Keeping cold

Milk tankers are insulated to keep the milk cold.

During many of the stages in making chocolate, ingredients need to be kept cold.

Usually, if we want to keep something cold, we put it in the fridge. Insulation can also help. The big tankers that transport milk are not refrigerated. They are heavily insulated to keep the milk cold.

Insulation is about reducing the transfer of heat – either in or out. It can keep things cold or hot. Environmental engineers are interested in insulation because it uses less energy than refrigeration. This helps the environment.

Imagine you're an environmental engineer. You need to find the best way to insulate the milk tankers that take milk from the dairy farm to the chocolate factory. First, you need to test the insulating qualities of different materials.

your task

You are going to investigate the effectiveness of different materials as insulators – that is, how well they insulate a cold liquid. Read the instructions carefully before beginning.

what you will need

- different insulating materials (newspaper, cotton wool, aluminium foil, etc.)
- beakers
- test tubes and bungs
- thermometer
- crushed ice
- water
- water bath at 30 °C

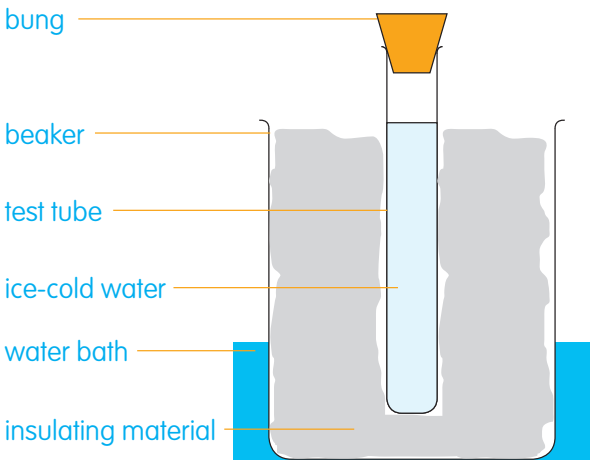
safety

Don't use fibreglass as an insulating material – it can irritate your skin.

what you need to do

1. Mix about 75 cm^3 each of crushed ice and water. Leave it until the water has cooled to near 0 °C.
2. Decide which insulating materials you are going to test. Your teacher will tell you what is available.
3. Put a 1 cm layer of one of the insulating materials in the bottom of a beaker.
4. Hold a test tube in the middle of the beaker, resting on the insulating material. Pack more of the material around it to hold it in place. The material must fit snugly against the test tube.
5. Repeat steps 3 and 4, using a different insulating material in each beaker.
6. Place the beakers into a water bath at about 30 °C, so the water level is about 2 cm up the beaker.
7. Use a thermometer to take the temperature of your ice-cold water. Record this as the starting temperature.

cross-section of the set-up



8. Working quickly but carefully, fill each test tube with the same volume of the ice-cold water (the water should be level with the top of the beaker). Note: There must be no ice in the tubes.
9. Place a bung in each test tube. Start your stopwatch.
10. Every five minutes:
    - ~ Remove the bungs.
    - ~ Stir each test tube gently.
    - ~ Read and record the temperatures in your results table.
    - ~ Replace the bungs.
11. Decide how many measurements you are going to take, or stop when the water reaches the temperature of the water bath.

results

- Record your results in a table like this:

materials	starting temperature (°C)	temperature of water (°C) after:			
		5 minutes	10 minutes	15 minutes	20 minutes
cotton wool					
aluminium foil					
newspaper					
etc.					

- Present your results as a set of graphs, drawn on the same pair of axes.

questions

- What do your results tell you about the different insulating materials?
- Explain your results in terms of heat energy transfer.
- What conclusions can you draw about which is the best insulating material?
- Share your results with the rest of the class. How do they compare?
- How reliable are your results?
- How could you improve your experiment?
- Can you think of any further investigations you could carry out?

extension

Use secondary resources (books and Internet) to find out how milk tankers are insulated.

What materials are used?

Learn about the differences between conduction, convection and radiation.

engineers

- There are four engineers shown on the poster. What other engineers do you think might be needed to help make chocolate products and other sweets?
- As well as helping to make chocolate products, where else might you find an environmental engineer? Try to think of at least three areas of work.

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Curriculum links

England and Wales (Key Stage 3 Science Programme of Study)	
key concepts	1.1a and b, 1.2a
key processes	2.1a-c, 2.2a and b, 2.3a
range and content	3.1a
curriculum opportunities	4a-c and k
Northern Ireland (Science Statutory Requirements)	
knowledge, understanding and skills	develop: enquiry skills; critical thinking; practical skills research information learn about: energy transfer and properties of materials
objective 1 – develop as individuals	mutual understanding: team work
objective 3 – as contributors to the economy/environment	identify skills used in: manufacturing design; thermal insulation economic importance and science behind: insulated transport
Scotland (SQA Science Outcomes)	
second level	SCN 232X
third level	SCN 309F

Introducing the activity

You could start by discussing what the pupils already know about thermal insulators and conductors. Be sure to establish the difference between thermal and electrical insulators and conductors. The pupils should, at least, be able to state that:

- thermal conductors allow heat to pass through them easily
- thermal insulators do not allow heat to pass through – or pass heat much less easily than conductors
- metals are good conductors so are used to make saucepans
- wood and plastic are insulators so can be used to make handles for saucepans

Pupils may be able to tell you that thermal insulators can also keep heat out, but they are less likely to have as good an understanding of this. They should be able to explain conductors and insulators in terms of heat transfer but are unlikely to know the mechanisms involved.

You will need to decide how much information about conduction, convention and radiation to give the pupils before they carry out the experiment. They will have the opportunity to do some research themselves later, and it could all be brought together in a plenary.

Discuss the need to keep food and drink refrigerated. Ask pupils to think about the properties of chocolate and the possible stages of making and producing chocolate (including transporting milk), and how refrigeration is important. Explain that insulation is also very important in aiding refrigeration, and also in keeping things cold outside of fridges, (for instance cool-bags for carrying frozen foods home).

Explain to the pupils that they are going to investigate the insulating properties of different materials.

The practical activity

This activity could work equally well with individual pupils, pairs or small groups. Availability of thermometers may be a limiting factor. If short of equipment, you may wish each pupil or group to investigate only one or two materials. In that case, each material should be tested at least twice, so that 'rogue' results can be spotted and discounted.

It is your decision as to how much of the activity you need to discuss with the pupils before they are confident, and you are confident in them, of carrying out the experiment correctly and safely.

You may wish to discuss

- How to make it a fair test – particularly how much of each material to use. How will they determine this, considering the different thicknesses of each material? Should they use equal size (surface area) or equal weight?
- What they are measuring – it doesn't matter if the starting temperatures are slightly different because it is the rate at which the temperature rises that is important.

Results will vary, depending not only on the material, but on how tightly it is packed around the test tube. In most cases the real insulator is air trapped by the material – between the layers, in air pockets in a crumpled material, in the bubbles of a foam, or between individual fibres.

To illustrate this, some pupils or groups could omit the insulating material, leaving only air between the test tube and beaker wall. This air must be trapped and isolated by putting a lid on the beaker – for instance, a cardboard disc, fitting snugly around the test tube and against the sides of the beaker, below the spout. The gap may be sealed with a strip of *Blu-tack*.

Foil is a good thermal conductor and, therefore, pupils might not expect it to be a good insulator. However, depending on how tightly the foil is packed around the test tube, air trapped in the crumpled-up foil could provide good insulation. Also, the shiny surface helps to reflect back heat, improving the insulating properties. This principle is put to use in 'space blankets' used by athletes, and in outdoor survival kits. Vacuum flasks are silvered inside for the same reason.

When later researching how milk tankers are insulated, pupils may discover that some tankers also rely on polished aluminium or stainless steel surfaces to reflect heat.

Some pupils may need help in interpreting their results. They need to appreciate that they are trying to find out which material is best at keeping the water cold. Guide them towards realising that this is the one for which the water takes longest to reach room temperature, or has the lowest temperature rise in a given time.

More scientifically, the best insulator is the material that minimises the rate of heat transfer, resulting in the lowest rate of temperature rise. Pupils should realise this can be deduced from the graphs – the lower the gradient, the lower the rate.

Equipment

(Per group)

- different materials (newspaper, cotton wool, aluminium foil, foam plastic, etc.) able to be packed around a test tube inside a beaker

  Safety note: don't use fibreglass (or anything similar) as an insulating material as it may irritate skin.
- beakers (to house the test tubes and insulating material, plus one to mix the ice and water)
- test tubes (the test tubes should be the same height as, or slightly taller than, the beakers)
- bungs (the student instructions say to remove the bungs when recording the temperature; if possible, they could use bungs with holes for the thermometer to avoid this)
- thermometer(s)
- crushed ice
- water
- water bath at 30 °C (This experiment also works using a sink of water; although it doesn't provide a constant temperature, if the starting temperature is about 35 °C, it will provide sufficient heat to produce significant results.)

Possible extension activities

- Try using layers of different insulation, for example: aluminium foil — cotton wool — aluminium foil
- Use secondary sources to find out how a thermos flask works.
- Find out about reducing energy waste.