

Energy and change

A project funded by the Nuffield Foundation

Theme E

Energy from hot to cold

Theme E - Energy from hot to cold

What is this theme about?

There are many kinds of situations in which energy is transferred. In this theme, we are concerned only with energy transfers due to *temperature differences*. Other kinds of energy transfer are taken up in other themes. However, looking at energy flow from hot to cold is of central importance, since it is a feature of so many changes. In addition, it is important in learning about energy, because in these activities we are attempting to provide pupils with ways of talking about energy which they will build on in further work. Energy flow from hot to cold is the simplest way of introducing the idea that energy *spreads out* from places where it is *concentrated*.

Energy is a difficult concept. It is not easy to find ways of thinking and talking about it in the classroom. The Appendix to these teaching notes provides some further information.

The activities

- E1 Concentrated energy
- E2 Energy on the move
- E3 Energy transfers in the kitchen
- E4 Getting hotter and colder
- E5 Insulation
- E6 Examples of insulation
- E7 Energy from hot to cold

Activity E1 - Concentrated energy

The aim of this activity is to introduce the notion that we can think of a 'concentration' of energy in the same way as a concentration of a substance.

The first sheet is an OHP which can be used alongside a simple demonstration to introduce the idea of a 'concentration' of energy. In the crystal, the purple dye is highly concentrated; in the red-hot nail, the energy is highly concentrated. When they are put into a small beaker of water, the purple dye and the energy spread out and become less concentrated. Similarly if the small beaker of water is poured into a bigger beaker, the concentration decreases again. This 'spreading out' process happens more easily than the reverse - it is harder to get the purple dye or the energy to become more concentrated.

Apparatus:

2 small beakers, 2 large beakers, very small crystal of potassium permanganate, nail, tongs, Bunsen, thermometer.

The second sheet is a pupil activity based on the ideas introduced in the OHP. It makes the point that while matter and energy spread out they do not disappear, even though they may have spread out so much that they are undetectable.

Apparatus for each group:

1 beaker, 1 stirring rod, 1 thermometer, access to dilute potassium permanganate solution, access to hot water.

Activity E2 - Energy on the move

This introduces the abstract pictures showing temperatures and energy flows which are used throughout this theme. The activity is a class discussion based on OHPs.

There are a set of 3 OHPs which introduce the conventions used in the abstract pictures. Each section on the OHPs has a question for the class to discuss and answer. In each section, there is a reminder of the important points to bring out in the discussion. Discussion is helped by having equipment to demonstrate the situations (needed are a beaker of hot water, an ice cube and a metal block).

Each picture shows an object and a background - the background represents the temperature of the room. The shading in these pictures shows how concentrated the energy is.

Sheet 1 - A beaker of hot water cools down

A Which shows a beaker of hot water best? Picture 1 shows something which contains concentrated energy (i.e. something hot). The energy in the background is less concentrated (i.e. the room is cooler).

B Which shows the energy transfer best? Picture 2 shows energy flowing from where it concentrated to where it is less concentrated (i.e. from hot to cold).

C Which shows what happens best? Picture 2 shows that the water has cooled down so that it is now at the same temperature as the background.

Sheet 2 - An ice cube melts in the room

A Which shows an ice cube best? Picture 3 shows something which contains less concentrated energy than the background (i.e. something cold).

B Which shows the energy transfer best? Picture 1 shows energy flowing from the background to the ice cube. (Some children may think that it is 'cold' that flows from the ice cube to the background.)

C Which shows what happens best? Picture 2 shows that after melting the water will end up at the same temperature as the background.

Sheet 3 - A metal block is put in hot water

We can make pictures which show what happens when there are two or more objects.

A Which shows the energy transfer best? Picture 2 again shows energy flowing from where it is hot to where it is colder. Energy is transferred from the water to the metal.

B Which shows what happens best? Picture 2 shows that the water and the metal end up at the same temperature. One has cooled down and the other has warmed up. The energy becomes spread out between the two. (Both water and metal are now warmer than background - eventually they will cool down to the same temperature.)

Activity E3 - Energy transfers in the kitchen

This activity builds on the ideas introduced in the previous activity. It is a pupil activity, in which abstract pictures are used to represent some everyday examples of energy flow from hot to cold.

The activity is best done as a small group activity, with discussion about the pictures, before pupils begin to write about the changes. Pupils should cut out the pictures on sheet 2 so that they can put these on the spaces on the worksheets before deciding on a final answer. Note that in some cases, the names of the boxes on the sheet have been deliberately omitted - e.g. in part D, pupils must decide whether to represent ice cubes in the left-hand box and lemonade in the right-hand box, or vice versa. Pupils should be encouraged to discuss the reasons why they make their selections, and there should be an opportunity for the whole class to discuss their selections after they have finished the activity.

Answers:

A 2 -> 8

B 2 3 -> 10 10

C 5 -> 8

D 4 5 -> 11 11

Activity E4 - Getting hotter and colder

This activity is intended as a stimulus to discussion about what happens in various situations in which there are temperature differences.

This could be done as a very quick activity (5 minutes) if the written part is omitted. The main point is to get pupils thinking about changes to temperature, and the idea that temperatures tend to become equal. Here they are presented with *values* for the temperatures, and some pupils have trouble with the idea that temperatures are not extensive quantities - for example, adding water at 20°C to water at 40°C does not produce water at 60°C.

Answers:

1 B 2 A

3 B 4 B

5 B 6 A

In all cases, temperatures become equal in the end, though this is easier for pupils to appreciate in some of these situations than others. In particular, many pupils believe that in situation 5 the fur will cause the water to warm up. This point is taken up in the practical task in the next activity.

Activity E5 - Insulation

The activity gives pupils practical experience in looking at the effect of insulation. More importantly it encourages them to think about how the idea of energy flow due to a temperature difference can be used to explain the phenomena.

Pupils have little difficulty in believing that insulation will help to keep hot things hot. However, they may find it more difficult to see that it can help to keep cold things cold. Particularly puzzling may be that it does not affect something which is at room temperature. These practical activities explore these ideas. If time each group of pupils could do all the situations, otherwise they could do one pair each and pool the results.

Apparatus for each group:

Beaker, thermometer, boiling tube, insulated boiling tube (wrap cotton wool around the tube, then a plastic bag and seal with rubber bands), stop clock, access to water at 80°C, 20°C and 5°C.

These situations should be interpreted by thinking about the direction and relative sizes of the energy flows due to temperature differences. The questions on Sheet 2 are intended to encourage pupils to do this. It may be useful to make this sheet up as an OHP for class discussion before they attempt the questions themselves.

Activity E6 - Examples of insulation

The activity builds on the previous practical activity, by relating the ideas of energy flow and insulation to more familiar everyday examples.

In this activity pupils match situations involving insulation with abstract pictures of energy flow. It could be done as a poster activity, with each group writing reasons for their matches on the poster. They should cut up the sheets showing the abstract pictures and lay them out on the poster in the arrangement shown below, leaving spaces to match the situations against them.

Answers:

1 A E H	2	3
4	5 D F	6
7	8	9 B C G

Having made their choices and written their reasons, the posters can form the basis for a class discussion.

Note that the situations have been selected to cover a range of cases, in which the insulated object is cooler, warmer or at the same temperature as the background, and in which the background may be cooler, warmer or the same as room temperature. Also note that of the abstract pictures only 1, 5 and 9 show possible changes (2 and 8 are possible if you allow the existence of a perfect insulator).

Activity E7 - Energy from hot to cold

This activity is intended to reinforce the ideas in this theme.

In this activity pupils begin by circling the correct words in a piece of text about energy flow from hot to cold. They then write their own explanations for a number of different phenomena - it is intended that the 'circling' activity will provide a prompt for the kind of explanations which are appropriate. They could be encouraged to make their own abstract pictures to represent what is happening. Note that in examples (d) and (f) one thing which is involved is not mentioned - i.e. the room cools because the outside air is colder, the Earth cools because space is colder, but the air and space are not mentioned. Also note that the a room heated by a radiator and the Earth are taken up in Theme J as examples of 'steady state' systems.

Appendix

Energy - why learn about it?

The word 'energy' is commonly used in an everyday sense (and often in school science courses and books) to explain what makes things happen - 'the battery in the torch makes the bulb light because it has energy'. However, used in its scientific sense energy is *not* what causes change - things change because *differences disappear* (or entropy increases) which means that energy or matter or both become more spread out and less concentrated.

If energy is not the cause of change and does not make things happen, then what role can it have in learning about science? Think about the following questions:

If you put a burning match under a saucepan of cold water, would it boil?

If you put an ice cube under a saucepan of cold water, would it boil?

The answer to both questions is no, but for different reasons. In the first case, the match will heat the water up but not enough to make it boil. In the second case, the ice cube makes the water colder not hotter.

So, in the first case the impossibility is a question about *amounts*. Energy is transferred from the burning match to the water, but more energy needs to be transferred in order for it to boil. This *quantitative* aspect is an essential part of learning about energy. It should involve comparisons of the amounts of energy transferred from and to various kinds of systems - for example, the amounts of energy transferred from burning fuels, from engines, from power stations, from torch batteries and the amounts of energy transferred to things being heated, to electrical appliances, to the surface of the Earth from the Sun, and so on. This aspect of energy is taken up in Theme I (How much energy?).

In the second case, the impossibility is a question about the *direction of change*. Energy flows from the cold water to the ice cube and not the other way. The reason lies in the *concentration of energy*. Energy is transferred from where it is concentrated to where it is less concentrated. The activities in this theme are concerned with this aspect of energy.

The main ideas which are drawn upon in these activities are:









- hot things have a greater concentration of energy in them than cold things
- temperature is a measure of energy concentration
- energy flows from where it is concentrated to where it is less concentrated (i.e. from hot to cold)
- concentration of energy tends to become even (i.e. energy spreads out and temperatures tend to become equal)

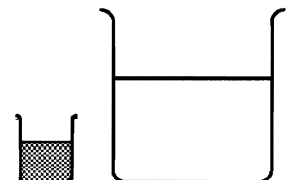


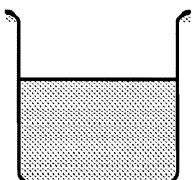
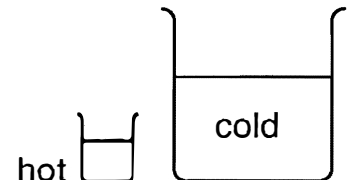


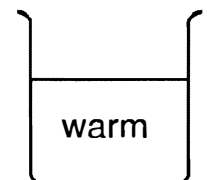
The National Curriculum refers to energy *transfers*, and makes no mention of talking about energy as being changed from one form to another (e.g. chemical to electrical). This is significant since it stresses the importance of thinking about energy as *staying the same kind of thing* but in *going from place to place*. This is very much the approach taken in these activities. The activities refer only to energy - the terms 'heat' and 'heat energy' are avoided. However, the term 'energy transfer' is simply a label for an idea - because the term appears in the National Curriculum does not mean that we are obliged to use it exclusively. What we should be doing is encouraging pupils to feel comfortable with rather more informal ways of expressing this idea.

So, as well as: 'energy is transferred from X to Y'

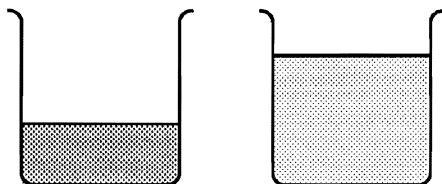
we can say

- 'the energy is going from here to there'
- 'the energy is spreading out'
- 'energy flows from the hot thing to the cold thing'
- 'energy is travelling from one place to another'
- 'the energy is concentrated here at the start, but some of it ends up there'.

<p style="text-align: center;">A crystal of purple dye</p> <div style="text-align: center;">  </div> <div style="text-align: center;">  <p style="margin-left: 100px;">water</p> </div> <div style="text-align: center;">  </div> <div style="text-align: center;">  </div> <p style="text-align: center;">Is the purple dye 'spreading out' or 'bunching together'?</p>	<p style="text-align: center;">A red-hot nail</p> <div style="text-align: center;">  </div> <div style="text-align: center;">  <p style="margin-left: 100px;">cold water</p> </div> <div style="text-align: center;">  </div> <div style="text-align: center;">  <p style="margin-left: 100px;">hot water</p> </div> <p style="text-align: center;">Is the energy 'spreading out' or 'bunching together'?</p>
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<p>Substances spreading out</p> <p>What is happening to the concentration of the purple dye?</p> <div style="text-align: center;">  <p style="margin-left: 50px;">purple dye</p> </div> <div style="text-align: center;"> <p>Which way is harder?</p> <div style="display: flex; justify-content: center; gap: 20px;">   </div> </div> <div style="text-align: center;">  </div>	<p>Energy spreading out</p> <p>What is happening to the concentration of the energy?</p> <div style="text-align: center;">  <p style="margin-left: 50px;">hot</p> <p style="margin-left: 150px;">cold</p> </div> <div style="text-align: center;"> <p>Which way is harder?</p> <div style="display: flex; justify-content: center; gap: 20px;">   </div> </div> <div style="text-align: center;">  <p style="margin-left: 100px;">warm</p> </div>
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- 1 Start with a beaker half-full with the purple dye. Fill the beaker up with water and stir. Can you still see the purple colour?

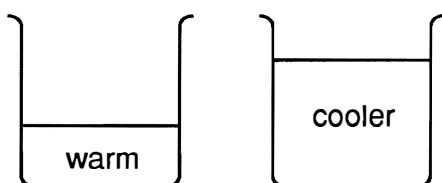


- 2 Pour half of the liquid away. Repeat what you have just done.
- 3 How many times can you dilute the dye before you can no longer see it?

Questions

- a) If you put a small amount of dye in a large lake, eventually you could not see it. Has it disappeared or is it still there?
- b) Would it be easy or difficult to get the purple dye back? Explain.

- 1 Start with a beaker half-full with hot water. Measure the temperature. Fill the beaker up with cold water and stir. Measure the temperature again. What has happened?



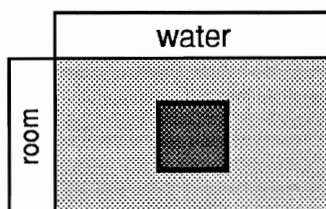
- 2 Pour half of the liquid away. Repeat what you have just done.
- 3 How many times can you 'dilute' the energy before you no longer notice the temperature changing?

Questions

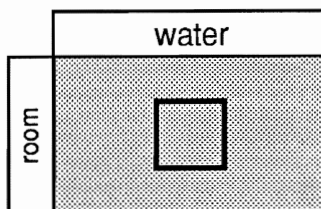
- a) If you put a small amount of hot water in a large lake, you would not notice that the lake had got any warmer. Has the energy disappeared or is it still there?
- b) Would it be easy or difficult to get the energy back? Explain.

A beaker of hot water cools down

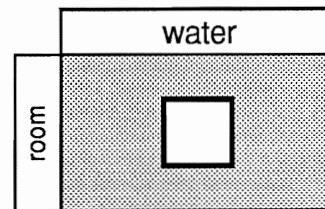
A Which shows a beaker of hot water best?



1



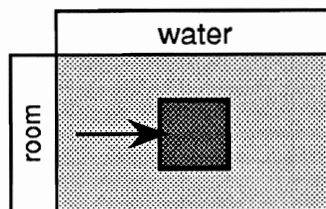
2



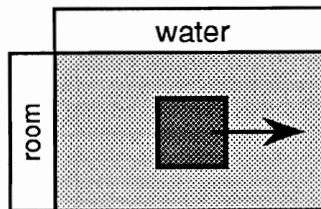
3

hot = high temperature = high concentration of energy = dark shading

B Which shows the energy transfer best?



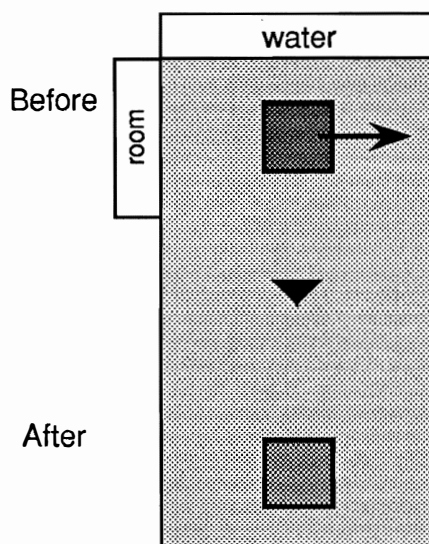
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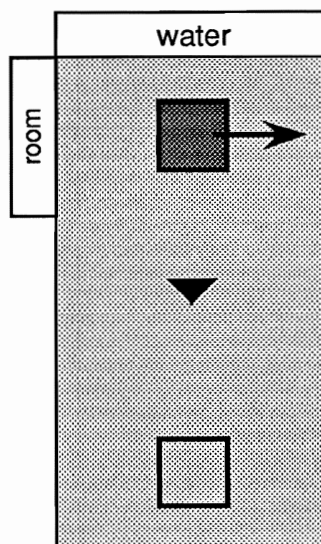
2

energy goes from hotter to colder

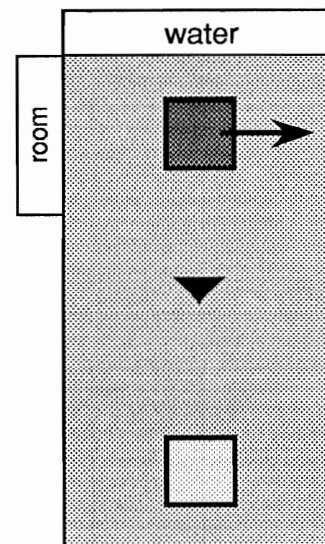
C Which shows what happens best?



1



2

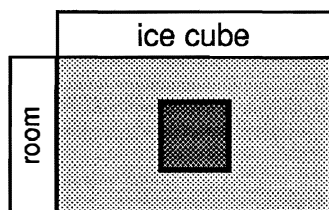


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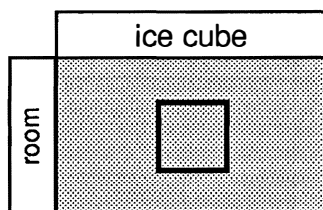
energy spreads out - concentration of energy becomes even - temperatures become equal

An ice cube melts in the room

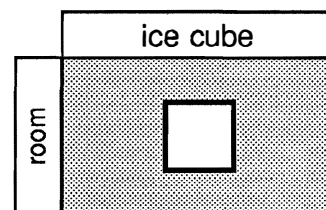
A Which shows an ice cube best?



1



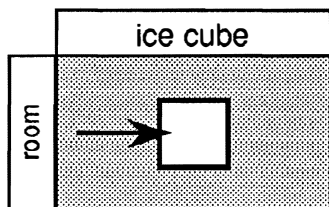
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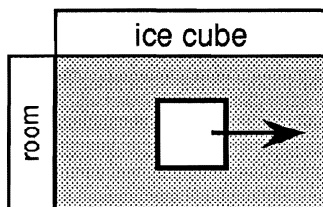
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cold = low temperature = low concentration of energy = light shading

B Which shows the energy transfer best?



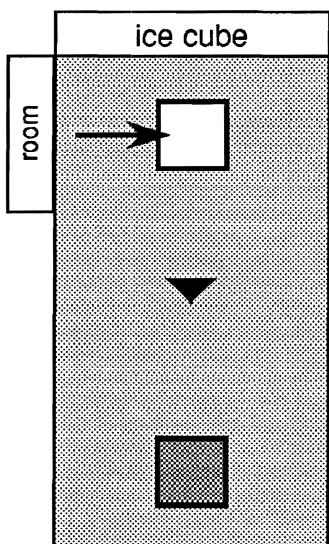
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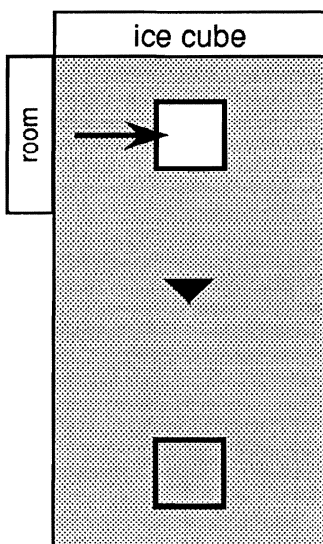
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energy goes from hotter to colder

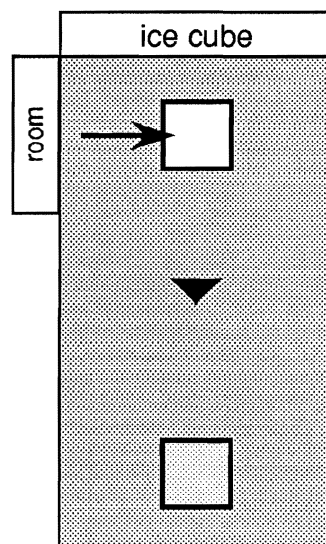
C Which shows what happens best?



1



2

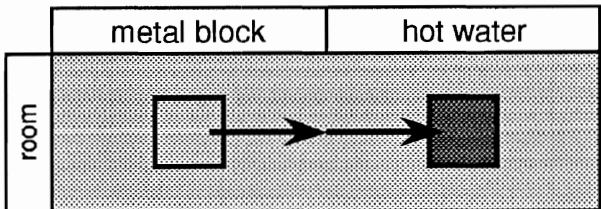


3

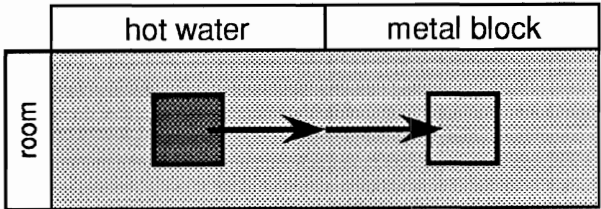
energy spreads out - concentration of energy becomes even - temperatures become equal

A metal block is put in hot water

A Which shows the energy transfer best?



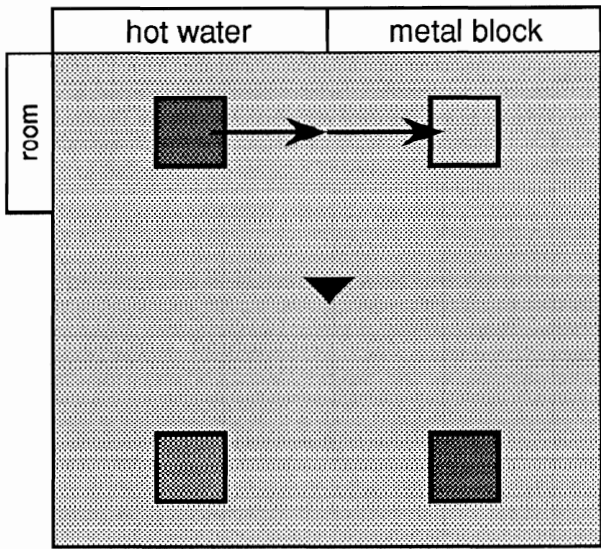
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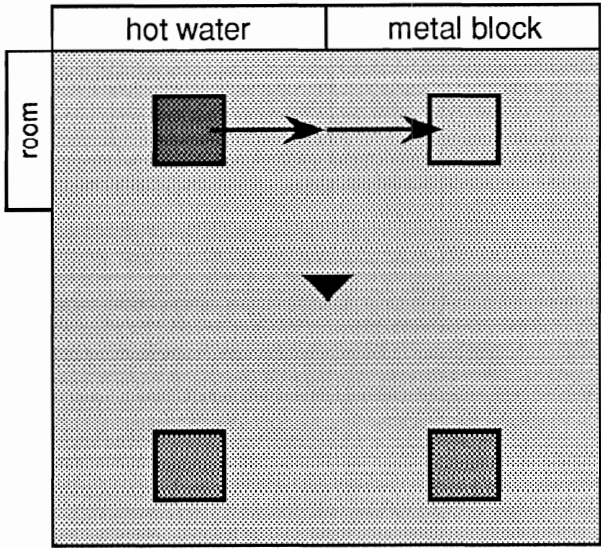
2

energy goes from hotter to colder

B Which shows what happens best?



1



2

energy spreads out - concentration of energy becomes even - temperatures become equal

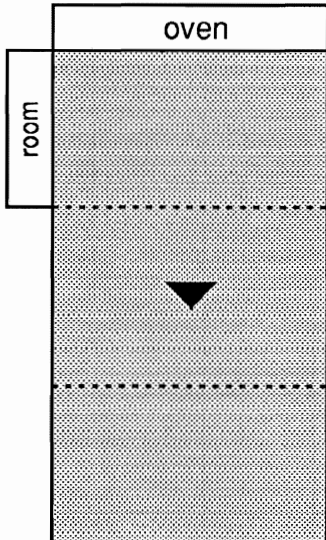
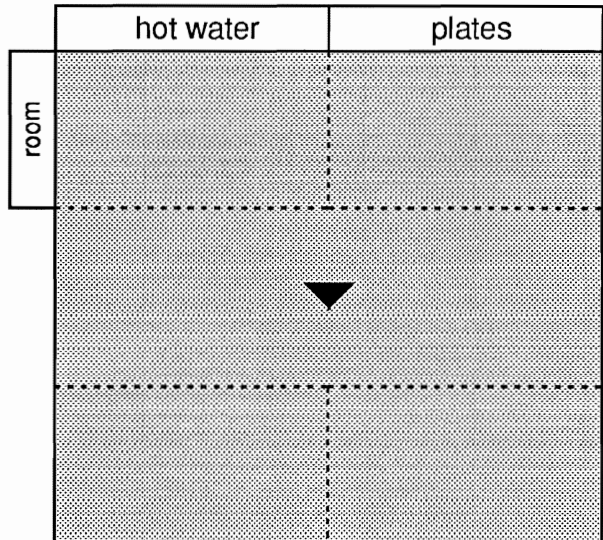
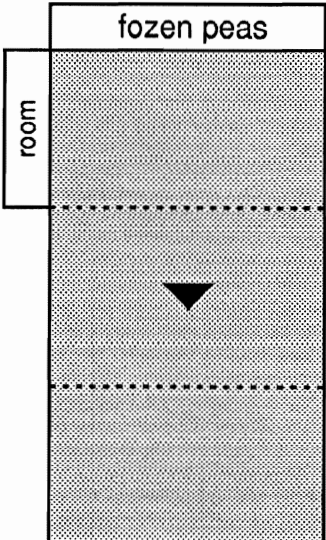
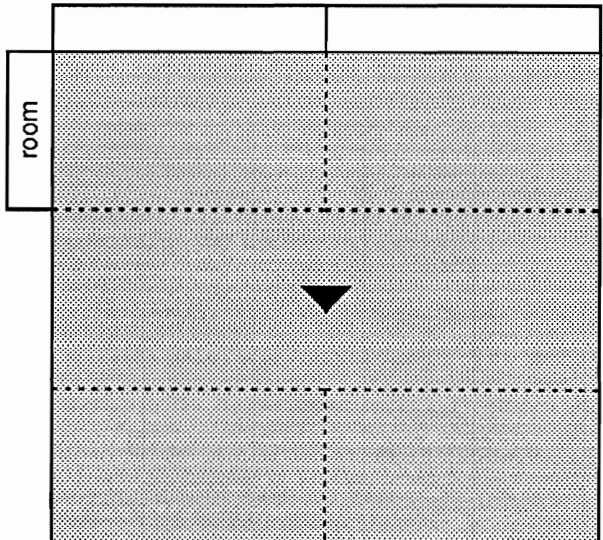
Energy transfers in the kitchen

Sheet 1

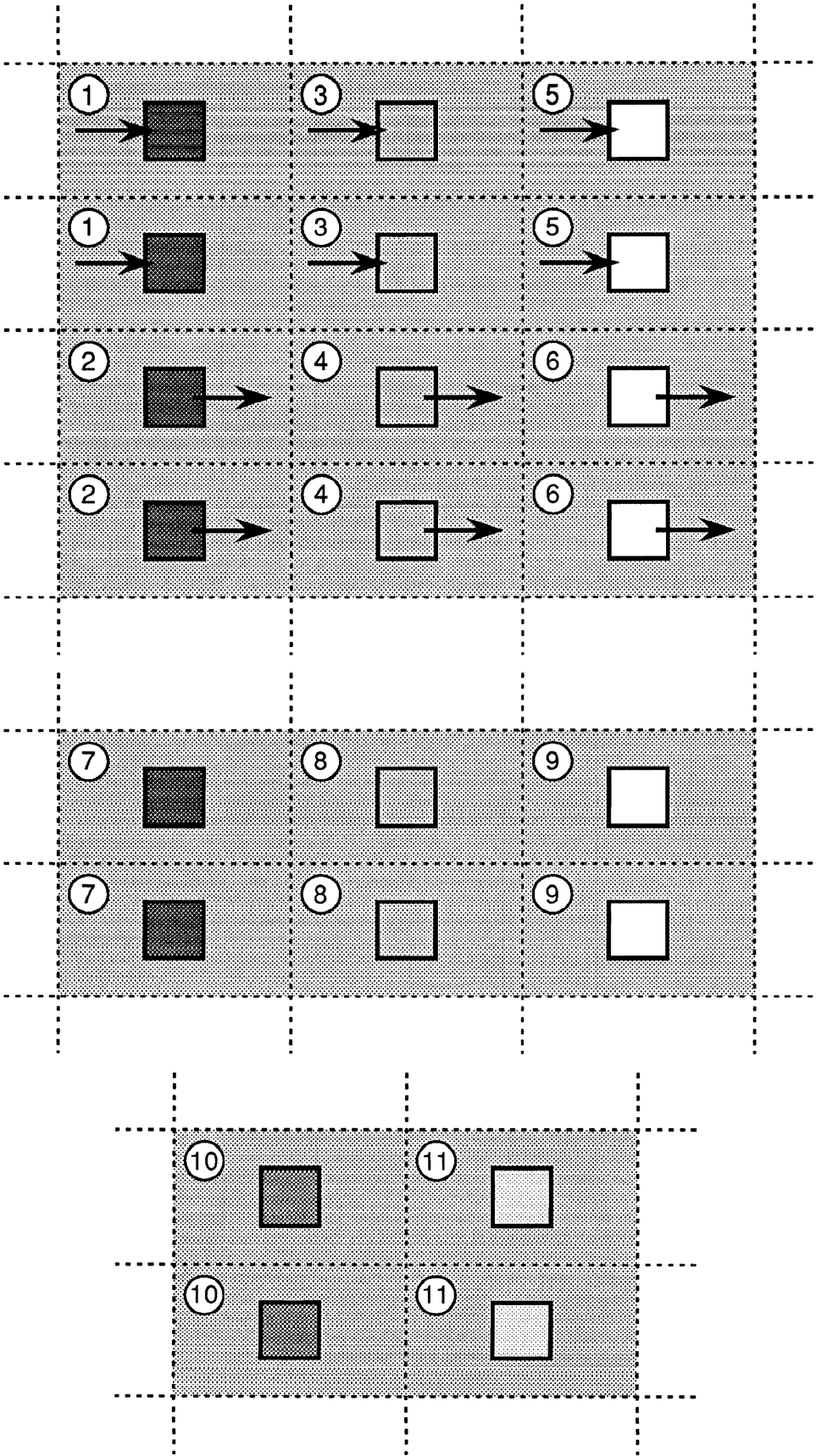
In a kitchen, we can find lots of things at different temperatures. Energy goes from hot things to cold things.

1 Below are some changes. Choose the pictures from sheet 2 you think are best to fill in the spaces. In some of the changes, you need to write in the labels at the top of the boxes.

2 When you have done all 4 changes, write about what the pictures show. You should explain where the energy is concentrated at the start, how the energy flows and where the energy is at the end.

<p>A a hot oven cools down</p> 	<p>B some plates are put in hot washing-up water</p> 
<p>C frozen peas left in a room</p> 	<p>D some ice cubes are put in a glass of lemonade</p> 

Cut out these pictures and match them to the spaces on sheet 1.



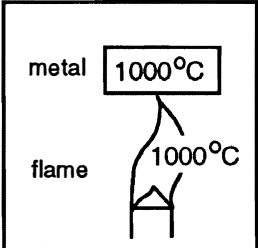
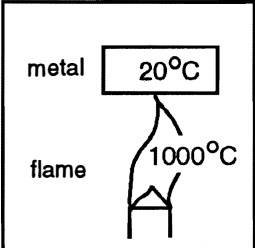
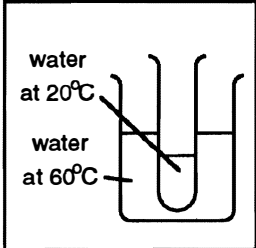
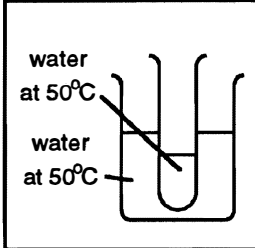
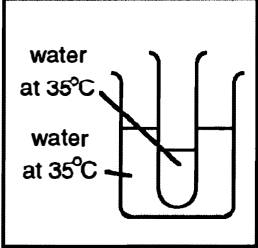
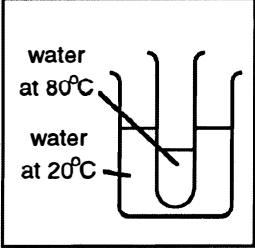
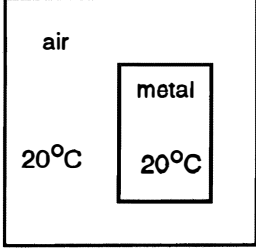
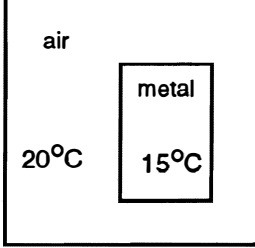
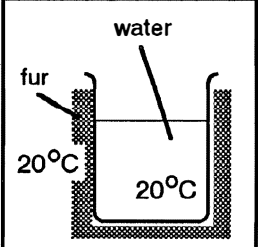
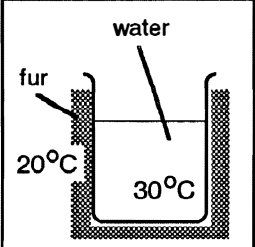
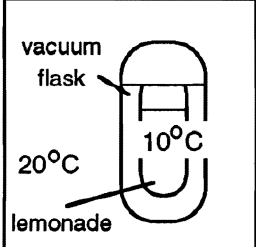
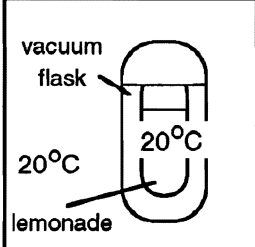
Getting hotter and colder

Sheet 1

1 Here are some changes. Each change has a 'before' and 'after' picture. Some of the pictures are in the wrong order.

2 In the space, write the letter of the picture you think comes first.

3 Now write about your reasons for for choices.

<p>1</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p>A</p> </div> <div style="text-align: center;">  <p>B</p> </div> </div> <p>First picture is <input style="width: 50px; height: 20px;" type="text"/></p>	<p>2</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p>A</p> </div> <div style="text-align: center;">  <p>B</p> </div> </div> <p>First picture is <input style="width: 50px; height: 20px;" type="text"/></p>
<p>3</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p>A</p> </div> <div style="text-align: center;">  <p>B</p> </div> </div> <p>First picture is <input style="width: 50px; height: 20px;" type="text"/></p>	<p>4</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p>A</p> </div> <div style="text-align: center;">  <p>B</p> </div> </div> <p>First picture is <input style="width: 50px; height: 20px;" type="text"/></p>
<p>5</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p>A</p> </div> <div style="text-align: center;">  <p>B</p> </div> </div> <p>First picture is <input style="width: 50px; height: 20px;" type="text"/></p>	<p>6</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p>A</p> </div> <div style="text-align: center;">  <p>B</p> </div> </div> <p>First picture is <input style="width: 50px; height: 20px;" type="text"/></p>

All of the pictures below show tubes containing water at 20°C. It is put into water at different temperatures, some with and some without insulation. Can you predict what will happen?

Prediction For each situation, predict what the temperature might be after 2 minutes. The first one has been done as an example.

Temperature at start

Temperature after 2 minutes

20 °C

	A	B
1	60 °C	
2		
3		

1	<div><div>A</div><div>B</div><div>hot (80 °C)</div><div>insulation</div></div>	
2	<div><div>A</div><div>B</div><div>room temperature (20 °C)</div><div>insulation</div></div>	
3	<div><div>A</div><div>B</div><div>cold (5 °C)</div><div>insulation</div></div>	

Results Now do the experiments and fill in this table.

Temperature at start

Temperature after 2 minutes

20 °C

	A	B
1		
2		
3		

Conclusion What can you say from these results?

1 The pictures below represent the situations you set up in the experiment. Draw arrows on these pictures to show what is happening to the energy. Use arrows of different sizes to show how much energy is flowing:



1	<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> A </div> <div style="text-align: center;"> B </div> </div>
2	<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> A </div> <div style="text-align: center;"> B </div> </div>
3	<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> A </div> <div style="text-align: center;"> B </div> </div>

2 Now write about what each of these pictures is showing. You should include in your answers:

- where the energy is concentrated at the start
- which way the energy flows
- how much energy flows
- what happens to the temperatures

Examples of insulation

Sheet 1

- 1 On sheets 1 and 2 are 8 pairs of situations. In each pair the first is without insulation, and the second is with insulation.
- 2 On sheet 3 are some pictures representing these changes. Cut them out and lay them out on a table.
- 3 Cut out each of these situations and match it against the picture you think is best.

A Hot chocolate left in a room

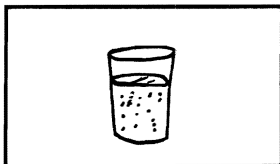


hot chocolate in a cup

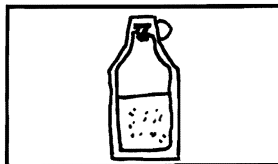


hot chocolate in a vacuum flask

B Cold lemonade in a warm room

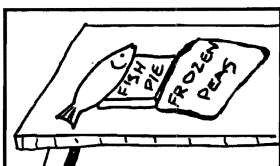


cold lemonade in a glass



cold lemonade in a vacuum flask

C Frozen food

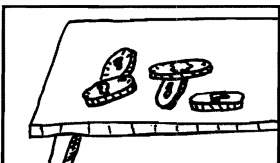


frozen food left on a table



frozen food wrapped in newspaper

D Coins at room temperature

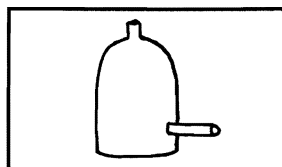


coins at room temperature left on a table

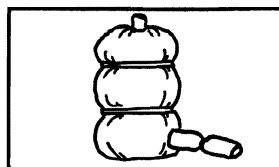


coins at room temperature wrapped in a woollen bag

E Hot water tank



hot water tank
without insulation



hot water tank
with insulation

F Snowman on a freezing day

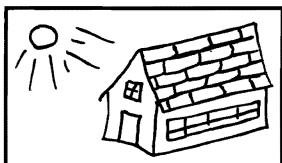


snowman on a
freezing day

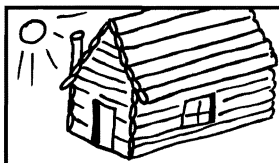


snowman wrapped in a
coat on a freezing day

G Sun shining on a house

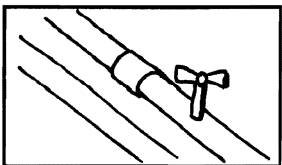


sun shining on a poorly
insulated house

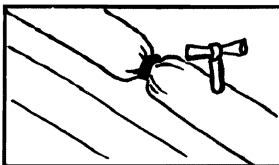


sun shining on a well
insulated house

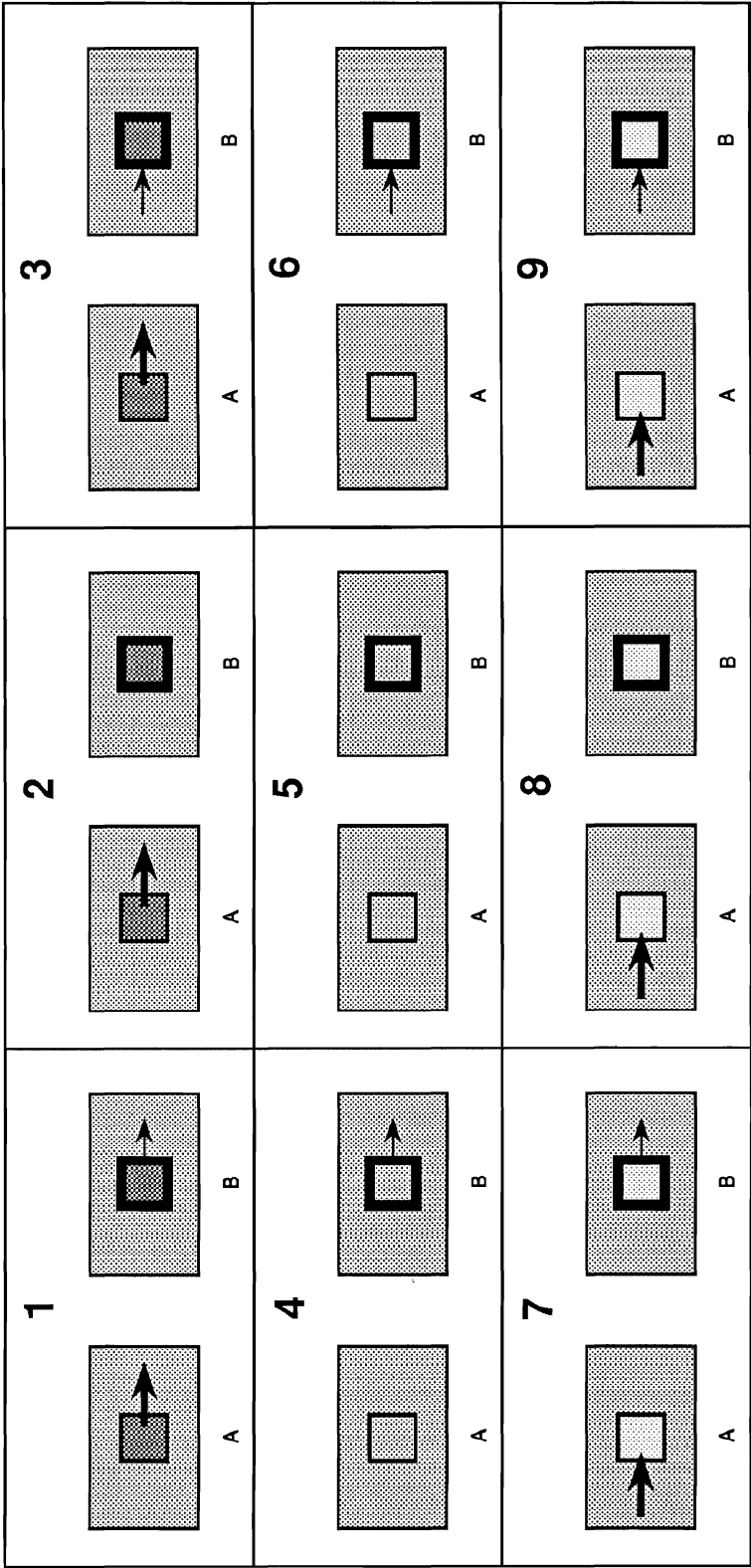
H Water pipes on a cold day in winter



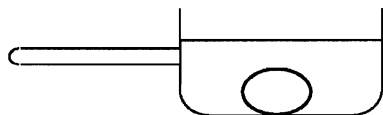
water pipes on
a cold day



insulated water
pipes on a cold day



Circle the correct words in the following:



When you put an egg into a saucepan of boiling water, the egg warms up. This is because the egg is **cold/hot** and the water is **cold/hot**. Energy passes from the **lower/higher** temperature to the **lower/higher** temperature. So energy passes from the **water/egg** to the **water/egg**. This makes the egg **cooler/warmer**. It also makes the temperature of the water **lower/higher**. Eventually the temperatures will be **the same/different**.

2 Now explain what happens when:

- a) a hot boiled egg is cooled by putting it in cold water
- b) a saucepan of water is boiled by putting it above the flame of a gas stove
- c) a radiator warms a room
- d) the room cools down when the radiator is switched off
- e) during the day, the air gets warmer
- f) at night, the air gets cooler