

6 forces

Water rocket

Austria

Breaking surface tension

You will need...

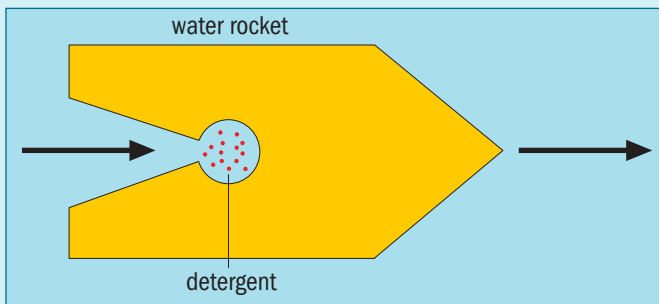
- ✓ a bowl of water
- ✓ some card
- ✓ a pair of scissors
- ✓ some washing-up liquid

Background

Some small insects can walk on the surface of water owing to surface tension.

Follow these steps

- 1 Using the template shown, cut out a paper rocket.
- 2 Place the rocket onto the surface of the water.
- 3 Put a drop of washing-up liquid in the central circle of the rocket (dip a pencil into the detergent then dip it into the water inside the circle) and watch what happens.



So what happened?

When the detergent is added it locally reduces the surface tension of the water. Owing to the shape of the card, the rocket shoots forward.

What next?

Try repeating this exercise several times in the same water. You will find that it only works two or three times before there is too much detergent present. Adding more has no effect – now the surface tension is low all over the surface.

If you push the wall, will it move?

Ireland

For every action there is an equal and opposite reaction

Background

This uses a simple classroom optical lever to demonstrate Newton's Third Law and the microscopic flexures of masonry walls created by human-scale contact forces.

Follow these steps

- 1 Upturn the bin, place a flat, smooth surface on top of it and position it about 0.5 m from a masonry wall.
- 2 Attach the small mirror to the pin with Blu-Tack.
- 3 Place a metre stick on its edge on top of the flat surface, one end attached to the wall with Blu-Tack.
- 4 Rest the other end of the metre stick freely on top of the bin.
- 5 Place the pin and mirror between the metre stick and the flat surface so that the end of the stick rests freely on top of the pin and mirror.
- 6 Position the laser pointer in the retort stand, directing the beam onto the mirror.
- 7 Position a second metre stick, to act as a scale, in the line of the reflected beam.
- 8 Observe the reflected spot on the scale.
- 9 Get a student to push against the wall and watch the reflected spot move up and down on the scale.

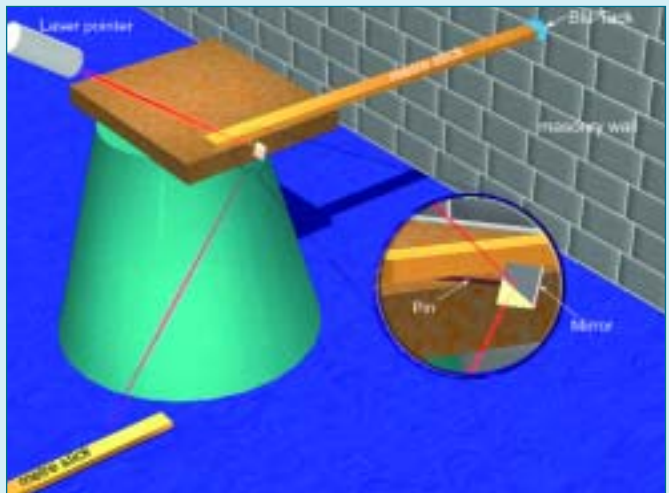
You will need...

- ✓ two metre sticks
- ✓ Blu-Tack
- ✓ a straight pin
- ✓ a small piece of mirror or CD (1 × 1 cm)
- ✓ a laboratory bin
- ✓ a laser pointer
- ✓ a retort stand
- ✓ a flat, smooth surface (e.g. hardback book)
- ✓ a masonry wall

So what happened?

According to Newton's Third Law, for every force (or action) between two bodies there is always an equal but opposite force (or reaction). So, as you push against the wall, the wall yields.

As the wall flexes, the first metre stick moves back and forth, rotating the pin and mirror and thus deflecting the laser spot at varying angles back to the scale.



What next?

Ideally, use a wall that you can both push and pull.

You can read more about this demonstration in

Daniel L Maclsaac and Michael Nordstrand 2001 Demonstrating and measuring the flexure of a masonry wall *Phys. Teach.* **39** 212.

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Has Newton's Law gone wrong?

Slovakia

Acceleration due to gravity acts at the centre of gravity of an object

You will need...

- ✓ a metre stick
- ✓ several coins

Background

Objects come in all shapes and sizes. When we apply Newton's law we assume that all of the mass is in the centre.

Follow these steps

- 1 Rest one end of a metre stick on the edge of a bench.
- 2 Support the free end of the stick with your hand so that it remains level with the top of the bench.
- 3 Pile two or three coins on the free end of the stick.
- 4 Let go of the stick and allow it to fall a short distance before catching it again.
- 5 Watch (and listen) to discover what happens.

So what happened?

You should hear the sound of the coins landing on the stick after you catch it. The coins must be falling at a slower rate to that of the metre stick. However, how can this be true if the acceleration due to gravity is the same for all objects, as Newton's Law of gravity tells us? Was he wrong?

Newton was not wrong. In this case the centre of gravity of the stick is at its midpoint

and it is here that the acceleration due to gravity is the standard 9.8 ms^{-2} . The outer end of the stick, as it falls, is actually rotating about the suspended end on the bench. This end is 50 cm farther away from the centre of gravity, so its total acceleration (angular and linear) will be greater and it moves faster than the coins, which are accelerating at 9.8 ms^{-2} .



What next?

Discuss how pole vaulters can curve their bodies over the bar so that their centre of gravity is below the bar.

Opening flowers

Austria

Capillary action

You will need...

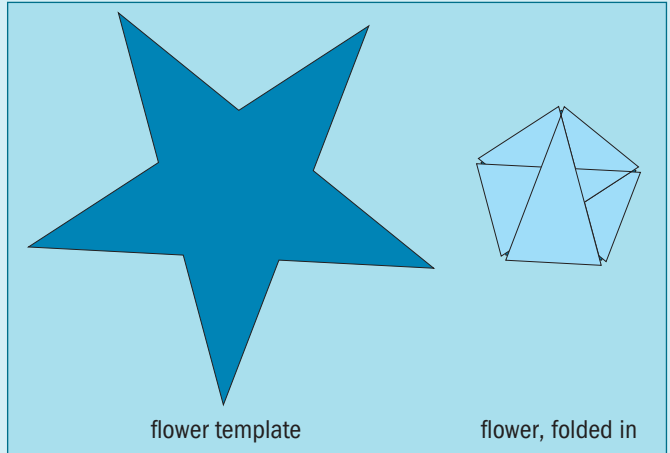
- ✓ a bowl of water
- ✓ some paper (coloured, if possible)
- ✓ a pair of scissors

Background

Plants rely on capillary actions to draw water up through a network of thin tubes.

Follow these steps

- 1 Using the template shown, cut out some paper flowers.
- 2 Fold in the points of each flower across its centre.
- 3 Place the flowers onto the surface of the water and watch what happens.



So what happened?

The base of the flowers absorbs the water and the water moves out through the petals in a capillary action. As the petals become soaked with water they open out owing to the force of the water travelling through the paper fibres.

What next?

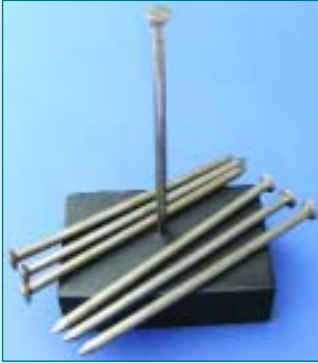
Discuss whether this experiment would work with plastic flowers.

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Can you balance six nails on one?

Hungary

Puzzle stimulates discussion on balance and centres of gravity



You will need...

- ✓ seven nails (6 inch/15 cm)
- ✓ a small block of wood

Follow these steps

- 1 Hammer one of the nails into the block of wood.
- 2 Pose the following problem: how do you balance the other six nails on top of the one in the wooden block?

So what happened?

Did any of the students figure it out? This is how it's done:

- 1 Lay the six nails flat on the table.
- 2 Arrange the nails as shown in the picture at top right. "Three heads are better than two" may be a useful way to remember the arrangement at each end.
- 3 Gripping the arrangement at the centre, carefully balance it on the upright nail.



How can a balloon lift a glass?

Slovakia

Pressure and friction conspire to produce an entertaining effect

You will need...

- ✓ a drinking glass
- ✓ a balloon

Follow these steps

- 1 Place the balloon inside the glass.
- 2 Slowly inflate the balloon.
- 3 Holding just the neck of the balloon, lift the glass.
- 4 Ask the students to explain what they see.

So what happened?

A seal is formed between the glass and the balloon. The resulting frictional force, due to the increased pressure, is greater than the weight (downward force) of the glass, so the glass doesn't slip off the balloon.

What next?

Discuss whether this would work with a paper bag, or if there was a layer of oil between the glass and the balloon.



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Anyone for tennis?

Belgium

Acceleration due to gravity is independent of the mass of an object

You will need...

- ✓ three identical tennis balls
- ✓ some water
- ✓ a needle and syringe (for filling one of the balls with water)

Background

Students intuitively expect heavy objects to fall faster than light ones.

Follow these steps

- 1 Out of view of the students, inject one tennis ball with as much water as it will hold.
- 2 Ask a student to drop two normal tennis balls from the same height and note whether or not they hit the ground at the same time.
- 3 Then ask them to hold two tennis balls, one of which you have filled with water, to feel the difference in weight.
- 4 Get them to drop the two different tennis balls from an equal height and note when they hit the ground.
- 5 Ask the students to try to explain what they see.



So what happened?

Students will expect the heavier of the two different balls to hit the ground first. In fact they should reach the ground at the same time.

This exercise is used to demonstrate how gravity is independent of the mass of an object. As the balls are the same size, students can ignore differences in air resistance, etc.

Safety note

- ☛ Remove breakables from the vicinity and do not stand over the balls as you bounce them.

What next?

There is a link to the video clip of the hammer and the feather being dropped on the moon, which demonstrates the same principle. You can see the video clip (broadband is required) at http://www.hq.nasa.gov/office/pao/History/alsj/a15/a15v_1672206.mpg.

“Bouncing balls” follows on from this experiment.

Bouncing balls

Belgium

Conservation of momentum – the effect of collisions

You will need...

- ✓ a tennis ball
- ✓ a basket ball
- ✓ a lofty room (e.g. a sports hall)



Safety note

- ☛ Remove breakables from the vicinity and do not stand over the balls as you bounce them.

Background

Momentum is the product of mass and velocity.

Follow these steps

- 1 Drop the tennis ball and the basketball independently from the same height and see how high they both bounce.
- 2 Hold the tennis ball on top of the basketball, then drop them both at the same time.
- 3 Watch how high the two balls bounce now.

So what happened?

If the tennis ball bounces off the top of the basket ball then it bounces high into the air – approximately nine times as high as previously.

This is a demonstration of conservation of momentum. Some of the momentum from the basket ball is transferred to the tennis ball, thereby causing the tennis ball to bounce higher.

There are also other reasons why the ball bounces higher, such as the different sizes, elasticity and air resistance of the two balls.

What next?

A number of people have looked at the maths of this exercise. You can find out more at <http://physics.ucsd.edu/students/courses/fall2001/physics2a/tennis-basket-balls.pdf> and at <http://www.physics.otago.ac.nz/teaching/PHS1110/jakub/Momentum.html>.

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Which syringe is easiest to push?

Austria

Force is proportional to area if the pressure is constant

Follow these steps

1 Connect the apparatus (see diagram), filling the syringes and plastic tubing with water. The nozzle of each syringe should be of equal size to connect the plastic tubing.

2 Hold a syringe in each hand and press evenly on them.

3 Note which syringe plunger is easier to push down. You may need to swap the syringes from one hand to the other to notice the difference, because the difference in the strength of your hands may counteract the difference in force required.

4 Try varying the amount of water in the system. About a third full should work best. If there is too little water it can be difficult to detect the difference in forces required. The greater the difference in the size of the two syringes the easier it will be to detect the difference in force required.



You will need...

- ✓ two syringes of different sizes (e.g. 5 and 20 ml)
- ✓ some plastic tubing
- ✓ some water

What next?

This is a good introduction to hydraulics, as used in the brakes of a car, as the basic principle is the same.

So what happened?

The plunger of the smaller syringe is easier to push down. As the pressure remains constant the force required is proportional to the area of the syringe.

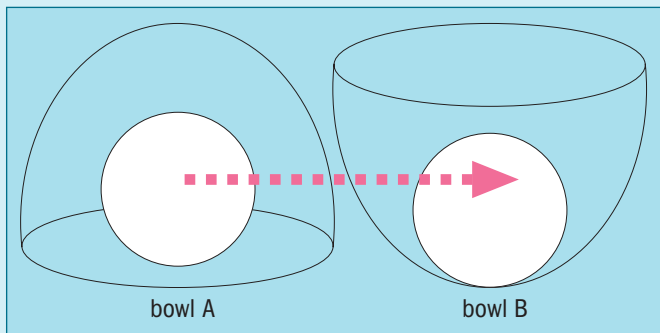
Centripetal force

Ireland

Forces acting on rotating objects

You will need...

- ✓ two circular bowls (Danone yoghurt comes in an ideal plastic container; see picture)
- ✓ a table-tennis ball or marble



Background

When going round a corner quickly in a car you feel as if you are pushed to the outside of the bend. In fact the car is exerting a force on you, called centripetal force, which makes you go round the corner with the car.

Follow these steps

- 1 Put the ball under one of the containers, placed face down.
- 2 Ask a student to move the ball from this container to the other container without touching the ball or the empty container.

So what happened?

You may have to give the student some clues. They need to move the first bowl in a circular motion, spinning the ball round fast enough that it moves up the sides of the bowl. This will allow them to lift the bowl quickly while the ball is still forced against the sides and place it over the other bowl, allowing the ball to drop into the second bowl without them having to touch either the second bowl or the ball.

Centripetal force, which keeps the ball against the sides of the first bowl, is responsible for preventing it from dropping out of the bowl until the student stops moving the bowl in a circular motion.

What next?

When a hammer thrower releases the hammer, in which direction does it go? This experiment can also lead to a discussion about governors used in engines, such as those on steam engines (e.g. the threshing engines seen at field days).

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Soap bubbles and films: 2-D and 3-D shapes

Spain

Surface tension determines the shape of soap films

Soap solution

You will need...

- ✓ some glycerine (~650 ml; can be purchased from a pharmacy)
- ✓ some water (~2 l)
- ✓ some washing-up liquid (~1.1 l)

Follow these steps

1 Stir the glycerine, water and washing-up liquid (proportions of about 1:4:2) for about 10 min.

Note: Too many bubbles forming at the top make it harder to get good shapes.

2 The solution can be stored in a sealed container (e.g. an empty water bottle). In time, some of the water may evaporate, so add more, as required.

Note: There are other recipes for soap solutions that can be found on the Internet. If your tapwater is hard you may need to use bottled water to create the bubbles.

2-D shapes



You will need...

- ✓ some coathanger wire
- ✓ some thread
- ✓ four pieces of clear Perspex (~10 × 20 cm each)
- ✓ a drill
- ✓ seven screws

Follow these steps

Demonstration 1

- 1** Make a wire circle and tie a piece of thread across it.
- 2** Dip the wire circle and thread into the soap solution.
- 3** Break the bubble on one side of the thread and note what happens to the thread.

Demonstration 2

- 1** Drill two Perspex sheets at the four points of a square and join the sheets with the screws through these holes, leaving a gap of about 2 cm, so that the screws form the edges of a cuboid shape.
- 2** Similarly, drill through three points of a triangle on the other two sheets so that the screws form the edges of a triangular prism shape.
- 3** Dip the 3-D shapes into the soap solution and note where the film forms.

So what happened?

The bubbles always move to reduce the surface area to a minimum, so the thread moves to minimize the size of the film; and, for both the square and the triangle, instead of being formed at the outside of the screws, the film comes in to the centre, forming 120° angles.

Soap bubbles, continued...

3-D shapes

You will need...

- ✓ soap solution
- ✓ some coathanger wire, solder and soldering iron; or a straw kit (used to create molecular shapes); or a magnetic kit (e.g. Cultimo Magnetic Construction Set; see right)



So what happened?

The bubbles always move to reduce the surface area to a minimum, so the films all form at the centre of the structures.

What next?

Ask students to measure the distances on the 2-D structures around the outside of the triangle/square where they expected the film to form. Compare this to the film of the bubble formed.

Follow these steps

- 1 Construct a 3-D pyramid and a 3-D cube (see pictures, right) using the magnetic kit and coathanger wire.
- 2 Dip the pyramid into the soap solution and note where the films form.
- 3 Burst some of the sides of the bubble and note what happens.
- 3 Dip the cube into the soap solution and note where the films form.



18 forces

Moments on a wheel

The Czech Republic

The turning effect depends on the distance from the axis

You will need...

- ✓ a CD
- ✓ a marker pen
- ✓ some small round magnets
- ✓ a retort stand

Background

Pupils should know that:

- 1 the moment of a force = force \times perpendicular distance from the axis;
- 2 the principle of moments states that in equilibrium the sum of the clockwise moments equals the sum of the anticlockwise moments. This experiment allows pupils not only to verify the principle of moments but also to see that the turning effect depends on the perpendicular distance from the axis without doing calculations.

Follow these steps:

- 1 Draw a grid of equally spaced squares on the silver side of the CD (1 cm square).
- 2 Support the marker pen in the clamp of the retort stand.
- 3 Balance the CD using the marker pen as the axis.
- 4 Attach two magnets, each side, at a fixed number of squares away from the axis along the diameter of the CD.

So what happened?

Note that the CD will become unbalanced. The direction of the moment of the force created by the magnets can easily be seen, thus introducing the terms “clockwise” and “anticlockwise” as applied to moments.

Ask pupils how to get the CD to balance again. This is simply done by putting two magnets on the opposite side of the CD at an equal distance from the axis.

The principle of moments can then be verified by using different numbers of magnets at various distances from the axis.

Younger pupils should use different numbers of magnets at various distances from the

axis. Ask them to bring the CD back into balance using only one magnet on the opposite side to check that they have understood the principle of moments.

Ask older pupils what will happen when the CD is in equilibrium if one set of the magnets is moved to the edge of the CD. The obvious answer is that the CD will become unbalanced.

However, this is not the case if the magnets are moved down (see picture). The perpendicular distance is the same, though the actual distance (the radius of the circle) has increased.

This clearly shows that the moment is calculated using the perpendicular distance and not the actual distance.



What next?

This can be compared to a bicycle wheel and shows why it is best for the footrest on a bicycle to be able to swivel so that the maximum distance (i.e. the diameter) is always obtained and thus the maximum turning effect is obtained using the minimum of force.

This can then be followed with mathematical calculations on moments.

Impulse and momentum

UK

A change in momentum is greater when there is a rebound

You will need...

- ✓ two balls of similar size and mass (one should be elastic and rebound well and the other inelastic with little or no rebound)
- ✓ a retort stand
- ✓ a block of wood



So what happened?

The wood should be knocked over much more easily by one side of the ball than by the other. This is because the elastic ball rebounds on impact with the wood, thus causing a bigger change in momentum due to the direction change, while the other ball does not rebound and therefore has a smaller change in momentum.

Background

Momentum = mass \times velocity and is a vector quantity.

Impulse = change of momentum.

This experiment is used to show that, since momentum is a vector quantity, the change of momentum is greater when there is a rebound (i.e. a change in direction).

Follow these steps:

- 1** Cut the two balls in half and, using one half of each, glue two halves together to make a composite ball, embedding one end of a length of string in the middle.
- 2** Suspend the composite ball from the clamp of the retort stand.
- 3** Set up the block of wood a short distance away from the ball so that the top of the wood is level with the ball.
- 4** Using one side of the ball, raise it through a fixed height from the top of the wood and then let it drop to see if it has enough force to knock over the wood.
- 5** Repeat this process using the other side of the ball.

What next?

This can be shown to have many applications in sports like tennis and squash.