Teacher and Technician Sheet

In this practical students will:

- Repeatedly measure the temperature of thermometers placed throughout the spectrum of light, and beyond.
- Calculate the mean change in temperature for colours in the light spectrum and beyond
- Interpret trends in the class' data for the experiment.
- Use their knowledge of electromagnetic radiation to explain trends found in the class data.

Introduction for Teachers

(This topic could start with a group discussion about the situation outlined in the student worksheet. Students could be asked if they have noticed this effect of black clothing being 'hotter' than white clothing. This could lead on to a discussion on light and electromagnetic radiation during which the teachers introduce the following ideas especially the words in bold. As part of the heritage of science and the lives of great scientists the discussion should include something of Herschel's life and accomplishments.

This experiment, that the students will carry out, is a modified version of the actual experiment conducted by Sir Frederick William Herschel (1738-1822) on 11th February 1800, in which he discovered a form of radiation other than visible light that we now call infrared radiation.)

The story of William Herschel is as follows:

Sir Frederick William Herschel (1738-1822) was born in Hanover, Germany. He was an astronomer and musician who moved with his father and family to live in England in 1757. He was to stay in England for the rest of his life. He began his career as a musician. Herschel was a very accomplished musician playing the oboe, violin, harpsichord and organ. During his life he composed numerous musical works, among them concertos, church music and 24 symphonies. In fact, six of his symphonies were recorded in 2002 by the London Mozart Players.

Herschel's life in music led to an interest in mathematics. He was friendly with the English Astronomer Royal, Nevil Maskelyne and this promoted a strong interest in astronomy. Herschel made many telescopes and he made his own lenses. Because of this interest he began an astronomical journal in which he noted his observations of Saturn's rings and the Great Orion Nebula (M 42). In 1781 Herschel discovered the planet Uranus, the first new planet to be found since antiquity.

In his work on astronomy Herschel worked closely with his sister, Caroline Herschel (1750–1848). Caroline recorded her observations of eight comets and eleven nebulae. Because of her work, and at the suggestion of her brother, she updated and corrected Flamsteed's work on a record of the position of stars; published as the British Catalogue of Stars. She was honoured by the Royal Astronomical Society in 1828.

On 11th February 1800 Herschel was testing filters to enable him to observe Sun spots. He noted that when he used a red filter there seemed to be a lot of heat produced. This was out of character with filters of the other colours.

Herschel devised a clever experiment to investigate his results. He decided to pass light through a prism to split the light into a rainbow of colours called a spectrum. He put a thermometer beyond the red end of the visible spectrum as a control to measure the room temperature. Herschel was surprised to see the temperature rise on this thermometer where there seemed to be no light. He concluded that there must be a non-visible form of radiation beyond the visible spectrum.

(To do the investigation it is better for students to work in groups of three or four. This allows good division of labour and allows for discussion about the method.)

Curriculum range

This activity is better suited to secondary aged students since the ideas are directly in the secondary science curriculum. The aim is to gain some understanding of the thinking of the way scientists use science to investigate artefacts in the world of art. It links with:

- setting up simple practical enquiries, comparative and fair tests;
- reporting on findings from enquiries and observations, including oral and written explanations, displays or presentations of results and conclusions;
- using straightforward scientific evidence to answer questions or to support their findings;
- building a more systematic understanding of electromagnetic radiation by exploring and comparing the properties of infrared;
- asking questions and develop a line of enquiry based on observations of the real world, alongside prior knowledge and experience;
- using appropriate techniques, apparatus, and materials during laboratory work, paying attention to health and safety;
- making and recording observations and measurements using a range of methods for different investigations; and evaluating the reliability of methods and suggesting possible improvements;
- presenting observations and using data to calculate using appropriate methods;
- interpreting observations and identifying patterns using those observations and calculations to draw conclusions;
- presenting reasoned explanations, including explaining data in relation to predictions and hypotheses; and

- learning about the concept of non-visible electromagnetic radiation and identifying infrared radiation by its physical property of raising the temperature of a thermometer.

Hazard warnings

Since the Sun is directly involved in this investigation, students will need to be reminded that it is dangerous to look directly at the Sun.

Equipment

- 1 glass prism
- 1 prism stand
- 3 sensitive heat sensors connected to a data logger (or thermometers with the bulbs painted black)
- Thermometers
- Matt black paint or a permanent black marker
- 1 pair of scissors
- Cardboard box (about 210 mm x 297 mm x 250 mm) with a white inside (An empty A4 copier paper box is ideal.)
- 1 blank sheet of white paper

Technical notes

Plastic prisms do not work well for this experiment so glass prisms are important.

Matt black painted temperature sensors work better than using black marker pens. This is probably best done by the technician in advance. The black paint will be very messy and then students will need to wait for the paint to dry before collecting data.

This investigation is a difficult one in which to get good results since it requires much manipulation of the apparatus and patience to persevere, but is satisfying when it does work.

The best conditions are a very bright clear sunny day and preferable near midday when the sun is strongest. It is also best to conduct the work outside so the glass in windows does not filter out some of the components of the electromagnetic radiation.

Doing the experiment at different times of the day will mean the temperature differences between the colours will change, but the *relative* comparisons of each colour will remain similar.

Results

The temperatures of the colours should increase from the blue end to the red end of the visible spectrum and should continue to just beyond the red end of the visible spectrum. The highest temperature should be just beyond the visible red end of the visible light spectrum. This is the infrared region of the spectrum.

Going further

Try the experiment during different times of the day; the temperature differences between the colours may change, but the relative comparisons should remain valid particularly if the students' pool and average their results.

Discuss the difficulties involved in completing the investigation and make suggestions about how the method might be improved.