B1: HEAT ENERGY AND TEMPERATURE

Overview

The energy within a system **cannot be created or destroyed**. It can only be **changed from one form to another**. This principle is known as the **Conservation of Energy**.

The **chemical energy** in a battery, for example, can be transferred into **light energy**, or into **kinetic energy** when used to make a mechanical toy move.

Heat is a transfer of energy between two bodies due to temperature difference. The temperature of a body is an indication of the direction of the flow of energy when two bodies come in contact with one another. When one body is at a higher temperature, then energy will flow from the region of higher temperature to the region of lower temperature until both bodies attain the same energy level. All of the activities in this section should provide students with opportunities to examine their understandings of heat, temperature, and the role of thermometers.

The purpose of these activities is to provide students with an introduction to heat energy and temperature. The calibration process of the thermometer in **B1 ACTIVITY 3 (II): CALIBRATING THERMOFILM** is not a rigorous one, as the purpose of the activity is only to relate measuring temperature to a visible physical change – a thermometric property. Two physical changes are used – the expansion and contraction of liquid, and colour change.

Using the smart material thermofilm (also known as thermochromatic film) shows the students that not all thermometers need to be accurate. In **B1 ACTIVITY 1: DESIGNING, CONSTRUCTING AND USING A THERMOMETER** students use the expansion and contraction of liquids resulting from the transfer of heat energy to construct a simple liquid-in-glass thermometer. In **B1 ACTIVITY 2: THE DIFFERENCE BETWEEN HEAT AND TEMPERATURE** the students examine the difference between heat energy and temperature.

B1 ACTIVITY 3: HOT VERSUS COLD introduces the students to thermofilm as another form of thermometer. Using a standard alcohol-in-glass thermometer, students calibrate the thermofilm and draw up a scale of temperature. They can then use the thermofilm to distinguish between hot and cold, and to explore the relationship between these terms and temperature.

In **B1 ACTIVITY 3 (III) VISUALISING ENERGY FLOW** the students use this film to observe the direction of heat flow with the aid of the scale they have drawn up in **B1 ACTIVITY 3 (II): CALIBRATING THERMOFILM**.

NOTE:

Energy in Action is an online schools resource from SEAI.
If you're reading a printout and wish to view this online to access links, visit www.seai.ie/energyinaction

Suggested approaches:

- Start with a short brainstorming session to discover what the students think ‘temperature’ is:
  - ? ***Can they name the units it is measured in?***
  - ? ***Can they name different types of thermometers, e.g. a meat thermometer, a fridge thermometer, a clinical thermometer, a strip thermometer (i.e. temperature strip held on forehead)?***
  - ? ***Can they give some reasons we might need to measure temperature?***
- Another approach might be to see if students can relate physical changes to temperature change, e.g. relating the colour of a gas flame to hotness.
  - ? ***Can they give you a number of examples?***
  - ? ***What do they understand by the term physical changes?***
- Introduce the term ‘thermometric property’ and challenge the students to explain it without looking it up.
  - ? ***Suggest that they ‘dissect’ the word, i.e. what about ‘therm’? What does it suggest? The second part, ‘metric’ – when might the word ‘meter’ be used?***
  - ? ***Check the spellings of ‘meter’ and ‘metre’ – do they represent the same concept?***
- Another approach might be to focus on finding out what ideas the students have about the direction of heat energy.
  - ? ***Why might a table feel initially cold when I put my hand on it?***
  - ? ***How long will it continue to feel cold?***
  - ? ***What about walking on carpet?***
  - ? ***What about walking on a tiled floor?***
  - ? ***What are our five senses?***
  - ? ***Could any of our senses be responsible for our responses to heat and cold?***
- Before the investigations, the following questions could be put to the students to provoke a short discussion:
  - ? ***Must all thermometers be accurate?***
  - ? ***What is the function of a thermometer?***
  - ? ***What information are we looking for when using a thermometer?***
  - ? ***Is accuracy an important feature of all thermometers?***

If the students are arranged in groups for this, have each group draw up their conclusions for reference at the end of the investigations.

B1 ACTIVITY 1: DESIGNING, CONSTRUCTING AND USING A THERMOMETER

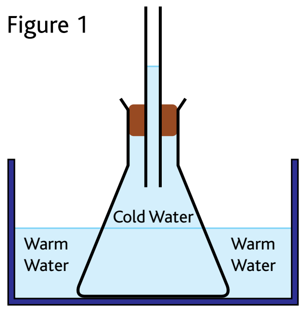
Background

This investigation is not a rigorous calibration of a thermometer (using fixed points of freezing water and boiling water and then dividing the length interval between these points into equal parts). The purpose of the activity is only to show that the physical changes of the expansion and contraction of liquids can be used as a means of constructing a thermometer.

Equipment required – per group:

- Lab flask or colourless medicine bottle
- Glass tube or straw
- Rubber stopper with hole to fit flask or medicine bottle
- Food colouring or ink
- Container of cold water
- Container of hot water
- Container of hand-hot water
- Tea light
- Matches
- Marker suitable for writing on glass

Figure 1



What to do:

1. Fit the lab flask or small medicine bottle with a cork and clear tube or glass straw.
2. Fill the lab flask to the brim with very cold water coloured with a drop or two of ink or food colouring, and cap it securely.

   ? ***Why are we using food colouring?***
3. Mark the water level on the glass tube.
4. Using a tongs lower the lab flask into a beaker of hot water.
5. Mark the water level in the tube.

   ? ***Describe and record what you observe happening to the water in the flask and glass tube.***
6. Remove the flask and put it into the container of cold water.
7. Again mark the water level in the tube.

   ? ***Describe and record what happens to the water level.***

   ? ***Is there a difference in the water level?***

   ? ***What conclusion could you arrive at?***
8. Lower the flask into hand-hot water and mark the water level on the tube.

   ? ***From the data you have collected what is your conclusion?***

   ? ***Consider what other things could increase the sensitivity of the thermometer.***

   ? ***What does 'sensitivity' mean?***

What next:

- Having constructed and used the thermometer, students can now investigate why mercury or alcohol is used in thermometers rather than water, despite water being freely available.
- Galileo is often credited with inventing the thermometer, but his invention is not, in fact, a thermometer. Can you explain?
- Ask the students to research Galileo in groups and present their results to the class. To discourage them from carrying out a cut-and-paste exercise and just reading from the text, do not allow them to use notes.

Figure 2: Familiar item labelled and sold as 'Galileo's thermometer'

Resources:

- The Galileo Project is an accessible and informative site that might serve as a useful source for students starting their research.
- The Brannan thermometer manufacturers website gives an overview of thermometer types and the different scales used.

B1 ACTIVITY 2: THE DIFFERENCE BETWEEN HEAT AND TEMPERATURE

Background

We do not measure temperature directly. Instead, we **read the changes** that heating and cooling produce.

Liquids **expand when heated** and **contract when cooled**. The **mercury thermometer** uses these facts to show temperature. The mercury in the thermometer absorbs heat and expands when it comes in contact with anything warmer than itself. It grows smaller when in contact with something cooler than itself. **Temperature is a measure of whether one object will give heat to, or absorb heat from, another object**.

This activity allows students to observe the **difference** between two bodies that both have the same temperature but contain different quantities of **heat energy**.

Equipment required:

- Test tube with support stand
- Beaker with tripod and gauze mat, or support stand
- Two candles (ideally tea lights)
- Matches
- Two mercury/spirit thermometers (best for this experiment)
- Stopwatch
- Access to water

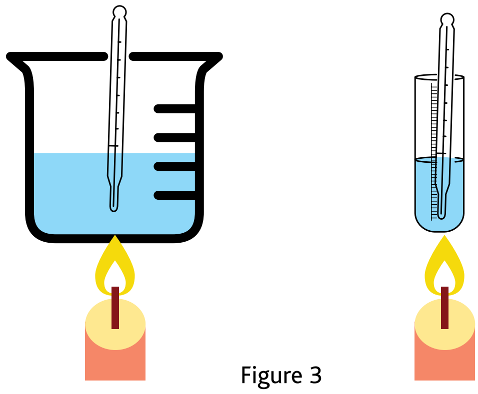


Figure 3

What to do:

1. Fill the beaker up halfway with water.
2. Add a small amount of water to the test tube.
3. Check the temperature of the water in both containers and make a note of it.
4. As indicated in Figure 3, position each container over the flame of a candle or a Bunsen burner. Use support stands, or tripod and gauze.
5. Heat both amounts of water for the same length of time and no more than five minutes.
6. Check and record the temperature of the water in each container.

    ? *Are the temperatures the same?*

    ? *If not can you explain why not?*

    ? *Which container contains the most heat energy?*

    ? *What are the variables in this activity?*

    ? *Which one did you keep constant?*

B1 ACTIVITY 3: HOT VERSUS COLD

Background

This activity aims at clarifying students' understanding of the distinction between the terms 'hot', 'cold', 'heat energy' and 'temperature' using thermofilm – a liquid crystal film that changes colour as it heats up. Using the thermofilm introduces students to another thermometric property suitable for measuring temperature – colour change. The colours that appear as the film reacts to heat energy are referenced against the standard glass-in-liquid thermometer.

Before using the thermofilm the students need to calibrate the film and draw up a reference chart to use.

Suggested approaches:

- Let the students brainstorm about their ideas of hot versus cold, and temperature versus heat. They should record their ideas for future reference. They can then carry out the first activity, **B1 ACTIVITY 3 (I): IT'S ALL RELATIVE (TEACHER-LED)**, in groups of four. After completing this activity they can revisit their original ideas and see if they should change their minds.
- Alternatively the students can carry out the activity first, and then have a brief discussion on hot versus cold and temperature versus heat.
- Keeping any questions on hold, the students can then use the thermofilm. They can learn how to calibrate it and then use it to demonstrate energy flow.

B1 ACTIVITY 3 (I): IT'S ALL RELATIVE (TEACHER-LED)

Equipment required:

- Four beakers to be used as follows:
  - Beaker A containing hot water (from the tap)
  - Beaker B containing a mixture of cold water and ice cubes/crushed ice
  - Beakers C and D both containing body-temperature water (approx. 37°C)
- Thermometer

What to do:

1. Select two volunteers from the class: **Volunteer 1** and **Volunteer 2**.
2. Without disclosing the temperatures of the beakers, ask **Volunteer 1** to hold **Beaker A** in one hand and **Beaker B** in the other.
3. Ask **Volunteer 2** to measure the temperature of **Beaker A** and **Beaker B**.
4. Ask **Volunteer 1** to confirm which of the beakers is hot and which is cold.
5. Now ask **Volunteer 1** to put one hand into **Beaker C** and one hand into **Beaker D**, and ask them to tell you which contains hot water, and which contains cold water.
6. Ask **Volunteer 2** to measure the temperatures of **Beakers C** and **D** and announce them to the class.
   - Discuss the students' original ideas about hot and cold and see if this demonstration has changed those ideas. Do not press too much for answers at this stage.
7. After the students have completed the activities **B1 ACTIVITY 3 (II): CALIBRATING THERMOFILM** and **B1 ACTIVITY 3 (III) VISUALISING ENERGY FLOW**, revisit what they learned from this demonstration.

   At this point, explain that our skins have temperature sensors able to detect the direction of energy flow along the surface of our bodies. There are two different messages sent along the nerves: that heat energy is flowing into the skin (hot); and that heat energy is flowing out of the skin (cold).

B1 ACTIVITY 3 (II): CALIBRATING THERMOFILM

Before using the **thermofilm** the students need to calibrate the film and draw up a reference chart to use. The different colours that occur as a result of heat energy should be referenced against the standard glass-in-liquid thermometer as follows: black corresponds to approximately 25°C; brown to approximately 26°C; green to between 29°C and 30°C; and blue to above 30°C.

Equipment required:

- Hot plate or Bunsen burner with tripod and wire gauze
- Heatproof mat
- 250 cm3 beaker
- Thermometer
- Test tube
- Piece of thermofilm (3 cm x 1 cm)
- **B1.3 printout: Thermofilm calibration chart**

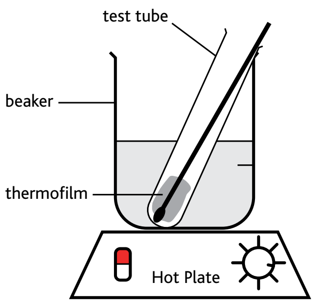


Figure 4

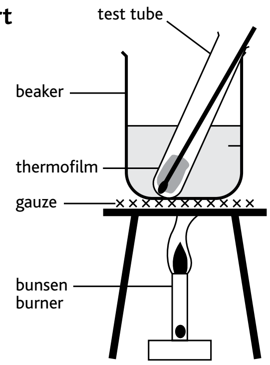


Figure 5

What to do:

1. Set up the hot plate or the Bunsen burner tripod and gauze as shown in Figure 4 and Figure 5.
2. Half fill the beaker with cold water and place it on the hot plate or the gauze.
3. Drop the thermofilm into the clean, dry test tube.
4. Place the thermometer into the test tube.
5. Place the test tube in the beaker of water.
   - Note the initial temperature of the water and the colour of the thermofilm.
6. Switch on the hot plate or light the Bunsen burner and slowly heat the water.
7. As the water heats up, the thermofilm changes colour.
   - Note the temperature readings for each of the colour changes.
   - ***What do you notice about the colour bands?***
   - ***What temperature range does each band cover?***
8. When the water temperature reaches 40°C switch off the heat.
   - ***Why do you think you should do this?***

B1.3 printout: Thermofilm calibration chart

TEMPERATURE RANGE	CORRESPONDING COLOUR

B1 ACTIVITY 3 (III) VISUALISING ENERGY FLOW

Equipment required:

- Two small empty aluminium cans (150 g tomato puree can is ideal)
- An aluminium sheet (3 x diameter of can)

  [Alternatively take two sheets of kitchen foil, put them together and laminate them as one. Gently peel the laminate cover apart giving two sheets which can then be cut to size. The laminated side can be stuck to the polystyrene.]
- Strip of thermofilm (5 cm x 2 cm)
- Thermometer
- Ice cubes
- Access to hot water
- Expanded polystyrene slab (approx. 25 cm x 10 cm)
- Calibration chart from previous experiment **B1 ACTIVITY 3 (II): CALIBRATING THERMOFILM**
- Insulating covers to fit cans (optional)
- Stopwatch

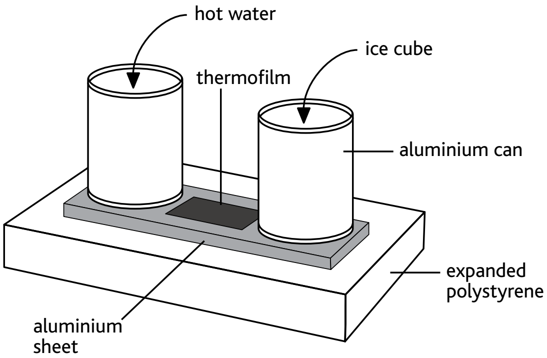


Figure 6

What to do:

1. Affix the thermofilm to the aluminium sheet as shown in Figure 6.
2. Place the aluminium sheet on the expanded polystyrene slab as shown in Figure 6.
3. Place the aluminium cans on either side as shown in Figure 6.
4. Put a cube or two of ice into one of the cans.
5. Fill the other can halfway with hot water.
6. Place the thermometer in the hot water and note the temperature.

   Observe what happens to the thermofilm, referencing the calibration chart from the previous experiment.
7. Repeat the experiment.

   This time, note the time it takes for the thermofilm to stop changing colour.

   ? *What is this colour?*

   ? *What has happened?*
8. Repeat again, this time placing lids on the cans.

   Compare time results.

   ? *If using laminated kitchen foil, is it important which side is facing upwards?*

   ? *Why?*

B1.3 Discussion points: Colour and Temperature

1. Students are familiar with mood rings, bracelets, etc. These come with a chart relating colours to emotions.
   - ? ***Is the colour-temperature range the same as that of the thermofilm used in*** **B1 ACTIVITY 3 (II): CALIBRATING THERMOFILM*?***
   - ? ***If the body temperature is 37°C when it is worn, why does the ring colour at lower temperatures?***
   - ? ***Is the colour-temperature range the same as the thermofilm?***
   - ? ***If the body temperature is 37°C, how can the ring change colour when it is worn?***

Figure 7: One of the many charts used with mood jewellery

Stressed
Fear
Nervous
Mixed Emotions
Normal
Relaxed
Calm
Cool
Lovable
Romance
Passion
Very Happy

RESOURCES:

- Search the National Stem Centre, UK for some great ideas on teaching heat and temperature.

B1.4 HISTORY NOTE A: CELSIUS AND THE REVERSE SCALE

The **Celsius temperature scale** dates back to 1742, when the Swedish astronomer **Anders Celsius** published a paper entitled 'Observations on two persistent degrees on a thermometer'.

After providing background on the various ways that temperature could be expressed at that time, the paper presents an account of Celsius' experiments with two fixed points for a temperature scale:

- The temperature of thawing snow or ice
- The temperature of boiling water

The idea of using the **freezing point of water** as a temperature calibration point had already been suggested by **Reaumur** and **Newton**. Celsius' approach was different. He wanted to use the point at which snow or ice thaw, rather than the point at which water freezes; the **melting point** of water, rather than the **freezing point**. In his paper, Celsius described an experiment which involved placing a thermometer in thawing snow. 'I have repeated this experiment many times over two years in all winter months...' he wrote, 'through different barometric changes, and always found precisely the same point on the thermometer... When it was strong winter I took the cold snow into my room and put it in front of the fire until it began to thaw...'

The second calibration point was more complicated. 'As far as the second fixed point is concerned,' Celsius wrote, 'it is well known that once water has begun to boil, it will not take up any considerable degree of heat even if one continues the boiling for long; thus the mercury in the thermometer will end at the same point.'

The intensity of the boiling might, however, affect the calibration point to a certain degree. Celsius proposed a standardised method for determination. He noted that when the thermometer is taken out of the boiling water the mercury level rises somewhat before it retracts. The explanation, Celsius suggests, is that the glass tube contracts before the mercury starts to cool off.

The second factor that affects the boiling point of water is the air pressure. This was already observed by Fahrenheit, and Celsius reports a series of experiments confirming this observation. His conclusion is that 'the height of the thermometer in boiling water is always proportional to the height of the barometer, thus eight "points" on the thermometer I use correspond to a change of one inch in the barometer reading; a thermometer which is somewhat more sensitive or has large degrees can be used as a barometer when put into boiling water, and would be easier to bring along when travelling at sea or land, especially on high mountains.'

Celsius proposed a standardised procedure for the calibration of a thermometer:

1. Put the cylinder AB of the thermometer (i.e. the bulb) in thawing snow. Mark the freezing point of water C. This should be at such a height over the cylinder at A that the distance AC is half the distance between C and the water boiling point marked D.
2. Mark the boiling point of water D at a pressure of approximately 755 mm.
3. Divide the distance in 100 equal parts or degrees; so that 0 degree corresponds to the boiling point of water, D, and 100 to the freezing point of water, C. When the same degrees have been continued below C all the way down to A the thermometer is ready.

Celsius thus put the boiling point at 0 degrees and the freezing point at 100. This is, of course, the reverse of the Celsius scale as we now know it.

It is often claimed that Carl von Linné (Carolus Linnaeus) instigated the reversal, but it appears more likely that the responsible person was Daniel Ekström, who manufactured most of the scientific instruments, including thermometers, used by both Celsius and Linné.

B1.4 HISTORY NOTE B: LORD KELVIN; THE IRISH CONNECTION

In 1848 the Irish-born scientist, **William Thomson**, formulated a temperature scale that was **independent of all thermometric properties**.

He proposed that the temperature at which all movement ceases (no heat energy available) should be called **'the absolute'** temperature. While the existence of a very low temperature was acknowledged, at the time it was Thomson who actually determined its value of approximately **minus 237.15°C**. He called the value the 'absolute zero' to distinguish it from zero degrees on the Celsius scale, which by then referred to the freezing point of water. Because minuses have a habit of getting lost, the Kelvin scale replaces −273.15°C with zero. The divisions on the **Kelvin scale** are the same as those of the Celsius scale.

Figure 8: William Thomson

According to the Kelvin scale:

− 273.15°C = 0 K

0°C = 273.15 K

This makes it easier to convert readings on the Celsius scale to the equivalent on the Kelvin scale.

The Kelvin is one of the seven basic units used in the International System of Units (SI).

The development of the Kelvin is only one of Thomson's great achievements. Born in Belfast in 1824 and raised for the most part in Glasgow, he was an avid **geologist** and **mariner** as well as a **scientist**. His list of achievements includes establishing the basic **laws of thermodynamics**, investigating the relationship between cable thickness and data flow (present day **bandwidth**), developing **submarine communication** systems, introducing accurate methods for **measuring electricity**, and inventing the **adjustable compass**. A great believer in the practical application of science, he was deeply involved in laying the **transatlantic telegraphic cables** for which he was knighted in 1866 and became known as **Lord Kelvin**. He died in 1907.

B2: HEATING PROJECT – SAVING ENERGY AT HOME

Overview

This section teaches students how they can save energy at home. By monitoring their energy use over time, students see for themselves the difference that small changes can make towards saving energy. The activity should take place over at least one billing period. This means it usually takes about two months or more.

Suggested approaches:

- Click here to view sample data sheets, but encourage students to create their own, rather than printing the templates.
- Begin by asking students to research energy efficiency using the **resources** provided below. Once the students have familiarised themselves with the resources, the teacher should facilitate a class discussion where students try to identify energy efficient changes they could make at home. Students can share ideas and try to identify which changes would be the most effective and practical for them.
- Ask students to adopt energy saving practices and monitor their subsequent home energy costs to see if the practices make a difference to their energy bills.
- The SEAI website has a wealth of information in the form of Top Tips found by clicking on the various items on the website.

Resources:

- The SEAI Publications page has a number of homeowner publications on saving energy which are free to download.
- To learn about the financial implications of energy consumption at home, students could check out bonkers.ie.

B2 ACTIVITY 1: HEATING PROJECT – SAVING ENERGY AT SCHOOL

Background

Recent legislation means that educational leaders are now required to pay close attention to energy usage and energy awareness in the very infrastructure of not only the school buildings, but the school ethos as well.

The 2010 Energy Performance of Buildings Directive was recast as one of the core moves for achieving the overall Europe 2020 Strategy. Binding targets have now been set for the energy efficiency of public buildings, including school buildings, to be transposed into national law and implemented via national regulations at defined dates. The National Energy Efficiency Action Plans (NEEAP) have set the public sector a target of 33% energy efficiency savings by 2020. All bodies must put energy efficiency programmes in place and report their energy efficiency actions to the European Commission annually.

Energy in Education is a partnership initiative of SEAI and the Department of Education and Skills set up to help this sector to attain its goals. While much of the responsibility for energy efficiency falls on management, parents, students and school staff also play an important role in making these changes happen.

Suggested approaches:

- Before any of these activities are undertaken, they must be discussed with management to ensure that they are appropriate.
- Click here to explore a wealth of information about SEAI energy efficiency training for schools. Teachers who have availed of this training have found it a very helpful foundation for starting energy education projects with their classes.

What to do:

1. One way for students to get involved in reducing energy waste is to monitor how energy is used at school. Brainstorm with the class to identify inefficient use of energy at school, and challenge the students to come up with ideas for increasing energy efficiency.
2. Divide the class into groups, and assign each group of students a room in the school. Ask them to make a list of the energy-consuming appliances in their assigned room. Over a fixed period (i.e. one week) they must check how often an appliance is left on standby. By checking the rating on the appliance, students can estimate how much it costs to keep the appliance on standby.
3. Some of the investigations in the strands could be used as lead-ins to monitoring usage. For example **C2 ACTIVITY 2: TESTING PERSONAL EFFICIENCY** could be used as a template to survey the school and maybe initiate a One Good Idea solution as described in **C2 ACTIVITY 5: ONE GOOD IDEA**.
4. Another area students could monitor is water usage in the school. **A3 ACTIVITY 2: VISUALISING: WHY SUSTAINABILITY? HOW MUCH FRESHWATER IS THERE?** provides a visually effective exercise to help students to understand why we should be mindful of our water consumption.

Resources:

- The Energy in Education site contains a wealth of background information, fact-sheets, and videos that can be very useful to teachers and students alike.

B3: HEAT TRANSFER BY CONDUCTION

Overview

This section is designed to introduce students to the concept of **heat transfer by conduction**. Students are presented with a selection of materials; two metals and two liquids. They are asked to predict whether the substances will **conduct heat** or not before testing them out. To motivate and engage students, the teacher challenges them to use their knowledge of **energy transfer** to **predict**, **observe** and **explain** what happens as they carry out the activities. They are then asked to **compare** their **predictions** with their **observations**. In this way, students are expected to develop an understanding of **heat energy by conduction**.

Suggested approaches:

- These activities can be used either as an **introduction** to **conduction of heat energy** or as a means of revision of material which may have already been covered.
- Encourage students to check out the equipment while you explain briefly what you are going to do.
- Before carrying out the demonstrations, ask students to predict what they think will happen.

B3 ACTIVITY 1: METAL KITCHEN SIEVE

Background

The metal in the sieve conducts so much heat away that the candle wax vapour cannot ignite above the wire mesh. The flame will reach the wire mesh, but does not go through it. The flame only passes through the metal lattice if it is made to glow by strong heating.

Equipment required (per group):

- Candle (lit)
- One metal kitchen sieve
- Metal sieves with smaller and wider meshes
- Access to a strong gas flame

What to do:

1. Ask the students to hold a metal kitchen sieve in a candle flame as in the diagram. Ask them to consider the following questions:
   - ? ***What do you observe about the flame?***
   - ? ***Why might this be?***
   - ? ***What do you think might happen if you used a metal sieve with a wider mesh?***
   - ? ***What might happen if a smaller mesh was used?***
   - ? ***How near to the flame would the mesh need to be in order to affect the flame?***
2. Ask them to hold the sieve with the smaller mesh over the flame and observe what happens.
3. Ask them to hold the sieve with the wider mesh over the flame and observe what happens.
4. Hold the flame from a strong gas flame close to the mesh and ask the students to observe any differences between holding a mesh to a gentle candle flame, and a stronger gas flame.

Figure 9

Resources:

- Click here to view this activity, with a detailed explanation, online.

B3.1 DISCUSSION POINTS: THE FLAME AND WIRE MESH

1. **Predict** what happens when the flame is held close to the wire mesh.

2. Explain what you **observe** in detail.

3. Does the **size of the mesh** matter? Explain your answer.

4. Do you **notice** any difference when holding the flame from a strong gas flame close to the mesh? Comment on what you observe.

5. The Emigrant Flame was lit in New Ross with a flame taken from the Eternal Flame on J. F. Kennedy's grave at Arlington Cemetery. How was this possible?

6. The Olympic Flame is carried by runners from Olympia in Greece to wherever the Olympic Games are being held. What measures are put in place to make this possible?

B3.2 HISTORY NOTE C: THE DAVY LAMP

The Davy lamp is a safety lamp that uses the principles encountered in this exercise. It was invented by Sir Humphry Davy in 1815 and was used by coal miners.

The only light source for the miners was an oil lamp. The greatest hazard of coal mining was a build-up of dangerous gases like methane and carbon monoxide in confined spaces, which would catch fire and cause explosions. The Davy lamp is designed to minimise the possibility of fire. A metal lattice surrounding the naked flame takes up so much heat that the gases in the mine cannot ignite.

More sophisticated safety measures are now used in the mining industry, but the concept behind the Davy lamp is still used when transporting a flame over long distances.

Figure 10

B3 ACTIVITY 2: COIN ON PAPER

Background

Metals are generally considered good **heat conductors**. Paper, on the other hand, will readily burn. But what will happen if paper is placed between a flame and a coin? The metal behaves as a **thermal conductor**, **drawing heat** away from the paper and thus preventing it from burning. Computers depend greatly on such thermal conductors, more commonly referred to as heat sinks. Because the computer's processes generate heat, these 'sinks' are strategically placed to draw this heat and prevent the machine from overheating. Similarly, the water in a car's radiator acts as a thermal conductor absorbing the heat from the engine.

Equipment required (per group):

- Two small squares of thin card or stiff paper
- Coin
- Candle
- Matches
- Tongs
- Timer
- Beaker of water

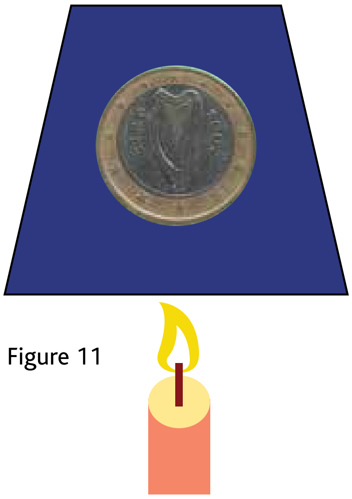


Figure 11

What to do:

1. Light the candle.

   ? ***How long do you think it will take for one of the small squares to burn if held over the flame? Remember, the hottest part of the flame is just above the tip of the flame.***
2. Hold one of the pieces of card in the tongs and position it just over the tip of the flame. **Time** how long it takes to **start smouldering**. (No need to set it on fire.) Record the time taken and carefully leave the card aside. (Why?)
3. Hold the second piece of card in the tongs, balance the coin on top of the card. Hold the card and coin just over the tip of the flame as shown in Figure 11 and at the same time start the timer.
4. When the timer reaches the same as recorded in step 2, remove the card and examine the side that was nearest to the flame.
5. Compare the state of the two pieces of card.

   ? ***Is there a difference?***

   ? ***Can you explain why?***

Resources:

- There is a video of this activity from Science on Stage.
  Click here to view it in English.
  Click here to view it in Irish.

B3 ACTIVITY 3: THE BALLOON THAT DOES NOT BURST

Background

This activity illustrates the coolant properties of water. Water has a high capacity for heat. In this activity, the water absorbs the heat given out by the candle, so the temperature of water in the balloon will rise while the balloon itself will remain intact!

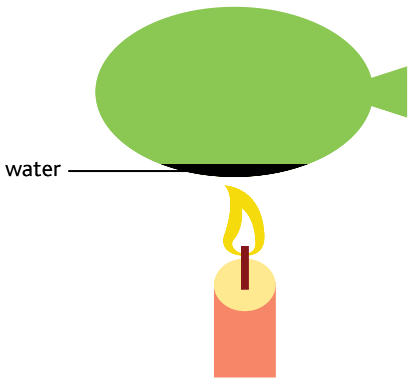


Figure 12: Water in balloon

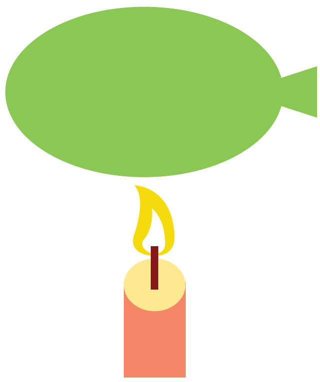


Figure 13: No water in balloon

Equipment required (per group):

- Two identical balloons
- A balloon pump
- Two candles
- Matches
- Access to tap water
- Two plastic lunch bags
- Thermometer

What to do:

1. Place a small amount of water in a balloon, blow it up and seal.
2. Blow up an identical balloon (without putting water in it).

   ? ***What will happen when burning candles are placed under the two balloons as shown in Figure 12 and Figure 13?***

   ? ***What did you observe?***

   ? ***Why was this?***

3. What temperature do you think the water would have to reach before the balloon would melt?
4. Check out this predication by repeating this experiment. This time use plastic lunch bags instead of the balloons. A thermometer inserted in the bags shows the temperature rising.

Resources:

- Click here to view a demonstration of this activity using plastic lunch bags instead of balloons.

B3 ACTIVITY 4: BOILING WATER IN A PAPER CUP

Background

This is another demonstration of the capacity of water to absorb heat energy. The water boils, but the cup is not even scorched. The water absorbs the heat transferred to the paper and begins to boil at a temperature of 100°C. The water does not get any hotter, so the paper does not reach a high enough temperature to burn.

Equipment required:

- Paper cup with small amount of water
- Wooden skewer or similar (i.e. knitting needle)
- Supports as shown in Figure 14
- Thermometer or data logger sensor

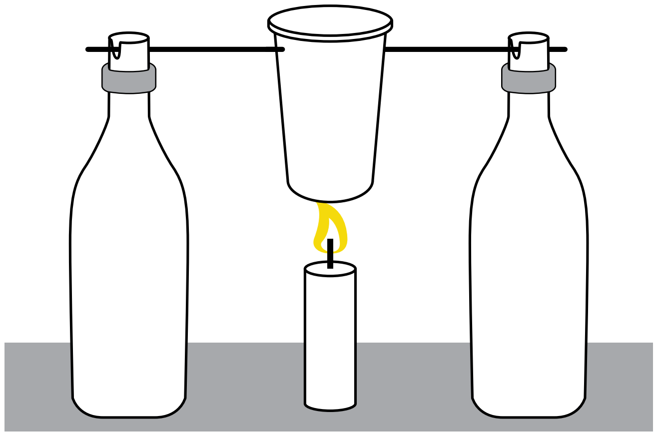


Figure 14

What to do:

1. Put a small amount of cold water in the paper cup.
2. Push the skewer through the rim of the paper cup.
3. Hang it between the two supports as shown in Figure 14.
4. Place the thermometer or data logger in the water and note the initial temperature.
5. **Predict** what will happen when the burning candle is placed under the paper cup.

   ? ***Will the cup burn immediately?***

   ? ***Will the thermometer or data logger register a temperature rise or a fall?***
6. Place the burning candle under the cup.

   Observe what happens and record these observations.
7. After two to three minutes quench the candle.

   Compare your observations with your predictions.

   ? ***Were there any surprising outcomes?***

   ? ***Do you think the outcome would be the same if a polystyrene cup was used instead?***

B3.4 Discussion points: Water Coolant

1. Water is used as a coolant for car engines. List all the advantages of water that make it an ideal coolant.
2. Some industries rely heavily on water as a coolant but this can present problems for local communities. What might these problems be?
3. Research these industries in Ireland.

   ? ***Where are they situated?***

   ? ***Who is tasked with monitoring them?***

   ? ***Why might monitoring be required?***

B4: HEAT TRANSFER BY CONVECTION

Overview

Students might be familiar with the term **convection** in the contexts of **convection currents**, **convection heaters**, **convection ovens**, **convection microwaves** and **convection air currents**, but often find it difficult to explain the process. These activities on convection challenge students to **use their knowledge** of energy and energy transfer to **predict**, **observe** and then **explain** what happens.

B4 ACTIVITY 1: TEABAG ROCKET is demonstrated by the teacher, and lends itself to plenty of questions from the class. **B4 ACTIVITY 2: SPINNING** is simple, but gives students a chance to experiment with various shapes.

B4 ACTIVITY 3: LAND AND SEA is a weather related activity showing the direction of wind breezes in terms of offshore and inshore breezes. **B4 ACTIVITY 4 (I): CONVECTION IN WATER** uses hot and cold water to show the direction of a convection current very clearly. A mini-house heating system in **B4 ACTIVITY 5: TRANSFERRING HEAT** can also be used to highlight the importance of insulating pipes. The direction of ocean currents are shown in **B4 ACTIVITY 6: SIMULATING OCEAN CURRENTS**.

Suggested approaches:

- By way of introduction, hold a short word-association session on the word 'convection'. If possible, ask the students to briefly explain what they understand by terms like 'convection oven', 'convection heater, etc. This will help you to decide which activities are best initially carried out by you. Asking questions as you demonstrate the activity will give you an opportunity to address any misconceptions that the class may have.
- All of these activities are ideal for using a '**predict**, **observe**, **explain**' approach. Students should be able to **predict** what they think will happen and describe what they **observe**. The **explaining** part may well take the form of a lively class discussion.

B4 ACTIVITY 1: TEABAG ROCKET

Background

Depending on the class, you may decide that this activity would work best as a teacher demonstration. If allowing the students to carry out the activity for themselves, be sure to demonstrate it first.

Hot or warm air rises because it is not as **dense** as cold air. When the top of the teabag is lit, the air within the cylindrical teabag heats and spreads out (more **kinetic energy**). As a result, the air in the teabag becomes less dense. This warm air then rises and the ash, and what remains in the teabag, are so light that the teabag takes off like a rocket.

Equipment required:

- One teabag (a similar shape to that shown in Figure 1
- Heatproof mat (or non-flammable surface)
- Matches or lighter
- Scissors
- Safety goggles

Figure 15

What to do:

1. Carefully remove the staple, string and tag from the teabag and empty out the tea.
2. Open out the teabag to its cylindrical shape.
3. Stand the cylinder on one end on a flat, non-flammable surface.
4. **Predict** what will happen when you light the top of the cylinder.
5. Light the top of the cylinder.

   ? ***What do you observe happening to the flame?***

   ? ***Is it what you predicted earlier?***

   ? ***What happens to the teabag itself?***

   ? ***Did you expect this?***

   ? ***Why did the teabag behave this way?***

Resources:

- A video of this activity is available from Science on Stage.
  Click here to view it in English.
  Click here to view it in Irish.

B4 ACTIVITY 2: SPINNING SPIRAL

Background

This activity uses a candle to heat the air, which then rises. The position of the candle enables this hot air to rise up through the spiral that is free to rotate and so spins. Students may be familiar with some decorations based on this principle. Either before or after the activity, students could research how hot-air balloons operate, as well as the oriental custom of releasing hot-air lanterns for significant occasions.

Equipment required (per group):

- One A4 sheet of light card or paper
- 15 cm length of string
- Retort stand and clamp
- Scissors
- Candle (ideally a tea light)
- Matches
- Drawing compass with pencil

Figure 16

What to do:

1. Using the compass, draw a circle of approx. 8 cm in diameter on the card or drawing paper as shown in Figure 17.
2. Cut a neat spiral leaving a small circle in the middle to attach the thread as shown in Figure 18.
3. Make a small hole in the centre of the circle and thread the piece of string through, securing it with a knot.
4. Hang the spiral from one of the claws on the clamp, ensuring that the spiral has plenty of room to move up and down without touching the bench.
5. Before you put the flame under the spiral **predict** what will happen.

   ? ***Will the spiral bob up and down?***

   ? ***Will it spin in a clockwise direction or perhaps anticlockwise?***
6. Allow the spiral to hang freely and then position a burning candle underneath it making sure it is not touching any part of the spiral.

   Observe the spiral's behaviour.

   Explain any differences from your initial prediction.

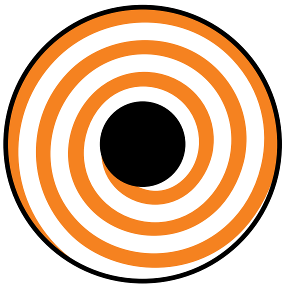


Figure 17

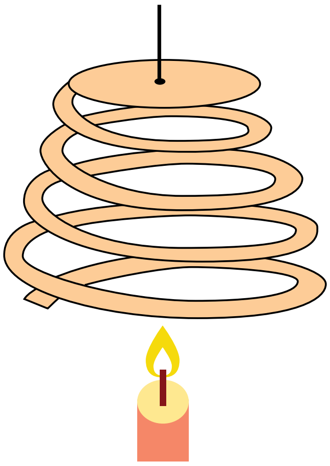


Figure 18

B4 ACTIVITY 3: LAND AND SEA BREEZES

Background

The aim of this activity is to examine the **causes of land and sea breezes**.

Heat energy flows from a region of high temperature to a region of low temperature. If there is a significant enough **temperature difference** or **gradient** we can feel a breeze or a draught. This is warmer air moving towards the colder air. In this activity, the air over the ice is at a significantly lower temperature than the air over the heated sand, so the hot air will move towards the cool air region. In order to see the air moving, a lighted taper is put out, creating smoke. The smoke will move in the direction of the air, or breeze.

For practical reasons, this activity might be best demonstrated by the teacher.

Equipment required (per group):

- Two shallow metal pans (i.e. baking trays)
- Sufficient ice to cover the base of one of the pans
- Sufficient sand to cover the base of one of the pans
- Matches
- Taper (a piece of thin paper will do)
- Oven gloves
- Heatproof mat
- Access to an oven

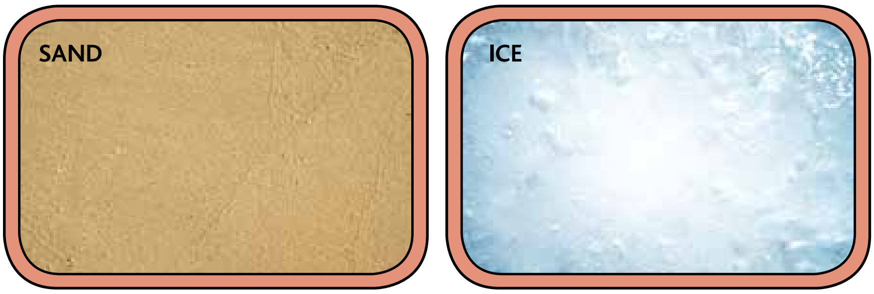


Figure 19: The sand represents land. The ice represents the sea

What to do:

1. Set up the investigation in an area protected from draughts.
2. Set the oven to about 200°C.
3. Pour some sand into one of the pans and put it in the oven to heat for about for five to eight minutes.
4. While the sand is heating up, light a candle, or paper taper, and then blow it out.

   ? ***Which direction does the smoke flow in?***
   (If there is no draught the smoke will flow straight up like a convection current.)

5. Fill the second pan full of ice.
6. Using oven gloves, carefully remove the tray of sand from the oven and put it on a heatproof mat beside the pan of ice.
7. Light the candle or paper taper again and blow it out.
8. Hold the smoking taper in between the two pans, right above the edge of the ice pan.

   ? ***What direction does the smoke now flow in?***
   (Because there is a temperature difference where the ice and sand meet, a breeze develops and the smoke floats sideways.)

B4.3 Discussion points: Breezes

1. What is meant by the phrases 'offshore breezes/winds' and 'onshore breezes/winds'?
2. How might these breezes affect the waves?
3. Why are surfers particularly interested in these winds?
4. What time of year might the offshore winds be high? Why?

Resources:

Vernier.com has another version of this activity using sensors. The illustration in Figure 20 is from that site where you can also view the full experiment.

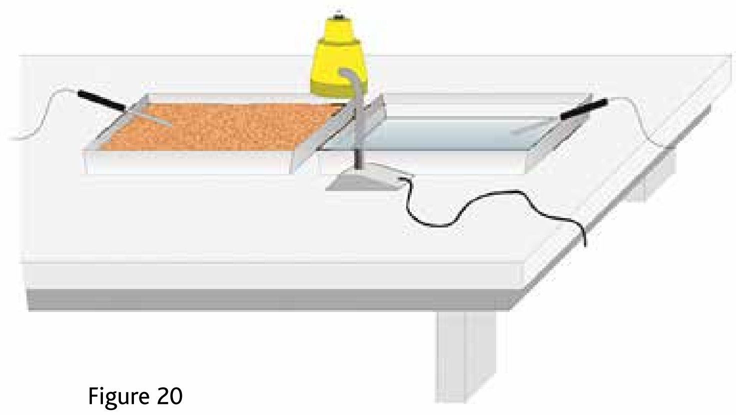


Figure 20

B4 ACTIVITY 4 (I): CONVECTION IN WATER

Background

Like air, liquid becomes less dense when warmed, and will rise. These two activities illustrate this in a colourful way. It is advisable to practise the first one beforehand. The alternative activity is just as spectacular.

Equipment required (per group):

- Two identical clear drinks bottles (plastic or glass)
- Hot and cold water from the tap
- A piece of card (4 cm × 4 cm)
- Two different food colourings
- An absorbent towel (to catch spills)

What to do:

1. Fill one bottle with cold water and one with hot water (tap hot water at approx. 60°C is suitable).
2. Add a different food colouring to each of the bottles as shown in Figure 21.
3. Place the piece of card on top of the bottle of cold water and hold it firmly in position.
4. Holding it over the towel, carefully turn the bottle of cold water upside down and put it on top of the bottle of hot water, leaving the card in place between both bottles.

   ? ***What do you predict will happen when the card separating the two bottles is removed?***
5. Making sure the necks of the bottles are lined up, carefully remove the piece of card.

   Describe what you observe.

   ? ***Were you correct in your prediction?***

   ? ***Can you explain why this happened?***
6. Empty the bottles and repeat steps 1 and 2, but this time place the piece of card on top of the bottle of **hot water** and hold it firmly in place.
7. Turn the bottle upside down and put it on top of the bottle with cold water.

   ? ***What do you think will happen when the card is removed?***
8. Again making sure that both bottles are lined up, remove the card.

   ? ***Can you explain why this happened?***

   ? ***Were you correct in your prediction?***

   ? ***Is the explanation different to the one offered when you placed the bottle with the cold water on top?***

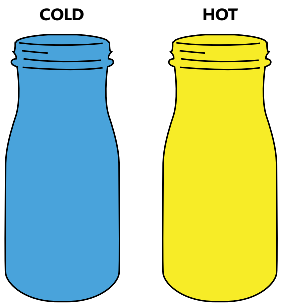


Figure 21

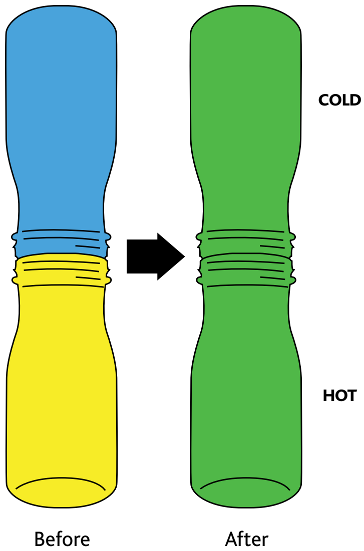


Figure 22

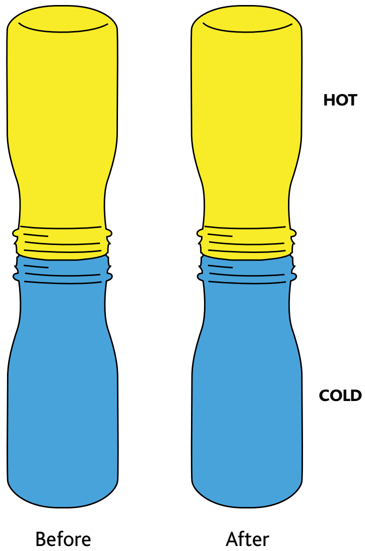


Figure 23

Resources:

- This activity is available on page 71 of Science on Stage 1 & 2. Visit their resources page for the full experiment.

B4 ACTIVITY 4 (II): CONVECTION IN WATER [ALTERNATIVE ACTIVITY]

Equipment required:

- Paper cup or similar
- Kitchen aluminium foil or clingfilm
- Tall jar, vase, or large soft drinks bottle (at least 1.5 litre) with the top cut off
- Hot and cold water from the tap
- Food colouring

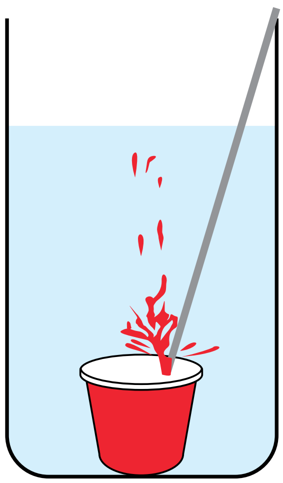


Figure 24

What to do:

1. Fill a cup with coloured hot water.
2. Cover the cup with aluminium foil or clingfilm.
3. Set the cup into a large clear jar or vase.
4. Pour cold water into the jar until the water goes over the top of the cup and nearly to the top of the jar.

   ? ***What might happen if you poke a hole in the foil/clingfilm?***

5. Use a stick to poke a hole in the foil/clingfilm.

   ? ***Was your predication in line with what happened?***

   ? ***What might be the explanation?***

B4 ACTIVITY 5: TRANSFERRING HEAT

Background

In this investigation the students examine the role played by convection currents in transferring heat. The movement of warm water can be observed using either thermofilm or food colouring. Plastic tubing represents the piping system and warm water is passed through it. If students have not used thermofilm before, **B1 ACTIVITY 3 (II): CALIBRATING THERMOFILM** should be carried out before this activity.

Equipment required (per group):

- Two boiling tubes
- Two-holed bungs to fit the tubes
- A boiling tube rack
- Plastic tubing and glass tubing to fit into bungs
- A strip of thermofilm (10 cm x 5 cm) or food colouring
- 100/250 cm^3 beaker
- Boiling water
- Thermometer or temperature sensor

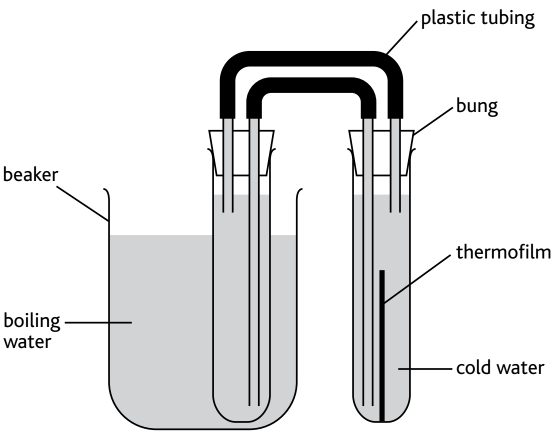


Figure 25: Using thermofilm

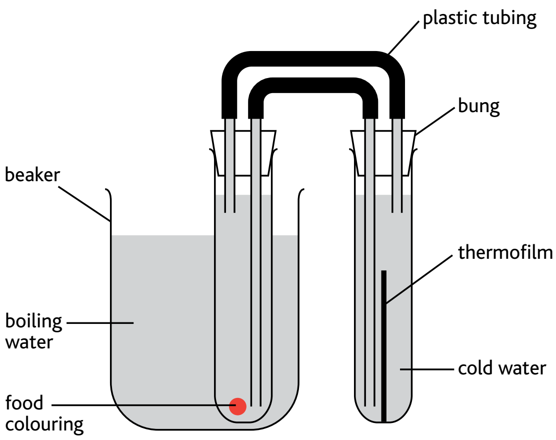


Figure 26: Using food colouring

What to do:

1. Set up the apparatus as shown in Figure 25 and connect the tubing as shown.
2. Place the thermofilm in one of the tubes, as shown in Figure 25 or add a few drops of food colouring as shown in Figure 26.
3. Fill both tubes with cold water and bung them, ensuring that there are no air bubbles in the system.
4. Support the boiling tube with the thermofilm using the rack and put the other one into the beaker. If using food colouring, put the boiling tube with food colouring in the beaker.
5. Fill the beaker with boiling water.
6. Use the thermometer or sensor to monitor the temperature of the plastic tubing while at the same time **observing** what happens to the film or the food colouring.

   ? ***Why was the boiling tube with food colouring put into the beaker rather than placing it in the support rack?***

   ? ***What was the point of monitoring the temperature of the plastic tubing?***

Resources:

- Click here to view the activity Harnessing Energy, available from The National Stem Centre, UK.

B4 ACTIVITY 6: SIMULATING OCEAN CURRENTS

Background

This activity provides a visual image of ocean currents that occur because different areas of water in the oceans are different temperatures. Food colourings are used to create a drift path, so that students can observe the convection currents that are set up.

Equipment required:

- Shallow glass trough or clear lunch box
- Two different food colourings
- Supports for the trough
- Hot and cold tap water
- Beaker to fit snugly under trough (as in Figure 27)

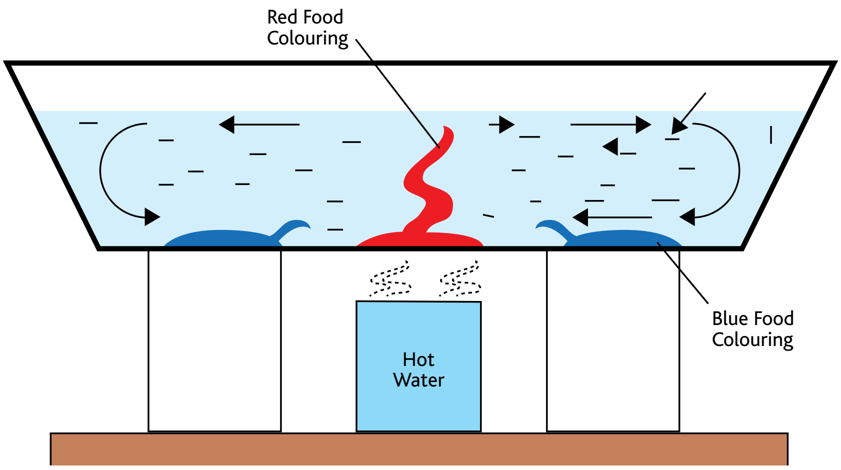


Figure 27

What to do:

1. Place the trough on supports.
2. Pour cold water into the trough until it is three-quarters full and allow the water to settle.

   ? ***Why is this settling important?***
3. Using a straw or long dropper, carefully place two drops of one of the food colourings at the bottom of the trough in the middle. This is shown as red food colouring in Figure 27.
4. Using a different straw carefully place two drops of the other food colouring at each of the two extreme ends of the container. This is shown as dark blue food colouring in Figure 27.

   ? ***What do you expect to happen when hot water is placed underneath the trough as in Figure 29?***
5. Place a beaker of hot water under trough just below the location of the first food colouring as shown in Figure 29.

   ? ***Are you surprised by what you observe?***

   ? ***Can you explain why this happened?***

B5: HEAT ENERGY BY RADIATION

Overview

Radiation is energy that originates in space. Our star, the **Sun**, is the **source** of this radiation energy on Earth. This energy is in the form of waves called **electromagnetic waves** such as **visible light**, **ultraviolet**, **X-rays**, **radio waves**, **gamma radiation**, **infrared radiation**, or **microwaves**. These activities concentrate on one form of radiant energy, namely infrared radiation in the form of **heat energy**. In **B5 ACTIVITY 1 (I): WHAT COLOUR SURFACES ABSORB HEAT?** students compare two different colours to see which absorbs the most heat. In **B5 ACTIVITY 2: WHAT TYPES OF SURFACES ABSORB HEAT?** two different surfaces are tested to see which absorbs the most heat. The heat source is an infrared (IR) bulb. Using the more sensitive digital thermometers or temperature sensors instead of the conventional liquid-in-glass thermometers allows for precise temperature readings.

In **B5 ACTIVITY 3: SOLAR HOUSE HEATING** students investigate the role played by glass in heat increase, and see how black card can transform visible light to heat (infrared radiation).

Suggested approaches:

- Start with a short brainstorm to ascertain what the students know about radiation as a form of heat transference.
  - ? ***How do we receive heat energy from the Sun?***
  - ? ***Does the nature or colour of the radiation surface play a part?***
- As the students carry out the two activities **B5 ACTIVITY 1 (I): WHAT COLOUR SURFACES ABSORB HEAT?** and **B5 ACTIVITY 2: WHAT TYPES OF SURFACES ABSORB HEAT?**, they could draw flow charts or posters to indicate the pathways involved. Using some cans with smooth exteriors alongside those with ridges, whilst keeping the same colour ranges, would demonstrate an interesting contrast.
- Another possible investigation would be to see if using different materials as covers (instead of paper) for the cans affected the outcome.
- As a follow-up exercise, students could research the role played by both surface texture and colour in buildings.

B5 ACTIVITY 1 (I): WHAT COLOUR SURFACES ABSORB HEAT?

Background

After this investigation the students will have a better understanding of the effect that colour has on heat absorption.

Equipment required (per group):

- Two used food cans of similar size and similar external surfaces
- Different coloured paper to cover the outside of the cans
- Digital thermometer
- Stopwatch
- A source of heat (i.e. an infrared (IR) bulb, heater or lamp)

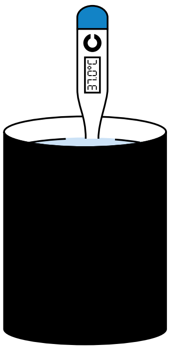


Figure 28

Figure 29: heater or IR lamp

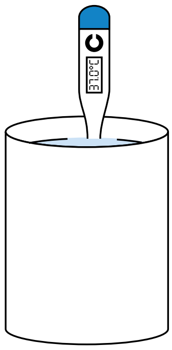


Figure 30

What to do:

1. Fill both containers with water of the same temperature.
2. Place both cans at equal distances from the heater or IR bulb (but not too close).
3. Record the temperature of both cans at two-minute intervals until they arrive at the same final temperature.
4. Graph the results and compare them with the results of other pairs who used different contrasting colours.

B5 ACTIVITY 1 (II): HOT BOXES (ALTERNATIVE ACTIVITY)

Equipment required (per group):

- Four ice cubes
- Four sheets of coloured paper (if possible use the same colours as in the previous activity)
- A few sheets of newspaper
- Heater (or warm sunlight)
- Pair of scissors
- Sellotape or glue
- Timer

What to do:

1. Using the template shown in Figure 31, make four boxes of different colours. Each one must be big enough to hold one ice cube. Fold and cut as indicated. Glue corners A and C to side 1. Glue corners B and D to side 2.
2. Place the sheet of newspaper near a heater or in a sunny spot and lay the boxes side by side with the opening facing away from the heat source.
3. Place an ice cube in each box and start the timer.

   ? ***Predict which ice cube will melt first.***

   Record the time each ice cube takes to completely melt.

   ? ***Compare these results with your predictions – were they similar or quite different?***
4. Construct a suitable graph which compares the melt times of the different colours.

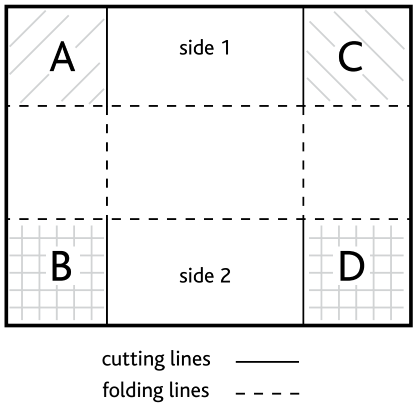


Figure 31

B5.1 Discussion points: Hot Colours

1. Should we wear white or black clothes on a hot day?
2. Should the exterior of a house be brightly painted?
3. What colour should a flat roof be painted?
4. Space shuttles are exposed to intense heat radiation on return to Earth. To protect them from these high temperatures, the surface is covered with tiles. The colour of these tiles is critical. Do you think the tiles are black or white? Give a reason for your answer.
5. What about solar panels? What colour are they?
6. White is the predominant building colour in some Mediterranean countries. Why do you think this is?

B5 ACTIVITY 2: WHAT TYPES OF SURFACES ABSORB HEAT?

Background

This activity challenges students to think about how the texture of a surface affects heat absorption – will a smooth surface absorb better than a rough one?

Equipment required (per group):

- Two used food cans with smooth exteriors
- Two used food cans with ridged exteriors
- Heater or an IR lamp
- Stopwatch
- Tea light
- Matches or lighter
- Tweezers or similar
- Thumbtacks

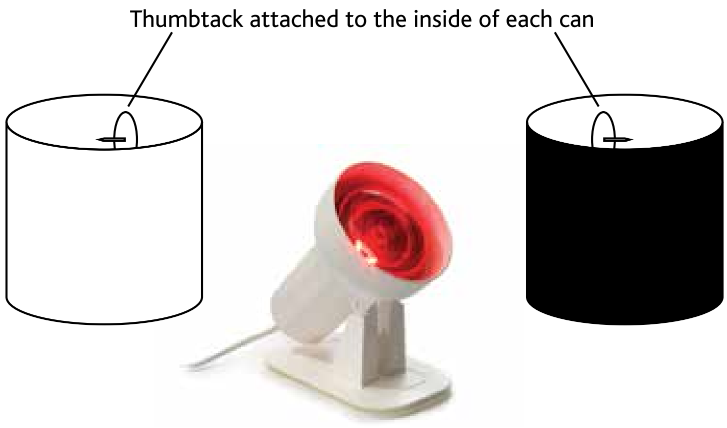


Figure 32

What to do:

1. Light the tea light.
2. When enough wax has melted, use the tweezers to dip the head of a thumbtack into the melted wax and then fix the thumbtack onto the inside of the can as shown in Figure 32. Repeat for the second can.
3. Place both cans at an equal distance from the lamp.
4. Switch the lamp on and, at the same time, start the stopwatch.
5. Time how long it takes for each tack to drop down. Note when you see the tack fall off, rather than when you hear the sound of it hitting the bottom of the can.
6. Repeat the above steps using different combinations of both surface types and colours.
7. Draw suitable graphs for the results and comment on them.

Discussion point:

- A useful follow-up research project is an investigation of the role played by both surface texture and colour on the exteriors of buildings across the world.

B5 ACTIVITY 3: SOLAR HOUSE HEATING

Background

This activity provides students with some experimental evidence of the **greenhouse effect**, as well as introducing them to **convection currents** as a means of heating houses using the Sun's heat. Again, use is made of the **thermofilm** and the **calibration chart** from **B1 ACTIVITY 3 (II): CALIBRATING THERMOFILM**.

Dark coloured materials absorb **infrared radiation** and **emit** the radiation readily. However, **glass is opaque to infrared radiation**.

During the investigation thermofilm, fixed onto black card which is inside a boiling tube, registers a rise in temperature. As it is the infrared radiation that, emitting heat energy, causes a change in temperature, students may ask why the temperature rises in the boiling tube.

The light energy from the lamp will pass through the glass tube. The black card will transform this visible light into infrared (heat). This in turn raises the temperature of the card as seen by the colour change of the thermofilm.

Students will now need to **explain** the rise in temperature. Because glass is opaque to infrared radiation, the air inside the tube is heated, so it rises to the top. This is why adding layers of glass to the outside of a building can result in heat gain inside.

Suggested approaches:

- Start with a short brainstorming session to learn what the students know about the greenhouse effect. Some key terms can be suggested.
  - ? ***Is global warming a problem or not?***
  - ? ***What if the Earth's surface was minus 20°C, the same temperature as the moon?***
  - ? ***There is a current focus on climate change and sustainability – why is there a focus on these issues now and what has using energy from the Sun got to do with it?***
- Let the students' ideas stand, and come back to them after the activity.

Equipment required (per group):

- Boiling tube
- Bung to fit boiling tube
- Test tube rack
- Two strips of thermofilm (10 cm x 5 cm) each on black card
- Lamp (an incandescent lamp is best)
- An energy efficient bulb
- Calibration chart for the thermofilm from **B1 ACTIVITY 3 (II): CALIBRATING THERMOFILM**

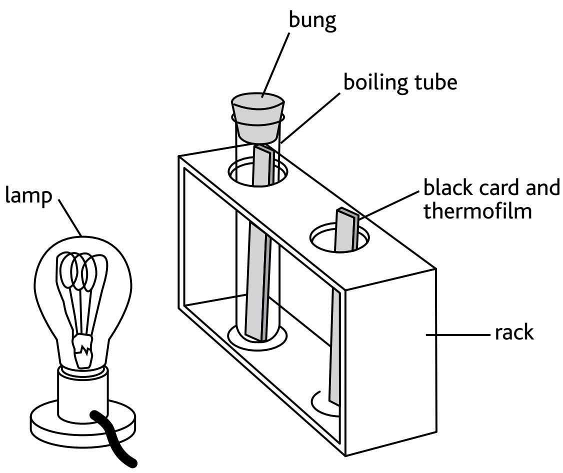


Figure 33

What to do:

1. Put one of the black strips with thermofilm into the boiling tube. Bung it and place it in the rack as shown in Figure 33, making sure that the thermofilm is facing the lamp.
2. Place the second strip in the rack near the boiling tube as shown in Figure 33 making sure this thermofilm is also facing the lamp.
3. Place the lamp about 40 cm from each strip.
4. Switch on the lamp.

   Observe and **record** any colour changes on the strips.
5. Using the calibration chart, relate the colour changes to the appropriate temperature.

   ? ***If there are changes, are they surprising ones?***

   ? ***Why?***

   ? ***Do you think we would obtain the same result if we used an energy efficient bulb?***
6. Repeat the experiment using an energy efficient bulb and compare your predictions with the outcome.

Resource:

- Click here to view this activity online from the National Stem Centre, UK.