MaterialWorks

Teacher's exhibition notes

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ScienceWorks and The Observatory Science Centre are part of Science Projects, an educational charity specialising in the communication of science through hands-on exhibits.

SURFACES

The surface of a material affects how it can be used
Surfaces vary how easily they're marked or kept clean

DESCRIPTION

There are a wide variety of different surfaces on display. Chalk is provided which pupils can use to try and draw on the surfaces and compare their differences. A cloth is available to wipe them clean.

CURRICULUM LINKS

Pupils should be taught:
Key stage 1
"to sort materials into groups on the basis of simple properties, including texture"
Key stage 2
"to compare everyday materials on the basis of their properties.......and to relate these properties to the everyday uses of the materials"
Key stage 3
"to recognise differences between solids......in terms of properties

RELATED EXHIBITS

Video microscope
This exhibit allows pupils to examine visually the surfaces of a range of materials.
Inappropriate materials
Shows various inappropriate materials used in a bicycle, including some which have wrong surface textures.
Types of materials
The properties of a range of different materials can be examined.

WHAT TO DO

Examine the materials.

Q: How do the surfaces differ?
(A: Some are smooth, others are rough.)

Try drawing on each of the different surfaces with a piece of chalk.

Q: Can you draw as easily on all the surfaces?
(A: No, some of the surfaces can hardly be drawn on at all, some quite easily and some wear off too much of the chalk.)

Q: Which is the easiest to draw on and which is the hardest?
(A: The slate is the easiest and the glazed tile and the glass are the hardest.)

Q: Why are there differences in the chalk drawing?
(A: Because of the different surface textures – the amount and size of tiny ridges, bumps and grooves on the surface.)

MORE THINGS TO DO

Try wiping the chalk off each surface using the cloth.

Q: Which surfaces are easiest to wipe?
(A: The smoothest ones.)

Q: Why are some more difficult to wipe?
(A: The chalk dust in the grooves of the roughest material can't be easily reached by the cloth.)

Examine the end of the chalk after you have used it on the different surfaces.

Q: What does it look like?
(A: Flat, with most of the surfaces - smooth with some surfaces, and loose and dusty with others.)

OTHER THINGS TO DO

Think what these materials could be used for with respect to their surfaces.

SURFACES: FURTHER INFORMATION

Surfaces in contact

To picture what is happening when using chalk for drawing it is best to imagine everything greatly magnified. No surface is completely smooth. Some, like brick, have a very rough surface, while others, like glass, feel very smooth but are still a little uneven when seen under a high-powered microscope.

What happens when two surfaces are rubbed together depends not only on the surface texture but on how hard each material is. The materials actually only touch where the high points on each surface touch. If one material is much harder than the other it may break off the high points of the softer material.

Slate is a metamorphic rock derived from sedimentary clay or volcanic ash and subjected to heat and pressure. Its layers are sharp and hard even though we can not feel them and soft materials like chalk are shaved leaving a mark on the surface. Glass with its very smooth surface does not abrade chalk. Some materials are designed to have low friction like the plastic (PTFE) used on non-stick pans.

Sandpaper

Examining different grades of sand paper is a good way to appreciate the different scale of the lumps and bumps of surfaces. The purpose of sandpaper is to rub the surface from a softer material.

INAPPOPRIATE MATERIALS

Properties of materials affect the way they are used More than one property usually determines the selection of a material for a particular use

DESCRIPTION

A small bicycle is supported in a frame. Certain parts of the bicycle have been removed and replaced by similar parts made of an inappropriate material. Pupils can investigate how this unsuitable material affects the working of the particular part.

The bicycle cannot be sat on. It is supported upright in its frame, and the rear wheel is raised so that it can be turned by means of the crank by hand.

CURRICULUM LINKS

Pupils should be taught:
Key stage 1
"that materials are chosen for specific uses....on the basis of their properties"
Key stage 2
"to compare everyday materials......on the basis of their properties....and to relate these properties to everyday uses of the materials"
Key stage 3
"to recognise differences in solids....in terms of properties"

RELATED EXHIBITS

Surfaces
This exhibit allows investigation of the effects of surface texture on the use of certain objects.
Video microscope
Magnified views of a range of materials can be explored.

WHAT TO DO

Carefully examine the bicycle.

Q: What parts of the bicycle have been changed?
(A: Both sets of brake blocks and brake cables, the saddle support and surface, the spokes, the tyres, the handlebars and the chain and cogs.)

Q: What materials have been used in each case?
(A: Toothbrushes and wooden twigs for the brakes, elastic and electrical wire for the cables, sandpaper for the saddle and rope for its support, elastic for the spokes, metal and cloth for the tyres, and a belt for the chain drive.)

MORE THINGS TO DO

Examine the things which have been changed and compare the properties of these materials with those which would have been on the bike originally.

INAPPROPRIATE MATERIALS: FURTHER INFORMATION

Considerations for choice of material
Each of the materials used in a bicycle has been chosen to fulfil a number of requirements. Some of the properties are general to the whole bicycle and these include cost, weather resistance, weight and attractiveness. Materials which are not generally used because of these considerations are, for example, leather for the saddle (usually too expensive), wood for the frame (would rot), solid plastic wheels (too heavy), and matt paint (unattractive and hard to clean).

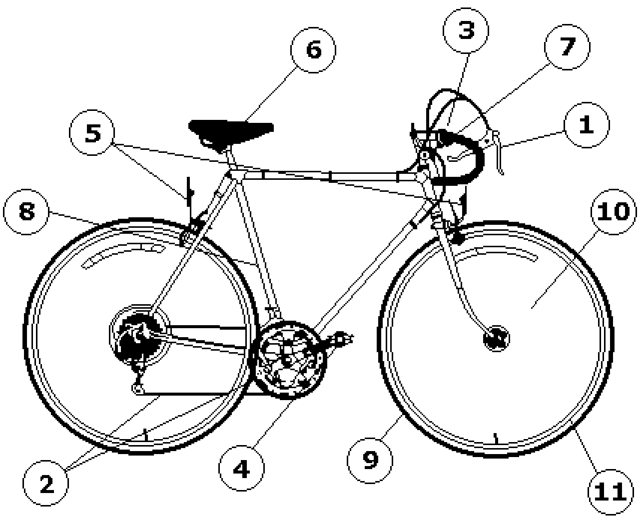
Materials for specific parts
Taking into account all the above considerations materials are then chosen according to the particular use of that piece. The frame (8) has to be strong and rigid but it also helps to be light so often in more expensive bikes the basic steel is replaced with aluminium or even titanium alloys. The wheel's rim (11) and spokes (10) are made of steel for its strength and rigidity (so that it stays round).

The handlebars (7) perform two main functions: to support part of the body weight and to steer the bicycle. Both of these require a rigid material in particular so that precise movements of the handlebars move the front wheel in a firm and reliable way. This is important not only to steer round corners but also to keep the bike balanced. The brake cables (3) have to be flexible but not elastic, and electrical wire is of no use as the wire cannot move in its sheath.

The brake blocks are made of rubber because this has a high friction when pressed against the steel wheel rims. They are often grooved like tyres to allow water to be dispersed so that it does not form a layer between the rubber and the surface it has to grip. Pedals (4) too are often made of grooved rubber. The saddle (6) is used for the rider's bottom so should be comfortable to sit on (it usually a soft plastic) and rigidly supported by steel or aluminium.

Tyres (9) consist of a rubber tube pumped up with air. The rubber has good friction properties for grip on the road. The air, under the right pressure, is hard enough to support the bike and rider but compressible enough to provide a cushion against uneven surfaces. The metal wheel would neither grip the road nor give a smooth ride but at least it would provide support. The cloth one would not even do that.

Steel chains and cogs (2) are used to transmit as much of the force as possible between the pedals (4) and the back wheel. Belts or similar materials would slip.



TYPES OF MATERIALS

Different kinds of materials have different properties These properties determine the selection of a material for a particular use

DESCRIPTION
A number of different materials can be examined. They include rock (marble), steel, aluminium, plywood, plastic (PVC) and rubber. A magnet, a conductivity tester and a thermometer are provided which children can use to determine their properties of the materials.

CURRICULUM LINKS
Pupils should be taught:
Key stage 1
"to recognise and name common types of material, e.g. metal, plastic, wood, paper, rock"
Key stage 2
"to compare materials, e.g. wood, rock, iron, aluminium....on the basis of their properties including hardness, strength, flexibility, and magnetic behaviour.... ..that some are better electrical conductors than others"
Key stage 3
"that most metallic elements are shiny solids...that most are good thermal and electrical conductors, and that a few are magnetic."

RELATED EXHIBITS
Surfaces
This exhibit allows investigation of the effects of surface texture on the use of certain objects.
Video microscope
Magnified views of the surfaces of a range of materials can be explored.
Inappropriate materials
The wrong use of some materials can be explored.

WHAT TO DO
Carefully examine each material.
Q: Do you know what they are?
(A: Rock (marble), steel, aluminium, plywood, plastic (PVC) and rubber.)

Place the prongs of the conductivity tester on each of the materials.
Q: Which ones make the red light appear?
(A: The metals - the steel and the aluminium will conduct electricity and when the circuit is made the LED lights up.)

Place the magnet on each of the materials.
Q: Which of the materials is magnetic?
(A: Only the mild steel plate. Note that stainless steel screws are non-magnetic.)

Put your hands on each material in turn.
Q: Which ones feel the coldest?
(A: The metals and the marble feel cold, while the wood feels quite warm.)

Now put the thermometer on the materials.
Q: Is there any difference in their temperatures?
(A: No - they're all the same. They only feel different because some materials conduct heat away from your hand more quickly than others.)

TYPES OF MATERIALS: FURTHER INFORMATION

Rock

Rocks are produced in a number of ways. Marble is a metamorphic rock: composed of sedimentary limestone (calcium carbonate, like chalk) and other substances, it has been subject to high temperature and pressure. White marble is produces from very pure limestone. The characteristic swirls and veins of many coloured marble varieties are due to mineral impurities such as clay (grey), silt, sand (orange to brown), iron oxides (red), serpentine (green) or chert (various colours) originally present as grains or layers in the limestone. The surface of this piece has been polished to show off its attractive appearance. It is a very hard material and frequently used for sculpture.

Metals

There are two metals on this exhibit: steel and aluminium. Both conduct electricity and heat well, and are used for this purpose. They are also ductile and malleable, and tend to be lustrous and sonorous. They are strong and can be used for creating structures.

Steel - made of ferrous metal - iron - is magnetic, though only in its 'mild' form. Stainless steel, like the screws, is not.

Aluminium is more expensive than steel but is a much lighter material, and is used where that property is required.

Wood

Wood is a poor conductor of heat which is why it feels so much warmer than the above materials. Heat is not conducted away from your skin so your temperature sensors record relative warmth. If the materials were left in the sun it would be the metals that would feel hot.

Wood is a fairly strong material but can break quite easily along the grain. The type in the exhibit is plywood in which the thin layers of wood are laid on top of one another with their grains at right angles to each other, and held together by resin. This makes it much stronger than ordinary wood.

Rubber

This is traditionally produced from the latex of the rubber tree, but much rubber these days is artificially manufactured from oil. It is flexible and has a surface which grips well, except when wet. When used for tyres or shoe soles it is grooved to allow water to be squeezed away from the contact area between rubber and road.

Plastic

This particular plastic is PVC and it is also used for the frame of this exhibit. It is cheap and easily formed and worked. It is used a lot in building for things like drainpipes and gutters and double-glazing frames. The clear plastic used for the label cover is a different one, polycarbonate, which is very strong. It is used for police shields, visors and crash helmets. It can be clear or coloured, when manufactured. However if it is painted afterwards or is badly scratched it loses its strength and can shatter.

COMPRESSION TEST

Solids and liquids are incompressible
Gases are compressible

DESCRIPTION

Eight flexible, transparent bottles are provided, each filled with a different material:
Air at low pressure
Air at normal pressure
Air at high pressure
Water
Rigid foam
Soft foam rubber
Polystyrene beads
Concrete

The bottles can be lifted and squeezed to investigate the compressibility and the weight of the contents.

CURRICULUM LINKS

Pupils should be taught:
Key stage 1,
"to use their senses to explore and recognise the similarities and differences between materials"
Key stage 2
"to recognise differences between solids, liquids and gases in terms of....maintenance of shape and volume"
Key stage 3
"to recognise the differences between solids, liquids and gases in terms of properties, e.g. density, compressibility.....and maintenance of shape and volume"

RELATED EXHIBITS

Atoms
How particles fit together in solids, liquids and gases can be related to their properties.

WHAT TO DO

Lift each bottle, examine it and squeeze it.

Q: What happens?
(A: Some of the bottles can be squeezed and some cannot. See further information.)

Q: Which is the heaviest bottle?
(A: The one with the solid concrete. The next heaviest is the water.)

Q: Which bottle has collapsed?
(A: The one with air at low pressure. The air outside is at higher pressure than inside and therefore it crushes the bottle.)

Q: Squeeze the other bottles with air in. What happens?
(A: One is very hard to squeeze, one is easier. High pressure inside one bottle pushes the sides out making the bottle rigid. This is how a bike or car tyre operates.)

COMPRESSION TEST: FURTHER INFORMATION

The bottles
Air at low pressure: The bottle has been squeezed by the air outside which is at normal pressure, so that it is flat.

Air at normal pressure: The bottle contains as much air as it would have if the top were removed. When the bottle is squeezed the air is squashed into a smaller space which raises the pressure of the air. At first the bottle is easy to squeeze but the more it is squashed the more difficult it becomes.

Air at high pressure: Like a bicycle tyre the bottle feels hard. It contains approximately ten times as much air as would be in it if the top were opened.

Water: The bottle is completely filled with water. It has not been pumped up or pressurized in any way. The bottle is heavy and when squeezed the bottle feels very firm and cannot be squashed.

Rigid foam: Like materials used in the gaps inside some doors and walls this foam contains many pockets of air. The stiff foam sets hard and forms a rigid structure so, even though the foam is full of air and therefore light, it resists being squashed.

Foam rubber: Like the rigid foam this material contains air but the material itself is rubbery and can easily be stretched or squeezed so the air can be compressed. The air in the bottle is at normal pressure, and the foam rubber makes little difference.

Polystyrene beads: Polystyrene is not very compressible, but the expanded beads contain a lot of air which is. When squeezed the beads squash a little and move past each other a small amount allowing the bottle to change shape. They are used in some seats - the beads make a filling which will mould to a new shape, but then become fairly incompressible to support a larger weight.

Concrete: This is totally non-compressible. It can only be squeezed under very considerable pressure and therefore makes a good building material. Because it is dense it is also a heavy material

Solids, liquids and gases
In principle any element can be in the form of a gas, liquid or solid depending on its temperature. The difference between each form involves the way each of the particles of the material can move about within the rest of the material. In a solid the particles can move only in a limited way - merely vibrating or rotating. In a liquid the particles can move past one another but are still squeezed up against other particles all the time. In a gas the particles can move anywhere and have plenty of room to do so. The general rule is that neither solids nor liquids are compressible, but that gases are.

Use of compressible materials
Examples of materials used because they are not compressible are bricks in buildings or girders in bridges. There are some solids which, like rubber, can be stretched and squeezed, but their volume remains the same. In foam rubber it is the air in the foam which gives the material its high degree of compressibility. Vehicle tyres contain air which is able to compress when going over a bump. Materials are often chosen or adapted or shaped to give a specific amount of compressibility, for example a crash helmet.

FLOW

Some liquids can move or flow more easily than others

DESCRIPTION
Four clear tubes, each containing a different liquid are fixed in a frame. The frame can be tilted one way or the other like a see-saw causing each of the liquids to flow down hill. Obstacles in each tube force the liquid to flow round them.

Each of the liquids has a different viscosity which determines the speed at which it flows.

The liquids are shower gel (pink); cooking oil (yellow); washing-up liquid (green); water (clear).

CURRICULUM LINKS
Pupils should be taught:
Key stage 1
"to use their senses to explore and recognise similarities and differences between materials"
Key stage 2
"to recognise differences between...liquids...in terms of ease of flow"
Key stage 3
"to recognise differences between....liquids...in terms of their properties, e.g.: ease of flow"

RELATED EXHIBITS
Viscosity
Liquids of different viscosity can be stirred and compared with a powder.
Mixing and un-mixing
This exhibit allows investigation of two liquids which do not mix.

WHAT TO DO
Tip the tubes so that the liquids run down inside. Watch each liquid carefully as it moves.

Q: What is happening?
(A: Each of the liquids moves at a different speed.)

Q: What happens when the liquids get to the obstacle in the tube?
(A: Some of the liquids run easily round the obstacles, others flow more slowly over them.)

Q: Can you guess what the liquids are?
(A: They are water, cooking oil, washing-up liquid, and shower gel.)

OTHER THINGS TO DO
Think of how you use these materials at home. When you have finished a shower gel refill the container with water and see what happens to the water when you hang it up.

FLOW: FURTHER INFORMATION

What is viscosity?
Viscosity is to do with how easily liquids flow. Water has a low viscosity and treacle has a high viscosity. Special tests exist which can give a numerical value to the viscosity of a liquid. For each liquid this test will give the same value unless the temperature is different. For liquids the viscosity decreases if the temperature rises.

Water is the most common liquid we have contact with but there are many other liquids which are made up of different substances. The shape and characteristics of the particles of different liquids has a large effect on how easily they flow.

Viscosity in real life
Viscosity of liquids is important in the way that they are used. For example, how well a liquid will flow through a thin nozzle when it is being dispensed. This applies to petrol pumps, and to washing up liquid bottles and toothpaste tubes in the home. When considering this aspect of a liquid, the size of the nozzle and the force which can be exerted to push the liquid through the nozzle must be taken into account. For example, toothpaste must be easy to squeeze out by hand through a large opening so that the toothbrush can be covered in one go. But it must also not flow out when the tube is held gently. The slowest mover in the exhibit is shower gel. Turn a bottle in the shower upside down and it takes a long time for it to reach the bottom but doesn't leak out unless you squeeze. It is so viscous it won't go through the nozzle unless under pressure, but still thin enough to rub easily on your body.

Viscosity in technology
There are many important technological uses of liquids where viscosity is highly important. Lubricating and cooling liquids are widely used in many types of machinery including bicycles, car engines, and other systems such as central heating, fuel pipes etc. Shock absorbers and similar devices like dashpots rely on high viscosity to work.

Many liquids become less viscous as they warm up. In a car engine the oil must flow to all the moving parts both when starting the engine on a cold day and when running it on hot days. Different oils are mixed together; one has the correct viscosity at low temperatures, the other has the correct viscosity at high temperatures.

Some fluids change their viscosity when subjected to force. Stirring and rolling are examples of a force that can affect such a fluid - non-drip paint is a good example. When force is applied the paint becomes thinner and can be rolled on. When the force is removed the paint becomes thicker and less likely to drip.

Viscosity of gases and solids
Solids generally do not flow. However, when in the form of powders solids can flow and this is used in the handling of, for example, sand, grain, salt etc. Powders behave differently from liquids when any forces making them move are low. For example placed on a slightly sloping tray treacle will flow slowly, but flour will not. The viscosity of a powder cannot be assigned a single value so viscosity cannot be considered to be a simple property of a solid material.

Compared to liquids, gases flow very easily. The viscosity of gases can be measured and, unlike liquids, the viscosity of a gas gets greater if its temperature is increased.

Note: This information is also relevant to the **Viscosity** exhibit.

VIDEO MICROSCOPE

The surface of a material affects how it can be used At the microscopic level, surfaces may vary a great deal

DESCRIPTION
Pupils can hold samples of different materials under a video camera, which will display a magnified image of the surfaces on a television screen. The magnification is approximately 25 times. Surface detail, not normally visible, can be clearly seen.

A variety of materials are provided to look at, and you can also look at your fingers, hair or other small objects.

CURRICULUM LINKS
Pupils should be taught:
Key stage 1
"to sort materials into groups on the basis of simple properties, including texture, appearance"
Key stage 2
"to compare everyday materials.....on the basis of their properties."
Key stage 3
"to recognise the differences between solids....in terms of properties"

RELATED EXHIBITS
Surfaces
The physical effects of the surface texture of a number of materials in everyday uses can be investigated using chalk.
Filters
The mesh nature of some materials is used to separate liquids from solids.

WHAT TO DO
Hold some of the samples under the camera and raise and lower them to bring them into focus.

Q: What do you notice?
(A: The surfaces look much rougher than they do normally.)

Q: Can you describe what the surfaces look like?
(A: You may think of words like: "rough", "pitted", "hills and valleys", "grooves".)

MORE THINGS TO DO
Look at other samples of materials, for example a piece of your clothing or your skin or hair. Try to find similarities or differences between the groups of materials.

Q: What do most pieces of clothing have in common?
(A: They are usually woven. Threads of material - cotton, wool, artificial fibre - are interlaced to create a piece of cloth.)

Q: What does your skin look like under the microscope?
(A: Not very nice! The pores, the cuts, the scrapes and the stains become all too visible.)

VIDEO MICROSCOPE: FURTHER INFORMATION

Surface texture and surface detail
Looking at the surface of a material shows its detail. This includes colour and the shape of the surface. Unless the surface is transparent only the outer-most part of the material can be examined. Surface texture involves not only the shape of the surface of the material, but also the way it responds to physical forces such as squeezing or sliding over other materials.

The surface detail of a material depends on how it has been made or prepared, as well as on the nature of the material itself. Many surfaces can be made very even and flat with sufficient smoothing and polishing. However, some of the internal structure of the material may well still show as colouration of the surface.

Surfaces of materials can be produced by various ways: growing, cutting and moulding, for example. These surfaces can then be altered by processes such as abrasion, scraping and polishing. In the case of moulding, the surface detail of the mould is taken up by the moulded material.

Surface wear
Surfaces which come into contact with other surfaces are affected or damaged by this contact. A harder material will cause more damage to a material with a softer surface when they touch, than to itself. This contact may take place in various ways from a scratch causing a large gouge, to a repetitive gentle contact, such as walking on carpet. In everyday use the wear on most objects is not noticeable - for example knives and forks and table tops etc. However over a long period of time the damage to the surface becomes more noticeable. Close inspection of surface detail can give information about how a material has been used and what has happened to it.

Uses of surface
Many of the useful properties of surfaces involve friction. Uneven surfaces generally do not slide as well over other materials. Car tyres, roads and non-slip floors demonstrate this. Materials which come into contact with another particular surface are often shaped to increase the friction when in use. Plastic objects are sometimes made with pimpled or ridged surfaces to make them easier to pick up. On the other hand sometimes materials are designed to have low friction like non-stick pans.

Optical microscope
Optical microscopes rely on glass lenses. The first ones were invented in the seventeenth century in the Netherlands.

Video microscope
The advantage of video microscopes is that image can be observed by several people at once. A video camera is attached to a magnifying lens. The lens in this exhibit has low magnification allowing easy appreciation of what is being looked at, but high power ones can be used to observe at the cellular level.

Electron microscope
Electron microscopes, which use beams of electrons instead of light, are designed for very high magnification usage. Electrons, which have a much smaller wavelength than visible light, allow a much higher resolution.

ATOMS

Solids, liquids and gases are made of small particles called atoms
Particles can fit together in different ways

DESCRIPTION
A number of balls representing atoms are provided. On the base of the frame are three grids onto which pupils can stack the balls. The grids have holes where the bottom layer of balls will locate. The three patterns are based on a square, a triangle and a circle.

The base of the exhibit can be used to move balls around in a mass, as an analogy for the way particles may move in solids, liquids and gases.

CURRICULUM LINKS
Pupils should be taught:
Key stage 2
"to recognise differences between solids, liquids and gases in terms of ease of flow and maintenance of shape and volume"
Key stage 3
"how the particle theory of matter can be used to explain the properties of solids, liquids, and gases....that elements consist of atoms"

RELATED EXHIBITS
Video microscope
Allows close visual inspection of materials, including crystals.
Compression test
Bottles containing solids, liquids and gases can be held and squeezed, and this can be related to their atomic structure.

WHAT TO DO
Try to stack the balls (atoms) up onto the grids with the holes in.

Q: How high can you make the stacks on each of the grids?
(A: The square and the triangle can be made about the same height; the circle cannot be built up nearly as far.)

Q: Which stacks fall apart most easily?
(A: The square-based grid makes the strongest stack, the circle makes the weakest.)

Q: Can you build more than one pattern of the balls on the triangle?
(A: Yes, there are two patterns - one is more densely packed than the other.)

The pyramid shapes that can be built on the grids are called crystals.

Q: Can you think of some solids which are in the form of crystals?
(A: Sugar and salt.)

MORE THINGS TO DO
Swish the balls around in a corner of the exhibit when there are a) not many balls, b) more balls or c) lots of balls.

Q: How do the balls move in each case?
(A: a) They move easily and can roll about quite fast (like a gas).
b) They still move about but not so easily because they are pushing into each other (like a liquid).
c) They jam up and form into the sorts of patterns which are on the grids (like a solid).)

ATOMS: FURTHER INFORMATION

As the wonderful Richard Feynman the quantum physicist remarked: "If the human race was wiped out and could only pass on only piece of knowledge the sentence should begin - "All things are made of atoms.....".".

Particles

Many of the properties of materials can be explained through an understanding of the tiny particles - atoms - of matter from which they are made. Some of the concepts involved in this idea are difficult to grasp, especially for younger children. Due to the importance of the concept later on some exposure to this idea may be useful however.

A collection of many round balls together is a simple analogy of how the particles of matter behave. It can help to give an appreciation of some properties even in this simple form. For example, it can be used to explain the difference between the behaviour of solids, liquids and gases, and the crystal-like structures of some materials.

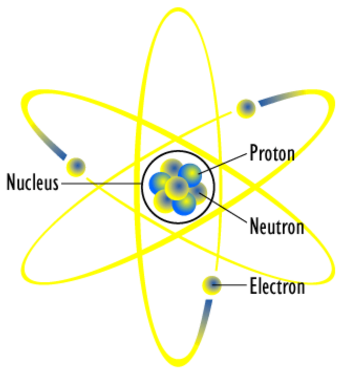
Crystal structures

There are many examples of crystals in everyday use, including salt and sugar. A close look at these materials shows that they often have flat sides. The way the particles of these materials behave is very like the balls in the exhibit. When close together, they fit with each other to form a grid-like pattern. Like the pyramids made with the balls, the edges of the structures tend to be flat faces. They are also fairly firm and strong unless knocked too hard, when they fall apart into many small bits.

Crystals form in the shape of the patterns used here but circular-based ones are not stable and are very rare. They are usually based on the square or triangular forms. Iron has its crystal shape on the pattern of the densely packed triangle. It may form in the looser pattern but when subjected to great pressure deep inside the earth it can be forced into the dense form.

Solids, liquids, gases

Using the comparison with the balls in this exhibit, a material is solid when the balls are so close together that they can not move about. If the balls are allowed a little more space they can move past each other, although not very fast, as in a liquid. If the balls have much more space they can move about very freely and quite fast, as in a gas.



Model of an atom

INSULATION

Heat is transmitted from warmer to colder objects Some materials are better at preventing heat loss than others

DESCRIPTION
A hotplate (35-40°C) can be tested for temperature using a thermochromic thermometer.
Different materials are provided: aluminium, wood, double glazing plastic, fake fur. Pupils can place these on the hotplate and test the degree of insulation by touch and by the thermometer.

CURRICULUM LINKS
Pupils should be taught:
Key stage 1
"to describe the way materials change ....when they are heated"
Key stage 2
"That temperature is a measure of how hot or cold things are ......that some materials are better thermal insulators than others"
Key stage 3
"That most metallic elements are good thermal conductors.....that non-metallic elements are poor thermal conductors"

RELATED EXHIBITS
Types of Materials
Different materials can be compared for their thermal conductivity.

WHAT TO DO
Feel the hotplate with your hand. It will feel quite hot. Place the thermometer on the plate to test its temperature - it takes some time to reach the correct reading.

Q: What temperature does it read?
(A: It should read between 35-40°C.)

Place the pieces of aluminium and wood on the hotplate and leave for a time. Put one hand on the material and the other on the underside of the hotplate.

Q: What do they feel like?
(A: The aluminium feels hot, the wood less so. You can confirm this using the thermometer.)

Try putting the double-glazing plastic or the fake fur on the plate and compare them with the other materials.

Q: Which feels the coolest?
(A: Both will feel a lot cooler than the aluminium and even the wood. The fur should be the coolest. Test with the thermometer

Q: Why is there a difference?
(A: Some materials transmit heat less well than others. These are good insulators. Double glazing is used to keep heat inside a house. Fur is used by mammals to prevent heat loss from their bodies.)

Q: Is this because the good insulators are thicker?
(A: No. The amount of material in the double glazing or the fur is less than the aluminium. It is just separated by air trapped within it. Air makes an excellent insulator.

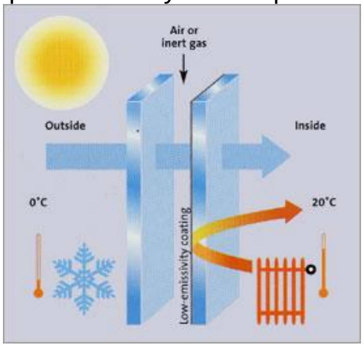
INSULATION: FURTHER INFORMATION

Thermal conductivity

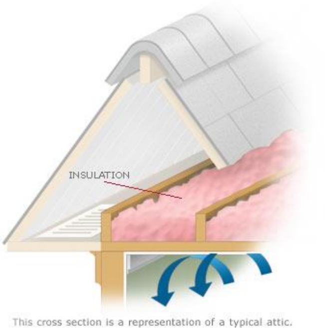
All materials have differing degrees of thermal conductivity - they all conduct heat. Some, particularly metals, are very good at transferring heat and are used for this purpose in the home and industry. They are very good for things such as radiators and cooker hotplates.

Materials which have low thermal conductivity make good insulators. The most effective insulator is air. Air like all gases is a very poor transmitter of heat because of its very low density. When a substance is heated its molecules are agitated. To transmit that heat they must be able to pass on that agitation to other molecules. Whereas in solids these are packed close together, in gases they are far apart.

Air must be trapped to be effective or the heated molecules will be replaced by cold ones. Moving air cools. Most good insulation aims to maximise the amount of air trapped in the material. In houses the amount of heat lost through the windows can be reduced by double-glazing. A layer of air is held between the two plates of glass or clear plastic. Similarly loft or cavity wall insulation consists of material which is predominantly made up of air.



Double-glazing



Loft insulation

The same principle occurs in clothing. One of the warmest items to wear is a string vest - provided it is covered with a shirt. It consists of little material but the air that is trapped between it provides the insulation.

Warm-bloodedness

Humans use clothing to substitute for hair we lost during evolution. Mammals generally rely on fur for their insulation as birds do on feathers. Both groups of animals are able to maintain a constant temperature (homeothermy) at the level at which their metabolic processes work best. In us this is 37^{o}C or 98.4^{o}F.

Seal fur

Feather

Incidentally, hair does not grow faster after it is cut or shaved and nor does it continue to grow for a time after death.

FILTERS

Some solids can be separated from liquids using filters
Some solids can be separated from other solids using filters

DESCRIPTION
There are two discs with clear fronts mounted vertically which can be rotated. One contains a number of different-sized plastic beads and is divided into sections by three barriers, each with holes that only some of the balls can pass through. When the disk is turned upside down, the balls fall through the holes and are sorted by their size into one of the four sections.

The second disc contains water with particles in it. There is a barrier with fine mesh across part of the disc. When rotated the water can flow through but the particles are caught by the filter where they will stay until the water is returned.

CURRICULUM LINKS
Pupils should be taught:
Key stage 1
"to ….recognise the similarities and differences between materials"
Key stage 2
"that solid particles of different sizes can be separated by sieving .....that insoluble solids can be separated from liquids by filtering"
Key stage 3
"about methods including filtration......that can be used to separate mixtures into their constituents"

RELATED EXHIBITS
Video microscope
This shows that some apparently solid materials actually have tiny holes which allow liquids through but are too small for most solid particles.
Mixing
Some materials do not mix fully and will separate by means of gravity.

WHAT TO DO
LEFT: Rotate the disc with the white beads in for half a turn. Rock them gently back and forth to help the movement.

Q: What happens to the beads?
(A: They fall through the holes. The largest beads stay at the top; the smallest beads go right down to the bottom.)

Turn the disc back for half a turn.

Q: What happens to the beads?
(A: The beads come back through the holes until they are all in the bottom compartment again.)

Q: Can you think of everyday objects that work on this principle?
(A: Sieves in the kitchen or garden rely on a mesh to separate different particles.)

RIGHT: Rotate the disc with the liquids in through half a turn.

Q: What happens to the water and the particles floating in it?
(A: The water drains through the barrier which has lots of small holes in it. The particles in the water are too large to pass through and pile up on the filter.)

Turn the disc back half a turn.

Q: What happens?
(A: The water comes back through the filter and mixes with the particles again.)

Q: Can you think of everyday objects that work on this principle?
(A: Filters are often used in the kitchen to separate liquids from solids, e.g. coffee filters, or the mesh of tea bags.)

FILTERS: FURTHER INFORMATION

Filters

Filters can be used to separate solids from fluids because they have holes which are too small for the solid particles to get through. This can work only if the solid particles are always bigger than the holes. For particles of differing sizes, several filters, each with holes of a different size can be used to separate out each size group. The filters must be used in the correct order.

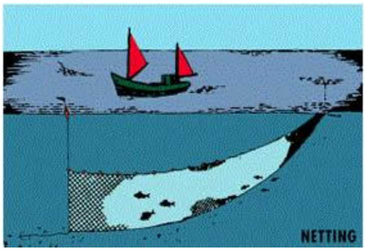
Filtering is reversible by passing the liquid back through the filter. This process is a useful way of cleaning filters, for example in swimming pools, where reversed flow water flushes the filtered material from the filters and is then discarded.

Filters can become clogged because larger particles get stuck in the holes, blocking them so that smaller particles cannot flow through. Filters such as those in washing machines, car engines or vacuum-cleaners require frequent cleaning or renewing to work effectively.

Fluids can pass through filters because their particles are small enough to go through the holes in the filter. Some materials have very small holes that cannot normally be seen, for example paper. Special paper can be used to filter liquids such as coffee.

Uses of filters

Filters may be used to remove unwanted solid particles such as soil and other material from drinking water, to separate infusions like tea or coffee from their plant sources, dust from the air sucked up by a vacuum-cleaner or to extract a solid material, e.g. fish, from an unwanted liquid such as when using fishing nets.



Sieves

Filters which separate different sized solid particles are usually referred to as sieves. Different-sized meshes are used to produce grades of material such as sand - from coarse to fine. The advantage of this is that the material will be consistent in its properties. They may also be used to separate one size of particles from another such as sifting lumps out of flour, or sieving stones from soil.

MIXING

Some liquids do not mix
Some solids sink through water at different speeds than others

DESCRIPTION
Two disc-shaped containers with clear fronts are mounted vertically, pivoted so that they can rotate. One disc contains two liquids: white spirit floating on top of coloured water. Turning the disc mixes the liquids which then separate again.

The second disc is full of water with a number of different sized particles of sand and small stones. Pupils can turn the container to mix up the particles with the water. The particles will then slowly separate again as they settle.

CURRICULUM LINKS
Pupils should be taught:
Key stage 1
"to use their senses to explore and recognise the similarities and differences between materials"
Key stage 2
"that some solids dissolve in water...but some do not........to describe and group soils on the basis of characteristics, including appearance, texture and permeability"
Key stage 3
"that mixtures contain constituents that are not combined…..that the rock cycle involves sedimentary processes"

RELATED EXHIBITS
Filters
This exhibit shows ways in which filters can be used to separate solids and liquids.
Video microscope
Allows close visual inspection of various materials, including some of the solid particles in this exhibit.

WHAT TO DO
LEFT: Look carefully at the disc with the two liquids in. You will see that they are clearly separated from each other. Now turn the disc around. Stop turning and watch what happens.

Q: What happens when you turn and then stop turning the disc?
(A: The two liquids mix up forming globules and bubbles in the middle. When still, the bits of the liquids which have become mixed move back up or down to join the main part of their liquid. After a short time the two liquids become fully separated again. The white spirit is always at the top and the water at the bottom.)

Q: Why is this?
(A: Some liquids do not mix, while others do like alcohol and water. The white spirit is always at the top because it is not as dense - heavy- as water which sinks to the bottom.)

RIGHT: Look at the disc with particles in it.

Q: What happens when you turn the disc a few times to mix the contents and then stop turning?
(A: When the container is turned the particles mix with the water. When the container is still again the large particles sink most quickly and form a layer at the bottom. More layers form until the smallest and lightest particles slowly sink down to form the top layer.)

MORE THINGS TO DO
Dig down into sand at a beach or mud by a river and you will find the layers are like those in the exhibit.

MIXING: FURTHER INFORMATION

Non-mixing liquids

Liquids which do not mix are also called immiscible. Whether or not a particular liquid mixes with another depends on the nature of the particles which comprise each liquid. The less dense liquid will float on top of the denser liquid. The density of the liquid is determined by the weight of a particular volume of it. For example, a litre of two different liquids will weigh different amounts.

The non-mixing of liquids can be used to separate them. Once they have separated, the more dense liquid can be drained off from the bottom of the vessel or the less dense one decanted from the top.

While ice is less dense than water and floats on the surface, above 4°C water gets less dense the warmer it becomes. Consequently, if hot and cold water are mixed without stirring the warm water will float on top. This occurs in the sea and in lakes. When the upper layer cools down sufficiently it can become denser than the layers beneath it and sinks stirring up the water and the sediments on the bottom. This is known as a sea change. A similar effect occurs with air in the atmosphere.

Density also depends on the salt content and in combination with temperature can ensure that layers of seawater stay separate over thousands of kilometres. Water from near the North Pole can be identified as far away as the south of India.

Sedimentation

Solid materials, denser than water, will sink at different speeds under the influence of gravity. If several materials are released together one will reach the bottom first forming a layer followed by the next which forms a second layer, and so on. The greater the density of the particle, the faster it will settle out. The speed at which the particles fall through the water is called "settling velocity."

How fast a material sinks depends on two things: the size and shape of the particles, and the density of the material. Just as with liquids, the density of a solid material is determined by the weight of a certain volume of it. Comparing the weights of identical sized blocks of two solid materials shows which is more and which is less dense.

If two solid materials mixed in water have particles of the same size, the more dense material will sink to the bottom first if the water is still. If two materials have the same density then the one whose particles are larger will usually sink fastest because its particles will be heavier.

But the shape of the particles also plays a part. If two particles have the same weight and the same density then the one with the largest surface area will experience the greatest resistance and so sink more slowly. This can easily be seen by watching a flat piece of foil and a balled-up piece of foil of the same size sink through water. This is also true in air.

Rivers when in full flow stir up the soil washed into it by rain and from the banks, eventually depositing it in layers like those in the exhibit. Sometimes enormous amounts of material settled in this way, dried out and then subject to pressure by new layers forming above become sedimentary rocks like sandstone or mudshales. Similar processes happens on sea shores.

VISCOSITY

Viscosity is a property of liquids related to their flow Objects move through some liquids more easily than others

DESCRIPTION
The exhibit comprises four transparent vessels. Three contain liquids of different viscosity. The fourth contains a fine powder made of tiny round glass beads.

The vessels have fish shapes inside which pupils can use to stir the materials. The ease with which the shapes can be moved gives a direct indication of the viscosity.

CURRICULUM LINKS
Pupils should be taught:
Key stage 1
"to use their senses to explore and recognise similarities and differences between materials"
Key stage 2
"to recognise differences between ...liquids... in terms of ease of flow"
Key stage 3
"to recognise differences between ... liquids ... in terms of their properties, e.g. ease of flow"

RELATED EXHIBITS
Flow
By tilting a frame some everyday liquids can be made to flow down tubes containing obstacles.

WHAT TO DO
Turn the knobs on the top of each of the vessels to move the fish. Feel how difficult they are to turn in the different materials. Watch carefully how the liquids move both during and after stirring.

Q: **How do the liquids differ?**
(A: Some need more effort to make the 'fish' move than others. They are more viscous (sticky).)

Q: **What happens after you have stirred the liquids?**
(A: The most viscous liquid gets stuck to the top and sides, and only very slowly moves downwards. The least viscous flows off the top and sides very quickly.)

Q: **What is the difference between the way the liquids move and the way the white powder moves?**
(A: The powder feels like a liquid with low viscosity (i.e. 'runny') when moved with the paddle. However, it does not stick to the top or sides of the vessel and after being stirred the surface does not level out as it does with even the most viscous liquid.)

SAMPLES
1. High viscosity silicone based oil.
2. Medium viscosity silicone based oil.
3. Low viscosity silicone based oil.
4. Powder of fine glass beads.

VISCOSITY: FURTHER INFORMATION

What is viscosity?
Viscosity is to do with how easily liquids flow. Water has a low viscosity and treacle has a high viscosity. Special tests exist which can give a numerical value to the viscosity of a liquid. For each liquid this test will give the same value unless the temperature is different. For liquids the viscosity decreases if the temperature rises.

Water is the most common liquid we have contact with but there are many other liquids which are made up of different substances. The shape and characteristics of the particles of different liquids has a large effect on how easily they flow.

Viscosity in real life
Viscosity of liquids is important in the way that they are used. For example, how well a liquid will flow through a thin nozzle when it is being dispensed. This applies to petrol pumps, and to washing up liquid bottles and toothpaste tubes in the home. When considering this aspect of a liquid, the size of the nozzle and the force which can be exerted to push the liquid through the nozzle must be taken into account. For example, toothpaste must be easy to squeeze out by hand through a large opening so that the toothbrush can be covered in one go. But it must also not flow out when the tube is held gently. Similarly shower gel must flow when squeezed but not leak out when not in use. The small size of the nozzle is finely calculated in relation to the high viscosity of the gel.

Viscosity in technology
There are many important technological uses of liquids where viscosity is highly important. Lubricating and cooling liquids are widely used in many types of machinery including bicycles, car engines, and other systems such as central heating, fuel pipes etc. Shock absorbers and similar devices like dashpots rely on high viscosity to work.

Many liquids become less viscous as they warm up. In a car engine the oil must flow to all the moving parts both when starting the engine on a cold day and when running it on hot days. Different oils are mixed together; one has the correct viscosity at low temperatures, the other has the correct viscosity at high temperatures.

Some fluids change their viscosity when subjected to force. Stirring and rolling are examples of a force that can affect such a fluid - non-drip paint is a good example. When force is applied the paint becomes thinner and can be rolled on. When the force is removed the paint becomes thicker and less likely to drip.

Viscosity of gases and solids
Solids generally do not flow. However, they can when in the form of powders and this is used in the handling of, for example, sand, grain, salt etc. Powders behave differently from liquids when any forces making them move are low. For example placed on a slightly sloping tray treacle will flow slowly, but flour will not. To get powders to flow freely they must be mixed with gases like air. Such an arrangement happens sometimes in volcanic eruptions producing a pyroclastic flow.

The viscosity of a powder cannot be assigned a single value so viscosity cannot be considered to be a simple property of a solid material.

Compared to liquids, gases flow very easily. The viscosity of gases can be measured, and unlike liquids, the viscosity of a gas gets greater if its temperature is increased.

Note: This information is repeated on the sheet for the **Flow** exhibit.

CHANGE OF STATE

Materials can exist in more than one state as solid, liquid or gas
Changes of state involve energy transfer

DESCRIPTION

A tray contains a thin layer of wax on a heater. When the heater is switched on the wax is warmed from below and begins to melt. When the wax is cooled by air from a small fan and the heater is switched off it returns to a solid state.

This wax has a low melting point of 48°C

CURRICULUM LINKS

Pupils should be taught:

Key stage 1

"to describe the way some everyday materials ......change when they are heated or cooled"

Key stage 2

"that heating or cooling materials can cause them to change; that temperature is a measure of how hot and cold things are...........that melting & freezing are changes that can be reversed"

Key stage 3

"that different materials change state at different temperatures......to relate changes of state to energy transfers"

RELATED EXHIBITS

Atoms

How particles fit together in solids, liquids and gases can be related to their properties.

Compression test

Bottles containing solids, liquids and gases can be held and squeezed.

WHAT TO DO

Press the RED button and hold it down to HEAT the wax.

Q: What do you see?

(A: The wax begins to melt and shows the pattern of the heating element beneath.)

Q: What is happening?

(A: The wax change from solid to liquid as the temperature rises above 50°C.)

Now press the BLUE button and keep it pressed down to blow COOL air over the wax. (The heater is also switched off when the blue button is pressed.)

Q: What happens when it starts to cool?

(A: The wax begins to solidify changing from clear to white where the air is blown over it and soon the whole layer solidifies as the temperature drops.)

OTHER THINGS TO DO

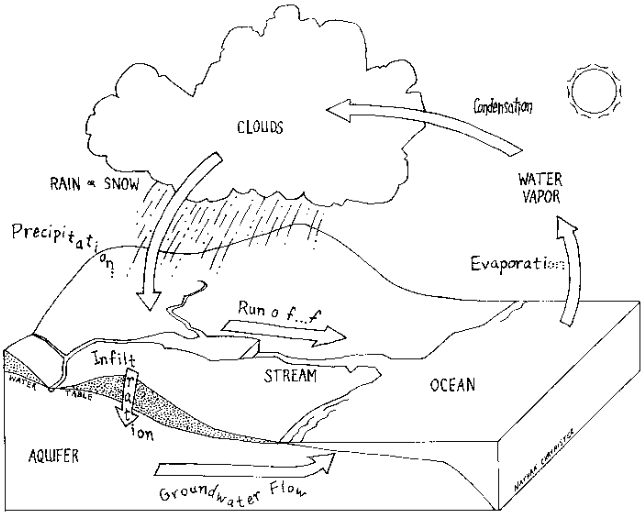
Watch a pan of fat when an adult is cooking. The fat will melt in the same way as the wax in this exhibit but at a higher temperature. Later as it cools down it will solidify again.

CHANGE OF STATE: FURTHER INFORMATION

Many materials can be changed from one state into another. The most obvious one is water which can exist as a solid - ice, a liquid and as a gas - water vapour or steam. To change from solid to liquid or liquid to gas requires energy input e.g. boiling a kettle. Changes in the opposite direction produce energy.

The Water Cycle

These characteristics of water are at the core of nature. Water that exists in the oceans is heated causing it to turn into vapour which can accumulate as clouds at high altitudes then cooling to form rain watering the plants on land and flowing via rivers back to the sea. It can also turn into ice, locking up much water in the ice-caps which if they melt under the effects of global warming will flood low-lying parts of the world.



Metal extraction

Even some very solid-seeming materials can exist as liquids. It requires very high temperatures to extract iron from its ore and it comes out molten. It can be poured just like water (only more carefully) into a cast to create ornaments.

Molten iron being poured in a foundry

Liquid rock

Some rocks can also exist as a molten liquid. Igneous rocks are called fire rocks and are formed either underground or above ground. Underground, they are formed when the melted rock, called magma, deep within the earth becomes trapped in small pockets. As these pockets of magma cool slowly underground, the magma becomes igneous rocks. Granite is formed this way.

Igneous rocks are also formed when volcanoes erupt, causing the magma to rise above the earth's surface. When magma appears above the earth, it is called lava. Igneous rocks like basalt are formed as the lava cools above ground.

Molten rock (lava) flowing down the side of a volcano