

## Unit 9L Pressure and moments

### About the unit

In this unit pupils:

- study pressure on solids and describe applications of this in everyday appliances
- study hydrostatic pressure in fluids and describe an application, *eg hydraulic jack*
- describe the operation of levers, including examples from the human body, which depend on the turning effect of a force
- learn about the principle of moments

In scientific enquiry pupils:

- make an appropriate number of measurements with adequate precision
- account for anomalous results in terms of experimental technique
- investigate balance about a pivot, evaluating strengths and weaknesses in their methods

This unit is expected to take approximately 7.5 hours.

### Where the unit fits in

This unit builds on unit 7K 'Forces and their effects' and links to unit 9K 'Speeding up'. Work on muscles as levers relates to unit 9B 'Fit and healthy'.

This unit lays the foundation for further quantitative work on forces in key stage 4.

This unit provides opportunities to revisit and revise topics met in other units, *eg forces, particle theory*. With some pupils, teachers may wish to concentrate on some of the new topics, extending activities, and with others to spend more time on revision of previous work.

### Expectations

#### At the end of this unit

##### in terms of scientific enquiry

**most pupils will:** plan an investigation into balance, making sufficient observations with precision; identify a pattern in their results and use this to draw conclusions, relating these to the principle of moments

**some pupils will not have made so much progress and will:** make systematic observations of balance and use these to draw conclusions

**some pupils will have progressed further and will:** account for anomalies in the observations of balance and evaluate their conclusions by reference to the principle of moments

##### in terms of physical processes

**most pupils will:** summarise key ideas about pressure; use the relationship between force, area and pressure between solids and within liquids and gases; explain the action of levers, including examples in the human skeleton in terms of the turning effect of a force; use the principle of moments to explain balance and give examples of its application, *eg crane counterweight*

**some pupils will not have made so much progress and will:** describe how force can be 'spread out' to reduce pressure or 'focused' to increase pressure; recognise that the turning effect of a force can be increased by increasing the length of the lever arm and give a use of this; describe how to balance a see-saw

**some pupils will have progressed further and will:** use the definition of pressure in calculations to explain the operation of a range of devices; relate hydrostatic pressure in liquids and gases to density; apply the principle of moments to explain a range of situations, including the action of levers

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## Prior learning

It is helpful if pupils:

- can identify the directions in which forces act and can represent these by arrows
- can calculate surface area of simple shapes
- know how muscles in the body are attached by tendons and produce movement by contraction of antagonistic pairs

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## Health and safety

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

- handle water and air under pressure
- may learn safe handling techniques for heavy loads

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.

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## Language for learning

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

- words relating to pressure, *eg force, area, hydraulic, pneumatic*
- words and phrases relating to balance, *eg moment, pivot, lever, turning effect, counterbalance*
- words and phrases relating to the human body, *eg antagonistic muscles*

Through the activities pupils could:

- present and listen to arguments based on scientific understanding

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## Resources

Resources include:

- examples or photographs of items which rely on high or low pressure, *eg snowshoes, skis, drawing pins, camels' feet*
- a hydraulic jack, or a video or model of a jack
- an aerosol air freshener
- video clip or photograph of a saline drip above a patient
- a tin with a lid, a lever to remove the lid, a range of household devices that operate on a lever principle, *eg bottle opener*
- photographs of gymnasts and cranes with counterbalance weights
- a household mop with string and pivot to model the human back

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## Out-of-school learning

Pupils could:

- watch a hydraulic jack operating and think about how it works
- watch a large building-site crane operating and identify the forces involved
- identify a number of devices in the home that rely on levers

Pupils should learn:

Pupils:

### What is pressure?

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| <ul style="list-style-type: none"> <li>• how the effect of a force depends on the area to which it is applied</li> <li>• how to use the quantitative relationship between force, area and pressure</li> <li>• about practical applications of this relationship</li> </ul> | <ul style="list-style-type: none"> <li>• Elicit pupils' ideas about what it would feel like to lie on a bed of nails and whether they would rather have their foot trodden on by an elephant or by someone wearing stiletto heels. Draw the conclusion that the area over which a force is concentrated makes a difference to its effect. State the relationship: pressure = force ÷ area (perpendicular to direction of force).</li> <li>• Ask pupils to work out the lowest and highest pressure they can exert on a part of their body. This requires them to weigh themselves in newtons and measure the cross-sectional area of any part of their body on which they are capable of balancing, <i>eg head, tiptoes, hands, full body</i>.</li> <li>• Ask pupils to contribute to a list of devices that rely on low pressure being exerted, <i>eg snowboards, snowshoes, camels' feet</i>, and a list where high pressure is required, <i>eg blades, drawing pins</i>. Demonstrate or show video clips of some of these.</li> </ul> | <ul style="list-style-type: none"> <li>• explain the relationship between force and area, <i>eg in terms of lying on a bed of nails</i></li> <li>• apply the quantitative relation between pressure, force and area to a number of situations, <i>eg skis, sharp blades</i></li> </ul> | <ul style="list-style-type: none"> <li>• Pressure is, technically, a hydrostatic process, ie the forces act in all directions. This is dealt with below in pneumatics and hydraulics. The concept described here is where the force is in one direction only, more precisely termed 'stress'. However, this treatment follows common usage of the term 'pressure'.</li> <li>• Encourage pupils to distinguish between the terms 'force' and 'pressure', and avoid saying the 'pressure is concentrated' instead of 'the force is concentrated'.</li> <li>• It is acceptable to use units of <math>\text{Ncm}^{-2}</math>, though pascals may be used.</li> </ul> |
| <ul style="list-style-type: none"> <li>• to present and listen to arguments based on scientific understanding</li> </ul>   | <ul style="list-style-type: none"> <li>• Ask pupils to take the role of a sales manager, select one item and make a spoof written report of a 'new, improved' version where the item in question exerts high pressure instead of low, or vice versa. They then have to 'sell' it, explaining its features, <i>eg the smallest snowshoes in the world, guaranteed to sink as far and as fast as possible; or the drawing pin with a new, improved thick pin</i>.</li> </ul>   | <ul style="list-style-type: none"> <li>• show, by the ability to apply 'reverse logic', that they have grasped the key ideas of pressure</li> </ul>  |  |

### What are pneumatics and hydraulics?

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| <ul style="list-style-type: none"> <li>• that gases can be put under external pressure, and some uses of this</li> </ul> | <ul style="list-style-type: none"> <li>• Introduce the word 'pneumatics'; ask about experiences of gases under pressure, <i>eg bicycle tyre ('pneu' – French for tyre)</i>. Remind pupils of the nature of gases and liquids as described by the particle model of matter, and elicit their ideas about why gases – unlike liquids – are compressible. Offer pupils empty syringes to show this, if required. Spray aerosol air freshener and elicit pupils' ideas as to how the freshener gets out – gas under pressure acts as a propellant for the liquid. Establish why the pressurised container can explode when on the fire.</li> <li>• The use of pressure to provide controlled movement could be demonstrated with a model steam engine, or pupils could find out about the work of, <i>eg Hero of Alexandria, Thomas Newcomen</i>.</li> </ul> | <ul style="list-style-type: none"> <li>• describe some effects and uses of gases under pressure, <i>eg car tyres, aerosols, pneumatic systems</i></li> <li>• apply the model of the particle theory of matter to explain the behaviour of gases under pressure</li> </ul> | <ul style="list-style-type: none"> <li>• Pupils may have had the opportunity in design and technology to make models/toys that are pneumatically or hydraulically operated or they may have used these systems for control, <i>eg in unit 9D 'Using control for electronic monitoring' in the design and technology scheme of work</i>.</li> <li>• Pupils will have been introduced to the particle explanation of air resistance in unit 7K 'Forces and their effects'.</li> </ul> |
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**Learning objectives**

Pupils should learn:

- to explain the transmission of pressure in terms of the particle model
- that liquids can be put under external pressure, and some uses of this
- that gases and liquids have internal pressure which depends on the weight of fluid above the point being considered

**Possible teaching activities**

- Elicit pupils' ideas about the effect of exerting pressure on a container of liquid. Offer them balloons or syringes filled with water to determine whether they can reduce the volume.
- Show a diagram of a simple hydraulic system where the liquid is transferred from a reservoir of unit area to one of 10 times unit area, and ask pupils to predict the force with which it will lift the plunger when a force of 10N is applied. Take votes on the outcome. Most will intuitively predict that the force is diminished rather than magnified. Reference to the distance moved by the applied force may help the understanding of this counter-intuitive outcome.
- Demonstrate, *eg using video*, the ability of a hydraulic jack to lift large loads, *eg a car*, with little effort, or model this with water-filled tubes.
- Show pupils a video clip or a photograph, *eg of a paramedic running alongside a patient's hospital trolley and holding a saline drip in the air, and ask why the drip has to be raised*. Establish the importance of the 'head of liquid'.
- Ask for pupils' experiences of swimming underwater at the deep end of the pool. Many will report discomfort in their ears. Associate this with the pressure exerted by the height of water above their heads.
- Elicit pupils' ideas as to why watches used by swimmers and divers are 'pressurised to three atmospheres'.

**Learning outcomes**

Pupils:

- apply the particle model of matter to explain why liquids are incompressible and gases are compressible
- apply the concept of transmission of pressure to predict the resulting force
- describe some effects and uses of liquids under pressure, *eg fire hoses, hydraulic systems*
- describe an effect of atmospheric pressure or underwater pressure

**Points to note**

- Pupils could find out more about the prolific inventor Joseph Bramak, who invented the hydraulic press and the flushing toilet, among other things.
- In unit 7G 'Particle model of solids, liquids and gases' pupils will have tried to compress syringes full of liquid.
- ⚠ **Safety** – be certain that the class can be trusted with items filled with water, such as balloons or syringes
- The divers' hazard called 'the bends' is due to atmospheric gases, which dissolve in the blood under pressure, suddenly forming bubbles and interrupting the blood supply.
- Modern digital watches are in sealed cases, which are often guaranteed not to leak while the wearer is swimming.

**Checking progress**

- to use ideas about force and pressure to interpret secondary sources
- Provide pupils with resources on relevant devices or situations and ask them to write summaries which link all the key ideas about force and pressure in solids, liquids and gases.
- show by the links they make that they have grasped the key ideas
- Some pupils may need prompt cards with phrases and sentences they can use in their summaries.

**How do levers work?**

- that a lever is a simple machine which uses a pivot
- about uses of levers
- that the turning effect of a lever depends on the force and its distance from the pivot
- Ask pupils how to remove the lid from a tin of paint. Offer a range of simple levers for pupils to try, and in each case ask them to identify the pivot and the position of the effort. Encourage pupils to appreciate use of a long lever arm, *eg ask pupils to cut paper with the tips of scissors and then to cut thick cardboard. They will intuitively put the card nearer the pivot to cut it*. Demonstrate a torque wrench and a wheel brace.
- Ask pupils to find out about devices in the home that rely on levers.
- describe how to make a task easier by increasing the distance between the effort and the pivot
- identify levers in a number of household devices
- This topic is made easier for pupils if reference is made to what they do intuitively when choosing where to apply a force.
- Refer also to pupils' work with models and tools in design and technology.
- about examples of levers in the body
- how pairs of antagonistic muscles produce turning effects at skeleton joints
- Ask two pupils to arm wrestle (gently) to demonstrate how arms act as levers. Elicit pupils' ideas about how longer arms are an advantage.
- Show or ask pupils to make a model of the arm with the biceps and triceps attached, as an example of antagonistic muscles. Identify the elbow joint as the pivot and ask pupils to explain how the forearm operates as a lever, both up and down.
- describe the arrangement of muscles on the arm and associate them with the parts of a lever
- explain how an antagonistic muscle pair works
- This relates to unit 9B 'Fit and healthy', in which pupils consider how simple joints function.

Pupils should learn:

Pupils:

### How do things balance?

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| <ul style="list-style-type: none"> <li>• that a force can make an object topple over (turn about a pivot)</li> </ul>   | <ul style="list-style-type: none"> <li>• Link to the previous section, with illustrations of gymnastic balance, <i>eg photographs or video clips of Olympic gymnasts</i>. Get pupils to try some balancing activities, <i>eg</i> <ul style="list-style-type: none"> <li>– stand with their heels touching a wall and try to pick up an object placed about 0.5m away, on the floor. Ask why this is impossible</li> <li>– stand about three foot-lengths from the wall and try to touch the wall with their noses. This may be possible for some pupils and not for others</li> </ul>           Ask whether there are any patterns.</li> <li>• Draw out ideas about muscles and levers and 'counterbalance'.</li> <li>• Demonstrate a toy crane or show photographs of cranes, explaining the role of the counterbalance weight.</li> <li>• Make a model of the human back to demonstrate the tension in the muscles when we bend. Tie string to a mop about one quarter of the way down from the head. Pivot the mop at the other end by drilling a hole through it to take a rod. Now try to balance the mop as it tilts by holding the string at an angle of about 10 degrees. This will show pupils that a large force is needed.</li> </ul> | <ul style="list-style-type: none"> <li>• describe how an object can be kept in balance, <i>eg human body, crane</i></li> <li>• apply the idea of the turning effect of a force to everyday situations, <i>eg lifting heavy objects</i></li> </ul>   | <ul style="list-style-type: none"> <li>• This is an opportunity to teach a safe lifting technique, ie reducing leverage on the back by keeping the spine as vertical as possible, thus preventing muscle strain.</li> </ul>  |
| <ul style="list-style-type: none"> <li>• that the turning effect of a force is called its moment</li> </ul>  | <ul style="list-style-type: none"> <li>• Describe the turning effect of a force as its moment. Ask pupils to make a mobile, or show them a mobile, <i>eg for a child</i>, and ask them to write notes about the mobile's construction using the terms 'pivot', 'balance' and 'moment'. Introduce the see-saw balance, <i>eg a pivoted metre rule</i>.</li> </ul>   |   | <ul style="list-style-type: none"> <li>• The concept of 'moments' is difficult and will only be covered by some pupils. Other pupils could be encouraged to talk about the 'turning effect' of a force and will simply associate a greater effect with the force being further away from the pivot.</li> </ul> |
| <ul style="list-style-type: none"> <li>• to plan and carry out an investigation</li> <li>• to devise a table to show results effectively and draw conclusions</li> <li>• to identify and explain anomalous results</li> <li>• to use the principle of moments to explain balance</li> <li>• to calculate moments about a single pivot</li> </ul> | <ul style="list-style-type: none"> <li>• Ask pupils to plan an investigation to find the rule of balancing. Encourage them to plan how to collect data systematically to determine the pattern.</li> <li>• Derive the principle of moments from their patterns and use them to calculate moments about a pivot. Help pupils to find anomalies in their readings and to identify the origins of these, <i>eg incorrect measurement, poor balance</i>.</li> </ul>  | <ul style="list-style-type: none"> <li>• plan to take appropriate measurements</li> <li>• present results in a way which helps them identify patterns</li> <li>• explain, in terms of experimental technique, how anomalous results might have occurred</li> <li>• recall the principle of moments and apply it to a range of situations</li> </ul> | <ul style="list-style-type: none"> <li>• A spreadsheet could be used with some pupils.</li> </ul>  |

### Reviewing work

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| <ul style="list-style-type: none"> <li>• to use the ideas of this unit</li> </ul> | <ul style="list-style-type: none"> <li>• Identify a range of situations where the turning effect of a force is used, <i>eg tools, gymnastics</i>.</li> <li>• Ask pupils a range of questions related to pressure and the principle of moments, requiring both numerical and descriptive answers. Discuss their answers with the pupils, asking them to explain their methods and the reasoning used.</li> </ul> | <ul style="list-style-type: none"> <li>• show, by their answers, that they have grasped the key ideas</li> </ul> |
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