Force and motion

Introduction

The topic of force and motion involves some quite counter-intuitive ideas. Informal conceptions of force are held by children and adults alike. Force and motion activities provide some rich opportunities for different representational modes: diagrams, graphs and charts, and metaphors to do with human action.

This topic overlaps considerably with other topics in these resource materials, such as 'Air and flight', 'Floating and sinking' and 'Magnets'.

Key concepts of force and motion

The activities in this topic are designed to explore the following key concepts:

Early years

- Forces can be thought of as 'pushes' and 'pulls'.
- Forces can make things move or stop or hold things up or squeeze things.
- Friction is a common force that stops things moving or slows things down.
- Gravity is a force that makes things fall.

Middle years

- Forces cause changes in motion, and are not (unlike momentum and energy) associated with motion itself.
- Forces are our way of describing the way effects such as pushes, pulls or gravity can influence the motion of things.
- A force is an effect *on* an object, not a property of the object or its motion. It is something that is done to, or acts on, things.
- A change in motion (speeding up, slowing down, swerving) is caused by an external effect and not by the object itself or something inside it.
- Forces occur in action–reaction pairs. Thus if you push on something it will push back on you. Your standing body pushes down on the ground, and the ground pushes back up on you.
- Pairs or sets of forces will add together to affect motion, but the addition must take into account direction. Forces can cancel each other.
- Common forces include contact forces (physical pushes, support or traction from the ground, friction, air or water resistance opposing motion, force from wind) and field forces (gravity, magnetic forces, electric field forces).

- Motion can be described by representing the distance something travels in a time interval.

Students' alternative conceptions of force and movement

Research into students' ideas about this topic has identified the following non-scientific conceptions:

- Forces are associated only with living things (i.e. people can apply force but things like gravity or friction are not forces).
- Force is thought to be the property of a moving object, rather than something acting on it from outside. Thus, constant motion requires or involves a constant force (rather than a net force causing speeding up or slowing down or deflection).
- The amount of motion is proportional to the amount of force (i.e. faster moving objects are thought to have a greater force).
- If an object is not moving there is no force acting on it, and if a body is moving there is a force acting on it in the direction of motion. (This is not true. For instance, there is no forward force on a rolling or sliding object—friction will act in a direction opposite to the motion. A stationary person standing in a room is subject to two forces.)

Activities

Force

ACTIVITY: FORCES ON PLAYDOUGH

Key ideas: Forces cause change in shape, or movement. Force can be represented by arrows.

You will need:

- **playdough**
- **photographs of activity (e.g. sport, games).**

Discuss with students what they might do to change the playdough. Let them experiment with different ways they can act on it. Get students to talk about the different things they did; for instance, twisted it, squeezed it, thumped it, rolled it.

As they talk, represent the pushing and pulling that they did with arrows. Collect different diagrams of forces on playdough on the board. Challenge students to use this arrow representation to think about what is happening when you squeeze a ball, sit on a soft chair, or push a chair across the floor.

Students can then use the arrow representation for other forces they can imagine. Distribute some sporting or game-playing photographs and get them to draw arrows to show the forces.

ACTIVITY: PUSHING AND PULLING A TABLE

Key ideas: Forces can add together or be opposed. Friction opposes movement and can be represented as a force.

You will need:

- **a table**
- **a sheet of felt**
- **stockings.**

Up-end a table on the floor, with a sheet of felt beneath it. Discuss with students what would be needed to move it. Challenge a student to pull it. Is it harder if someone stands on it? Use a stocking to pull. The stretch can provide an informal representation of the amount of force.

What difference does it make if two people both pull? What happens if one person pulls and the other pushes from the other end? What happens if two people push at opposite ends?

Using the arrow notation, represent the forces needed to move the table. Challenge students to represent the effect of the drag from the floor, and imagine what would happen if the table had rollers on it.

ACTIVITY: MAKING A YACHT

Teaching note: Help students with the construction and probe their ideas about what makes the best floater, and also what is likely to move the best in a wind and why. A class trial will require a trough with a fan at one end.

Key idea: Wind provides a force that depends on the shape and size of sails.

You will need:

- **polystyrene**
- **cartons**
- **plastic bottles**
- **drinking straws**
- **icy-pole sticks**
- **sticky tape**
- **plasticine**
- **paper**
- **wooden skewers**
- **cotton material for sails**
- **a trough**
- **a fan**
- **a bucket of water and jugs.**

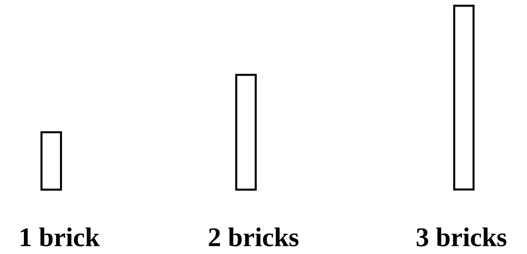
Construct a boat with a mast and sail. Work with a trough of water to trial its floating and sailing capacities. The aim is to construct a boat that will move fast in a wind. You can either blow or use a fan to make the boat move during trials.

Draw a diagram of the boat and write about why it went well, or why it didn't. What makes a good yacht work well?

ACTIVITY: BRICK FRICTION

Teaching note: Organise comparisons of the various methods before the students record their findings. After they record, demonstrate the effect on the force of having two bricks or three bricks under the same conditions.

Use lengths of a streamer to compare the amount of stretch. Stick these on the board like a bar chart.



Key ideas: Different surfaces have different amounts of friction. Force can be measured. Rollers reduce friction.

Each group will need:

- **a brick with a hook attached**
- **elastic bands**
- **various surfaces (two of each) to sit the brick on: plastic, paper, sandpaper, silk and wool cloth, aluminium foil**
- **an enamel tray**
- **an aluminium tray**
- **two wooden dowels**
- **four hexagonal pencils**
- **six marbles**
- **ten wooden skewers**
- **a coloured streamer.**

Move a brick using as small a pulling force as possible. Use an elastic band to pull. The stretch on the band can be measured, to represent the force with which the elastic band is pulling. Demonstrate the fact that the elastic band will stretch more as the pull gets greater.

Discuss some possible ways of making the brick move with as little pull as possible. Use the streamer to measure the stretch of the elastic band just as the brick begins to move.

How did you move the brick with only a little pull? Why did this work?

Force and movement

ACTIVITY: RAMP ROLL

Teaching note: This activity is discussed in some detail in Chapter 3 of *Teaching primary science constructively* (Keith Skamp 2004, Thomson, Melbourne), which includes a discussion of the science.

Key idea: The shape and size of a roller affect its motion down a ramp and along a floor.

You will need:

- **a ramp**
- **two identical jam jars (one full and one empty)**
- **a range of cylindrical and spherical rollers, some solid and some hollow (e.g. bits of plastic pipe, batteries, dowelling, toilet rolls, tennis and golf balls, marbles and ball bearings, carts).**

Find out what makes things roll best down a ramp and along the floor.

Compare a full and an empty jam jar. Which reaches the bottom first? Which goes along the ground furthest? Do you think it is weight that makes a difference, or size, or being hollow or solid?

Try with the different rollers (cylinders and balls, hollow or solid) to find out. Draw what you found and write what you think is happening.

ACTIVITY: CARTS THAT WORK

Key ideas: Large wheels reduce friction on rough surfaces. Friction acts to slow things down. Aspects of the design process: investigate, design, make, evaluate.

You will need:

- **a ramp**
- **cartons**
- **wheels**
- **wooden skewers**
- **straws**
- **sticky tape.**

Use cartons, wheels, skewers and straws to make a cart that rolls down a ramp and furthest along the floor. What are the factors that make the cart go best? Weight? Size of wheel? Type of axle?

Draw and label what you made and write about why it works well.

ACTIVITY: SPEED AND TIME

Teaching note: This activity asks students to think of speed in terms of distance travelled in a timed interval. This is a challenge for middle years students.

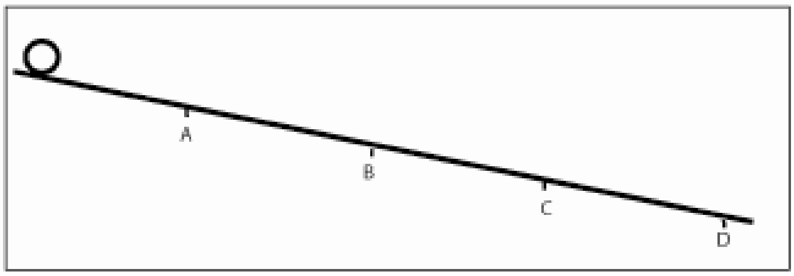
Key idea: Speed is distance travelled in a unit of time. Motion can be represented by measuring distance travelled in successive time intervals.

You will need:

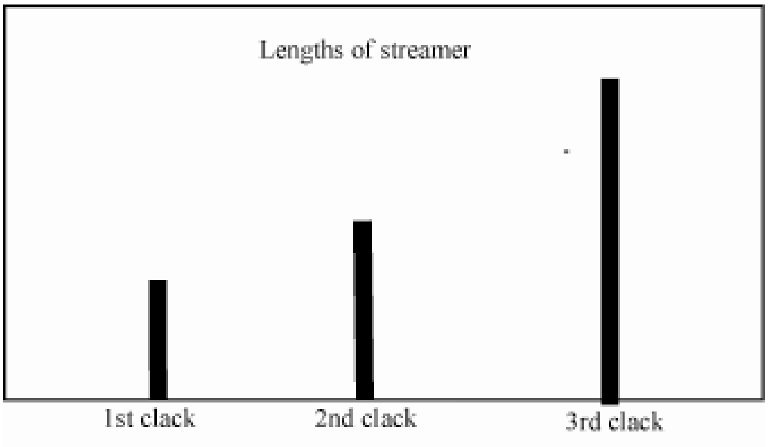
- **a long table raised at one end to make a slope**
- **a ball**
- **a stick**
- **scissors**
- **a streamer.**

Galileo used a ball rolling down a slope to study motion. The figure below represents a ball about to roll down a slope. Consider the following questions and design an experiment to investigate them.

- **How much longer do you think it takes the ball to roll to D, compared to A?**
- **Design a timing device to check your prediction.**
- **Where is the ball going fastest?**



Roll a ball down the sloped table. Have someone clack a stick at regular intervals, so that three or four clacks occur while the ball is rolling down the slope. Lay a piece of streamer down the slope to mark the position of the ball. Mark on the streamer where the ball is at each clack (i.e. at equal time intervals). Cut the streamer up to represent the distance travelled by the ball during each clack. Arrange the pieces of streamer side by side.



What does this 'graph' tell you about what happens to the speed of the ball as it rolls down the slope?

Inertia

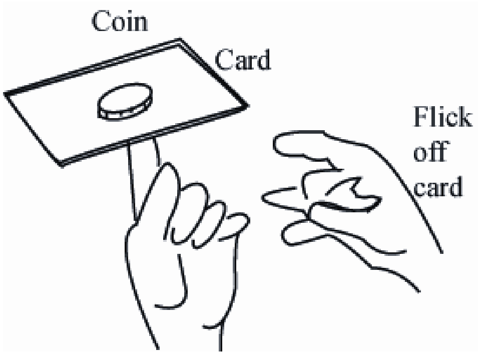
ACTIVITY: CARD FLICK

Key idea: Objects will tend to resist changes to their motion, to a degree influenced by their inertial mass.

You will need:

- **a 20c coin**
- **a playing card in good condition.**

Balance a 20c coin in the middle of a playing card, on top of your index finger. Having achieved this balance, use your other hand to flick the card horizontally off your finger. The coin stays in place!



ACTIVITY: REMOVING THE TABLECLOTH

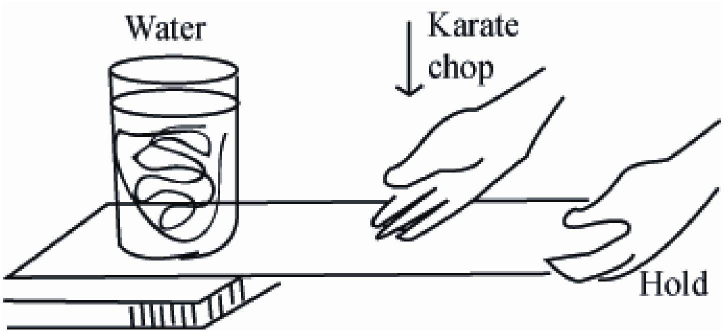
Key idea: Objects will tend to resist changes to their motion, to a degree influenced by their inertial mass.

You will need:

- **paper (A4 or larger)**
- **a sturdy glass full of water**
- **a table with a smooth surface and edge.**

A similar trick involves sitting a glass of water near a table edge, with a strip of paper under it projecting out from the table. For this trick the glass and table must be quite dry.

Hold the other end of the paper with one hand, and bring your other hand down on the paper in a karate chop motion to pull the paper from under the glass. The glass should stay in position because of its inertia. If the motion is too slow, the friction between the paper and the glass will be sufficient to pull the glass off the table.



Explanatory note: 'Inertia' is a word that is used to describe the tendency of objects to stay where they are, or to keep on going if they are moving. The *Card flick* and *Removing the tablecloth* activities both rely on the idea that a really fast pull or flick will not allow the coin or glass to be forced into motion by friction. A slow movement would allow friction to accelerate the coin with the card, but the acceleration of the card is far too great for the coin to stay with, since not that much friction is available. It stays where it is as the card slips out.

Balance

There are many intriguing visual illusions and unexpected situations associated with balance. These activities can be explored in terms of intuitive ideas about the distribution of weight in an object, or they can be studied more formally in terms of the centre-of-mass concept. Expressions like ‘most of the weight is …’ or ‘the heaviest part is here, and balances that part …’ can be quite explanatory at an informal level, if the formal centre-of-mass concept is beyond the reach of students. Centre of mass is a concept, however, quite accessible to middle years students.

Key concepts of balance

- Objects have a balance point, which depends upon the distribution of matter in the object.
- An object can be made to balance around a pivot point if the distribution of weight in the object is adjusted.
- The centre of mass of an object represents where the mass seems to be concentrated.
- The centre of mass can lie in midair.
- The position of the centre of mass can be altered by adding mass to an object.
- An object will hang so that the centre of mass lies directly below the suspension point.
- An object will be stable as long as its centre of mass lies above its base; otherwise it will topple.
- Objects with wide bases are more stable.

Balance oddities and illusions

ACTIVITY: FORK AND SPOON HOVER

Key ideas: When an object hangs, the weight is distributed so that the bulk is directly below the pivot point. The centre of mass of a system of connected objects lies directly below the pivot point.

You will need:

- **a fork**
- **a spoon**
- **a glass**
- **matches.**

Put the round end of a spoon into the prongs of a fork. Use a match inserted in the prongs and resting on the edge of a glass to suspend the fork and spoon in midair. Why do they hover like that?

The secret is in the way the weight is distributed. Where is most of the weight of the fork and spoon? Where do you think the centre of mass is?

If you want some extra excitement, light the match at both ends. What do you predict will happen?

Explanatory note: The *Fork and spoon hover* can be explained once you realise that most of the weight of the fork and spoon are in the handles, and that despite the fact that visually they seem to project out into space, in fact, as a unit, the bulk of the mass lies back below the pivot point as one might expect. Formally, we can identify that the centre of mass of the fork–spoon system (the match has negligible mass) lies in midair somewhere between the handles, and exactly underneath the point at which the match sits on the rim of the glass.

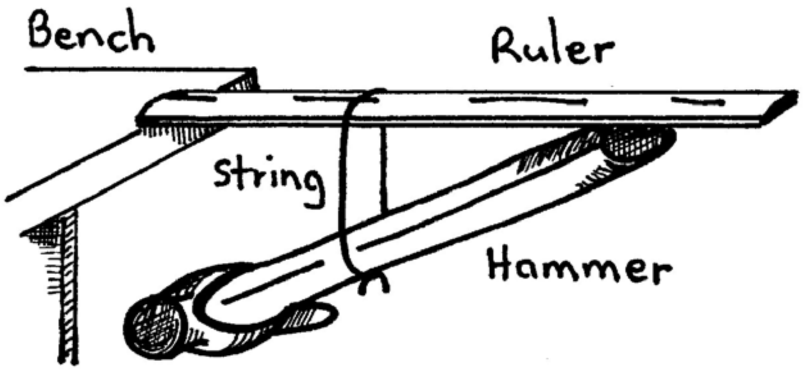
ACTIVITY: HAMMER HANG

Key ideas: When an object hangs, the weight is distributed so that the bulk is directly below the pivot point. The centre of mass of a system of connected objects lies directly below the pivot point.

You will need:

- **a hammer**
- **a ruler**
- **Blu-Tack**
- **string, or an elastic band.**

Loop a piece of string (or an elastic band) around a hammer and a ruler as shown in the figure below. You may find Blu-Tack useful for stopping them sliding apart.



Where is most of the weight of the hammer? Where, roughly, is the weight of the ruler–hammer arrangement concentrated? Can you find where the centre of mass of the model is? Can you adjust your model to make the ruler slant upwards from the support point? Can you explain how the ruler is supported in midair, out from the bench?

Explanatory note: The *Fork and spoon hover* explanation also applies to the *Hammer hang*. The centre of mass of the ruler–hammer system is located close to the head of the hammer, where most of the mass is. The illusion of projection is achieved because the ruler and hammer handle contain only a minor part of the total mass of the system.

ACTIVITY: BALANCE ILLUSIONS

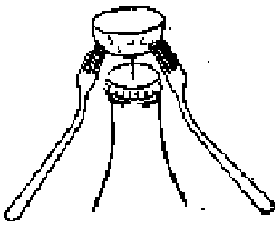
Key ideas: When an object hangs, the weight is distributed so that the bulk is directly below the pivot point. The centre of mass of a system of connected objects lies directly below the pivot point.

You will need:

- **a cork**
- **a potato**
- **two forks**
- **plasticine**
- **wire**
- **pliers**
- **a plastic soft-drink bottle**
- **a polystyrene ball**
- **plastic knitting needles**
- **matches**
- **a piece of cotton thread.**

Make a few balancing puzzles to surprise students. Where does the weight have to be, for a successful balance?

The figure opposite shows two forks stuck in a potato (a cork will also work), with their handles mostly below the pivot point. You can improve the illusion if you have large, light objects such as paper wings sticking up and sideways out of the potato (e.g. using knitting needles).



A variation on this arrangement involves using a cotton thread to balance this arrangement. Replace the wire with a matchstick with a V cut in the bottom end to sit on the thread. The match will slide along the thread if it slopes, like a tightrope walker.

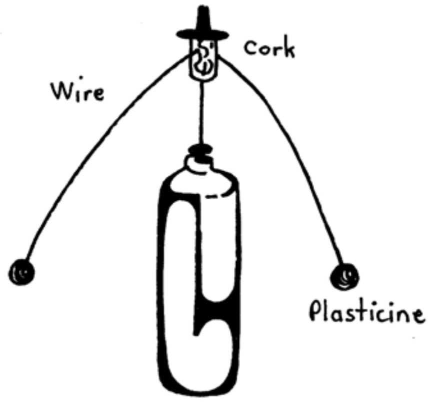
ACTIVITY: MR TRIX

Key ideas: When an object hangs, the weight is distributed so that the bulk is directly below the pivot point. The centre of mass of a system of connected objects lies directly below the pivot point.

You will need:

- **a plastic squeezy bottle or similar**
- **wire (thinner than a coathanger, but stiff)**
- **a cork**
- **plasticine.**

Make the toy shown in the figure below, and experiment with what happens when you modify the weight and position of each of the plasticine hands and the angle of the arms. Predict in each case what will happen to Mr Trix.



ACTIVITY: TIGHTROPE-WALKER

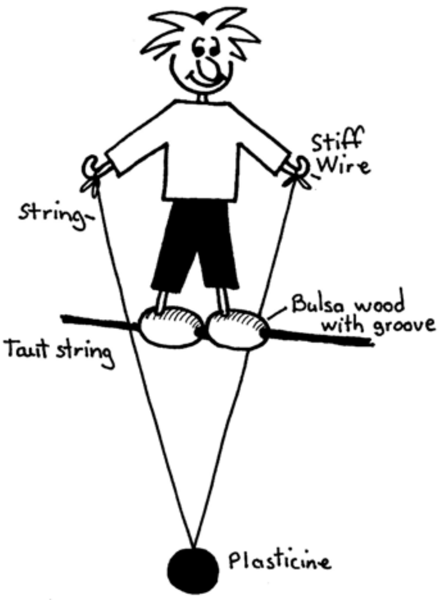
Key ideas: When an object hangs, the weight is distributed so that the bulk is directly below the pivot point. The centre of mass of a system of connected objects lies directly below the pivot point.

You will need:

- **plasticine**
- **cotton thread**
- **string**
- **balsa wood**
- **a knife**
- **a small polystyrene ball**
- **wire or a pipe-cleaner**
- **coloured paper.**

Make the model doll shown. Shape the doll from one piece of wire so it is rigid, and shape the balsa wood shoes so they are also rigidly supported and have a groove to sit along the taut string. The plasticine needs to hang centrally below the doll, as shown in the figure below.

Can you work out a rule that tells us how to make the doll balance?



ACTIVITY: BUTTERFLIERS AND ACROBATS

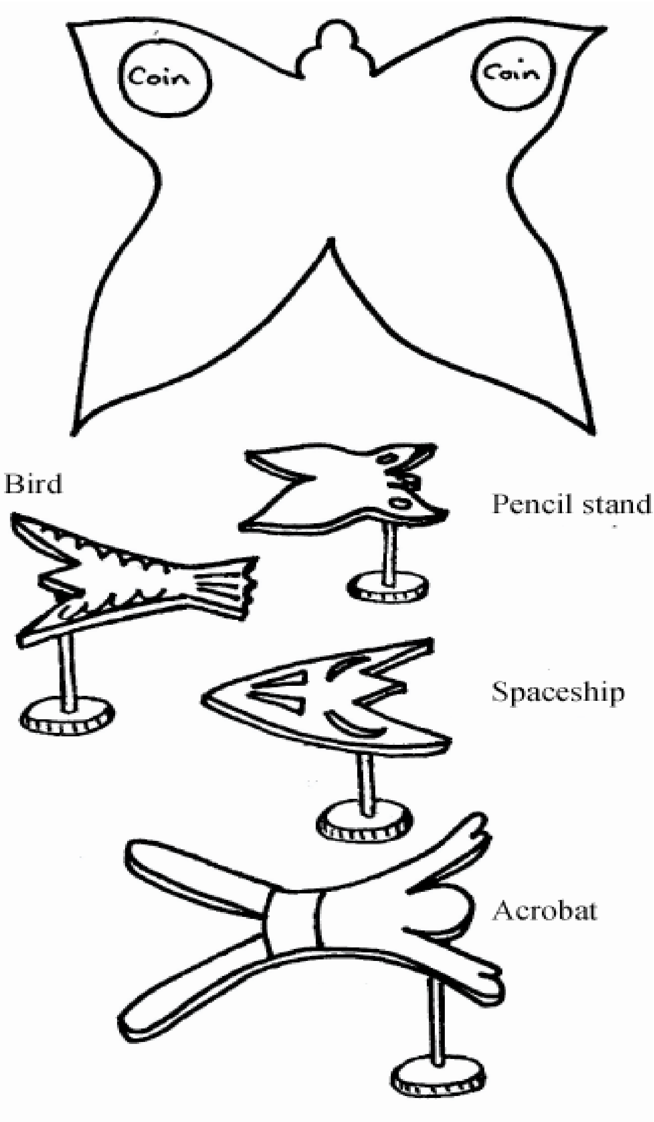
Key ideas: When an object hangs, the weight is distributed so that the bulk is directly below the pivot point. The centre of mass of a system of connected objects lies directly below the pivot point.

You will need:

- **two coins (or pieces of Blu-Tack)**
- **lightweight cardboard**
- **sticky tape or Blu-Tack**
- **a pencil**
- **plasticine**
- **scissors.**

Cut the shape you want out of thin card. A butterfly shape works well! Stick two coins (Blu-Tack should work as well as coins) on the underside as shown in the figure below. Make a stand (a pencil stuck in plasticine will do) and balance the butterfly on its head.

Try some other shapes. Where does the balance point have to be in relation to the coins? Can you make some shapes different to those shown here?



Explanatory note: The principle that was used to explain the *Fork and spoon hover* and *Hammer hang* activities applies to all these illusion tricks, including *Mr Trix*, *Tightrope-walker* and *Butterfliers and acrobats*. In each case, the bulk of the mass lies below the pivot point even though the most obvious features seem to lie above, projecting into space. Formally, if you were to locate the centre of mass, it would lie directly below the pivot.

Standing upright

ACTIVITY: POP-UP DOLL

Key idea: In a balance situation where objects are standing, the weight will be distributed to be above the base on the floor. The centre of mass must be over the base if the object is not to fall over.

You will need:

- **a half ping-pong ball**
- **plasticine**
- **an icy-pole stick**
- **coloured paper.**

Make the pop-up man in the figure below, using a half ping-pong ball and plasticine, and an icy-pole stick or matches for the body.

Where is the weight of the toy concentrated? Explain why he pops up again when you push him.

Can you arrange it so that he pops up when you push him, but stays down if you push him right over?

Explanatory note: The pop-up doll is a stability trick. The secret is that most of the weight of the doll is in the base, and that gives stability. More formally, the centre of mass of the doll is about one-third of the way into the plasticine. If the doll is on its side, the centre of mass is on the base side of the pivot point, which is the rim of the ball, and will up-end the doll to right it.

An interesting challenge is to make the doll so that it lies down if pushed totally over, but rights itself for anything less than that. This can be done by adjusting the level of plasticine in the base, or by adding plasticine to the head of the doll. In either case it is a matter of adjusting the position of the centre of mass within the base.

ACTIVITY: DARE TO PICK UP, DARE TO STAND UP

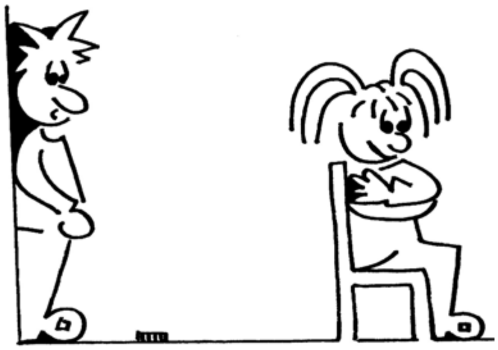
Key idea: In a balance situation where objects are standing, the weight will be distributed to be above the base on the floor. The centre of mass must be over the base if the object is not to fall over.

You will need:

- **a coin**
- **a chair**
- **a wall.**

Challenge a friend! He must put his heels against the wall, and bend over to pick up the coin you put near his feet. He must not fall over! He cannot bend his knees.

Can you stand up from a straight-backed chair without leaning forward? You must not use your arms. Your back must be kept touching the chair. How do you usually get up from a chair?



Explanatory note: These *Dare to …* challenges depend on the fact that you can’t be stable unless your weight distribution, or your centre of mass, lies above your shoes (your baseline).

In the first challenge, leaning forward projects your weight outside the line of your toes and makes you unstable. You could do it if the wall were not there, because your bottom would inevitably move backwards (left in the diagram) to compensate for the movement forwards by the upper body. We have spent a lifetime learning to do this sort of thing without thinking about it!

In the second challenge, standing straight up will have the weight of the upper body above the chair and not above the feet. What we normally do in getting out of a chair is to move our feet backwards and lean forwards so that in every part of the action the weight (i.e. the centre of mass) lies directly above where the feet are planted, or at least is outside in a way that allows a controlled topple!

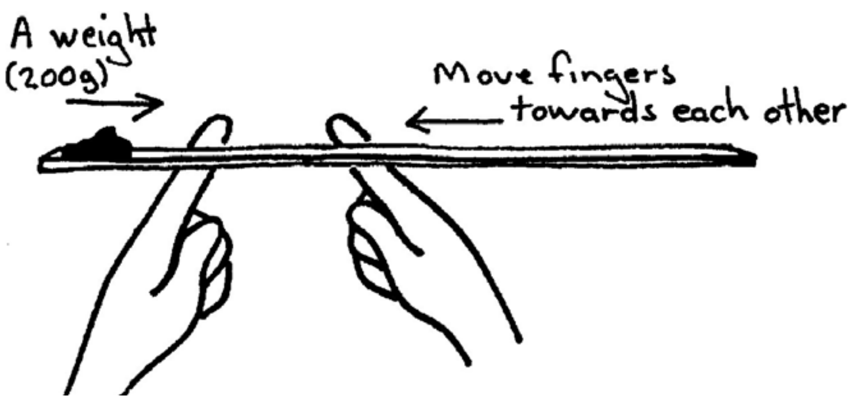
ACTIVITY: METRE-RULE MAGIC

Key idea: In a balance situation where objects are standing, the weight will be distributed to be above the base on the floor. The centre of mass must be over the base if the object is not to fall over.

You will need:

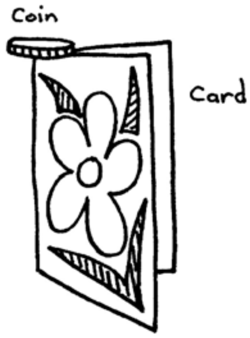
- **a metre rule or stick with flat surfaces**
- **weights**
- **a coin**
- **a greeting card**

Take a metre rule, or any metre-length stick with flat surfaces, and balance it on your two outstretched index fingers at each end. Now move your hands smoothly together, still letting the rule sit on your fingers. It does not fall!



Try it again, moving one hand only. Try it again, this time putting weights near one end of the rule. Again, you should be able to achieve a perfect balance without trying! What is happening?

A more subtle balancing act can be done with a 20c or 50c coin. Place the coin on the V of a greeting card standing on a flat surface. Carefully open out the card until it is straight. The coin is still balanced!



Explanatory note: In the metre-rule trick, the rule doesn't topple because once the weight distribution becomes a bit imbalanced it puts pressure on the finger nearest the middle of the rule, and reduces the pressure on the finger near the end. The reduced pressure reduces the friction between the rule and that finger, which will slide along the ruler until it is closer to the centre than the other finger and pressure on it will increase. Any tendency to tip will cause an adjustment in terms of which finger moves next, without our having to think about it!

Balance rules (OK?)

ACTIVITY: MATHEMATICAL MOBILE

Key idea: Objects will balance if the product of distance multiplied by weight is the same on either side of the balance point.

You will need:

- **a box of identical nuts, bolts or small weights**
- **cotton thread**
- **lightweight sticks.**

Make as big and as complicated a mobile as you can, using the weights. Use combinations of one, two or three weights at different points along the length of the sticks.

Can you find a rule to describe the point on each stick at which the next stick and set of weights must be hung?

ACTIVITY: BALANCING THE BUDGET

Key idea: Objects will balance if the product of distance multiplied by weight is the same on either side of the balance point.

You will need:

- **a ruler (30 cm)**
- **a pencil**
- **twenty small coins.**

Use the pencil (on its side) as a pivot to balance the ruler on its own.

Where must the ruler go? What is special about the place on the ruler needed to balance it?

Place one coin at one end of the ruler. Challenge a friend to place two coins somewhere on the ruler, on the other side of the pencil, to make the ruler balance again. Where must the two coins be put?

Repeat the process, but this time give your friend three coins to balance. What is the rule that tells your friend where to put the coins? Where is the centre of mass for the balanced ruler, in each case?

Try some more difficult challenges. Put two coins down at the end of the ruler and ask your friend to balance them with three coins. Ask if it is possible to balance this arrangement using one coin.

Put one coin at the end and one halfway on the ruler and challenge your friend to balance this using three coins. Don't allow your friend to experiment … they must predict where the balancing coins should go!

Explanatory note: There are simple mathematical rules that govern the way objects are arranged round a pivot point if they are balanced, and that determine the position of the centre of mass. The rule with both the *Mathematical mobile* and *Balancing the budget* activities is that, on either side of the pivot, a single mass placed two or three or four or more units from the pivot can be balanced on the other side by two or three or four or more units of mass placed one unit from the pivot point. Mathematically, balance will be achieved if the distance and mass multiplied together is the same on both sides.

Centre of mass

These activities locate the centre of mass explicitly, in contrast to the more intuitive activities above.

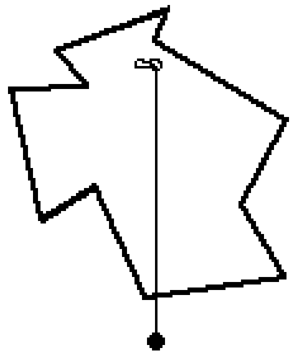
ACTIVITY: SPINNING SHAPES

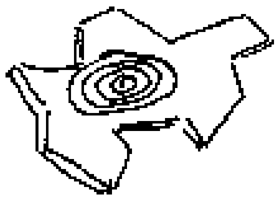
Key ideas: The centre of mass always lies directly beneath a pivot point. The centre of mass follows a simple path through the air even if the object is spinning in a complex way.

You will need:

- **a sheet of cardboard**
- **a compass fitted with a thick pen or marker**
- **Blu-Tack**
- **cotton thread**
- **a nail**
- **a weight (e.g. a nut).**

Find the 'centre' as shown, of a piece of crazy cardboard. To do this, make a hole at two different points on the cardboard, and for each, hang the cardboard from a nail poked through the hole. Hang a piece of cotton with a weight on it from the nail (a 'plumb-bob'), and draw a line along the cardboard where the thread hangs. Where the two lines meet, we shall call the 'centre' of the cardboard shape.





Mark the 'centre'. Balance the cardboard on the tip of a pen, as best you can. Is the balance point the same 'centre' point you just found?

With a compass, draw a series of circles centred on the 'centre'. You will need to draw the circles accurately, and in thick pen or marker, for effect. On the other side of the cardboard, draw another set of circles, centred around a different point.

Throw the piece of card, spinning, into the air. What do you notice about the circles? The cardboard spins about its 'centre of mass' and those circles appear not to wobble.

Can you attach a piece of Blu-Tack to the cardboard to make the point your other circles are drawn around the new balance and spin-centre point?

ACTIVITY:
EMPTY CENTRE

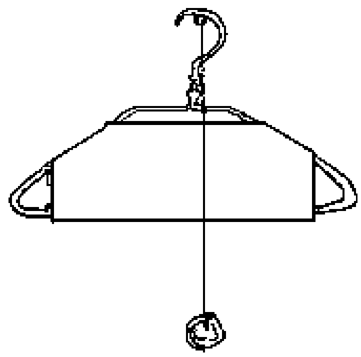
Key idea: The centre of mass will always lie directly below the pivot point. The centre of mass may be in a part of the object where there is no mass.

You will need:

- **a coathanger**
- **a sheet of paper**
- **sticky tape**
- **a nail**
- **cotton thread**
- **a weight (e.g. a nut).**

Where would the centre of mass for a coathanger be?

Use sticky tape to attach a sheet of paper across the gap in a coathanger, so that you can mark the centre of mass on it. Use the 'plumb-bob' method as used in the *Spinning shapes* activity to find the centre of mass.



Explanatory note: With the *Spinning shapes* and *Empty centre* activities, the centre of mass is located by using the principle that it always hangs directly below the pivot point. There are other examples in previous balance illusions where the centre of mass is in midair (*Fork and spoon hover, Mr Trix …*). Can you identify where the centre of mass is in all those previous illusions? *Spinning shapes* uses the principle that an object will spin around its centre of mass. Try spinning a hammer in the air—you will find it spins around a point in the head. Adding Blu-Tack of course changes the position of the centre of mass (it shifts towards the Blu-Tack).

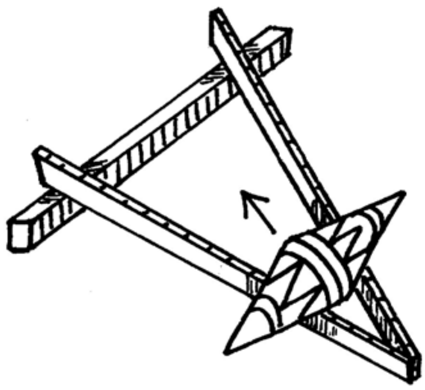
ACTIVITY
FUNNELS THAT ROLL UPHILL

Key idea: Gravitational energy changes can be traced by treating an object as though all its mass is at the centre of mass.

You will need:

- **two metre rules or long straight pieces of wood, joined at one end**
- **two identical, large funnels (glass, or plastic, or shaped out of card)**
- **a block or books to raise the end of the rulers.**

Tape a pair of funnels together (you can make the funnels out of card). Arrange two rulers as shown, to make a track for the funnels to run on. If you get the angles right, the funnels will run uphill. But look carefully at what is happening to the centre of the funnels. Is the centre running uphill?



Explanatory note: *Funnels that roll uphill* is based on a visual illusion. If you look carefully at what happens to the centre of mass of the funnels (which is at the centre of their joining circle), you will find that in this case it runs downhill even though the rulers are sloped upwards. The geometry is misleading!