Unit 7K Forces and their effects

About the unit

In this unit pupils:
- consolidate and build on their concept of force and its measurement
- identify the origin of friction, air resistance, upthrust and weight and describe situations in which these forces act
- distinguish between mass and weight
- use the concept of speed
- relate forces acting to changes in motion
- identify situations in which forces are balanced and unbalanced

In scientific enquiry pupils:
- consider why it is important to repeat measurements
- measure distance, time and force including weight
- construct and interpret line graphs and use them to make predictions
- investigate floating in water of varying salinity, ensuring relevant variables are controlled
- investigate friction between solids, ensuring relevant variables are controlled

This unit is expected to take approximately 8 hours.

Where the unit fits in

This unit uses ideas developed in the key stage 2 programme of study. It builds on ideas introduced in unit 4E ‘Friction’ and unit 6E ‘Balanced and unbalanced forces’ in the key stage 2 scheme of work.

Together, this unit and unit 6E ‘Balanced and unbalanced forces’ in the key stage 2 scheme of work can be used as bridging units.

This unit lays the foundation for unit 9J ‘Gravity and space’, unit 9K ‘Speeding up’ and unit 9L ‘Pressure and moments’. It also relates to unit 7D ‘Using control to control a display’, unit 8A(ii) ‘Exploring materials (resistant materials)’, and unit 9A(ii) ‘Selecting materials (resistant materials)’ in the design and technology scheme of work.

Expectations

At the end of this unit

in terms of scientific enquiry

most pupils will: make predictions about upthrust, test these and relate their findings to scientific knowledge; make suitably precise observations, including repeats to check reliability, and use these to plot graphs; investigate friction, identifying and controlling key factors

some pupils will not have made so much progress and will: make predictions about upthrust, test these and identify patterns in their results; with help plot graphs of their results; make relevant observations using appropriate equipment

some pupils will have progressed further and will: explain how they made a fair comparison in their investigation of friction; interpret their results on floating, using knowledge of balanced forces to explain conclusions; explain how the scales they chose and lines they drew on graphs enabled them to show data effectively

in terms of physical processes

most pupils will: identify directions in which forces act and describe situations in which forces are balanced; distinguish between mass and weight, giving examples; describe some ways of reducing friction and some situations in which friction is useful; describe what is meant by speed

some pupils will not have made so much progress and will: identify forces, *eg friction, upthrust and weight*; recognise that friction opposes motion, upthrust pushes upwards and weight pulls downwards; compare speeds qualitatively

some pupils will have progressed further and will: show how forces can combine to give a resultant effect which depends on both the sizes and directions of the forces; describe how weight is caused by gravity and how gravity is different on the Earth and on the Moon; explain contact friction in simple terms

Prior learning

It is helpful if pupils:

- know that pushes and pulls change the speed, direction or shape of an object
- know how to measure distance and how to use a forcemeter to measure force in newtons
- know that forces act in a particular direction and this can be indicated by arrows
- have experience of the effects of a variety of forces, *eg magnetic, gravity, friction, air resistance*

Health and safety

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

- use heavy weights
- stretch springs and rubber bands

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

Language for learning

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

- words and phrases with different meanings in scientific and everyday contexts, *eg drag, upthrust*
- words with a more precise meaning in scientific contexts than in everyday contexts, *eg weight, mass, density*
- words and phrases relating to scientific enquiry, *eg repeat reading, line of best fit*

Through the activities pupils could:

- identify the main points of a talk, TV programme, etc

Resources

Resources include:

- immersion tank for objects to float and sink in
- scales marked in grams, kilograms and newtons, including personal scales
- lubricants, *eg car oil, graphite*
- videos/pictures of the effects of friction, and of a person floating in the Dead Sea or similar
- *Highway Code* (stopping distances)

Out-of-school learning

Pupils could:

- collect advertising and publicity material relating to streamlining and reducing friction, *eg in cars, bicycles, sports clothing, oils and lubricants*
- think about buoyancy and what helps them to float when swimming
- think about gravitational attraction when viewing films, videos and television programmes showing activities such as hang-gliding or skydiving

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
Where do we come across forces?			
• about a range of forces • how to measure forces	• Review what pupils know about forces by presenting them with a number of quick activities, *eg* – *weighing objects with a forcemeter* – *pushing an ice cube and a wooden block across a smooth surface* – *tying or untying a knot in plastic and natural string* – *explaining how the time taken for a piece of paper to fall varies with the amount it is crumpled up* – *pulling strong magnets apart* – *stretching a spring* and questions, *eg* – *What force is acting here?* – *What is its direction?* – *Why are the forces changing?* • Discuss observations and answers with pupils.	• identify forces, *eg magnetic attraction, friction* • use a forcemeter • explain the observations they make, *eg the plastic string is smoother so there is less friction and it is easier to untie*	• This activity is intended to help teachers find out what pupils know and understand about forces from work in key stage 2. Teachers will need to take this into account in later work. • Pupils are likely to have encountered a range of forces at key stage 2 and to have measured them using a forcemeter.
Why do things float?			
• that when objects are immersed in water there is an upthrust on them • to draw conclusions from experimental results • that when objects float the upthrust is equal to their weight • that density is mass divided by volume	• Present pupils with floating objects which they can push down to feel the upthrust pushing up. Extend the range of objects and ask pupils to predict which will float, and to weigh them in air and immersed in water. Compile a table of results and ask pupils to identify patterns and draw conclusions from these. Ask pupils to record their results and explanations, *eg by annotated drawings showing the forces acting on the objects.* Discuss pupils' ideas with them, referring to the work of Archimedes. Encourage generalisations, *eg light for size*, and show how to calculate density. Displacement of water can be used to measure volume (refer again to Archimedes).	• state that all the objects weigh less in water than in air • explain their observations in terms of an upward force from the water 'cancelling out' some of the downward force of the weight • recognise that objects which float show a zero weight reading • state that an object will float in water if it is less dense than water	• Pupils may have met the term 'density' but will need help with calculations. • Pupils will measure the density of objects using displacement in unit 8H 'The rock cycle'. • Archimedes checked the purity of a gold crown by measuring its volume by displacement.
• to choose which measurements and observations to make • to compare results with those of others in order to evaluate their work • that upthrust is different in different liquids	• Show pupils pictures either of people floating in the Dead Sea or of similar situations. Tell them of claims that it is easier to float in sea water than in fresh water. Ask them to suggest how they could test this. Remind them of the previous activity, provide them with samples of fresh water and sea water of varying salinity and ask them to investigate the claim and to produce a brief account using a combination of methods, *eg drawings, tables, bullet points*. Ask pupils to explain to others what they did, why they chose to do it that way, what conclusions they drew and to ask questions about other pupils' methods. Draw together the outcomes and discuss the methods chosen, *eg depth of immersion, number of measurements.*	• make measurements which enable them to test the claim • evaluate their methods • state that some liquids produce a greater upthrust on an object than others	• As in the previous activity, teachers may wish to extend this work to a discussion of density. • Pupils could be asked to find out about buoyancy aids and how these help them to float.

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
• that when an object is stationary the forces on it are balanced • that the direction of a force can be represented by an arrow	• Remind pupils that when an object floats its weight is balanced by the upthrust. Ask them to suggest why we cannot float in air. Demonstrate a number of situations in which there are easily identifiable balanced forces on a stationary object, *eg a tug of war, a paper clip or magnet held up by magnetic attraction or repulsion, a helium balloon floating at a fixed height*, and ask pupils to identify the forces, and the directions in which they are acting. Extend to other contexts, *eg a book resting on a table, an object suspended from a string*. Test pupils' understanding by showing them diagrams in which forces of given magnitude are represented by arrows and ask them questions, *eg* – *Are the forces balanced?* – *Will it begin to move? In which direction?* – *What force would be needed to stop the object sinking?* – *Why can't we float in air?*	• identify the forces on an object and the direction in which they are acting • demonstrate understanding that forces on a stationary object, *eg upwards and downwards*, are equal	• At this point balanced forces are considered in relation to stationary objects. The effect of balanced forces on a moving object will be covered in unit 9K 'Speeding up'. • A video can be used to show a range of balanced-force situations.
How do different materials stretch?			
• to draw an appropriate curve/ line graph to fit quantitative data, including choosing the scales • why it is important to repeat measurements • to describe and compare trends shown in graphs • to make predictions from a graph • to use a graph to identify anomalous data	• Ask pupils about work they did on stretching materials in key stage 2. Establish that they understand that the greater the force pulling down on a material the more it stretches. Ask pupils to explore this in more detail by adding weights to a spring, measuring the extension and predicting the extension when additional weights are added. Help them to plot a suitable graph of their results. • One way of supporting graph plotting is to get each pupil to stand in line at a height representing the value. Two other pupils, suitably marked, represent the axes, and lie on the ground and stand to the left. (For more details see *Getting to grips with graphs* (AKSIS, ASE, 1999).) • Ask pupils to repeat the experiment with a rubber band and to plot a similar graph. Before they draw a curve through the points suggest they repeat their readings once or twice. Plot all readings and help pupils to decide what line to draw. Show examples of the graphs for both the spring and the rubber band. Ask pupils to describe the differences between them and to explain what they show about the differences in stretch.	• represent the collected data on an appropriate line graph • explain how they decided on their line of best fit, using repeated measurements and identifying anomalous results • describe and compare relationships shown by the graphs, *eg with the spring, every time you add 0.1N it extends another 0.5cm, but with the rubber band the prediction is more difficult*	• If some pupils need additional help with graph plotting, this could be done while others take repeated readings, which could then be treated as a class set. • The force/extension graphs for rubber bands are nonlinear at the extremes. • With some pupils it may be better to measure length, not extension, and to compare springs of different stiffness. • Other pupils could be encouraged to relate the stretching of materials to the idea of forces between particles. Unit 7G 'Particle model of solids, liquids and gases' includes an introduction to particle theory (not including interparticle forces). ⚠ **Safety** – keep feet out of the way in case the elastic band breaks, *eg by putting a large box or tin underneath so that feet are automatically clear*
Checking progress			
• that there are many situations in which forces are balanced • how to represent balanced forces with arrows	• Review the way the direction of a force can be represented by an arrow. Tell pupils they can also be scaled to show size. Give representations of the floating, sinking and stretching situations. Ask pupils to draw arrows to show that the forces are balanced. Discuss how the elastic force in a spring/rubber band increases to balance the increased weight of an object.	• identify the forces which are balanced in a range of situations • use arrows to scale to show situations in which forces are balanced	• Interactive CD-ROMs could be useful for recapping this section and to introduce the next.

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
What is weight?			
• that mass is the amount of matter in an object and is measured in kilograms • that weight is a force and is measured in newtons • that weight is caused by gravity acting on a mass	• Ask pupils to 'weigh' objects using scales marked in both grams or kilograms and newtons. Use bathroom scales for pupils themselves if possible. Collect data and help pupils distinguish mass (in g/kg) as a measure of 'stuff' in an object and weight as a force measured in newtons. • Alternatively provide a range of labelled masses and ask pupils to weigh them with forcemeters. Ask pupils to draw a graph of mass against weight and use this to work out the weight of other masses shown on their scale. Discuss these results and establish that the relationship shown is (approximately) 1 kilogram (1000 grams) mass has a weight of 10 newtons. Provide pupils with household items whose mass is marked and ask them to work out the weights.	• distinguish between mass and weight • record measurements of mass and weight in appropriate units • describe and use the relationship between mass and weight, *eg on Earth a mass of 1kg has a weight of about 10N*	• Pupils will have weighed objects in grams/kilograms and measured force in newtons at key stage 2. • Some pupils may be sensitive about their weight (or mass). • In unit 9J 'Gravity and space' pupils will study the importance of gravitational attraction in the solar system and its effect on the weight of objects on different planets. • Extension: tell pupils that weight is caused by gravity, and that gravity on Earth is different to gravity on the Moon. Pupils could find out what effects gravity had on astronauts when they visited the Moon. ⚠ **Safety** – take care when lifting heavy weights
What does friction do?			
• that friction is a force which opposes motion • how friction between two surfaces can be reduced with a lubricant	• Remind pupils of the experiments they did at the beginning of the unit and ask them why the wooden block and ice cube or string and plastic thread behaved differently. Carry out some quick demonstrations, *eg oiling a wheel,* to illustrate the importance of lubricants, and ask pupils to explain how the lubricants work.	• explain differences in behaviour in terms of differences in frictional forces • identify characteristics of lubricants, *eg often liquid*, *smooth*, and explain their action, *eg smooth out rough surfaces*	

Learning objectives Pupils should learn:	**Possible teaching activities**	**Learning outcomes** Pupils:	**Points to note**
• about factors affecting frictional forces • to investigate one variable while keeping others constant • to represent quantitative data in a graph • to make predictions from a graph	• Ask pupils to suggest what other factors might affect friction between an object, *eg a wooden block or weighted margarine tub,* and a surface. List the suggestions and tell pupils you are going to show them how to set up an investigation. Do so making deliberate mistakes, *eg changing the surface area of the block when investigating the effect of weight; saying the same person must always measure the time taken to slide down a ramp*. Ask pupils to point out any mistakes you make and to tell you what you should do. • Help pupils to plan what to investigate and how to do it, ensuring that the plan will result in data that can be represented on a graph. • Ask them to use their graphs to predict a value not measured and then test this value experimentally. Compile a class set of information about factors affecting friction.	• identify factors, *eg weight, surface area,* that might affect the frictional force between two surfaces • identify and explain which variables need to be kept constant in order to obtain reliable data • plot a suitable graph from their data and explain what it shows • make and test a quantitative prediction from a graph	• Pupils are likely to have had many experiences of controlling variables in key stage 2, although they may not have used these terms. However, they may find it difficult to distinguish between quantities they need to keep constant and those that are not relevant. • In key stage 2 pupils are likely to have investigated friction by dragging shoes or weighted containers across different surfaces. If so, they should be encouraged to investigate other factors, *eg weight, surface area, effect of lubricant such as water*.
• that frictional forces can be useful • to identify the main points of a talk	• Present pupils with a set of cards with a series of statements, *eg friction always slows things down, shoelaces stay tied because of friction, friction is useful to gymnasts, matches light because of friction, cars need friction to keep moving*, and ask pupils to say if they are true/partly true/false. Discuss answers with the pupils and draw out the idea that friction is often helpful. Emphasise the importance of friction in walking and for wheeled vehicles, *eg by showing a video clip of cars, people on ice or of vehicles stuck in sand*. Show pupils pictures/examples of the treads on tyres and ask them to suggest how they work, or ask them to write a story of imagination, 'A world without friction'. Ask pupils to produce an information card, *eg 'Ten things you never knew about friction'*.	• describe examples where frictional forces are helpful • explain why friction is important in the movement of vehicles • present information about friction clearly and concisely	• The phrase 'the real McCoy' is thought to have originated from lubrication systems for locomotives, invented by the American Elijah McCoy, son of a runaway slave. • Extension: pupils could be asked to find out about safety regulations for car tyres and why these are important.
What affects how quickly a car stops?			
• that stopping distances of vehicles relate to frictional forces and speed • about speed and the units in which it is measured • how to interpret distance/time graphs qualitatively	• Remind pupils of the importance of friction in driving cars forward and ask them to describe what happens when cars/bicycles try to stop suddenly on greasy/wet/smooth roads and which factors affect stopping distances. • Show pupils the speed/stopping distance data in the *Highway code* and ask for interpretations. Some pupils could plot stopping distances against speed and be asked to describe the trend shown. • Draw out pupils' understanding of what speeds actually tell them. Explore pupils' qualitative understanding of speed by posing questions, *eg How would you find out who in the class runs fastest*? • Extend this by giving pupils distance/time graphs, *eg of a journey to school partly on foot and partly on a bus, a journey home on a tricycle, a trip in a lift up a high building,* and asking them to 'tell the story' of the journey. Discuss with pupils and tell them a story of a journey and ask them to turn it into a graph.	• identify that, for a given car, the stopping distance relates to its speed • explain in words the units of speed, *eg mph, km/h* • describe the journey shown in a speed/time graph, *eg for the first ten minutes he didn't go very far, about a quarter of a mile, but in the next ten minutes he went four miles, so he probably got a bus or a lift*	• Speed may be the first derived unit pupils have encountered. • The stopping distances in the *Highway code* are historical and are based on the performance of a Ford Anglia. Most modern cars are better than this, with sports cars typically having the shortest stopping distances and 'people carriers', among family cars, having the longest. • A spreadsheet could be used to model stopping distances under different conditions.

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
Reviewing work			
• to recognise useful and unhelpful frictional forces • to bring together ideas about forces and motion and to make links between them	• Present pupils with a context, *eg a bicycle or a picture in which there is a variety of examples of friction.* Ask them to identify these and explain which are useful and which are not. • Draw together pupils' knowledge of the key ideas in the unit by asking them to draw a concept map using appropriate terms, *eg balanced, friction, upthrust, gravity, weight, mass, movement, speed*. Discuss pupils' maps with them. It may be helpful to agree a class summary map.	• identify, and draw representations to show, useful frictional forces, *eg at brakes,* and unhelpful frictional forces, *eg at wheel axles* • make appropriate links and explain their reason for them	• Extension: teachers may wish to extend this work with some pupils to the formal definition of speed. This is covered in unit 9K 'Speeding up'. It is not necessary to distinguish between speed and velocity at this stage. • Many pupils will be familiar with making concept maps from their work in primary science. (A concept map is used in unit 7E 'Acids and alkalis'.)