# UNIT 3: Heat Transfer

This unit is comprised of 8 activities that have been informed by the ENERGE Energy Literacy Framework. An overview of these activities is provided in table 3.1 A guide to the ENERGE Energy Literacy Framework can be found in UNIT 0. In activities 3.1, 3.5, 3.6, 3.7 and 3.8 students explore through scientific inquiry, the same principles of science and engineering that are taken into account in the construction of a real home or building. These include, heat transfer by conduction, convection, radiation, passive solar lighting and the greenhouse effect. In activity Activity 3.2, 3.3 and 3.4 students have the opportunity to build, test and evaluate insulation materials and use experimental evidence to decide on everyday problems concerning insulation, glazing, thermal storage, and passive heating and cooling in buildings. In particular, the energy literacy outcomes, the associated skills & competencies addressed and how the activities link to the national curricula are outlined in tables 3.2-3.4.

## Overview of UNIT 3 Heat Transfer

Table 3.1 Activities and titles are given, the time required to complete the activity and the ISCED classification.

| | **Activity Title** | **Estimated time (min)** | **Level** | |
|---|---|---|---|---|
| | | | **ISCED 2** | **ISCED 3** |
| Activity 3.1 | Heat Transfer in solids, liquid and gases | 45-60 | X | X |
| Activity 3.2 | Observing ice liquefying in plates of different materials | 30-45 | X | X |
| Activity 3.3 | Build and test insulation materials | 20-30 | X | X |
| Activity 3.4 | Build a model green roof | 20-30 | X | X |
| Activity 3.5 | Heat transfer by convection in liquids and gases | 30-60 | X | X |
| Activity 3.6 | Investigating Heat transfer by radiation | 30-45 | X | X |
| Activity 3.7 | The Greenhouse Effect | 30-45 | X | X |
| Activity 3.8 | Investigate passive solar lighting solutions for buildings | 60-90 | X | X |

## Activities Mapped to Subjects in National Curricula

| | Science | Technology Informatics | Engineering | Mathematics | Home Economics | Geography | English | Design architecture | Civics & politics | Society & Health | Business Economics |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Activity 3.1 | X | | | | | | | | | | |
| Activity 3.2 | X | X | X | | | | | | | | |
| Activity 3.3 | X | X | X | | | | | | | | |
| Activity 3.4 | X | X | X | | X | X | | X | | | |
| Activity 3.5 | X | X | X | | | X | | | | | |
| Activity 3.6 | X | X | X | | | | | X | | | |
| Activity 3.7 | X | X | X | | X | | | X | | | |
| Activity 3.8 | X | X | X | | X | | | X | X | X | X |

Table 3.2 Activities are mapped to subjects in National Curricula

## Activities Mapped to Energy Literacy Characteristics

Table 3.3 Activities are mapped to Energy literacy Characteristics.

| | C1 | C2 | C3 | C4 | C5 |
|---|---|---|---|---|---|
| Activity 3.1 | X | | | | |
| Activity 3.2 | X | | X | | |
| Activity 3.3 | X | | X | | |
| Activity 3.4 | X | | X | X | |
| Activity 3.5 | X | X | X | | |
| Activity 3.6 | X | | | | |
| Activity 3.7 | X | | X | X | |
| Activity 3.8 | X | X | X | X | |

## Skill & Competencies Addressed

Table 3.4 Activities are mapped according to Skills & Competencies addressed.

| | Decision Making | Problem Solving | Designing innovating | Data Analysing | Collaborating | Communicating | Research | Critical Thinking | Numeracy |
|---|---|---|---|---|---|---|---|---|---|
| Activity 3.1 | | | | X | X | | X | X | |
| Activity 3.2 | | | | X | X | | X | X | |
| Activity 3.3 | X | | X | | | | X | X | |
| Activity 3.4 | | | | X | X | | X | X | |
| Activity 3.5 | | | | X | X | | X | X | |
| Activity 3.6 | | | | | | | | | |
| Activity 3.7 | X | X | X | X | X | | X | X | X |
| Activity 3.8 | | X | | X | X | | X | X | X |

# Activity 3.1 Heat transfer by conduction in solids, liquids and gases

This activity comprises of a series of consecutive mini science practicals that look at heat transfer by convection in liquids and gases. These activities on conduction challenge students to use their knowledge of energy and energy transfer to predict, observe and then explain what happen. By allowing students to see with their own eyes the influence of different materials on the transfer of thermal energy by convection between bodies at different temperatures, the activity gives them a chance to develop a deeper understanding of the nature of insulation and the role of insulators as building materials that mitigate the loss of heat from homes and buildings. This activity has been developed by Cookstown High School in Co. Tyrone, Northern Ireland.

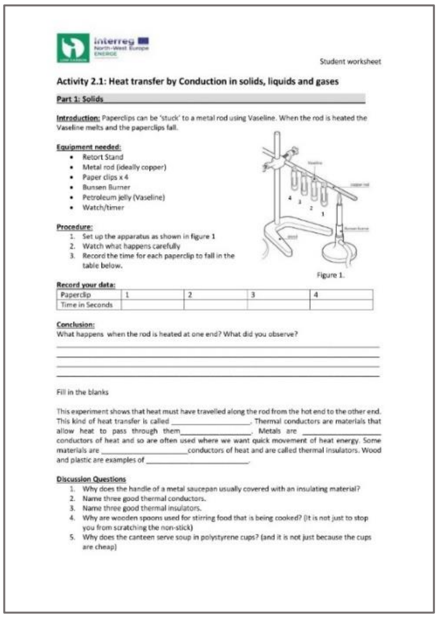
| **Duration** | | | |
|---|---|---|---|
| • 45-60 minutes | | | |
| **Energy Literacy Characteristics addressed:** | | | |
| **C1** | Has a grounded understanding of the science and how energy is harnessed and used to power human activity. | | |
| **Skills & Competencies addressed:** | | | |
| • Problem Solving | | • Research | |
| • Communicating | | • Data Analysis | |
| **Subject links in National Curricula:** | | | |
| • Science | | | |
| **Level:** | | | |
| • ISCED 2 | | | |
| • ISCED 3 | | | |

## Suggestions for use:

1. 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 in the science curriculum. Encourage students to check out the equipment while you explain briefly what you are going to do.

2. Before carrying out the demonstrations, ask students to predict what they think will happen.

3. Follow-up discussion can include the role of insulators as building materials to mitigate heat loss from buildings.



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Student worksheet

**Activity 2.1: Heat transfer by Conduction in solids, liquids and gases**

**Part 1: Solids**

**Introduction:** Paperclips can be 'stuck' to a metal rod using Vaseline. When the rod is heated the Vaseline melts and the paperclips fall.

**Equipment needed:**
- Retort Stand
- Metal rod (ideally copper)
- Paper clips x 4
- Bunsen Burner
- Petroleum jelly (Vaseline)
- Watch/timer

**Procedure:**
1. Set up the apparatus as shown in figure 1
2. Watch what happens carefully
3. Record the time for each paperclip to fall in the table below.

Figure 1.

**Record your data:**

| Paperclip | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Time in Seconds | | | | |

**Conclusion:**
What happens when the rod is heated at one end? What did you observe?

Fill in the blanks

This experiment shows that heat must have travelled along the rod from the hot end to the other end. This kind of heat transfer is called ________. Thermal conductors are materials that allow heat to pass through them________. Metals are ________ conductors of heat and so are often used where we want quick movement of heat energy. Some materials are ________conductors of heat and are called thermal insulators. Wood and plastic are examples of ________.

**Discussion Questions**
1. Why does the handle of a metal saucepan usually covered with an insulating material?
2. Name three good thermal conductors.
3. Name three good thermal insulators.
4. Why are wooden spoons used for stirring food that is being cooked? (It is not just to stop you from scratching the non-stick)
5. Why does the canteen serve soup in polystyrene cups? (and it is not just because the cups are cheap)

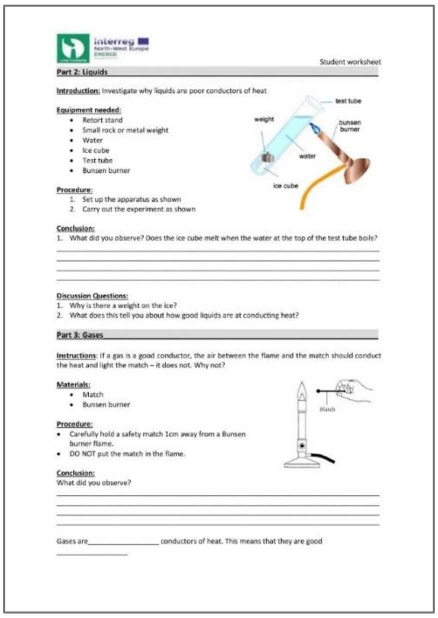
Fig. 1. Activity 3.1 Student Worksheet

Fig. 2. Activity 3.1 Student Worksheet

## Materials:

- [Activity 3.1 Student Worksheet]

| | |
|---|---|
| - Bunsen burner | - Tongs |
| - Metal rod (copper) | - Paper Clips |
| - Retort stand + clips | - Petroleum Jelly |
| - Test tube | - 200 ml water |
| - Stone or metal weight | - Ice cubes |



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Student worksheet

**Part 2: Liquids**

**Introduction:** Investigate why liquids are poor conductors of heat

**Equipment needed:**
- Retort stand
- Small rock or metal weight
- Water
- Ice cube
- Test tube
- Bunsen burner



**Procedure:**
1. Set up the apparatus as shown
2. Carry out the experiment as shown

**Conclusion:**
1. What did you observe? Does the ice cube melt when the water at the top of the test tube boils?

**Discussion Questions:**
1. Why is there a weight on the ice?
2. What does this tell you about how good liquids are at conducting heat?

**Part 3: Gases**

**Instructions**: If a gas is a good conductor, the air between the flame and the match should conduct the heat and light the match – it does not. Why not?

**Materials:**
- Match
- Bunsen burner



**Procedure:**
- Carefully hold a safety match 1cm away from a Bunsen burner flame.
- DO NOT put the match in the flame.

**Conclusion:**
What did you observe?

Gases are________ conductors of heat. This means that they are good ________

## Activity 3.2 Observing ice liquefying in plates of different materials

In this activity, students undertake a science practical which allows them to visualise heat transfer by conduction. Moreover, by touching different materials in equilibrium with the environment it seems that they are at different temperatures since they supply different sensations of hot or cool. All these facts show different behaviours of materials in presence of a temperature gradient. This can be the starting point of the inquiry analyzing this kinds of behaviours. As a first step, the melting time of equal ice cubes, at the same temperature and placed in different plates, will be analysed. This activity was adapted from the ESTABLISH project. The ESTABLISH Teaching and Learning Units conform to the ESTABLISH definition of Inquiry Based Science Education (IBSE) and link to real world and industrial applications.

| **Duration** | | | |
|---|---|---|---|
| • 60-90 minutes | | | |
| **Energy Literacy Characteristics addressed:** | | | |
| **C1** | Has a grounded understanding of the science and how energy is harnessed and used to power human activity. | | |
| **C3:** | Students are sensitive to the need for energy conservation and the need to develop alternatives to fossil fuel-based energy resources. | | |
| **Skills & Competencies addressed:** | | | |
| • Data Analysing<br>• Collaborating | | • Critical Thinking<br>Research | |
| **Subject links in National Curricula:** | | | |
| • Science<br>• Design & Architecture<br>• Home Economics | | • Civics & Politics<br>• English<br>• Social & Health | |
| **Level** | | | |
| • ISCED 2<br>• ISCED 3 | | | |

## Suggestions for use:

1. The teacher can show the apparatus (see fig.1a) and stimulate students to make predictions about the melting times

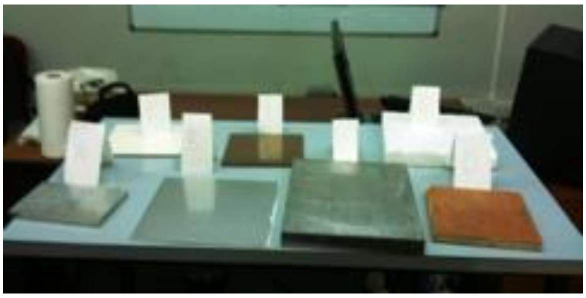


Fig. 3. Activity 3.2 Student Worksheet

NOTE: It could be useful, at this stage, to discuss about the feeling of warmness and coldness coming from touching different bodies, and also ask students about their bodies' temperature. At this stage, it is also interesting to discuss about the concept of thermal equilibrium.

1. After the observation, the whole class will discuss the results, by confronting them with their own predictions and making hypotheses about the influence of different parameters on melting times

2. Teachers will introduce the concept of thermal conduction by discussing with pupils how to analyse the different parameters influencing the results (see fig.1b)

Fig. 4. Activity 3.2 Student Worksheet

## Materials

- Activity 3.2 Student Worksheet

## Activity 3.3 Building and testing insulation materials

In this activity, students design hot water containers for use in a hypothetical newly built house using plastic bottles and are given a variety of materials with unknown insulation capabilities and are asked to conduct a scientific experiment that incorporates design based learning to determine which material provides optimum insulation for the hot water in the container. Students employ data analysis skills that involves measuring and recording change in temperature over time for each of the water containers. Student's then graph this data and determine which material provides the most superior insulation.

| **Duration** | | | |
|---|---|---|---|
| • 30-45 minutes | | | |
| **Energy Literacy Characteristics addressed:** | | | |
| **C1** | Has a grounded understanding of the science and how energy is harnessed and used to power human activity. | | |
| **C3:** | Students are sensitive to the need for energy conservation and the need to develop alternatives to fossil fuel-based energy resources. | | |
| **Skills & Competencies addressed:** | | | |
| • Critical Thinking | | • Designing | |
| • Problem Solving | | • collaborating | |
| • Research | | | |
| **Subject links in National Curricula:** | | | |
| • Design & Architecture | | • Science | |
| • Home Economics | | • Engineering | |
| • Technology | | • Civics & Politics | |
| **Level** | | | |
| • ISCED 2 | | | |
| • ISCED 3 | | | |

## Suggestions for use:

1. Divide the class into teams of two to four students each. Hand out a worksheet to each team.

2. On the board, write the problem question that will be addressed today. (Example: Which type of insulation would keep my house warmest in the winter?)

3. Show the students the four insulation materials to be tested. Ask them to hypothesize which they think is the best insulating material. Have them circle their predictions on their worksheets.

4. Wrap the four plastic bottles with equivalent amounts of each material—newspaper, wool sock, aluminum foil and plastic bag—to serve as insulators. (You may want to discuss and determine as a group what this means for your experiment, for example, same material area, weight, thickness; covers same amount of bottle surface; tight or loose plastic on the bottle, etc.)

5. Pour equal amounts of hot tap water into each bottle. Immediately after the hot water is poured in the bottle, measure its temperature. Record these beginning temperatures on the worksheets. Set aside the water-filled bottles in areas with the same ambient conditions (such as all in shade on the same surface material).

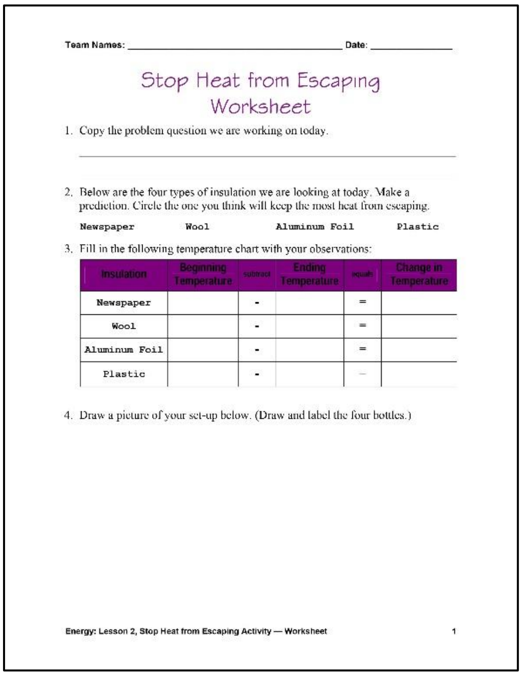
6. For 15 minutes, have students sketch their setups on their worksheets. After 15 minutes, again measure and record the (ending) temperature of the water in each bottle. To calculate the change in temperature for each bottle, subtract the ending temperature from the beginning temperature.

7. Ask the students to determine which material was the best insulator based on their data. Which had the smallest change of temperature? What material(s) do you recommend? How do your findings compare to your predictions?

8. As a class, agree on a concluding statement for the experiment based on everyone's research findings. Have the students suggest ideas for potential future insulation tests they may want to conduct

## Materials

- [Activity 3.3 Student Worksheet]()



Team Names: ______________________________ Date: ____________

Stop Heat from Escaping Worksheet

1. Copy the problem question we are working on today.

2. Below are the four types of insulation we are looking at today. Make a prediction. Circle the one you think will keep the most heat from escaping.

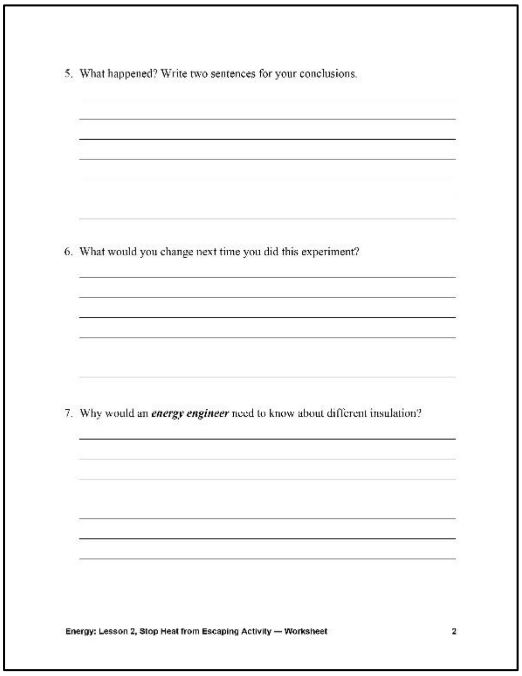
Newspaper     Wool     Aluminum Foil     Plastic

3. Fill in the following temperature chart with your observations:

| Insulation | Beginning Temperature | subtract | Ending Temperature | equals | Change in Temperature |
|---|---|---|---|---|---|
| Newspaper | | - | | = | |
| Wool | | - | | = | |
| Aluminum Foil | | - | | = | |
| Plastic | | - | | = | |

4. Draw a picture of your set-up below. (Draw and label the four bottles.)

Energy: Lesson 2, Stop Heat from Escaping Activity — Worksheet 1



5. What happened? Write two sentences for your conclusions.

6. What would you change next time you did this experiment?

7. Why would an ***energy engineer*** need to know about different insulation?

Energy: Lesson 2, Stop Heat from Escaping Activity — Worksheet 2

Fig. 1. Activity 3.3 Student Worksheet



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## Extensions to Activity 4.2

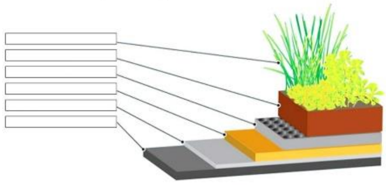
# Activity 3.4 Build a model green roof

Students are introduced to the landscape architecture profession and learn that green roofs are one type of project that landscape architects create. Students build a mini green roof in the lid of a shoebox. This activity aims to engage students in making design decisions that affect the transfer of energy between a building and the outside environment and to help students identify and consider the types of decisions involved in improving a building's energy profile and analyse the benefits and disadvantages of green roof option with regards to local climate, economy and society.

| **Duration** | |
|---|---|
| • 60-90 minutes | |
| **Energy Literacy Characteristics addressed:** | |
| **C1** | Has a grounded understanding of the science and how energy is harnessed and used to power human activity. |
| **C3** | Students are sensitive to the need for energy conservation and the need to develop alternatives to fossil fuel-based energy resources. |
| **C4** | Is cognisant of the impact of personal energy-related decisions and actions on the global community; |
| **Skills & Competencies addressed:** | |
| • Creating/Innovating<br>• Decision Making<br>• Critical Thinking | • Research |
| **Subject links in National Curricula:** | |
| • Science<br>• Design & Architecture | • Civics & Politics<br>• Geography |
| **Level** | |
| • ISCED 2<br>• ISCED 3 | |

## Suggestions for use:

1. Label the components of a green roof



2. Can you list 5 environmental benefits of having green roofs?
3. Do you think that there are also disadvantages to green roofs?
4. How can green roofs improve the energy efficiency of homes and buildings when the weather is cold and conversely when the weather is hot?

**2. Design & build your own green roof**

A green roof replaces traditional roofing with a lightweight, living system of soil, compost, and plants. It creates a thin, green skin atop a building that gives a little something back to the world. The plants—and the dirt and gravel that hold them—filter rainwater and some of its pollutants and they produce oxygen that helps clean the air. A green roof reduces a building's heating and cooling costs, acting as a form of insulation. They also lessen the heat island effect, which happens when buildings warm up so much that they heat the area surrounding them.

Materials

- Paper to cover tables
- Glue sticks or liquid glue
- Craft materials (foam shapes, buttons, pipe cleaners, construction paper, tissue paper, etc.)
- Markers
- Masking tape
- Forks (10 or so)
- Paper cups (10 or so) filled with ¼" of grass seed
- Extra grass seed (to refill cups as needed)
- Scissors
- Shoe boxes (one per student)
- Aluminium foil sheets (sized to line each shoe box lid)
- Potting soil with fertilizer (enough to fill each shoe box lid)
- Plastic bags (to transport potting soil and grass seed if green roof will be assembled at home)
- Hand washing supplies: water, soap, towels
- Trowels for scooping potting soil

Fig. 8. Activity 3.4 Student Worksheet

Equipment

| | |
|---|---|
| • Sink, water, soap, towels<br>• Broom and dustpan | • Cloths (to wipe tables)<br>• Tables and chairs (number depends on your audience) |

Procedure

| | |
|---|---|
| 1. Choose a box and lid from the supply table.<br>2. Move to a worktable and securely tape the upside-down lid to the bottom of the box.<br>3. Line the inside of the box lid with aluminium foil. Glue the foil in place to create a tight fit.<br>4. Decorate the outside of the box and lid to create a building: house; apartment building; grocery store; fire/police station; community center; church; etc. | 5. Bring the decorated box to the supply table for potting soil. Spread the soil evenly on top of the aluminium foil. For easier transporting, potting soil and grass seed can also be placed in plastic bags so participants can finish them at home.<br>6. Sprinkle grass seed from one cup onto roof soil. Use a fork as a hoe to evenly distribute the seeds in the soil.<br>7. Wash your hands when you are finished with the project. The soil contains fertilizer. |

How to Care for Your Green Roof

1. Once you bring your green roof home, place it in a bright window so it can soak up plenty of sunlight.
2. Sprinkle 1/2–3/4 cup of water over your roof when you get home and then every few days or when the soil is dry. Remember, your roof is made of cardboard, so be careful not to add too much water.
3. Within two to three weeks your grass should germinate (sprout). You may want to trim your grass with scissors if it gets too long.
4. With good care, your green roof should continue to grow.
5. Enjoy!

**This activity has been adopted from the following resource "Build a Green Roof available at the American Society of Landscape Architects (www.asla.org)**

**Link to source:** https://www.asla.org/greenroofeducation/index.html

Fig. 9. Activity 3.4 Student Worksheet

## Materials

- Activity 3.4 Student Worksheet

# Activity 3.5 Heat transfer by convection in liquids and gases

Convection is an important physical process that relates to the differential heating, and therefore density differences, that give rise to movement of fluids like air and water. We can see convection happening in a pot on the kitchen stove, in the rise and fall of a hot air balloon, in the circulation of ocean currents, in the molten liquid part of the earth's core, and in the formation of thunderstorms. This activity is comprised of two laboratory practicals looking at the processes of heat transfer by convection as demonstrated in gases and then in liquids. Students sketch and observe the movement of heat by convection and give explanations as to what is happening. Students can apply heat transfer knowledge to real-world scenarios.

| **Duration** | |
|---|---|
| • 30-45 minutes | |
| **Energy Literacy Characteristics addressed:** | |
| **C1** | Has a grounded understanding of the science and how energy is harnessed and used to power human activity. |
| **C2** | Understands the impact that energy production and consumption have on all spheres of our environment and society |
| **C3** | Students are sensitive to the need for energy conservation and the need to develop alternatives to fossil fuel-based energy resources. |
| **Skills & Competencies addressed:** | |
| • Critical Thinking<br>• Inquiry | • Research |
| **Subject links in National Curricula:** | |
| • Science<br>• Technology | • Engineering<br>• Geography |
| **Level** | |
| • ISCED 2<br>• ISCED 3 | |

## Suggestions for Use:

1. These activities can be used either as an introduction to convection of heat energy or as a means of revision of material which may have already been covered.

2. By way of introduction, hold a short word-association session on the word 'convection'.

3. 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.

4. Teachers can choose to carry out one practical or both practicals depending on the time and resources available.

   - Practical 1 allows students to see normally invisible air convection currents in action by tracking the movement of smoke. In this practical students can apply their knowledge of heat transfer scenarios and can appreciate the importance of ventilation, insulation and draftproofing of buildings.

   - Practical 1 looks at convection in water and simulates ocean currents and illustrates this in a colourful way. Like air, liquid becomes less dense when warmed, and will rise.

5. Students should complete the student worksheet accompanying each practical activity and conclude their investigation with a statement of understanding.

6. Following the practical, students can answer the discussion questions included in the worksheet looking at real-world scenarios involving convection.

## Extensions to Activity 3.5

## Materials

- Activity 3.5 Student Worksheet
- Activity 3.5 Worksheet Solutions
- Activity 3.5 Student Factsheet

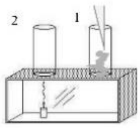
**Section 1: Convection in air**

**Practical 1: The chimney experiment**

**Instructions:** use a piece of smouldering paper to create smoke and we hold it above the chimney before and after lighting the candle.

**Materials:**

- Small box made from cardboard or wood
- Scissors and tape
- Piece of rolled up paper
- 1 sheet of hard clear plastic
- Small Candle




**Procedure:**

1. Cut a large window into one side of your box. Cover the window with half of your plastic sheet using tape.
2. Cut a small closable door into one side of the box
3. Cut two equal sized holes onto the side of the box that is above the window
4. Using your remaining plastic cut and tape two identical open ended cylinders
5. Set up the apparatus as shown in the diagram.
6. Light the candle and place it inside the box under tube 2. Let the candle burn for a minute or two.
7. Light the piece of paper on fire and quickly extinguish it to the point of smoulder. Insert the smouldering paper roll into tube 1.
8. Draw arrows on the diagram to show how the smoke moves.

Discussion Questions:

1. Convection happens when molecules of a gas or a liquid are __. This gives them __energy than cooler regions and so they can move faster. This hotter molecules move to a ___region, taking their heat energy with them.
2. Convection only happens in _ and __. This is because the atoms or molecules in a __ or ___ are _ to move from place to place, whereas the atoms or molecules in a solid are not.

Convection is the method of heat transfer that heats our homes from radiators. The radiator is made very hot so that it gives heat energy to the air around it. These air particles will then start to move and spread the heat around the room. Think back to the way the water moved when it was heated.

3. Add arrows to the room below to show how the hot air would circulate.


4. Can you think of three other things which are heated using convection?
5. Describe how the heating element in a kettle heats all the water.

Fig. 10. Activity 3.5 Student Worksheet.

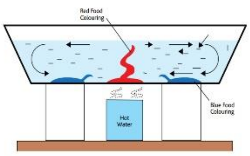
**Section 2: Convection in liquids**

Experiment 3: Modelling ocean currents

**Instructions:** Observe a beautiful demonstration of heat convection.

**Materials:**

- Shallow glass trough or clear lunch box
- Two different food colourings
- Supports for the trough
- Hot and cold tap water
- Beaker, glass or cup to fit snugly under trough




**Procedure:**

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.
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

What do you expect to happen when hot water is placed underneath the trough?

5. Place a beaker of hot water under trough just below the location of the first food colouring as shown

Discussion Questions:

1. What did you observe?
2. Can you explain why this happened?

**Discussion Questions:**

1. Describe what happened when the water was heated.
2. Can you explain why this happened?

Fig. 11. Activity 3.5 Student Worksheet

## Activity 3.6 Investigating Heat transfer by Radiation

This activity demonstrates radiation. Students carry out experiments with basic materials to demonstrate how some colours, reflect heat, while others absorb heat. For this you will just need two white coffee cups with one painted matt black on the outside, hot water, two insulating lids with holes for thermometers and stirrers, thermometers and a darkened room.

| **Duration** | |
|---|---|
| • 30-45 minutes | |
| **Energy Literacy Characteristics addressed:** | |
| **C1** | Has a grounded understanding of the science and how energy is harnessed and used to power human activity. |
| **Skills & Competencies addressed:** | |
| • Critical Thinking<br>• Inquiry | • Research |
| **Subject links in National Curricula:** | |
| • Science<br>• Technology | • Engineering<br>• Geography |
| **Level** | |
| • ISCED 2<br>• ISCED 3 | |

### Suggestions for Use:

1. Practical 1. Setting up the experiments:

a) Two metal cans per set are required for this practical, one needs to be painted in thick matt black paint on the outside. Acrylic paint is good for this as it is waterproof and quick drying.

b) An infrared thermometer may be used during this experiment to show how much heat is escaping from the outside of each can during cooling.

c) The other can needs the label taking off and cleaned so it has a shiny metal outside surface.

d) Both cans should be filled to the same level with hot water and a thermometer placed in each.

e) At set intervals, the water should be stirred with the thermometer and the temperatures taken. After several minutes it should be clear that the black can cools quicker.

f) The shiny can is a poor radiator and so should contain hotter water than the black can after several minutes.

g) The dull black surface is a good absorber of heat and so the water in the can should be warmer than in the shiny can over a few minutes. The shiny can is a poor absorber as it reflects much of the heat energy away.

2. Discuss the real-life applications that this practical demonstrates:

- Kettles mainly have shiny metallic surfaces, so they do not radiate (and therefore do not lose) too much heat through their surfaces.

- Cooling fins at the back of refrigerators are usually dull black in colour in order to radiate as much heat away as possible.

- Photographs of these may be required to show pupils the practical applications of the science behind this experiment.

### Extensions to Activity 3.5

1. The same two cans can also be used to measure how much thermal radiation they absorb. Pour the same amounts of cold water into each can and insert a thermometer. Put both cans either in direct sunlight or equally near a desk lamp or heater. Observe the temperature readings.

Practical 2. Setting up the experiments:

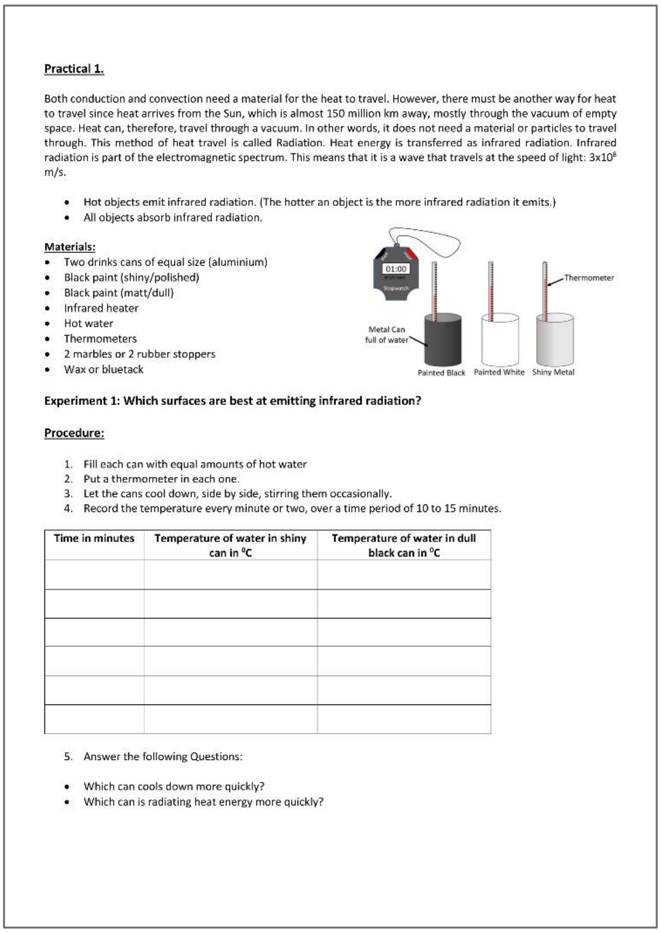
a) Remove the top and bottom of the drinks cans from practical 1. Open out the material to create two identical plates of metal.
b) Place the two metal plates equal distances from an infrared heater. One should be painted black and one left shiny.

c) On the back of each plate a marble is stuck using wax.

2. Students should complete the section of the student worksheet that covers Practical 2.

## Materials

- Activity 3.6 Student Worksheet
- Activity 3.6 Worksheet Solutions
- Activity 3.6 Student Factsheet



**Practical 1.**

Both conduction and convection need a material for the heat to travel. However, there must be another way for heat to travel since heat arrives from the Sun, which is almost 150 million km away, mostly through the vacuum of empty space. Heat can, therefore, travel through a vacuum. In other words, it does not need a material or particles to travel through. This method of heat travel is called Radiation. Heat energy is transferred as infrared radiation. Infrared radiation is part of the electromagnetic spectrum. This means that it is a wave that travels at the speed of light: $3x10^8$ m/s.

- Hot objects emit infrared radiation. (The hotter an object is the more infrared radiation it emits.)
- All objects absorb infrared radiation.

**Materials:**
- Two drinks cans of equal size (aluminium)
- Black paint (shiny/polished)
- Black paint (matt/dull)
- Infrared heater
- Hot water
- Thermometers
- 2 marbles or 2 rubber stoppers
- Wax or bluetack



**Experiment 1: Which surfaces are best at emitting infrared radiation?**

**Procedure:**

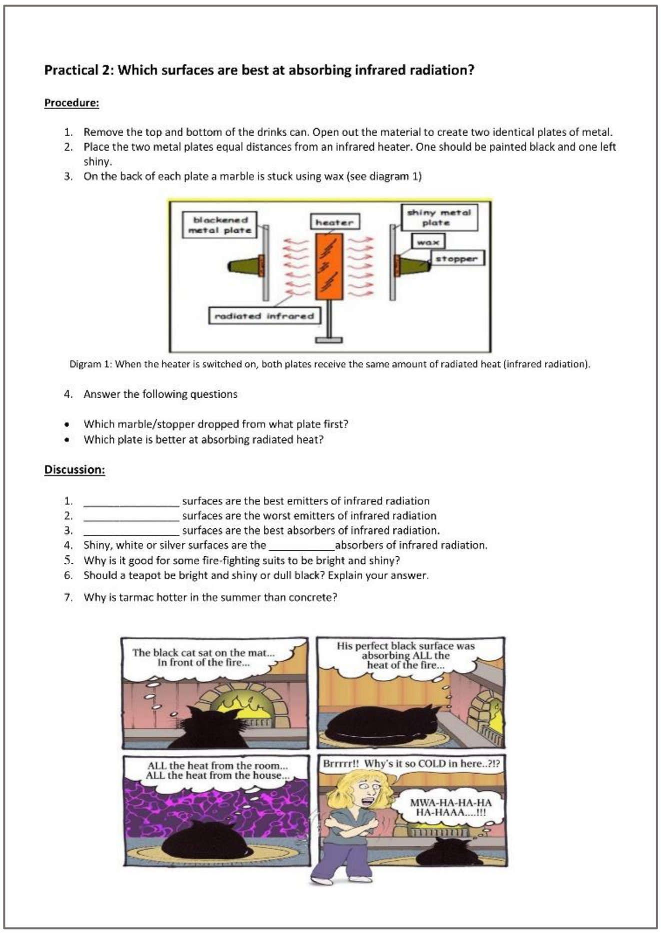
1. Fill each can with equal amounts of hot water
2. Put a thermometer in each one.
3. Let the cans cool down, side by side, stirring them occasionally.
4. Record the temperature every minute or two, over a time period of 10 to 15 minutes.

| Time in minutes | Temperature of water in shiny can in °C | Temperature of water in dull black can in °C |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

5. Answer the following Questions:

- Which can cools down more quickly?
- Which can is radiating heat energy more quickly?

Fig. 12. Activity 3.6 Student Worksheet



**Practical 2: Which surfaces are best at absorbing infrared radiation?**

**Procedure:**

1. Remove the top and bottom of the drinks can. Open out the material to create two identical plates of metal.
2. Place the two metal plates equal distances from an infrared heater. One should be painted black and one left shiny.
3. On the back of each plate a marble is stuck using wax (see diagram 1)



Digram 1: When the heater is switched on, both plates receive the same amount of radiated heat (infrared radiation).

4. Answer the following questions

- Which marble/stopper dropped from what plate first?
- Which plate is better at absorbing radiated heat?

**Discussion:**

1. _______________ surfaces are the best emitters of infrared radiation
2. _______________ surfaces are the worst emitters of infrared radiation
3. _______________ surfaces are the best absorbers of infrared radiation.
4. Shiny, white or silver surfaces are the ___________absorbers of infrared radiation.
5. Why is it good for some fire-fighting suits to be bright and shiny?
6. Should a teapot be bright and shiny or dull black? Explain your answer.
7. Why is tarmac hotter in the summer than concrete?



Fig. 13. Activity 3.6 Student Worksheet

## Activity 3.7 The Greenhouse Effect

The temperature increase of object exposed to solar light is a well-known phenomenon. 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 buildings using the Sun's heat. Dark coloured materials absorb infrared radiation and emit the radiation readily. However, glass is opaque to infrared radiation. In investigation thermofilm, fixed onto black card 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 investigate the role played by glass in heat increase and see how black card can transform visible light to heat (infrared radiation).

| **Duration** | |
|---|---|
| • 30-45 minutes | |
| **Energy Literacy Characteristics addressed:** | |
| **C1** | Has a grounded understanding of the science and how energy is harnessed and used to power human activity. |
| **C3** | Students are sensitive to the need for energy conservation and the need to develop alternatives to fossil fuel-based energy resources. |
| **C4** | Is cognisant of the impact of personal energy-related decisions and actions on the global community; |
| **Skills & Competencies addressed:** | |
| • Critical Thinking | • Research |
| • Inquiry | |
| **Subject links in National Curricula:** | |
| • Science | • Engineering |
| • Technology | • Geography |
| **Level** | |
| • ISCED 2 | |
| • ISCED 3 | |

Suggestions for Use:

1. 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?
2. Include 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 go to do with it?
3. Let the students' ideas stand, and come back to them after the activity.
4. Give out copies of the student handout.
5. Setting up the experiment:
   - 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

a) Put one of the black strips with thermofilm into the boiling tube.
b) Bung it and place it in the rack as shown in figure 1 making sure that the thermofilm is facing the lamp.
c) Place the second strip in the rack near the boiling tube as shown making sure this thermofilm is also facing the lamp.
d) Place the lamp about 40 cm from each strip. Switch on the lamp.
e) Observe and record any colour changes on the strips.
f) Using the calibration chart, relate the colour changes to the appropriate temperature.
g) Repeat the experiment using an energy efficient bulb and compare your predictions

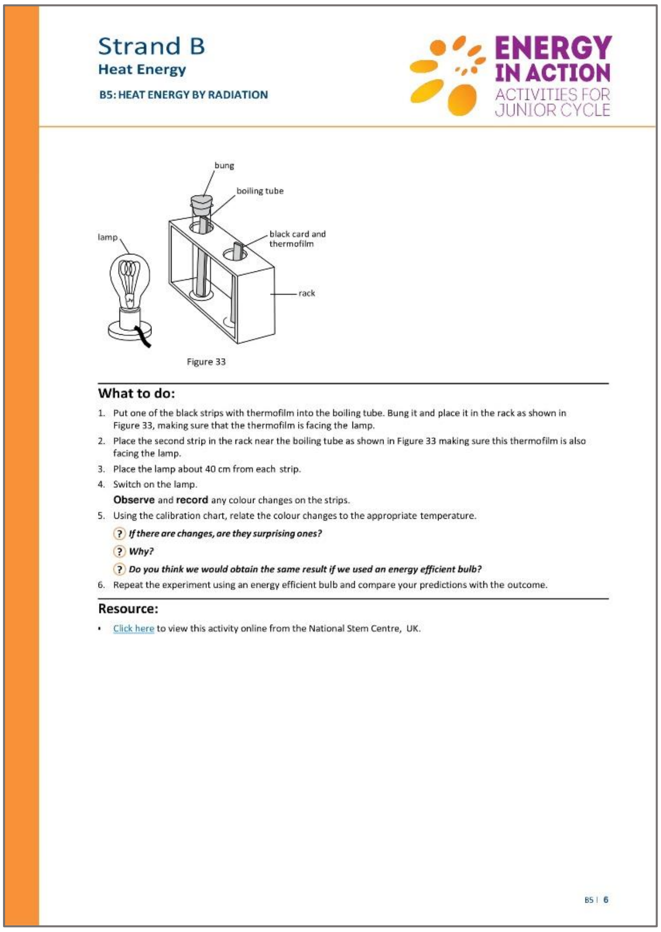
with the outcome. Ask students the following questions:

- 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?

## Extensions to Activity 3.7

## Materials

- Activity 3.7 Student Handout.


Strand B
Heat Energy
B5: HEAT ENERGY BY RADIATION

ENERGY IN ACTION
ACTIVITIES FOR JUNIOR CYCLE



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.

B5 | 6

Fig. 14. Activity 3.7 Student Handout.

## Activity 3.8 Investigate passive solar lighting solutions for buildings

Students explore the many different ways that natural solar lighting can act as energy efficient lighting sources when incorporated into interior spaces and buildings. Students research & explore various methods of daylighting and sketch a design for a small home with passive solar lighting instillations. Students are asked to calculate the total energy savings per day attributed to daylighting. As an extension, students have the option to implement and test their design by constructing a model of their building and by simulating the sun with a desk lamp. Activity 3.8 is suitable for both lower and upper secondary level students. The source of this activity and worksheet is the teachengineering.org digital library collection which has been developed by the University of Colorado Boulder. The ENERGE Project has been granted permission by the authors to promote this activity.

| **Duration** | | | |
|---|---|---|---|
| 30-45 minutes | | | |
| **Energy Literacy Characteristics addressed:** | | | |
| **C1** | Has a grounded understanding of the science and how energy is harnessed and used to power human activity. | | |
| **C2** | Understands the impact that energy production and consumption have on all spheres of our environment and society | | |
| **C3** | Students are sensitive to the need for energy conservation and the need to develop alternatives to fossil fuel-based energy resources. | | |
| **C4** | Is cognisant of the impact of personal energy-related decisions and actions on the global community; | | |
| **Skills & Competencies addressed:** | | | |
| • Critical Thinking | | • Research | |
| • Problem Solving | | • Data Analysis | |
| • Inquiry | | • Numeracy | |
| **Subject links in National Curricula:** | | | |
| • Science | | • Engineering | |
| • Technology | | • Geography | |
| **Level** | | | |
| • ISCED 2 | | | |
| • ISCED 3 | | | |

### Suggestions for Use:

1. Visit the following link to the activity on the Teachengineering.org digital library:

   [https://www.teachengineering.org/activities/view/cub_housing_lesson03_activity](https://www.teachengineering.org/activities/view/cub_housing_lesson03_activity)1

2. Students can work alone or in groups. Make copies of the student worksheets and the accompanying student handouts.

3. Prior to discussing daylighting with students, teachers should make themselves familiar with the resources on daylighting that accompany this activity. Students can also be provided with the resources to review prior to completing the worksheet.

4. Discuss with students the daylighting techniques used in various types of architecture, such as windows, solar tubes, light shelves, clerestory windows and skylights. Sketch or display using a projector Fig. 15. on the board.

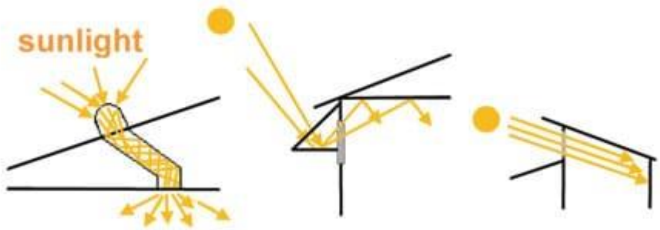



Fig. 15. Solar Lighting

5. For each design, have students explain the path that daylight will follow to get to the inside of the house. Use the arrows shown in Fig. to show the path of light entering the building (yellow).

6. Extend the discussion to each of the designs as real-world daylighting technologies, exploring the amount of natural lighting each device provides within a structure. Explain the importance of solar geometry in designing the daylighting system for the house. Refer to the resources, as appropriate.

7. Students should complete the worksheet.

## Extensions to Activity 3.8

Student groups can carry out a design challenge which involves building a model home with solar lighting solutions using foam core board. Students can test the model house using a desk lamp to simulate the sun. Students should record any observations about the levels of natural light in each room due to your daylighting devices. Students should determine whether or not this has an impact on the amount of artificial light you designed the house to use. Have each group present their model to the class, explaining each type of daylighting used, as well as observations made during testing.

## Materials

The following materials and resources have been made available by Teach Engineering at the following link:

https://www.teachengineering.org/activities/view/cub_housing_lesson03_activity1

Daylighting Design & Technique Worksheet (pdf)

Daylighting Design & Technique Worksheet (doc)

Daylighting Design & Technique Worksheet Answers (pdf)

Daylighting Design & Technique Worksheet Answers (doc)

Solar Geometry Handout (pdf)

Solar Geometry Handout (doc)

Solar Elevation vs. Azimuth Plot Handout (pdf)

Solar Elevation vs. Azimuth Plot Handout (doc)