)
Developing/Securing/Exceeding
FA
These pages give the formula for calculating speed, show how distance–time graphs can be used to represent a journey and introduce the idea of relative motion. An **AT** link allows you to turn the labels on and off on figure C if you wish students to interpret the graph before they have read the explanation in the book. The **AT** interactive *Concept cartoon: What does it show?* will prompt discussion of what a distance–time graph shows.

Questions 2 and 5 can be used for formative assessment. Worksheet 9Ic-1 is the Access Sheet.

Course resources
AP: Worksheet 9Ic-1.
AT: interactive *Concept cartoon: What does it show?* Labels on/off *Distance–time graph*.

2: 9Ic Equations and graphs (Student Book)
Developing/Securing/Exceeding
FA **WS**
These pages remind students how to use a formula triangle to rearrange simple formulae (first introduced in Topic 8Ia) and shows how the gradient of a line on a graph can be calculated. You may wish to omit the work on gradients with students working at Developing.

3: Measuring speed demonstration
Developing
Prac
Demonstrate how a light gate can be used to measure the speed of a toy car or trolley down a ramp. If more than one light gate is available, gates could be set up at different places down the ramp and the speed of the car compared at different places. This is a good opportunity to revisit the idea of unbalanced forces producing a change in movement by discussing with students how the speed of the car changes as it goes down the ramp, and asking them to describe the different forces acting on the car and what the overall resultant force is. Alternatively, a digital video camera could be used to record the movement of the car, with a stop clock in the frame.

Securing/Exceeding: This is a good opportunity to reinforce the meaning of accuracy and reliability.

Explain to students that the datalogger calculates speed by timing how long it takes a card to go through the light gate and needs to know the length of the card. The datalogger produces precise and reliable (i.e. repeatable) results, as long as the correct length is input. You could demonstrate this by making measurements on repeat runs for the same starting point of the car. Then change the length of the card, or change the value that is input to the datalogger, and repeat. The new set of results will still be precise and repeatable, but will no longer be accurate (there will be a systematic error).

Equipment (for demonstration)
Toy car or trolley, ramp, blocks, light gates and datalogging equipment.
Optional: digital video camera.

4: Distance–time graphs 2

Securing

The **AT** animation *Distance–time graphs* illustrates a journey and builds up a distance–time graph during the journey. A second journey is illustrated, which can be paused to ask students to describe what the corresponding distance–time graph should look like before continuing the animation.

Course resources
AT: Animation *Distance–time graphs.*

5: Relative motion

Securing

The **AT** presentation *Time and tides* explains the fact that water in the Thames sometimes flows inland and gives some tidal stream speeds at different states of the tide. This is followed by questions for class discussion aimed at reinforcing ideas about relative speed and giving a few examples for students to calculate speeds relative to the water and to the ground.

The clips of boats in moving water on the **AT** video *Relative speeds* could also be shown here.

Exceeding: The final section of the presentation looks at relative speed in two dimensions, by looking at the direction a boat would have to steer to cross a tidal stream directly. You could supplement this using the video clips on the **AT** video *Relative speeds* showing an aeroplane doing a cross-wind landing and a kayaker crossing a fast-flowing river, or look for video clips online showing kayakers doing a 'ferry glide' to cross a river.

Course resources
AT: Presentation *Time and tides*. Video *Relative speeds.*

PLENARIES

Most plenaries can be used for formative assessment. Suggested assessment, feedback and action strands of formative assessment can all be modified. See the ASP for further information and ideas on formative assessment.

1: Quick Check

Developing/Securing/Exceeding

FA

Assessment: The 9Ic Quick Check sheet provides a set of true-false statements for students to classify and correct, and a distance–time graph for students to label and interpret. Students should work through the sheet alone or in pairs.

Feedback: Ask for volunteers to suggest answers for each question. Each time, ask for a show of hands to say whether or not the idea is correct and ask for volunteers to improve answers that have been suggested.

Action: Note any misconceptions and explain them or plan future activities to consolidate these. Students should make sure they have corrected any incorrect answers on the Quick Check sheet.

Course resources
ASP: 9Ic Quick Check.

2: Quick Check WS

Developing/Securing/Exceeding

FA **WS**

Assessment: The 9Ic Quick Check WS sheet provides questions asking students to calculate speeds, distances and times, and to work out gradients from a speed–time graph. Students work through the sheet alone or in pairs.

Feedback: Ask students to volunteer answers to the questions. Ask the class to comment on the validity of the answers given and suggest corrections to any incorrect answers.

Action: Ask students to make a summary of their strengths and weaknesses when answering this type of question. Identify any misconceptions or areas of weakness and go over these immediately or in future lessons.

Course resources
ASP: 9Ic Quick Check WS.

3: Thinking about speed

Developing

FA

Assessment:

Plus, Minus, Interesting: All cars should have a maximum speed of 30 mph. (Possible answers:

Plus – there might be fewer road deaths/injuries if cars travelled more slowly; **Minus –** it would take longer for people to get to their destinations; **Interesting –** would more people use trains or buses if car journeys took longer? In 1865, the speed limit for 'locomotives on the highway' was 2 mph in towns, and they had to have a person walking in front of them with a red flag.)

Consider All Possibilities: One car completes its journey in a shorter time than another. (Possible answers: it travels faster; it does not stop and the other does; it does not have as far to go.)

Odd One Out: aeroplane, car, train. (Possible answers: an aeroplane can have a speed vertically as well as horizontally; an aeroplane cannot measure its speed by counting how many times its wheels go round in a given time; an aeroplane is the only one that can have more than one speed at the same time, i.e. groundspeed and airspeed; a train is the only one whose direction of travel is fixed by the rails it runs on.)

Feedback: Students answer the thinking skills questions individually and then discuss their answers in groups, thereby feeding back their thoughts to one another. Ask students to write down their best answers and consider why they think they are the best. Ask them to do the same for their weakest answers, trying to identify what they find difficult about these.

Action: Ask a spokesperson from a number of groups to read out their best answers. Compile a class list of 'features of good answers' and a second list of areas of this topic that need to be reinforced. Identify any ideas that are missing and share them with the class. Students could revise one of their less good answers in the light of this discussion. If understanding is poor then revise the material at the start of the next lesson. The **AT** presentation *9Ic Thinking skills* can be used for this activity.

> **Course resources**
> **AT:** Presentation *9Ic Thinking skills.*

4: Spot the mistakes

Developing

FA

The **AT** presentation *Spot the mistakes* shows a set of questions with answers on the content of this topic, but each answer has one or more things wrong with it.

Assessment: Show students the presentation and ask them to work in pairs to note down what is wrong with each answer. They should jot down a corrected version of the answer.

Feedback: Take each question in turn and ask for a volunteer to explain what is wrong. Ask the rest of the class to give a thumbs up/thumbs down to say whether or not they think the explanation is correct. You could use a similar technique to get students to indicate how confident they are in their judgement. Ensure that at the end of the discussion all students can see what is wrong with each worked answer. Students should note down the ideas that they have become more confident about during this activity.

Action: Identify any areas of particular difficulty and revise them.

> **Course resources**
> **AT:** Presentation *Spot the mistakes.*

5: Going up?

Securing

FA

Assessment: A clip in the **AT** video *Relative speeds* shows skydivers opening their parachutes. When watching such clips, students often comment that the skydiver opening their parachute has 'gone upwards'. The clip is provided twice – the first shows the whole sequence, which is then repeated with pauses to pose questions. Show just the first one at this stage and ask students to jot down a short description describing the motion they have seen.

Feedback: Ask for volunteers to read out their descriptions and give others a chance to query or correct them. Note any misconceptions evident in their discussion.

Action: If there are any comments that one of the skydivers is moving upwards, show the second version of the clip, pausing the playback when each question is posed. If necessary, discuss each point until students are happy with the explanations. Ask students to sketch a diagram of a skydiver's fall, with a note describing what happens at each stage.

> **Course resources**
> **AT:** Video *Relative speeds.*

HOMEWORK TASKS

1: Cycling speeds 1

Developing/Securing

Worksheet 9Ic-6 describes how cycle computers work and provides some simple questions to help consolidate the work in this topic.

Course resources
AP: Worksheet 9Ic-6.

2: Cycling speeds 2
Developing/Securing
Worksheet 9Ic-8 describes how cycle computers work and provides questions to help consolidate the work in this topic.

Course resources
AP: Worksheet 9Ic-8.

3: Airspeed and groundspeed
Securing/Exceeding
Worksheet 9Ic-9 develops the work on relative speeds by describing airspeed and groundspeed and why both are important for the operation of aircraft. The final question is an optional challenge.

Course resources
AP: Worksheet 9Ic-9.

ActiveLearn
Four ActiveLearn exercises are available for this topic: Speed 1; Speed 2; Speed 3; Changing the subject.

9Id
Turning forces

This grid shows the basic concepts met in this topic, together with a scheme of cognitive progression for each concept. Opportunities to cover learning and progression are given. Working Scientifically concepts are integrated throughout the materials.

Conceptual statement	Cognitive progress					
	Remembering (a)	Understanding (b)	Applying (c)	Analysing (d)	Evaluating (e)	Synthesising & creating (f)
Simple machines (in addition to levers) can make it easier to lift or move objects.	State what is meant by: pulley, ramp, gear, force multiplier.	Describe how a simple pulley system can magnify [force, distance]. Describe how using a ramp can reduce the force needed to lift an object.	Describe how gears affect the force needed and the speed of movement. Explain why simple machines are used in a variety of everyday applications.	Explain how gears work using ideas about moments.	Evaluate the use of simple machines in common devices.	Explain why force multipliers conserve energy, i.e. in terms of the smaller force needed has to move through a greater distance.
Levers can magnify forces or magnify distance moved.	State what is meant by: lever, load, effort, pivot, fulcrum, force multiplier, distance multiplier.	Describe how a simple lever can magnify [force, distance].	Identify the [pivot, load, effort] in [Class 1, Class 2, Class 3] levers.	Explain how levers are used in common devices.	Evaluate the use of levers in common devices.	
The turning effect of a force is called the moment.	State what is meant by: a moment of a force. Recall the units of moments. Recall that something will balance if the moments are equal and opposite.	Describe how forces can move an object around a pivot, i.e. if moments are unbalanced. Describe the factors that affect the size of a moment.	Use the formula relating moment, force and perpendicular distance.			Determine the weight of a ruler using moments.

Objectives

Developing:

1. Describe how a simple lever can magnify force or distance.
2. Identify the pivot, load and effort in Class 1 levers.
3. Explain how levers are used in common devices.
4. State what is meant by a moment of a force and recall its units.
5. Recall that an object will balance if the moments are equal and opposite.
6. Describe the factors that affect the size of a moment.

Securing:

7. Identify the pivot, load and effort in Class 2 and Class 3 levers.
8. Use the formula relating moment, force and perpendicular distance.

Exceeding:

9. Describe how gears affect the force needed to move an object and the speed of movement.
10. Explain how gears work using ideas about moments.

Student materials

Be prepared
Explaining 4 requires a bicycle, preferably one with multiple gears.

STARTERS

1: Levers brainstorm

Developing

BA

Start by asking if any students know what the word 'lever' means. If necessary, explain that a lever is something, often with a long handle, that is used to increase a force. Ask students to work in pairs to write a list of five different levers that they use. Then form groups to swap ideas before combining all their ideas on to a master list on the board. If necessary, tell students to think about opening bottles, tins or doors, which should help to get them started on their lists. You could also demonstrate these things.

Equipment
Optional: Bottle opener and bottle, custard tin and spoon.

2: Examples of levers

Developing/Securing

Prac

Show students a couple of different examples of the same type of machine, such as a pair of embroidery scissors and a pair of kitchen scissors, or a small and large spanner. Ask students why the things are made in different sizes and ask them to suggest situations in which they would use the large or the small example. Elicit the idea that these things are levers and that the ones with the longer handles allow more force to be applied to the object being cut/moved, using only the same amount of effort. You could also show a tin with a tightly fitting lid, such as a paint tin, and ask students whether they would use a coin or a long screwdriver to get the lid off.

Exceeding: Give students a scenario where they have a tin of paint and five different screwdrivers of different lengths (5 cm, 10 cm, 15 cm, 20 cm and 25 cm). Ask them to write down which screwdriver they would choose and why, using as much physics as they can in their answers, including the words 'pivot', 'load' and 'effort'.

⚠ Take care if students are allowed to use machines.

Equipment
One or more pairs of machines (such as embroidery scissors and kitchen scissors, wire-cutters and bolt-cutters, garden hand-secateurs and long-handled loppers, small and large spanners).
Optional: tin of paint, coin, screwdrivers of different lengths.

3: Balancing demonstrations

Securing

Prac **FA**

Get students thinking about balancing with one or both of the following activities.

A: Ask students to stand with their heels touching a wall and place an object on the floor about 50 cm in front of them. Ask them to pick it up without moving their feet or touching the floor with a hand and then discuss why they cannot do it. Motivation can be provided in the form of a £5 note to be picked up. You could follow this up by asking a student to stand with his or her heels on a line drawn on the floor and ask them to pick up an object (although it is suggested that £5 is not used this time!). Ask the rest of the class to observe carefully and explain why the formerly impossible task is now relatively easy (they can move one leg backwards to act as a counterweight and so can bend over without losing their balance).

B: Ask students to stand about three foot-lengths from a wall and then touch the wall with their noses without overbalancing or moving their feet. Some students may be able to do it. Then tell them that they can raise one foot off the ground – all students should then be able to manage the feat by using one leg as a counterbalance. Ask them to explain why this task is easier if they are allowed to raise one foot. Agree an explanation of how humans use counterbalance when they bend over and then ask students to write this in their own words.

⚠ Ensure that students cannot fall on anything that will hurt them if they overbalance and have someone standing by to support them.

EXPLORING TASKS

1: Using levers

Developing/Securing

Prac

Set up a circus and allow students to try different levers. Suitable examples are using a variety of levers to open an empty custard tin (e.g. 50p piece, teaspoon, long-handled screwdriver), using the tips of scissors to cut paper, using scissors to cut thick cardboard, using secateurs and branch-cutters, using cutters to cut a piece of metal. Other items, such as torque wrenches and wheel braces, may have to be items for discussion, unless you have something suitable to use them on. You could also demonstrate cutting things with wire-cutters and bolt-cutters.

In all cases, ask students to identify the pivot and the position of the effort. Ask them to note the different way they use scissors when cutting paper or thick card and why bolts cannot be cut with small wire-cutters.

Also include examples of levers, such as a hammer used to remove a nail, where the lever is not a straight bar. Point out that the lever also changes the direction in which the force acts.

⚠ If cutting metal, ensure that students take care not to cut themselves on sharp edges. You may not wish to allow some classes to use items such as secateurs etc. Bolt-cutters should not be used by students. Do not cut towards hands or body. Care should be taken to prevent tools slipping in use. Count all sharps in and out.

Equipment (for class circus)
As many of the following as possible: custard tin and spoon, 50p piece, long-handled screwdriver, scissors, paper and thick card, wire-cutters and wire, secateurs, branch-cutter, thin and thick branches, metal-cutters, metal sheet (old food cans will do).
Optional (for demonstration): torque wrench, wheel brace, bolt-cutters, hammer and nail in block of wood.

2: Investigating levers
Developing
Prac WS

The aim of this practical is to show that a longer lever makes lifting a load easier. Ensure that the sandbags (if used) have a suitable mass and can be lifted using the masses available.

Developing: Instructions are given on Worksheet 9Id-2. Students working with this sheet will investigate the number of masses needed for different lengths of lever.

Securing: Worksheet 9Id-3 encourages a more open-ended approach to investigating levers, and students using this sheet may need to be reminded that a 100 g mass has a weight of 1 N.

⚠ Sandbags should not be any heavier than 2 kg.

Course resources
AP: Worksheets 9Id-2; 9Id-3.

Equipment (per group)
Metre rule, sandbag, triangular block of wood (pivot), 100 g slotted masses.

3: Balance challenge
Developing/Securing/Exceeding
Prac WS

This is best carried out before students use the Student Book, as it is leading them to discover that moments are equal when objects are balanced.

Students use a metre rule, masses and a pivot to investigate the idea that ‘weight × perpendicular distance from the pivot’ on both sides is equal when the ruler balances. This can be carried out using coins as a unit of force or actually using masses and working out the weights of the masses used.

Securing: Worksheet 9Id-4 provides questions to help students to plan and evaluate their investigation.

Exceeding: Students are not given the worksheet. Show students the apparatus and ask them to find out how many different ways they can arrange the coins/masses to make the ruler balance; and if they can work out a rule for predicting whether or not a particular arrangement will work.

Course resources
AP: Worksheet 9Id-4.

Equipment
Metre rule, triangular block of wood (pivot), 100 g slotted masses or 2p coins.

4: Make a mobile
Securing
Prac WS

Show students a hanging mobile and discuss its construction, bringing in the words pivot, balance and moment. Students can then make their own mobiles. Encourage them to work from the bottom sections upwards.

Developing: Students may find the balance points by trial and error, but encourage them to use the idea that a larger weight will be closer to the pivot than a smaller one, to make things balance.

Securing: Encourage students to use the equation for calculating moments to work out the balance position for each suspension point based on the weights of the shapes to be suspended from the arm.

Equipment
Hanging mobile, card, florist's wire, scissors, string, coloured pencils.

5: Different kinds of lever

Securing

Follow up Explaining 3 by asking students to find images of different classes of lever and to produce a poster or computer presentation describing examples of the three classes, and identifying the load, effort and pivot on each one.

Exceeding: Ask students to find a picture of someone rowing a boat, and challenge them to identify the load, effort and pivot. (The pivot is not the rowlock when the oars are being used to move the boat forwards – see the Background information for this topic.)

EXPLAINING TASKS

1: 9Id Turning forces (Student Book)

Developing/Securing/Exceeding

FA

These pages introduce the idea of levers, show students how to calculate the moment of a force and explain that objects balance if clockwise and anticlockwise moments are equal.

Questions 4 and 7 can be used for formative assessment. Worksheet 9Id-1 is the Access Sheet.

Course resources
AP: Worksheet 9Id-1.

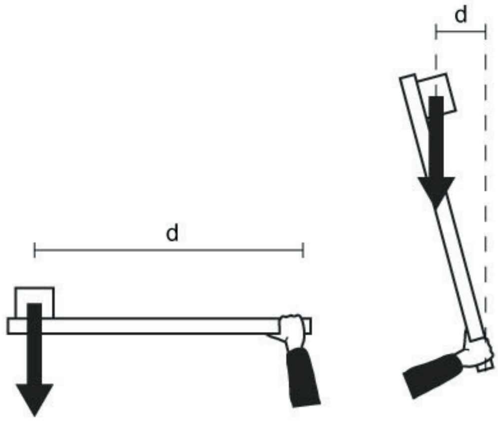
2: Perpendicular distances

Securing

Prac

This demonstration is intended to reinforce the idea that, when working out a moment, the distance used must be perpendicular to the force. You will need a long object with a weighted end. A broom would do, but it may be more practical to fasten some masses to the ends of metre rules, so that several students can try the demonstration at once. Ask students to grasp the rule at the unweighted end and hold it horizontally, then turn their wrist so that the rule becomes almost vertical. They should notice that the twisting force needed from their arm is considerably less with the ruler near vertical, showing that the moment from the weight they are balancing is also less.

On the board, calculate what the moment of the weight is using the length of the ruler and also using the horizontal distance from their hand to the ruler (the correct version), ignoring the mass of the ruler itself. They should see that the reduction in twisting force corresponds to the change in moment when calculated using the perpendicular distance to the force.



Equipment
Broom or metre rules, stacking masses, sticky tape.

3: Classes of lever

Securing

The **AT** presentation *Different classes of lever* introduces the idea of different classes of lever and gives examples. Students are expected to be able to work out from the relative positions of load, effort and pivot whether the lever is being used as a force multiplier or a distance multiplier, but will not be expected to recall the definitions of the three classes of lever. Follow up with Exploring 5.

Securing: Omit the final example of a rowing boat.

Exceeding: Challenge students to work out the class of lever represented by an oar.

Course resources
AT: Presentation *Different classes of lever.*

4: Bicycles – levers and gears

Securing

Bring a bicycle into the lab and ask students to identify all the levers involved and what they do.

The **AT** presentation *Bicycles* provides images of different parts of a bicycle and can be used if it is impractical to use a real bicycle.

Gear ratios are normally given in terms of the number of teeth on the gear wheels (or sprockets – this is the name for any toothed wheels that are connected with a chain, as on a bicycle). The explanation in *Bicycles* is given in terms of the radii of the different sprockets, but this is effectively the same thing. The spacing of the teeth is set by the spacing of the links in the chain, so the number of teeth will be proportional to the radius. As it is the ratio between the numbers of teeth on two sprockets that defines the force or distance multiplication, using the ratio of radii will give the same result.

Exceeding: The final section of the presentation explains how gears on a bicycle work in terms of moments.

Course resources
AT: Presentation *Bicycles.*

Equipment
Bicycle.

5: Balance it!
Securing

The **AT** animation *Balance it!* provides a simulation of a ruler balancing on a pivot. Weights can be dragged to different points along the ruler and the user can then test if their combination will balance. There is also an option to show the calculation of the moments in each direction.

Developing: Drag a weight to one side of the ruler and ask for suggestions where a weight should be placed to balance it. Test this, then ask more complex questions, such as where a single weight should be placed on one side to balance two weights in the same place on the other side. Demonstrate and test all suggested answers and help students to explain why any incorrect suggestions did not work.

Securing: Demonstrate a couple of examples to students, then ask them to work in pairs to write down suggestions for several different combinations that should balance. You could include constraints, such as having to use an odd number of weights altogether, or not being allowed to put more than one weight in each location. Ask for volunteers to describe their suggestions, set up the situation described and then ask for other groups to comment on whether or not it will balance before testing it.

Course resources
AT: Animation *Balance it!*

PLENARIES

Most plenaries can be used for formative assessment. Suggested assessment, feedback and action strands of formative assessment can all be modified. See the ASP for further information and ideas on formative assessment.

1: Quick Check
Developing/Securing/Exceeding
FA

Assessment: The 9Id Quick Check sheet provides questions on the content of this topic.

Feedback: Ask for volunteers to answer each item, then ask others in the class to comment on their answers.

Action: List any misconceptions on the board and ask students to discuss why these areas are problematic. Recap any areas from the lesson that are causing particular difficulty.

Students could note any questions on areas of uncertainty, to be answered in the following lesson. Make it their responsibility to make sure they are answered by the end of the topic.

Course resources
ASP: 9Id Quick Check.

2: Thinking about levers
Developing/Securing
FA

Assessment:

Plus, Minus, Interesting: All levers in our bodies should be longer. (Possible answers: **Plus –** muscles would not have to contract as much for the same movement; **Minus –** muscles would have to be stronger; **Interesting –** we would be much taller because our legs would be longer. The woman with the longest legs is Svetlana Pankratova, who is 1.95 m tall with legs 1.32 m long.)

Plus, Minus, Interesting: All levers should be force multipliers. (Possible answers: **Plus** – we would need less force to do many things; **Minus –** our arms might not work very well; **Interesting –** what would our arms look like – would the muscles have to be in different places? You could balance an elephant on a seesaw if you could sit 100 m from the pivot!)

Consider All Possibilities: You cannot lift a heavy mass using a lever. (Possible answers: the mass is too far away from the fulcrum; the lever is not long enough; you cannot provide enough force.)

Feedback: Give students five minutes to think up their responses, then pick students to give their answers. Get as many different answers as possible and then ask students to comment on whether or not any of them are scientifically incorrect.

Action: Ask students why they found certain questions more difficult. Get students to use 9Id Turning forces in the Student Book to improve their response to the question they found most difficult – writing their improved answer down for you (or peers in a group) to check.

The **AT** presentation *9Id Thinking skills* can be used for this activity.

Course resources
AT: Presentation *9Id Thinking skills.*

3: Spot the lever
Securing
FA
Assessment: The **AT** interactive *Spot the lever* shows an image that includes several levers. Ask students to identify different levers and what they do, and to describe the locations of load, effort and fulcrum.

Feedback: Give students five minutes to work in small groups, then ask for a volunteer to describe one of the levers shown and explain what it does. Then roll over the relevant part of the image and see the answer provided. Ask for a thumbs-up/thumbs-down show of hands to see how many groups got the answer correct and, if necessary, give them some time to amend their answers for the other levers before asking for a volunteer to describe the next lever.

Action: Note any points of difficulty. These can be addressed in the next topic, where the subject of simple machines is continued.

Course resources
AT: Interactive *Spot the lever.*

4: Beg of my neighbour
Developing/Securing
FA
Ask each student to write down three things that they think the person sitting next to them should have learnt and when they would have learnt it. Then ask students to ask each other in pairs whether or not they agree on the things they should have learnt. Ask them to agree a final list of the three most important points. Ask students to identify any areas of uncertainty too – this could be in the form of three questions to be addressed in the following lessons.

HOMEWORK TASKS

1: Levers and moments 1
Developing/Securing
Worksheet 9Id-5 provides simple questions on levers and moments.

Course resources
AP: Worksheet 9Id-5.

2: Levers and moments 2
Securing
Worksheet 9Id-6 provides questions on levers, moment calculations and balancing.

Course resources
AP: Worksheet 9Id-6.

3: Gears
Developing/Securing/Exceeding
Worksheet 9Id-7 develops the work in this topic by explaining how the gears on a bicycle work in terms of moments, including calculations. It will be helpful if students have seen the **AT** presentation *Bicycles* (Explaining 4).

Course resources
AP: Worksheet 9Id-7.
AT: Presentation *Bicycles*.

ActiveLearn
Three ActiveLearn exercises are available for this topic: Turning forces 1; Turning forces 2; Turning forces 3.

9le
More machines

This grid shows the basic concepts met in this topic, together with a scheme of cognitive progression for each concept. Opportunities to cover learning and progression are given. Working Scientifically concepts are integrated throughout the materials.

Conceptual statement	Cognitive progress					
	Remembering (a)	**Understanding (b)**	**Applying (c)**	**Analysing (d)**	**Evaluating (e)**	**Synthesising & creating (f)**
How an object behaves will depend on the interaction of the different forces acting on it.	Identify the forces acting on a [moving, stationary] object and the directions in which they act. State what is meant by: resultant force.	Interpret and draw a free-body force diagram.	Calculate the resultant of forces acting in one dimension.		Use scale drawings to find the resultant of forces in two dimensions. Use the idea that a force can be represented by two orthogonal forces.	
Simple machines (in addition to levers) can make it easier to lift or move objects.	State what is meant by [machine, pulley, ramp, gear, force multiplier].	Describe how a simple pulley system can magnify [force, distance]. Describe how using a ramp can reduce the force needed to lift an object.	Describe how gears affect the force needed and the speed of movement. Explain why simple machines are used in a variety of everyday applications.	Explain how gears work using ideas about moments.	Evaluate the use of simple machines in common devices.	Explain why force multipliers conserve energy, i.e. in terms of the smaller force needed has to move through a greater distance. Explain the effects of friction on the total amount of energy needed to use a simple machine.
Levers can magnify forces or magnify distance moved.	State what is meant by [lever, load, effort, pivot, fulcrum, force multiplier, distance multiplier].	Describe how a simple lever can magnify force or distance.	Identify the [pivot, load, effort] in [Class 1, Class 2, Class 3] levers.	Explain how levers are used in common devices.	Evaluate the use of levers in common devices.	
Work is a way in which energy can be transferred.	Recall how you can tell when a force does work.	Describe the relationship between work done and energy transferred. Describe the factors that affect the total work done.	Use the formula relating energy/work, force and displacement.	Describe the need for distance to be measured in the same direction as the force.	Justify the braking distances given in the Highway Code numerically in terms of kinetic energy being taken away by work done by the braking force.	

Conceptual statement	Cognitive progress					
	Remembering (a)	Understanding (b)	Applying (c)	Analysing (d)	Evaluating (e)	Synthesising & creating (f)
Energy cannot be created or destroyed, but in most energy transfers some energy is lost in a form that is not useful.	State the meaning of: efficiency. Recall the law of conservation of energy. Recall some advantages of low-energy appliances.	Identify useful and wasted energies. Describe whether a machine is more efficient than another.	Calculate energy efficiencies. Use data to consider cost efficiency by calculating payback times.	Explain why the efficiency can never be greater than 1 or greater than 100%.	Use data to evaluate [processes, objects, energy-saving devices].	

Objectives

Developing:

1. Describe how a ramp or a simple pulley system can reduce the force needed to lift an object.
2. Recall that if the force needed is decreased the distance it moves is increased.
3. Describe the relationship between work done and energy transferred.
4. Describe the factors that affect the total work done.

Securing:

5. Use the formula relating work, force and distance moved.
6. Use ideas about conservation of energy when explaining how simple machines work.

Exceeding:

7. Work out the mechanical advantage of simple machines.
8. Explain why the actual mechanical advantage may not be the same as the theoretical value.
9. Use the idea that a force can be represented by two orthogonal forces.

Student materials

Topic notes

- Both moments and work are calculated by multiplying a force and a distance. Ensure that students understand the difference between the two and do not mix up the units (N m and J).

Be prepared
Exploring 3 requires a variety of construction materials to build mousetrap cars.

STARTERS

1: Using forces

Developing/Securing

The AT video *Using forces* provides images of various simple machines in use. Initially, show the video to students with the sound turned off. Ask students to identify various forces in action and any machines that they can see that are helping to magnify forces or distances. This starter can be followed up with Exploring 4, where students are asked to write a voiceover script for the video, or with Plenary 3.

Course resources
AT: Video *Using forces.*

2: Revising words

Developing/Securing

FA

Revise the content of the previous lesson by asking students to match words to meanings.

Developing: The AT interactive *Match the meanings* asks students to match words relating to forces with their meanings. Use this as a front of class activity, or give students the words and definitions cut from the 9I Word Sheets to match up.

Securing: Give students a list of the key words from the previous topic and ask them to write their own definitions.

Ensure students have matched up the cards correctly or written suitable definitions. Revise the meanings of any words that are causing difficulty.

Course resources
ASP: 9I Word Sheets.
AT: Interactive *Match the meanings*.

3: Sure or unsure?

Developing/Securing **FA**

Help students to secure the knowledge gained in 9Id before building on it in this topic.

Assessment: Ask students to individually write down one thing about levers and moments that they are sure about, and one thing they are unsure about. Statements could be in a two-column table. Then ask them to work in groups of five or six to come up with group lists of statements in each column.

Feedback: Ask a spokesperson from each group to say what that group has decided, and reach a consensus as a class about what things students are generally confident about and what things they are less confident about.

Action: Revise the things that students are having difficulty with, or plan to cover these areas in any revision activities at the end of the unit. Pair groups to explain to each other if any of the tables of statements are complementary (i.e. one group confident; the other not confident about a particular idea).

EXPLORING TASKS

1: Investigating ramps

Developing/Securing/Exceeding

Prac **WS**

Students investigate the force needed to pull an object up ramps of different slopes. This investigation can be used to carry out a Working Scientifically Investigation. A set of assessment descriptions/descriptors is provided in the ASP. Worksheets are provided at two bands, but if this practical is being used for a complete Working Scientifically assessment, students should do their own planning.

Developing: Students follow the instructions on Worksheet 9Ie-2. Note that using this worksheet will limit the marks students can get in the planning strand.

Securing: Students plan their own investigation with the help of Worksheet 9Ie-3. If they wish to plot results against the angle of the ramp (instead of using the height at the end of the ramp), the **AT** spreadsheet *Angle calculator* will help them to do this. Show this to students before they start planning. It may also be worth ensuring that they realise that the pulley shown in one of the suggested methods is only being used to change the direction of the force – it is not affecting the size of the force.

Exceeding: As above, but follow up by allowing students to work through the **AT** spreadsheet *Ramps and energy* (Explaining 5) and see if they can use ideas from this in their conclusions and evaluations. Students are more likely to detect friction effects if they pull a block of wood up the ramp rather than a trolley, so you may wish to suggest this.

⚠ Ensure ramps are securely supported. It may be best to work on the floor if pulling the trolley or block to avoid them falling onto feet.

Course resources
AP: Worksheets 9Ie-2; 9Ie-3.
ASP: 9I WS Investigations.
AT: Spreadsheets *Angle calculator*; *Ramps and energy.*

Equipment
Trolley or block, string, force meter, pulley and clamp, stacking masses (range of sizes, including 5 g masses if available), long ramp (2 metres), blocks or lab jacks for supporting ramp, metre rule.

2: Investigating pulleys

Developing/Securing

Prac **WS**

Students investigate the force needed to lift a given mass with different numbers of pulleys in the system and also how far the mass and the pulling force move. It may help if students have seen the pulleys part of Explaining 3 before starting their own investigation. Remind students how to convert a mass to a force (multiply by 9.81 N/kg rather than 10 N/kg as a more precise value will help them to see the relationships). Students should find that the force needed to raise a mass is equal to the mass divided by the number of pulleys involved and that the distance moved by the force is the distance moved by the mass multiplied by the number of pulleys.

Developing: If necessary, help students to spot the relationship between the number of pulleys used and the size of the force needed to lift the load.

Securing: Students should calculate the work done in each case. Small discrepancies in the work done are likely to be due to errors in readings or to friction in the pulleys.

Exceeding: Once students have worked out what the force needed to lift a weight with each pulley system should be, ask them to calculate the work that should be done theoretically to lift a given weight. They should then compare it to the actual work done and explain any differences.

Equipment (per group)
Stacking masses, string, pulleys, force meter, metre rule.

3: Mousetrap cars
Developing/Securing
Prac WS

'Mousetrap cars' are vehicles propelled by the force of a standard mousetrap being sprung. There are numerous videos available on the Internet showing contests with mousetrap cars and also how to make them. This is a very open-ended task, to allow students to use some of their knowledge about forces and simple machines to make a car that will travel as far as possible on one snap of the mousetrap. In particular, there is a WikiHow page that gives specific hints about improving performance.

Show students a video of a mousetrap car challenge and then introduce the competition. There are some planning hints on Worksheet 9Ie-4. You may wish to limit the materials available, or allow students to plan their design and then have the necessary materials made available in the following lesson. Designing the car could be a homework task, particularly if students have access to the Internet at home.

Students should be encouraged to work as a team on this. If teams of four or more are used, students could work in pairs to design the wheels, or the mousetrap mechanism, etc.

Credit in marking (or in judging the competition) should be given to cars that go the furthest, but also for good plans and explanations of the features of the cars.

A suggested list of apparatus that might be needed is given below.

Securing: When the cars are built, ask students to suggest how they might work out the efficiency of their cars. Elicit the idea that they will need to measure the work done in winding up the spring, and also the work done to propel the car forwards. Ask them to suggest some ways of doing this. Note that both are complex measurements to make, as the force needed/produced varies, and students are not expected to actually make the measurements. Explaining 6 looks at *why* measuring the work done in winding the spring is not a straightforward task.

⚠ Warn students to handle the mousetraps carefully to avoid getting fingers trapped.

Course resources
AP: Worksheet 9Ie-4.

Equipment (per group)
Possible apparatus includes: mousetraps, string, stiff tubes (such as biro cases) or rods (bamboo barbeque skewers or florist's wire) for axles, CDs or stiff card from which discs can be cut to use as wheels, balloons (rings of rubber can be cut and used as tyres), screw-in hooks or eyes, sticky tape, glue (hot glue guns if possible: the technology department may be able to help), scissors.

4: Using forces – voiceover
Securing

The AT video *Using forces* provides images of various simple machines in use. Show the video to students with the sound turned off and ask them to write a script that could be used as a voiceover to the video. Note that they may already have seen some or all of the video in Topic 9Ia and in Starter 1 above.

The Literacy work from Topic 9Ib could be developed by asking students to write two different versions – one to introduce the idea of simple machines to Year 6 students and one to be shown to another Year 9 class.

Course resources
AT: Video *Using forces.*

5: Debate
Developing/Securing
Lit

There is an opportunity for a debate on Student Book 9Ie Supplying the energy. Refer to Skills Sheet RC 5 from the Year 7 Activity Pack for ideas on how to run a debate.

Course resources
AP: Skills Sheet RC 5 (Year 7).

EXPLAINING TASKS

1: 9Ie More machines (Student Book)
Developing/Securing/Exceeding
FA

These pages introduce ramps and pulleys as other examples of simple machines. Questions 5 and 6 can be used for formative assessment. Worksheet 9Ie-1 is the Access Sheet.

Course resources
AP: Worksheet 9Ie-1.

2: 9le Supplying the energy (Student Book)

Developing/Securing/Exceeding

FA

This page looks at the idea of an 'atmospheric railway' and compares this with modern electrified tracks. Students are asked to consider the benefits and drawbacks of electric and diesel trains. This is a good opportunity to carry out some extra revision on energy resources and climate change if you wish. There are also questions that help to revise some of the earlier content in the unit. The **AT** interactive *Concept cartoon: What does it show?* will help with question 3.

> **Course resources**
> **AT:** Interactive *Concept cartoon: What does it show?.*

3: Pulley and ramp demonstrations

Developing

Prac

Demonstrate how pulleys and ramps reduce the force needed to move an object upwards. Set up pulleys with two, three and four pulleys and measure the force needed to lift a mass each time. If students are to follow this up with Exploring 2 you may wish to only demonstrate one pulley system.

Similarly, show that the force needed to pull a trolley or wooden block up a ramp is smaller with shallower ramps. Elicit the idea that you are not getting 'something for nothing' as when a smaller force is used the force has to move further. Link this to the idea of work.

> **Equipment**
> Pulleys, string, clamp and stand, force meter, ramp, lab clamp or books or blocks to support end of ramp, mass to lift with pulley, trolley or block of wood to pull up the ramp.

4: Why pulleys work

Securing

The **AT** presentation *Why pulleys work* explains why adding pulleys to a system decreases the force needed, but increases the distance moved by the effort force.

> **Course resources**
> **AT:** Presentation *Why pulleys work.*

5: Ramps and energy

Securing

The **AT** spreadsheet *Ramps and energy* explains how a force can be resolved into two forces at right angles to each other and how this idea can help students to think about the effects of friction on the force needed to pull an object up a ramp. This is intended to be used to help students to process their results from the ramp investigation in Exploring 1.

> **Course resources**
> **AT:** Spreadsheet *Ramps and energy.*

6: Energy changes on deformation

Securing

Prac

The **AT** presentation *Energy changes on deformation* reinforces the idea that energy is transferred when a force moves through a distance, and reminds students that energy is stored in deformed objects.

Developing: Show students the presentation as far as the screen about snooker balls, encouraging them to attempt to answer the questions posed on-screen before showing the answers.

Securing: Show the rest of the presentation, which looks at the difference between elastic and inelastic collisions. The final screen is a question about how much energy is stored in a stretched spring. Students working at this band are not expected to be able to answer this themselves, but should understand the following demonstration.

Build up a force–extension graph by stretching a spring horizontally (this avoids the need to consider gravity in the discussion). Fasten one end of a spring and then stretch it horizontally using a force meter. Ask a student to note on the board the force and extension at intervals. Help the class to calculate the work done for the first increment of extension using the measured force and the extension, then for the next increment, and so on to five or six increments of extension. Total these, and compare them with the value that would be calculated if you took only the final value of force and the total extension.

Exceeding: Ask students to try to explain which of the statements on the final screen is correct, before demonstrating. If necessary, get them to sketch a graph of force against extension for a spring, or to look at figure C in the Student Book 9Ld Links between variables. Follow this up with the demonstration suggested above, then ask students to evaluate the estimate of work done made using the incremental values. Elicit the idea that a more accurate value would be obtained with smaller steps.

Homework 3 in Topic 9Ld follows this up by showing how the area under a force–extension graph can be used to find the work done.

Course resources
AT: Presentation *Energy changes on deformation*.

Equipment
Spring, force meter, means of clamping one end of the spring horizontally.

PLENARIES

Most plenaries can be used for formative assessment. Suggested assessment, feedback and action strands of formative assessment can all be modified. See the ASP for further information and ideas on formative assessment.

1: Quick Check

Developing/Securing/Exceeding

FA

Assessment: The 9Ie Quick Check sheet provides a mark scheme for an exam-style question about simple machines as well as a student's answer. Students are asked to mark the answer given and then to rewrite it so that it would gain a higher mark.

Feedback: Ask for a show of hands to suggest the mark the student should be given for question 1 on the sheet. Briefly discuss any disagreements. Then ask for volunteers to read out their answers to question 2 while the rest of the class use the marking scheme on the Quick Check sheet to decide on how many marks to give. Discuss the verdicts and then ask for more volunteers to read out any answers they think might gain better marks. Repeat the process for question 3.

Action: Note any areas that caused difficulty and revise these. Get students to note their own areas of strength and weakness relating to exam technique.

Course resources
ASP: 9Ie Quick Check.

2: Thinking about machines

Developing/Securing

FA

Assessment:

Consider All Possibilities: One woman can lift a heavier load than another. (Possible answers: she is using a ramp; she is using a pulley; she is using a lever; she has stronger muscles.)

Odd One Out: ramp, lever, pulley. (Possible answers: ramp is the only one that does not move itself when the load is moved; pulley can be used to change the direction of a force as well as changing the size; lever is the only one that can be used to *increase* the size of the force needed/increase the distance moved.)

What Was The Question: friction. (Possible questions: Why does it take more energy overall to lift something with a lever/pulley/ramp than to lift it directly? Why is it harder to drag something over rough ground than smooth ground? Why do moving parts in machines get hot?)

Feedback: Use the pose–pause–pounce–bounce method to obtain feedback for each of the questions above. Give students a few minutes to think of their answers, then pounce randomly on a student for an answer, before bouncing that answer to another student, asking 'What did you think of the answer?'.

Action: Identify any misconceptions or areas for which students have poor recall and list these on the board. Depending on the areas of difficulty, the other plenary activities may help to consolidate knowledge from this lesson. Re-check the list after these activities.

The AT presentation *9Ie Thinking skills* can be used for this activity.

Course resources
AT: Presentation *9Ie Thinking skills.*

3: Open-ended Assessment Task

Developing/Securing/Exceeding

FA SA

Assessment: Worksheet 9Ie-5 provides some information about ways in which archaeologists think that the stones used to build Stonehenge may have been transported and erected. Students use the information as source material to produce a display that could be used at an archaeology exhibition. The AT video *Moving the stones at Stonehenge* will help, and the Engineering Timelines website (http://www.engineering-timelines.com/) has a good explanation and series of diagrams for students wishing to research further and expand their explanations.

Developing: Ask students to suggest their ideas about likely speeds and timings for moving the stones by land (very, very slow), upriver (perhaps 1 km/h) and downriver (a little faster). Students could cut out the diagrams on the worksheet and use them as part of their presentation.

Securing: Students follow the task as set.

Exceeding: Students could be given only the details of the journey from the worksheet and the list of things to include in their presentation. They could carry out their own Internet research on possible methods of raising the stones.

Students present their ideas in the form of a series of small posters or story boards describing the transport (including a distance–time graph) and how various simple machines may have been used to help erect the stones, including explanations for why they are useful.

Feedback: Other students rate the presentations – this could be done as a class (by posting sticky notes on each other's work) or by clusters of two or three small groups peer-reviewing each other's presentations. This is most effective if criteria for judging the presentations have been agreed beforehand.

Action: If there are some areas of persistent difficulty, revisit them using a different approach from our list of Approaches for learning (see the ASP).

This activity can be done as an assessed task for summative assessment. You can assess this activity by using the Open-ended Assessment Task sheet or students can assess their own performance by using the Assess Yourself! sheet (see the ASP).

Course resources
AP: Worksheet 9Ie-5
AT: Video *Moving the stones at Stonehenge*
ASP: 9I Assess Yourself!; 9I Open-ended Assessment Task.

Equipment
Internet access.

4: Quick Quiz revisited
Developing/Securing/Exceeding
FA SA
Revisit the 9I Quick Quiz to test students' knowledge of the content of this unit. Students could fill in their answers on the 9I Quick Quiz Answer Sheet. Encourage students to identify areas for themselves that are still weak and write down how they are going to remedy this. Make it clear how you intend to check whether or not they have carried out their plans.

Course resources
ASP: 9I Quick Quiz; 9I Quick Quiz Answer Sheet.

5: End of Unit Test
Developing/Securing/Exceeding
SA
Use either or both of the End of Unit Tests. A Mark Scheme is given in the ASP. Encourage students to identify areas that are still weak and to formulate plans to strengthen those areas. Encourage revision in pairs – followed by reflection on which methods worked well and which less well for each pair. Summary Sheets are provided to help students with revision.

Course resources
ASP: 9I End of Unit Test Standard (S); 9I End of Unit Test Higher (H); 9I Mark Scheme; 9I Summary Sheets.

6: Progression Check
Developing/Securing/Exceeding
SA
Students should circle the stars next to each statement on the Progression Check to record what they feel they know, and how certain they are of it. Encourage students to plan how to do further work on the things about which they remain unsure.

Course resources
ASP: 9I Progression Check.

HOMEWORK TASKS

1: Lifting loads 1
Developing
Worksheet 9Ie-6 provides simple questions on ramps and pulleys.

Course resources
AP: Worksheet 9Ie-6.

2: Lifting loads 2
Developing/Securing
Worksheet 9Ie-7 provides questions on ramps, pulleys and work.

Course resources
AP: Worksheet 9Ie-7.

3: Mechanical advantage
Developing/Securing
Worksheet 9Ie-8 looks at the idea of mechanical advantage and helps students to apply this to the simple machines they have studied.

Course resources
AP: Worksheet 9Ie-8.

ActiveLearn
Three ActiveLearn exercises are available for this topic: More machines 1; More machines 2; More machines 3.