# 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.

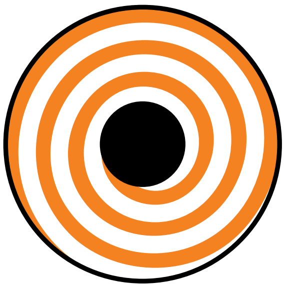

Figure 17

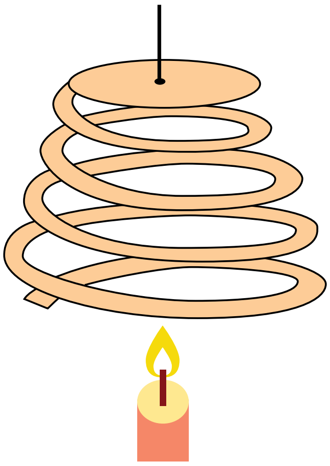

Figure 18

# 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

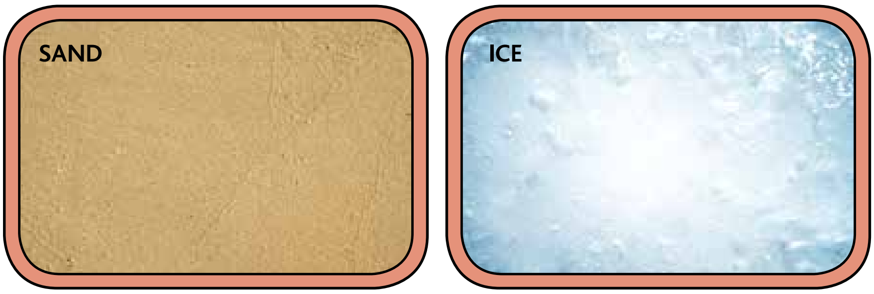


Figure 19: The sand represents land. The ice represents the sea

## 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.

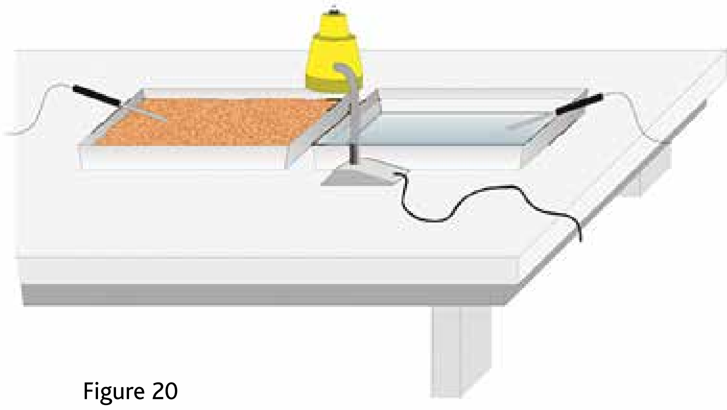

Figure 20

# 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?***

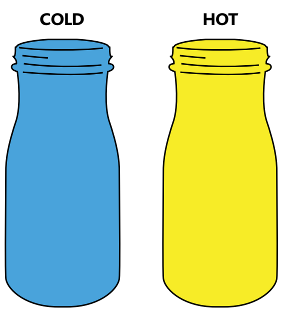


Figure 21

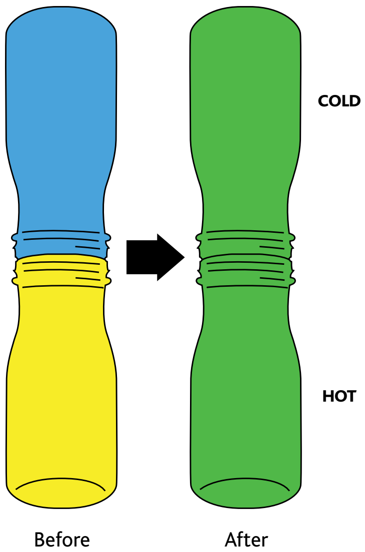


Figure 22

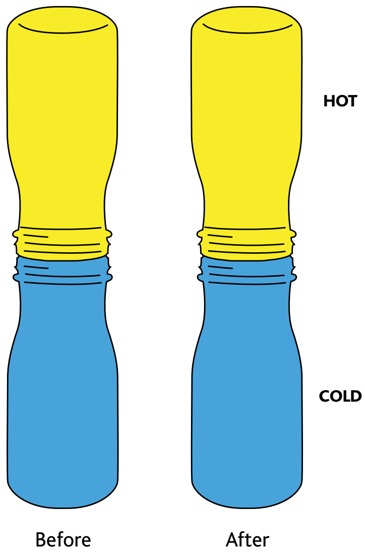


Figure 23

## 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

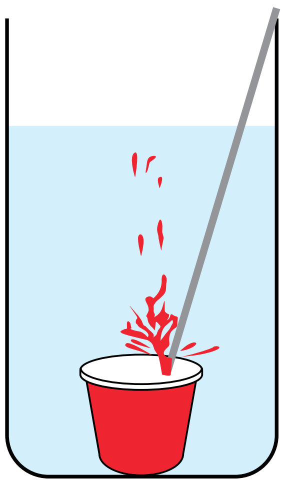

Figure 24

## 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

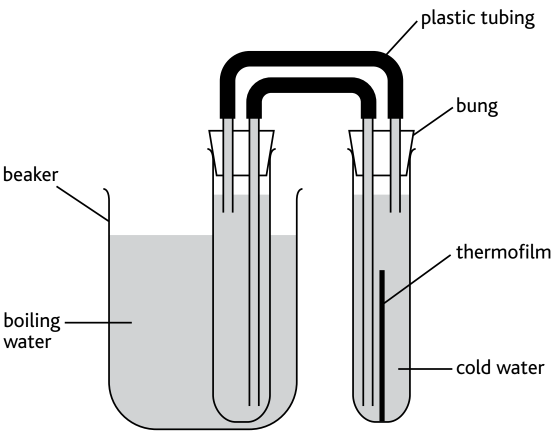


Figure 25: Using thermofilm

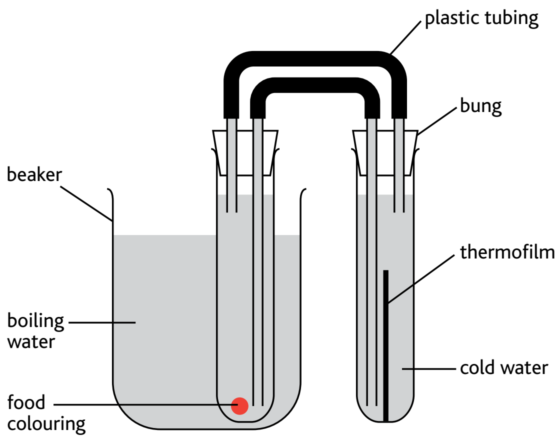


Figure 26: Using food colouring

## 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)

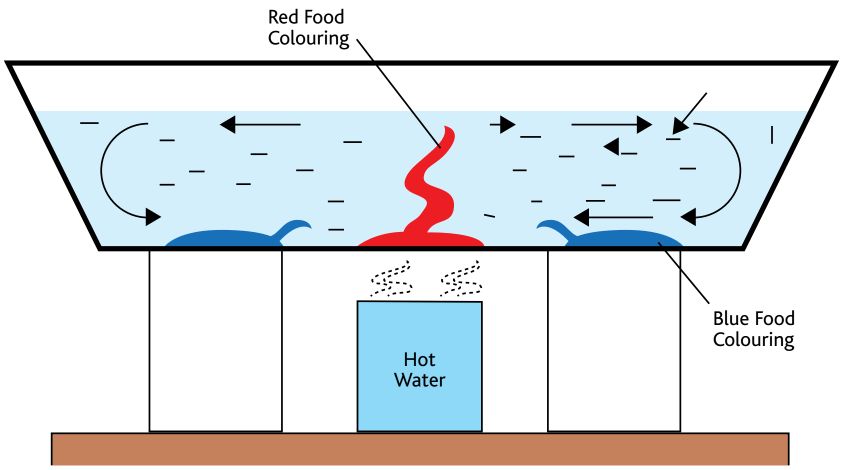


Figure 27

## 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?***