

ACTIVITY BRIEF

Investigating thermography

The science at work

Skin temperature is a useful clue to possible health problems. The human body maintains a fairly constant internal temperature by homeostasis. It's about 37 °C. If your temperature:

- rises above 37 °C, your body responds by causing blood vessels carrying blood to the skin to swell (vasodilation). More blood gets close to the skin and is cooled by heat transfer to the air. When body temperature returns to normal the blood vessels shrink back to their normal size (vasoconstriction).

Causes: inflammation and excessive blood circulation

- falls below 37 °C, your body responds by causing blood vessels carrying blood to the skin to shrink (vasoconstriction). This reduces the flow of blood to the skin and, therefore, the rate of cooling by heat transfer to the air. When body temperature returns to normal the blood vessels swell to their normal size (vasodilation).

Causes: degeneration processes, fibrosis and circulation problems

Thermography is one of the many sophisticated screening and diagnostic methods available to healthcare professionals. An infrared camera maps skin temperature by using sensors that measure the intensity of emitted infrared radiation.

Your brief

You will find out about thermography and some of their applications in medicine. Infrared cameras are quite expensive and it's unlikely you will be able to use one in your school. However, you will use an infrared thermometer to map temperature variations across surfaces and convert these data into an image.

Task 1 Finding out about thermography

Use *Study sheet: Thermography* to help you gather a suitable set of notes about thermography – how it works and its applications.

Task 2 Creating a thermogram

You will be provided with an infrared thermometer. Unlike most other temperature measuring devices it does not have to be in contact with the object whose temperature is being measured. Use the infrared thermometer to produce a thermogram. *Practical sheet: Creating a thermogram* will guide you.

STUDY SHEET

Thermography

Use the following questions and prompts to build up a set of notes about thermography.

Find out about 'hot body' radiation.

- Explain the term 'black-body radiation'.
- Describe how the spectrum of 'hot-body' radiation varies with temperature.
- Describe how the total radiation given off by a surface varies with temperature.

You will be able to find out about this in most advanced level physics books.

Some useful web references

<http://www.bbc.co.uk/schools/gcsebitesize/physics/waves/electromagneticspectrumrev1.shtml> (GCSE revision)

<http://www.bbc.co.uk/dna/h2g2/A270037>

http://en.wikipedia.org/wiki/Black_body

Find out about the use of thermography in medicine.

- Describe some situations where thermography is a good diagnostic tool, e.g. to provide quantitative information about circulatory problems, arthritis and rheumatism.
- Summarise the advantages and disadvantages of using thermography.
- Evaluate the appropriate use of thermography for diagnosis in a variety of situations.

If you are interested in other applications as well as medicine:

- explain, giving one specific example of each, applications of thermal imaging such as:

*detection
of disturbed ground*

weapon systems

*remote sensing
from satellites*

forensic

night sights

burglar alarms

*detecting survivors
in collapsed buildings*

*engineering,
e.g. non-destructive testing,
electric circuit fault detection*

- outline the advantages of thermal detecting/imaging systems.

Some useful web references

<http://en.wikipedia.org/wiki/Thermography> Useful introduction and overview

<http://www.ebme.co.uk/arts/thermog/> A very good overview of medical thermography

Try typing the following words into your favourite search engine to find more references:

thermography thermal imaging infrared imaging infrared camera thermogram

PRACTICAL SHEET

Creating a thermogram

In this practical work you will use an infrared thermometer to 'map' temperature variations across an object non-invasively. It involves two steps:

- measuring and recording temperature at various points of the object
- converting the temperature into a colour to produce a 'thermogram' of the object.

Using an infrared thermometer

An infrared thermometer detects the infrared radiation emitted by an object and converts it electronically into a temperature reading. The area from which the infrared radiation is gathered depends on the distance from the thermometer and the object. It can be calculated from the 'distance:spot diameter' ratio for the thermometer, i.e.

distance from the thermometer to the object : diameter of the 'spot' (the circular area over which the temperature is read)

- If the ratio is 1:1, when the infrared thermometer is 6 cm from the object, the spot diameter is 6 cm (diagram A).
- If the ratio is 6:1, when the infrared thermometer is 6 cm from the object, the spot diameter is 1 cm (diagram B).

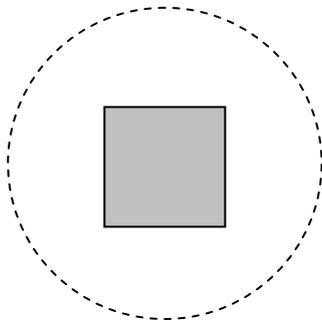


Diagram A

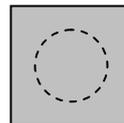


Diagram B

For a given distance between thermometer and object, the higher the ratio, the smaller is the area whose temperature can be measured accurately.

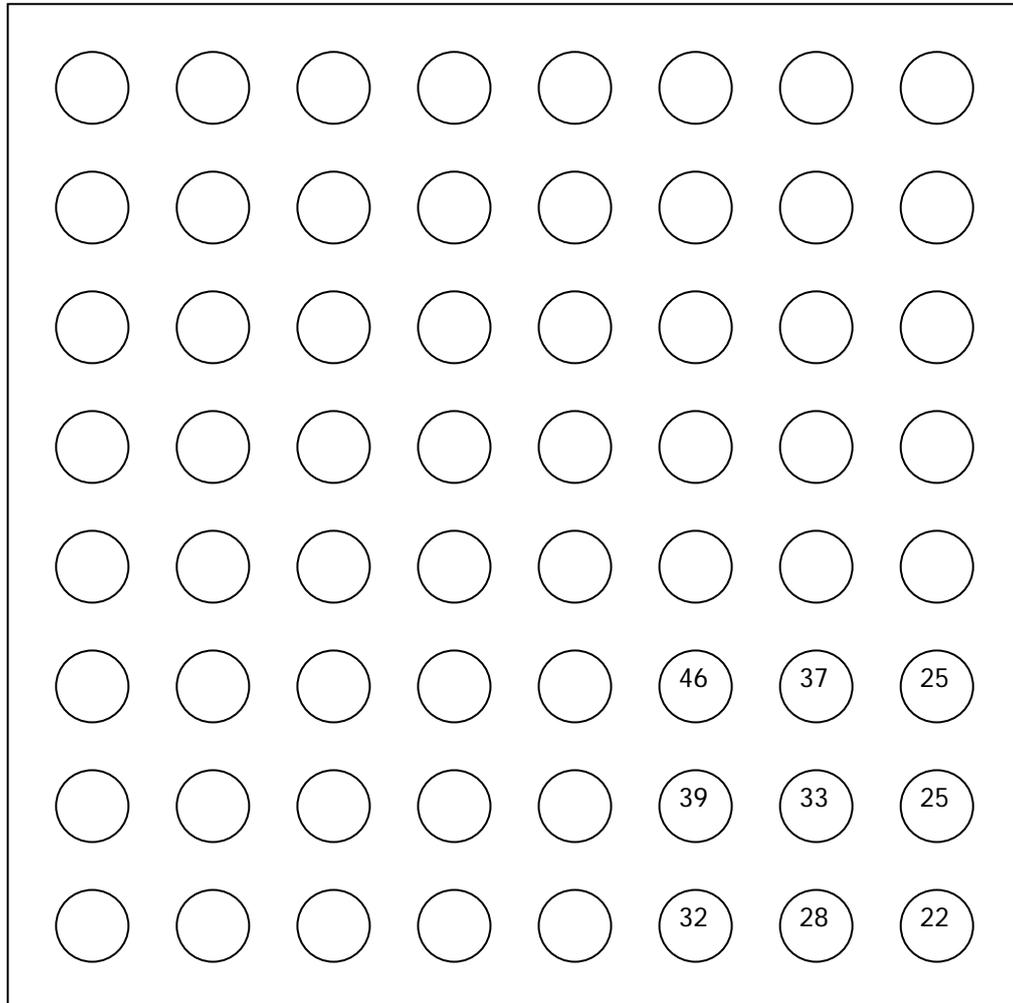
So if you want to measure the temperature of a 1 cm diameter circular area you need to calculate how close you must hold the thermometer. The 'distance:spot diameter' ratio can be found in the specifications for an infrared thermometer, usually given on the packaging or instruction sheet. The temperature range over which the thermometer may be used and its accuracy are also usually specified.

Infrared thermometers with a high distance:spot ratio are usually more expensive because of their better optical system.

Scanning a surface

You will be given an object to investigate. It will consist of a number of wells made in a block of polystyrene (or other insulating material). The wells have been filled with water at different temperatures.

Make a drawing of the block. It may look something like similar this:



Now use the infrared thermometer to measure the temperature of the water in each well. Do not dip the thermometer into the water, just point it at the surface. You do not need to turn the thermometer on and off between readings, but you must allow 2-3 seconds before you take the new reading.

Record the temperatures in your grid (see diagram).

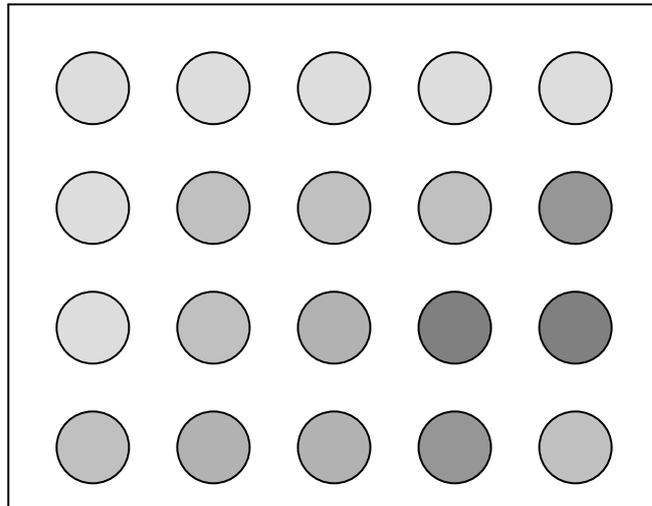
Creating a thermogram

For this you will need to make an electronic copy of your grid.

Then decide which temperature ranges to assign a different 'greyness' to. For example:

20-25 °C	10% grey	25-30 °C	20% grey	30-35 °C	30% grey
35-40 °C	40% grey	40-45 °C	50% grey	45-50 °C	60% grey

Now fill in your grid with the appropriate greyness, for example:



You will have created an image from the infrared radiation that was being emitted from the surface of your object.

Coloured thermograms

Images are usually monochromatic, but they can be 'coloured' to make differences in intensity easier to see. Normally the hottest parts are coloured white, then red, working through the spectrum to blue for the coldest parts.

You might try converting your monochromatic thermogram into a coloured one by assigning colours to the temperature ranges rather than percentages of grey.

Teacher notes

This activity relates to:

- **AQA Unit 8 Medical physics**
- **OCR Unit 16 Working waves**

Both units are **externally assessed**. Therefore, there is no compulsion for practical work. However, this activity provides a practical investigation that should help students understand the principles of thermography (infrared imaging).

These are the relevant parts of the units' specification:

AQA Unit 8 Medical physics

Thermography and its uses

Students should:

- *know how a thermograph is produced*
- *know some situations where thermography is a good diagnostic tool and the advantages and disadvantages of using thermography*
- *be able to evaluate the appropriate use of thermography for diagnosis in a variety of situations.*

OCR Unit 16 Working waves

How infrared imaging works

Students need to:

- *describe how the spectrum of 'hot-body' radiation varies with temperature*
- *describe how the total radiation given off by a surface varies with temperature*
- *describe how thermal imaging cameras produce images corresponding to surface temperatures*
- *explain applications of thermal imaging, including detection of disturbed ground; night sights; weapon systems; burglar alarms; remote sensing from satellites; detecting survivors in collapsed buildings; medical, e.g. to reveal quantitative details of circulatory problems, arthritis and rheumatism; forensic; engineering, e.g. non-destructive testing, electric circuit fault detection*
- *outline the advantages of thermal detecting/imaging systems.*

Practical sheet: Creating a thermogram

Infrared thermometers

These may be bought from various suppliers, e.g.

http://www.thermometersdirect.co.uk/acatalog/Thermometers_Direct_Infrared_thermometers_6.html

<http://www.maplin.co.uk/Module.aspx?ModuleNo=46033&source=2001&doy=search>

Trials were made with **IR 77 Pocket Infrared Thermometer** from Thermometers Direct:

Features	Specification
LCD temperature display	Distance to spot-size ratio 6:1
Easy to use: hold it within one foot of the area to be measured and push the button	Measuring Range: -30 °C to 270 °C
Back light illuminates display for taking measurements at night or in areas with low light levels	Display Accuracy: $\pm (2.5\% + 2 \text{ }^\circ\text{C})$
Integrated Torch	Display Resolution: 1 °C
Auto data hold (reading displayed for 7-8 seconds after trigger released)	Dimensions: 60(W) x 28(D) x 95(L)mm
Auto power off	Display Size: 25(W) x 25(H)mm
Reading Time: Less than 1 second	Replaceable battery: AAA

The price is around £30 (including VAT).

It is possible to get infrared thermometers that are a little cheaper, but they may have a distance to spot size ratio of only 1:1. Generally speaking, the higher the distance to spot size ratio, the more expensive the infrared thermometer will be.

Surface for examination

There are many ways of preparing a suitable surface for examination. Here is one approach using the IR 77 Pocket Infrared Thermometer.

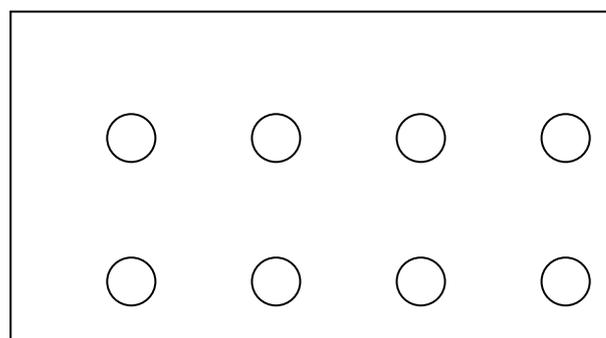
- 1 Cut two pieces of expanded polystyrene sheet 30 cm x 22 cm x 5 cm.

Possible sources:

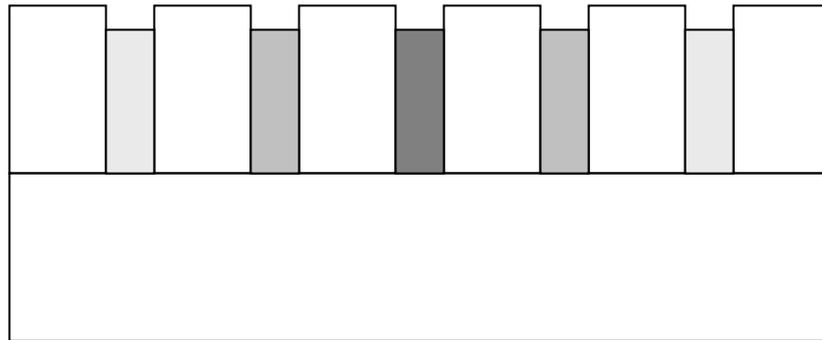
Jablite Universal Insulation Board (Single) White 120 cm x 45 cm x 5 cm may be bought from B&Q for about £3

Wickes Polystyrene 24 cm x 60 cm x 5 cm for about £7

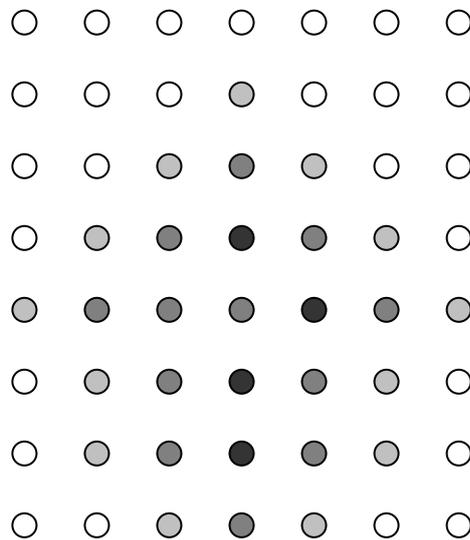
- 2 Drill a pattern of 1 cm diameter holes in one sheet, leaving 2 cm between holes:



- 3 Stick the two pieces of polystyrene together using tile adhesive to make a block 10 cm deep, with holes 1 cm diameter and 5 cm deep.
- 4 Immediately prior to the practical, fill the holes with water at different temperatures, to create a temperature pattern across the surface.



Note: One way is to put different volumes of cold water into each hole using a measuring cylinder, and then top up with hot water. You may wish to create a specific pattern for students to identify. For example,



The idea is to create a temperature profile in which there is one or more 'hot spots' and the temperature gradually decreases from these.

Creating the thermogram

One way to do this is to produce an electronic version of the grid using the Word drawing tool. Circles can be filled in by selecting them and using the 'Fill color' tool to fill with different shades of grey.* This is the equivalent of a 'false-colour image' captured by a monochromatic infrared camera where wavelength range of the emitted infrared radiation is converted into greyscale on black and white film.

*Note: Only 4 shades available as standard. Students need to choose the 'More Colors ...' option.

A pseudo-colour thermogram is derived from a greyscale image. Each pixel is converted to a suitable colour. Pseudo-colouring does not provide more information than greyscale, but it can increase the ease with which features in the thermogram can be seen. Students can try converting their greyscale thermogram into a pseudo-colour thermogram using the same method, but filling with colours rather than shades of greyness.