Lesson 4

‘Not too hot, not too cold’

The Goldilocks Zone

Curriculum links

England Change of state | Thermal conductivity, reversible change | Light

Scotland Energy sources

Wales Sustainable earth | Properties of materials and their uses | Enquiry skills

Northern Ireland Properties of materials and their uses | Design and production of everyday objects

Credit: NASA Ames/JPL-Caltech/Tim Pyle

Background

Infrared is a form of electromagnetic radiation but it is not visible light. We can sometimes feel its heating effect on our skin. Everything that is warm also emits infrared radiation; this includes planets, stars and people. As energy is transferred away from a heat source, it is dispersed over an ever-increasing area. This means that the further away an object is, the more difficult it is to detect. Astronomers looking for exoplanets use infrared telescopes to reveal the faint glow of objects in outer space; they can detect objects too cool and therefore too faint to be seen in visible light.

In this lesson children will use data loggers to measure temperature over distance and use thermochromic paper to measure the rate of energy transfer through different materials.

Objectives

To learn:

- planet Earth orbits the Sun in the Goldilocks Zone at just the right distance and temperature
- exoplanets beyond our solar system range from very hot to very cold depending upon their distance from their star
- astronomers use special infrared telescopes to detect these very distant bodies
- energy is transferred from a higher temperature to a lower temperature and its intensity decreases as the distance from its source increases
- to work scientifically by predicting, observing, recording and using data to draw conclusions

Resources per group of four

Tablets or mobile phones with thermal imaging app (if available)
Colour-changing thermochromic paper cut into small squares
Variety of materials and surfaces
Plastic petri dish with lid
Timer
Insulated cup eg coffee cup with lid
Metal skewer or spoon
Adhesive tape
Two cans (optional)
Thermometer x 2 (optional)

Advance preparation

Selection of infrared/ normal images for display

https://spaceplace.nasa.gov/ir-photo-album/en/

Data loggers and laptop for demonstrations.

Remove labels from two cans. Paint one can black, using matt acrylic paint or cover the can with black paper. Prepare a set for each group if required.

Hot water (max 50c).

Above are views of Mount Etna erupting. The bottom two are taken by NASA's thermal infra red detector. Copyright: NASA.

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Activity

Introduction

Show the children a few images on the whiteboard of telescopes which collect information from space. Some telescopes, such as the Spitzer Space Telescope, collect information about the temperature of planets, stars and dust; we call these infra-red telescopes. Another example is the James Webb Space Telescope, due to be launched in 2018. See http://jwst-miri.roe.ac.uk or https://www.jwst.nasa.gov/.

Play the infra red game on the whiteboard using https://spaceplace.nasa.gov/ir-photo-album/en//. By passing the 'camera lens' over the images, the children can experience how the world would look if our eyes could see infra red radiation. Explain that some smart phones and tablets have technology to detect infra-red radiation. The children can investigate how thermal / infra-red imaging applications on smart phones or tablets, if available, can be used to detect temperature differences. Can the children think of any every day uses?

Teacher demonstration

Place a lit candle behind a 2 litre bottle of cola, so that the candle is not directly visible. Point a mobile phone in camera mode towards the centre of the bottle; the candle should now be seen clearly glowing brightly on the phone screen. The near infra-red part of the spectrum is just a bit further into the red than our eyes can see. Some smart phone cameras do not have a near infra-red filter fitted, especially on the front facing camera. This enables us to see some of the electromagnetic radiation (light) that is produced by hot objects. One example of this is viewing a candle flame through a bottle of coke. The flame is much more visible using the camera than with the naked eye. It is also possible to modify a webcam to remove the infra-red filter.

http://www.instructables.com/id/Infrared-IR-Webcam/

Further examples of images in the visible and infra-red can be found by following this link http://coolcosmos.ipac.caltech.edu/image_galleries/shoe.html

Provide each group with a few squares of thermochromic paper and let the children explore its properties by handling. Can they explain what is happening? Briefly explain how the material works. (See teacher information). In groups, the children further investigate the properties of the thermochromic paper. They can try placing the paper on different surfaces or in hot or cold hands and observing the colour changes.

After exploring the colour changes, the children plan an investigation to compare the effectiveness of various materials as heat conductors. They heat the thermochromic paper by placing the squares on the lid of a petri dish half filled with hot water (max 50c). When the paper has changed colour, they quickly place the squares onto the materials to be tested. The children can investigate the thermal conductivity of a variety of materials and surfaces, by first predicting and then measuring the time taken for the paper to lose heat and revert to its original colour. They decide the method of recording their results, such as in tables or charts, placing the materials in order of thermal conductivity.

Plenary

The results from each group may be collated on the whiteboard and discussed and can later be displayed in graph form.

Which material was most effective at conducting heat?

Which material was not a good thermal conductor?

How would these results be useful?

Can they think of any practical uses for thermochromic materials?

Explain that energy travels from a source and is conducted or travels through a material; the further away from its source, the lower the temperature. Some materials such as metals are very good heat conductors, allowing heat to pass through them whilst others are insulators, meaning that the material is not very effective at letting heat travel through. In space, heat energy is carried through the vacuum of space by a process called radiation.

Extension

To show conduction of energy through a metal: The groups half fill an insulated disposable cup with hot water (max 50c). Place a metal skewer or spoon into the cup, replacing the lid, so that one end of the metal is below the surface of the water and the rest of the metal threaded through the hole in the lid. Seal any gaps around the metal using tape. The children predict what they think will happen to the temperature of the free end of the skewer or spoon. One member of the group holds the end of the metal, whilst another starts the timer, and informs the group when a temperature increase can be detected; the time is noted. The groups then compare and discuss their results. If data loggers are available, the temperature sensors could be used to record temperature changes of the spoons or skewers; teachers could then connect the data logger to a laptop and display to the class the graph of temperature over time drawn from the data collected.

To demonstrate the radiation of heat

Teachers may decide to use this as a class demonstration or allow each group to set up its own experiment. Pour the same volume of cold water into each of two identical metal cans, one painted with thick black matt acrylic paint or wrapped with black paper and insert a thermometer or data logger temperature probe into each. Place both cans in direct sunlight or under a heat source such as a lamp. Over time, the water in the black can should be warmer than that in the shiny can. The shiny can is a poor absorber of heat because it reflects much of the heat energy away. The black surface is a good absorber of radiant heat and so the water temperature rises.

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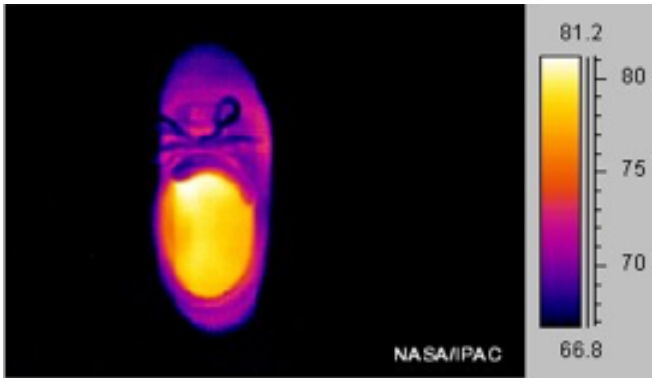
Teacher information

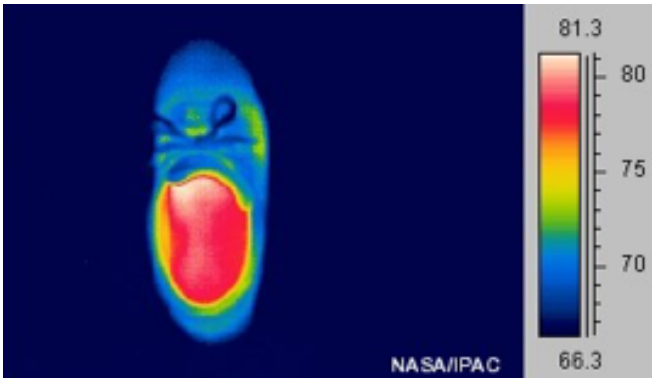
Heat energy moves from hot objects to cold ones by three methods: convection, conduction and radiation. Of these, only radiation does not require contact. In space, heat energy has nothing to travel through and travels in waves through the vacuum of space by radiation. Infra-red is a form of light that falls just outside visible light on the electromagnetic spectrum. Light waves carry energy; shorter wavelengths have higher energy whilst longer wavelengths have lower energy. Cooler objects will glow at longer wavelengths whilst warmer objects will glow at shorter wavelengths. No particles are involved in this process, unlike in conduction, so radiation can occur through the vacuum of space. Astronomers looking for exoplanets use infrared telescopes to reveal the faint glow of objects in outer space. Exoplanets are easier to detect when they are large and orbit their star every few days. 51 Pegasi b is one example and is known as a hot Jupiter. Such planets reach very high temperatures as they are so close to their star and glow strongly in infra-red light. Spitzer became the first Space telescope to enable astronomers to detect the light from hot Jupiters.

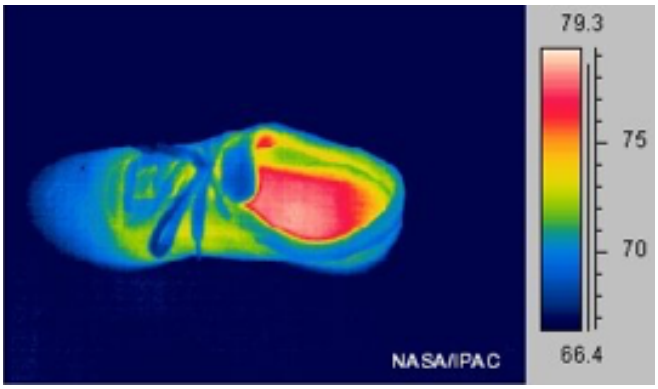
Image shows the Spitzer Space Telescope. Copyright: NASA.

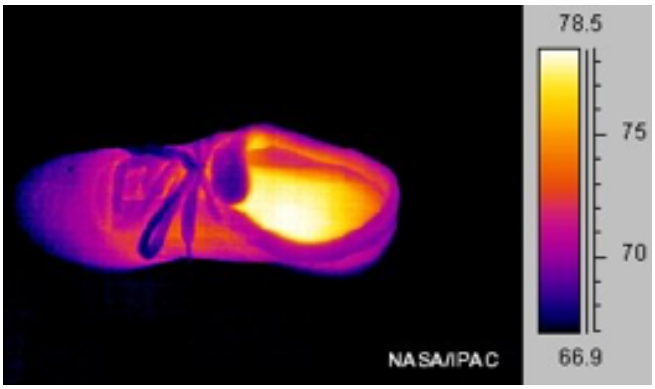
Thermochromic paper contains pigments sensitive to temperature. They change colour when they are heated up or cooled down. Thermochromic materials can be used to test a material’s ‘thermal conductivity’ or ability to conduct heat.

Metals are extremely conductive materials. Conduction allows hot, energetic atoms to collide with cooler atoms further along the metal and in turn makes those atoms more energetic. In this way, heat energy moves along the object.









Infrared images showing a training shoe just after being worn.

Further examples of images in the visible and infrared can be found by following this link:
http://coolcosmos.ipac.caltech.edu/image_galleries/shoe.html