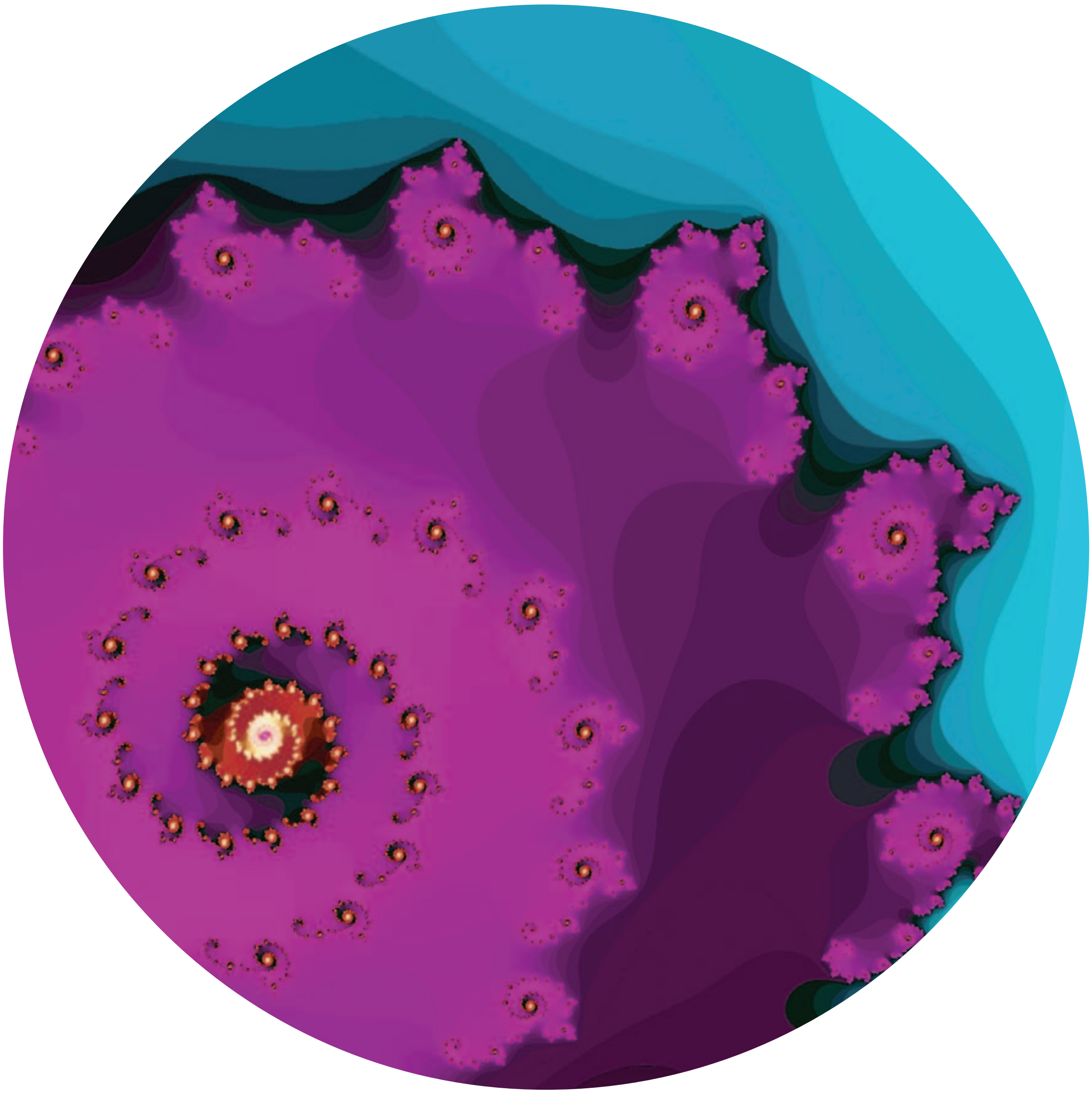
Scattering



see it!

Scattering

What's it all about then?

This experiment lets you explore the way that light is scattered by particles and also shows the effect of polarisation.

What you can explore through this experiment

- Light is a wave
- White light is made up of all the colours of the rainbow
- Different colours of light have different wavelengths on the electromagnetic spectrum
- Light is scattered by particles in the atmosphere
- Polarisation

How to present it

This is a guideline of how to present the experiment to the students. You do not have to follow it exactly, just as long as you allow the students to explore the concepts outlined above. You can expand or shorten this experiment as necessary to fill the time allocated.

The kit

- Light box
- Power supply - do not turn this up above 8V
- Plastic tubes
- Dettol
- 1 ml Syringes
- Beakers
- Polaroid filters
- Fructose

Image of equipment

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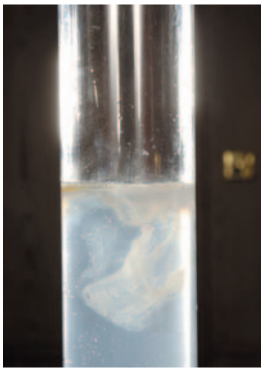
Introduction

Start this experiment by asking the students why the sky is blue, or why they think we get sunsets. Take some ideas and introduce the students to the experiment kit that they will be using to investigate this.

Part 1: Creating a sunset using water and Dettol

1.1 Start with a tube of water which is ¾ full. Place this on the light box so that the students can see the light shining through it. Using the syringe ask a student to measure 0.2 ml of Dettol to add to the tube of water. To mix the water and Dettol place the bung on the tube and gently turn the tube over and back upright again. Do not shake the tube as this creates bubbles.



Adding Dettol to the water

1.2 Place the tube back onto the light box and to see if there are any colours appearing within the solution. Angle a mirror so that the students can see the filament of the light box shining through the tube. This filament will look white to begin with, but as more Dettol is added it will begin to appear red.

1.3 Repeat these steps until the group agrees that they can clearly see a sunset form within the tube with the solution appearing blue at the base closest to the light source and orange at the top. A 'perfect' sunset uses 1.2 ml of Dettol. If the students add too much Dettol then you can ask them to think of a way to make the solution more dilute.

1.4 Ask the students to call out what colours they can see at different heights in the tube and write them down on the board. It should become clear that all the colours of the rainbow are present with the blue scattering out first at the base of the tube and the red travels through the entire tube to be scattered at the top.

1.5 Discuss what causes this effect with the students. Think about the white light shining through the tube and the colours being changed by the amount of solution that it shines through. This could lead on to a discussion about white light being made up of all the colours of the rainbow and these colours having different wavelengths on the electromagnetic spectrum. We have prisms onboard if you wish to show how white light is split into all the colours of the rainbow and we have slinkies to demonstrate how a transverse wave would travel.

1.6 Ask the students if they have any ideas about why the light acted in this way? The Dettol adds tiny particles to the water which the different wavelengths of light are scattering off.

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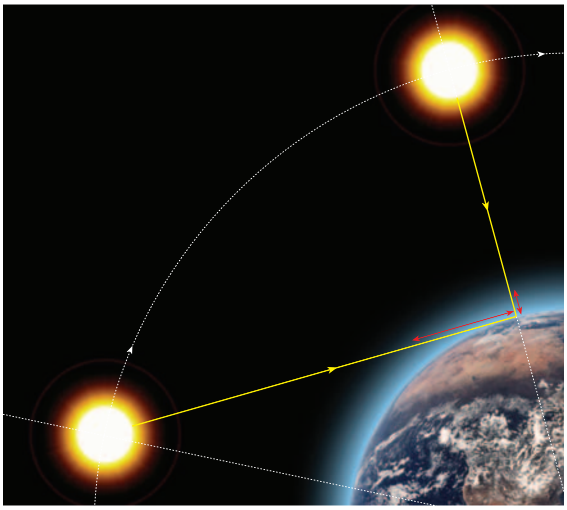
Draw a picture of a globe on the board and ask the students what they think is surrounding the earth? Atmosphere. Ask the students what is in the atmosphere? Air, water, dust are all suspended in our atmosphere.



Add to your drawing the path of sunlight reaching your eyes when you are looking at it at midday and at sunset. As you look at the sunset you are looking through more atmosphere.

The particles in the atmosphere, particularly the atoms of nitrogen and oxygen are just the right size to scatter blue light as it comes into contact with them. As you look through less of the atmosphere at midday you see this blue light scattered off. When the sun is setting you are looking through much more of the atmosphere and so you see the red light which remains to be scattered off. Always try to allow the students to reach these conclusions themselves through referring to the experiment.

Part 2: Creating a spiral rainbow using fructose solution

2.1 Before the session prepare some fructose solution. This is a saturated solution and requires one box of fructose for 300 ml of hot water. Add this solution to a tube and discuss what fructose is.

Place this tube on the light box. The spiral rainbow requires the light source to be polarised so make sure that a polaroid filter is slotted in place in the light box.

2.2 Hand each of the students a polaroid filter. View the fructose solution through the filter. See what happens if you hold the polaroid filter up to the light of the wall mounted LCD television screen and rotate it. As you turn the filter there will be a point when the filter goes dark and no light passes through. This is because the LCD screen contains a Polaroid filter itself. If you think of the Polaroid filters then as the grills lying on top of one another, then as one turns there will be a point when the grills will lie at right angles to each other, completely blocking any light coming through. You can also hand the students two filters to turn until the filters block out the light coming through them. See if you can see the spiral rainbow form in the solution. Rotate the polaroid filter for the spiral rainbow to appear as if it is moving. Angle the mirror and ask each of the students to view the filament colour through their filters, each student should see a slightly different colour.

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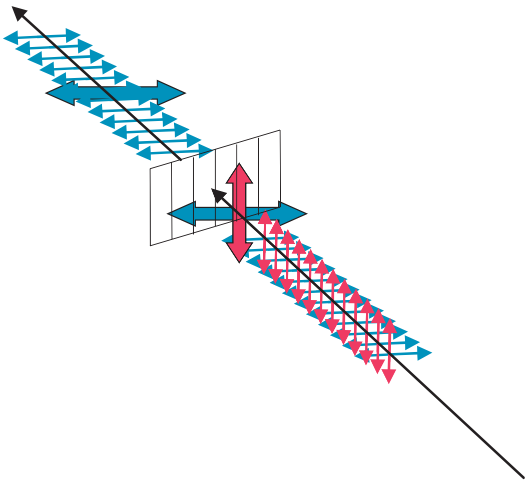
Questions you may be asked:

What is making the spiral rainbow?
The molecules of fructose are like little spirals. The polarised light entering the tube hits these molecules and is rotated slightly. As different colours of light have different wavelengths they are twisted by different amounts up the tube giving a spiral rainbow effect.

Different types of sugars have different effects. Glucose is also known as dextrose because solutions of glucose rotate the plane of polarised light to the right. Fructose is also known as levulose because it behaves oppositely to glucose in that it rotates polarised light to the left. You could say that fructose is left handed and glucose is right handed. This is called 'chirality' and it can be very important to understand how molecules that are mirror images behave in slightly different ways. The drug thalidomide contained both left and right handed molecules. One type helped with morning sickness and the other was to blame for birth defects.

The molecules responsible for the smell in lemons and oranges are mirror images of each other. The slight difference gives you a different smell.



How do polaroid filters work?
Electromagnetic waves such as light are transverse waves; they have two parts, an electric field and a magnetic field that oscillate at right angles to the direction it is travelling in. When an electromagnetic wave is polarised some of these vibrations on the electric field are blocked and only vibrations in one particular orientation get through.

A polaroid filter can be thought of as a type of grill which causes this polarisation, however, it does not block out the vibrations that transect the grill, but blocks those that are parallel to the grill. Therefore, if the filter is vertical, then the horizontal electric field vibrations get through, if the filter is horizontal then the vertical vibrations get through.

Light can be polarised by a filter or by reflection. Light reflected from a wet road is polarised parallel to the road and some sunglasses and windscreens are made of polaroid to cut out glare.

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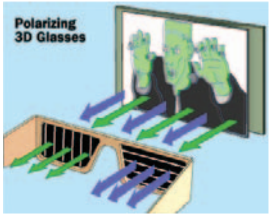
Where else can you see polarised electromagnetic waves?

Liquid Crystal Display screens (LCD)

LCD screens work by sandwiching a layer of liquid crystal between two Polaroid filters. The liquid crystal will rotate the polarisation of light unless an electric field is applied. By applying an electric field to the liquid crystal the LCD screen is able to turn on and off individual pixels which have different colour filters in front.

3D films



Polarisation is sometimes used in 3D films. Two different polarised images are simultaneously projected onto a screen. The 3D glasses contain two lenses of different polarisations which match the projections. Each lens only allows one image through to each eye which the brain combines to perceive the film as 3D.

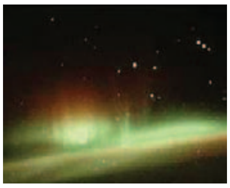
Animals

Many animals can perceive polarised light and some insects including bees use polarised light as a navigation tool. Cuttlefish use polarised light for communication, changing unpolarised light into polarised through reflecting it in certain patterns on their skin.

Television aerials

Television and radio waves are also electromagnetic waves and they are polarised. If you look at an aerial on a roof the rods will face in one direction as they must be parallel to the electric field of the transmitter. The transmitter transmits radio waves by making currents oscillate in a rod. To receive the signal, the rods must be parallel to this rod.

What are the northern lights?



The surface of the sun is a very violent place and small particles (protons and helium nuclei) can be blown off the surface in a solar wind. When these particles hit the magnetic field of the Earth they get diverted along the magnetic field to the poles. When these particles hit the gas in the atmosphere it glows making the brightly coloured aurora over the North and South Pole.

Why is the grass green?

As with any coloured objects, grass appears green because it is absorbing all the other frequencies of colours on the spectrum apart from green.

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Glossary

Electromagnetic wave (EM wave)
A wave that travels as a vibration of an electric and magnetic field. EM waves can travel where there is no matter (in a vacuum). Unlike sound waves, they don't need stuff to travel through. Our eyes can only see a small part of the electromagnetic spectrum (visible light). The spectrum includes microwaves, radio waves, ultra violet (sunburn), infra-red (remote controls) and X-rays (broken bones).

Polarisation
When EM waves are plane polarised, the vibrations that come out the other side are going in one direction only. Any vibrations going in other directions have been blocked by the polaroid filter.

Scattered
When light hits a mixture of small particles different wavelengths are affected by different amounts. The molecules in the earth's atmosphere are the right size to scatter blue light.

Frequency
The number of waves or vibrations that pass a point in a unit time. Low frequency sound is low in pitch. Low frequency light (EM radiation) has a longer wavelength, like radio waves (3m) or microwaves (12m). High frequency sound is high in pitch. High frequency IEM radiation, like X-Rays and Gamma Rays, has a short wavelength. This makes sense because the speed of all EM radiation is constant (in a vacuum), and since frequency is equal to speed divided by wavelength, the higher the frequency, the shorter the wavelength.

Wavelength
The distance between one peak and the next peak in a wave (ocean wave, light wave or sound wave)

For more information about polarisation the following websites may be useful

www.polarization.com

www.colorado.edu/physics/2000/polarization/index.html

www.atoptics.co.uk

www.sciencemadesimple.com/sky_blue.html

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Notes

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Designed & produced by to the point, London ref: 6084