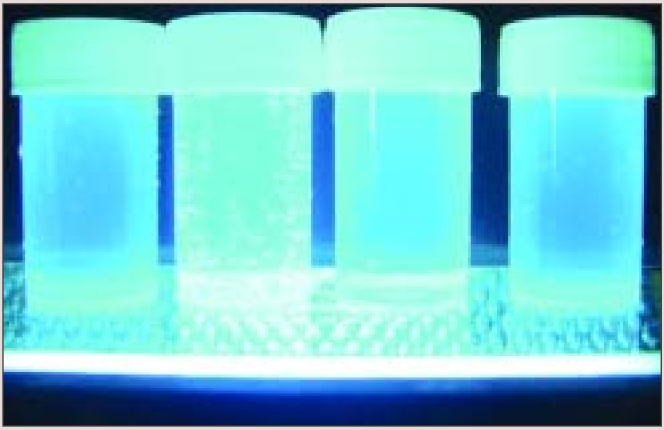
Which one is the tonic water?

Bulgaria

Fluorescence

You will need...

- ✔ four identical bottles with screw tops, three containing water and one containing tonic
- ✔ an ultraviolet lamp



Background

Ultraviolet light is invisible to the human eye but you can still see its effects.

Follow these steps

1 Present the four bottles to the class and ask them to check that one contains tonic and the others tap water.
2 Bet them (a week's homework!) that, without touching the bottles, you can identify which contains tonic.
3 Get a student to muddle them up out of your sight.
4 Shine the ultraviolet light on the apparently identical bottles.

So what happened?

The tonic fluoresces bright blue in the ultraviolet light so is easily identified. A component of tonic water (quinine) absorbs the ultraviolet light, which is not visible to the human eye, thereby exciting its electrons. This is an unstable state, so the electrons emit energy as photons of light in the blue end of the visible spectrum. The bottle containing the tonic therefore emits a blue light under the ultraviolet lamp.

What next?

Discuss why white materials dazzle in a disco.

Also, try viewing a passport/drivers' licence/euro note under ultraviolet light.

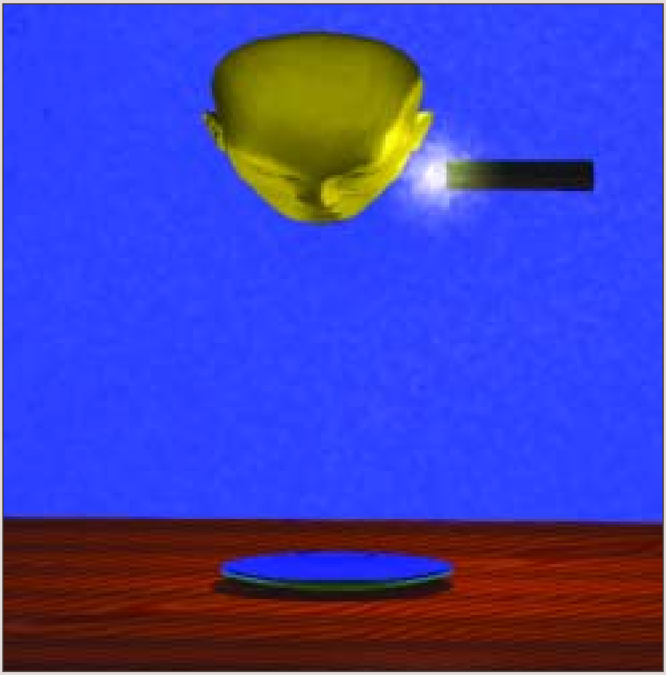
Dirty mirror

The Czech Republic

An unusual method to demonstrate interference

You will need...

- ✔ a concave shaving mirror
- ✔ a torch
- ✔ some dirt



Background

Interesting effects are created when thin films are illuminated.

Follow these steps

1 Sprinkle a thin layer of fine dirt onto the shaving mirror. A suspension of fine mud or chalk smeared onto the mirror and allowed to dry should also work, while a film of milk allowed to dry on the mirror is a good alternative.

2 Remove the head of the torch to expose the bulb, which should be clear so that the filament acts as a small point-source of bright light. Look directly at the mirror while holding the light source close to your temple.

So what happened?

You should see a pattern in the mirror consisting of bright and dark bands due to reflections from different heights on the surface, in an effect known as thin-film interference.

What next?

If you use a plane mirror you will need to hold it a bit farther away from you to see the effect clearly (about 1.5 m should be fine).

The closer you bring the light source to your eye, the better is the interference effect. In fact, if the light is in front of your eye, a circular pattern can be seen provided that the bulb is not so bright as to dazzle you.

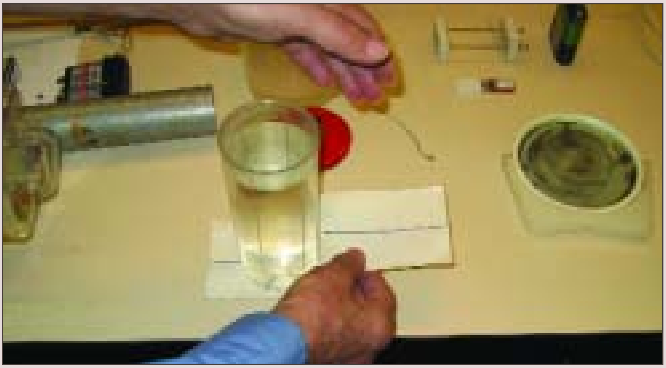
Real depth and apparent depth

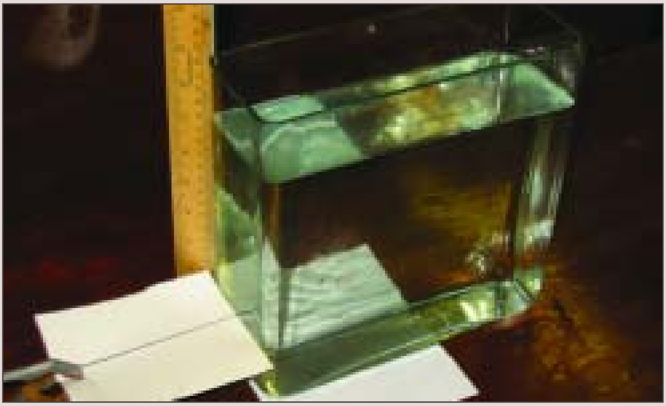
The Czech Republic

Finding the refractive index of a liquid

You will need...

- ✔ a deep glass container
- ✔ two pieces of paper





Background

Look down at your feet when you're standing in a swimming pool to see an example of refraction.

Follow these steps

1 Draw a straight line on both pieces of paper.
2 Place one of the sheets under the glass container.
3 Looking down into the container from above, raise the second sheet of paper until the two lines appear to coincide with no parallax.
4 Record the real and apparent depths.
5 Calculate the refractive index from the formula:

$$\text{refractive index} = \frac{\text{real depth}}{\text{apparent depth}}$$

So what happened?

The light travels more slowly through the water than through the air so the wavefront changes direction.

What next?

To improve the accuracy of this experiment, use a deep container with straight sides, such as a chromatography jar. You may wish to use a waterproof card placed in the water to eliminate any errors due to the refractive index of the glass in the bottom of the container. If the glass is thin compared with the depth of the water there will not be a significant error in your calculation.

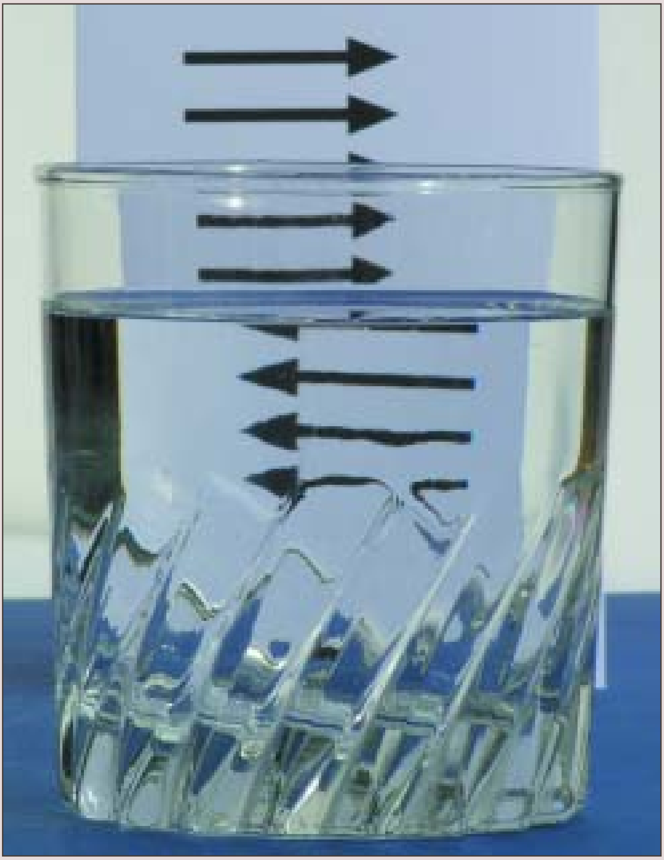
The water lens

The Czech Republic

Lenses can be made of many different materials

You will need...

- ✔ a glass of water
- ✔ a piece of card with an arrow drawn on it



Background

This demonstration shows the inversion of images and also that lenses can me made from several materials other than glass.

Follow these steps

1 Place the card behind the glass of water.
2 View the arrow through the water.

So what happened?

The direction of the arrow is reversed when viewed through the water. This is a simple way to introduce the way in which lenses work.

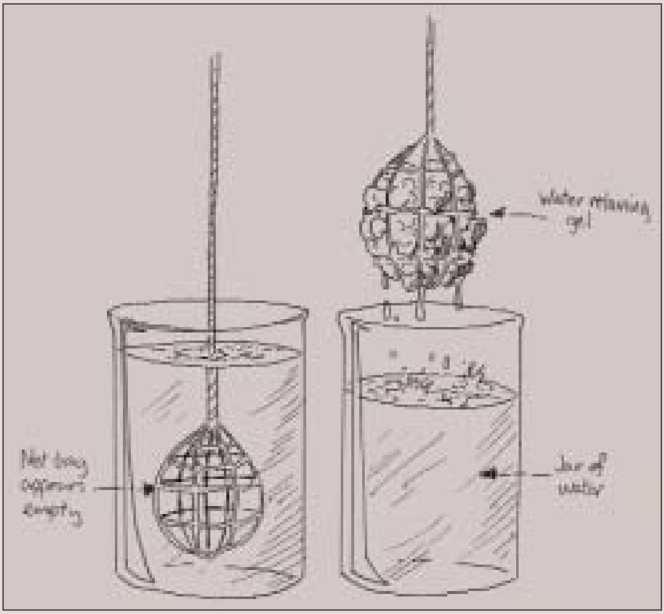
What next?

Further work can be done by producing ray diagrams for the water lens.

Disappearing crystals

Ireland

An intriguing introduction to refraction and refractive index



Background
The speed of light depends on the type of material that it's travelling through.

You will need...
- ✔ a container of water
- ✔ a small net bag to hold crystals (e.g. the type in which vegetables and fruit are often sold)
- ✔ a piece of string to secure the net
- ✔ Chempak Supergel crystals or equivalent (sold in garden centres to conserve water in hanging baskets, etc)
- ✔ a spoon

Follow these steps
1 Soak a few of the crystals in lots of water. Water that has been boiled and cooled works best as the gel formed contains fewer air bubbles, which are easily visible because the refractive index of air is so different from that of water.
2 Use a spoon to transfer some of the gel to the net bag.
3 Tie the bag at the top with string and lower it into the container full of water until it is completely immersed.
4 Note what happens to the appearance of the gel in air and in water.

So what happened?
The gel is visible when held in the net bag in air. However, when immersed in water the bag looks empty. The refractive index of the gel is the same as that of the water. When immersed in water, light is not refracted at the junction between the gel and the water, so the junction can't be seen.

What next?
Explore the refractive index of various materials.

Disappearing glass rod

Bulgaria

Another illustration of refraction and refractive index

You will need...

- ✔ two glass rods
- ✔ two small beakers
- ✔ Clinique body oil (or a cheaper alternative, if you can find one)

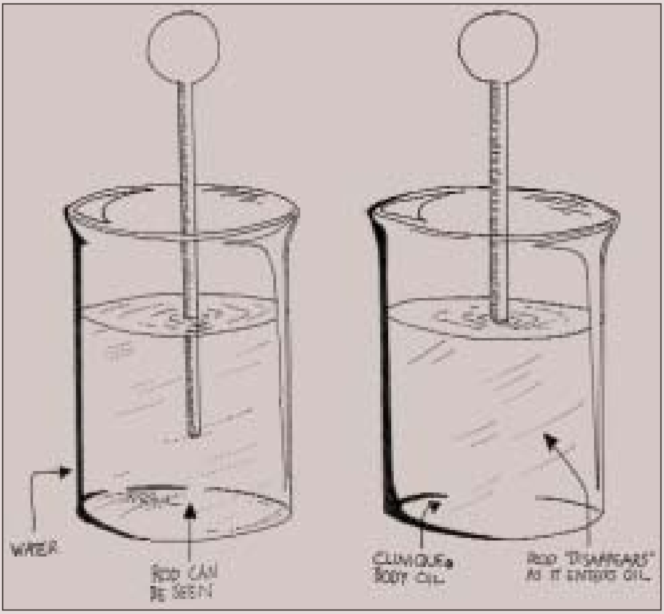
Background

Solids and liquids can have the same refractive index.

Follow these steps

1 Put water into one of the beakers and the body oil into the other.

2 Slowly lower a glass rod into each and record what happens.



So what happened?

The rod is visible in the water because glass and water have different refractive indices. The light rays are refracted as they pass from one to the other, so the junction between the two is easily seen. The rod seems to disappear as it enters the body oil, because this has the same refractive index as the glass.

What next?

This can lead to an explanation of how this technique is widely used in forensics to establish the precise source of fragments of glass found at a crime scene (e.g. from a particular type of car headlamp or window). The glass fragments are placed in standard oils of known refractive index. The oil in which the fragments “disappear” has the same refractive index as the glass.

How to make a wooden mirror

Slovakia

An unusual way to illustrate total internal reflection

You will need...

- ✔ a thin piece of wood
- ✔ a polythene pocket
- ✔ a container of water

Background

Total internal reflection can occur when a ray of light passes from water to air.

Follow these steps

1 Pose the question: how can you make a mirror from a piece of wood?

2 Place the wood in the polythene pocket and then into the water, making sure that no water is able to enter.

3 Vary the angle of the wood in the water. At a particular angle the part of the wood that is submerged will act like a mirror.

So what happened?

At a particular angle, total internal reflection occurs in the layer of air, between the wood and the polythene, so that it behaves like a mirror.

What next?

See what happens when you put your finger into a glass test tube and then lower it into a beaker of water.

Images in a shiny can

The Czech Republic

You can't trust images reflected from a curved surface

You will need...

- ✔ a shiny can
- ✔ some cocktail sticks

Background

This exercise will give the students an understanding of how images are formed at curved surfaces.

Follow these steps

1 Ask the students to form patterns with the cocktail sticks while not looking at the sticks themselves but using only the reflection in the can to guide them.

So what happened?

Curved mirrors produce distorted images.

What next?

A similar exercise can be carried out using concave mirrors.

Investigating colour

Ireland

How are colours made using stage filters?

You will need...

- ✔ some red, green and blue stage filter paper
- ✔ a pair of safety spectacles
- ✔ a colour table to view with the spectacles and fill in (see table). You can create the table using colour marker pens or by printing one out (Paint Shop Pro or similar software may be useful)

Colour	Red	Green	Blue	White

Background

All colours can be made from the three primary colours: red, green and blue.

Follow these steps

1 Cut the filter paper so that it can be inserted inside the safety spectacles.

2 Ask the students to view each of the colours in the table through each of the colour filters and with no filter, then record whether each colour appears light, medium or dark.

3 Review with the students how the colours appear.

So what happened?

Coloured light is made up of red, green and blue light. When you look at a yellow object through a primary blue filter, only blue light is allowed through, so that is the colour that the object appears to be. When you look through a primary red filter at a primary blue object, the object will appear black or at least very dark, because the red filter does not allow the blue light from the object through. (Primary colour filters work best.)

What next?

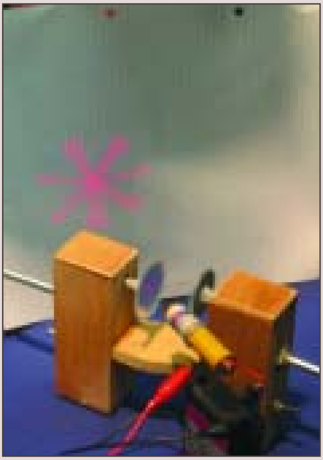
Put the students into teams of three, each student wearing a red, green or blue pair of spectacles. Then hold up objects of different colours and ask them to identify the colour of each object.

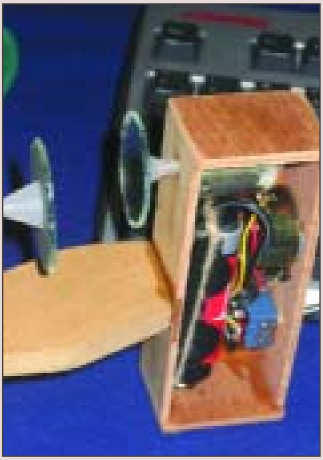
This exercise leads nicely into looking at how the eye sees colour; examining colour blindness; and investigating how colour is created on a television screen.

Laser show

Greece

Simple apparatus for a laser light introduces reflection





You will need...

- ✔ two dental mirrors
- ✔ two DC electric motors
- ✔ two plastic pipette droppers
- ✔ two 1.5 V batteries and holders
- ✔ two DPDT switches
- ✔ two 2.2 kΩ potentiometers
- ✔ a piece of white paper to act as a screen

Background

A simple laser light show can be created by shining a pocket laser onto a set of rotating mirrors.

So what happened?

As you vary the speed of the motors and the direction of the laser light, different patterns are created on the screen.

Follow these steps

1 Mount a mirror on the end of the axle of each electric motor. The plane of the mirror must be tilted slightly with respect to the axle of the motor. To achieve this, use the end of a plastic dropper pipette cut at the required angle and glued to the back of the mirror with epoxy glue. The tip of the pipette should fit snugly onto the axle.

2 Wire each motor to a 1.5 V battery. The motor speed can be controlled by a 2.2 kΩ potentiometer in the circuit. Varying the speed of the motor will allow you to change the laser pattern produced. A switch to reverse the direction of each motor should also be included.

3 Arrange the mirrors and laser so that the laser light reflects from one mirror back onto the second one before hitting the screen. Arranging the apparatus for the first time may take a bit of fiddling about. Once you have found an arrangement that works, attach the components to a base.

Hot headlamps

The Czech Republic

An everyday application of reflection of light in concave mirrors

You will need...

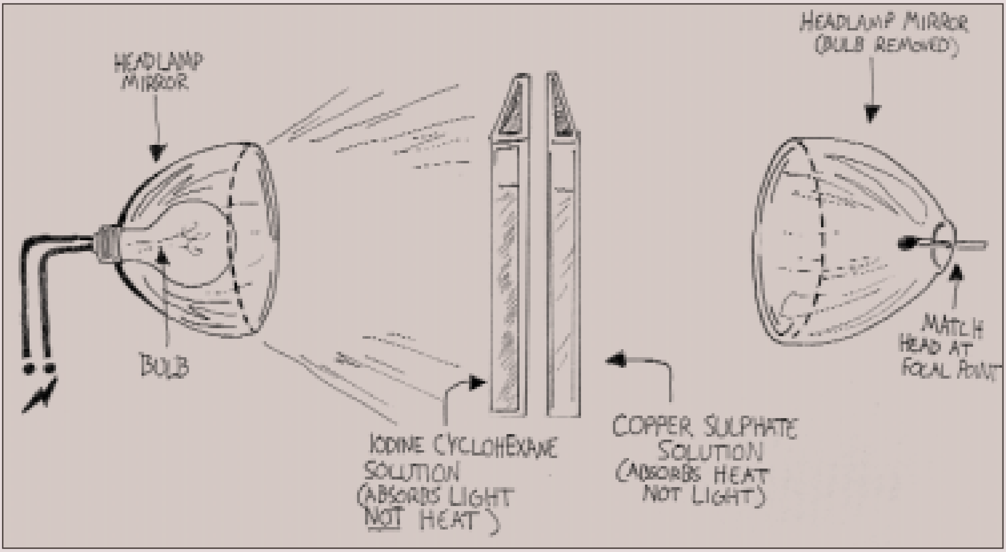
- ✔ two car headlamps (the older round ones are probably the best – not the sealed units – available reasonably from scrapyards)
- ✔ some matches
- ✔ four panes of glass
- ✔ some waterproof sealant in a gun
- ✔ a dilute solution of copper sulphate (~0.2 Molar)
- ✔ a solution of iodine in cyclohexane (~1 Molar)
- ✔ a power pack
- ✔ two retort stands

Follow these steps

1 Remove the bulb and the reflector in front of the bulb from one of the lamps.
2 Clamp this lamp.
3 Clamp the second lamp directly facing the first about 0.5 m away from it.
4 Connect the power pack to the back of the second lamp to illuminate the bulb.
5 Hold a match in through the hole at the back of the first lamp so that the match head is roughly at the focal point of the mirror and watch what happens.
6 Place a line of sealant along three sides of two panes of glass and place a second pane of glass on each, thus making two narrow containers that can hold liquids. Allow them to dry.
7 Fill one of the containers with dilute copper sulphate solution.
8 Grind iodine crystals with a pestle and mortar and add cyclohexane to them to make a dark purple solution. Then pour this solution into the second container.
9 Repeat step 5, first with the copper sulphate solution and then with the iodine solution between the two headlamps.

Safety notes

- When connecting the power pack, take care not to exceed the voltage of the bulb (usually 12 V).
- Copper sulphate and iodine are both toxic, so use gloves.
- Don’t put your finger in the hole at the back of the headlamp to feel if it is hot – it is.



So what happened?

When the match head is held at the focal point of the lamp it smoulders then bursts into flame. The bulb at the focal point of one mirror produces visible light and infrared radiation, which are reflected off the mirror in a parallel beam to the other mirror. Here they are reflected into the focal point, where the match head is.

This is the principle behind some types of solar power stations. The copper sulphate solution absorbs infrared but only a little of the visible light. The light is reflected to the focal point of the mirror but the match doesn't ignite.

The iodine absorbs most of the visible light but not the infrared. Only a little light passes through to be reflected off the mirror but the match still lights, showing that the infrared passes through the solution and is reflected into the focal point.

After a few "ignitions" the second mirror can get very sooty and doesn't work as well, so clean both mirrors periodically with a soft cloth.

What next?

This can lead on to solar power, the visible spectrum and infrared radiation.

Words in a tube

The Czech Republic

Refraction and lenses

You will need...

- ✔ a test tube or boiling tube and bung
- ✔ water
- ✔ words written on a sheet (see diagram)

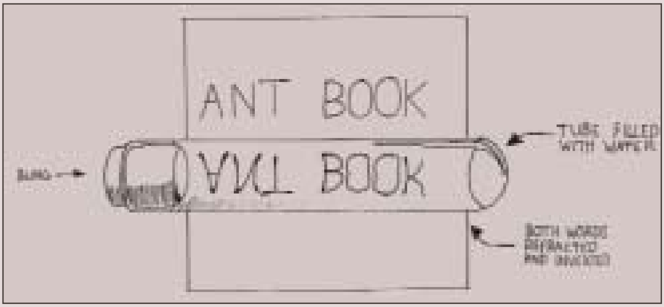
Follow these steps

1 Fill the tube with water and insert the bung securely.
2 Hold the tube horizontally, over the words.
3 Move the tube up and down (towards and away from your eyes) until you can see the words.
4 Describe what you see.

So what happened?

It will appear that one word in each pair is inverted while the other is not. In fact, both words are inverted but the words are chosen so that one is formed entirely from symmetrical letters, so that it appears the same when inverted.

So many school experiments are very predictable, whereas this simple activity will really surprise and stimulate thought and discussion to determine what is happening.



BOOK	WAY
HIDE	PRAM
BED	MUST
DOCK	SAY
DEED	START
CODEX	LAMP

What next?

An alternative means of illustrating the same point is to write CARBON DIOXIDE on one side of a bottle and then rotate it so that you are viewing the words through the bottle.

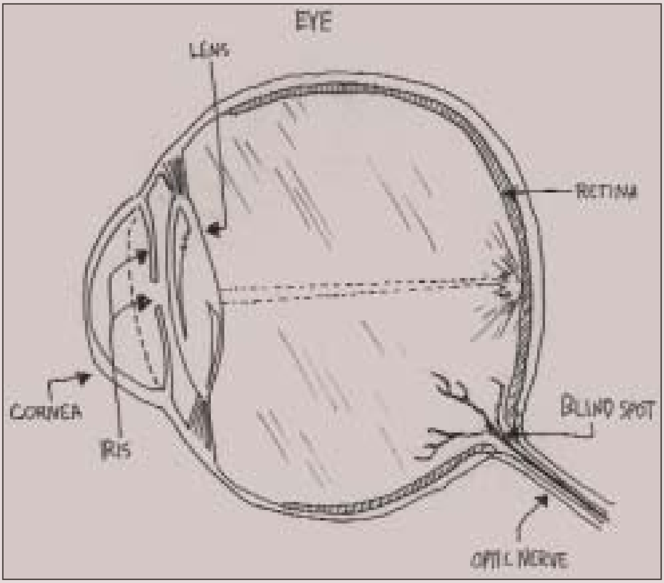
How the eye works: introduction

Bulgaria

How the different parts of the eye and brain contribute to vision

You will need...

- ✔ an overhead projector and screen
- ✔ small circles of red and green filter (diameter ~2 cm)
- ✔ green and red filters (106 and 139 from suppliers of filters for stage lighting)
- ✔ an image from the Internet (www.ebaumsworld.com/manillus.html)
- ✔ for each person, a square of black card (~4 × 4 cm), a pin, a rubber band, two matches and a long measuring tape
- ✔ some plain white paper
- ✔ a thick black marker pen
- ✔ an optician's Snellan chart



Background

The following experiments are equally relevant to physics students studying the refraction of light by lenses and to biology students studying vision. They have the enormous dual advantages of involving students actively in the experiments yet requiring only very simple equipment.

The nine experiments show in turn how the following parts of the visual system contribute to human vision: the aqueous humour, the pupil, the lens, the retina, the rods, the cones and the brain.

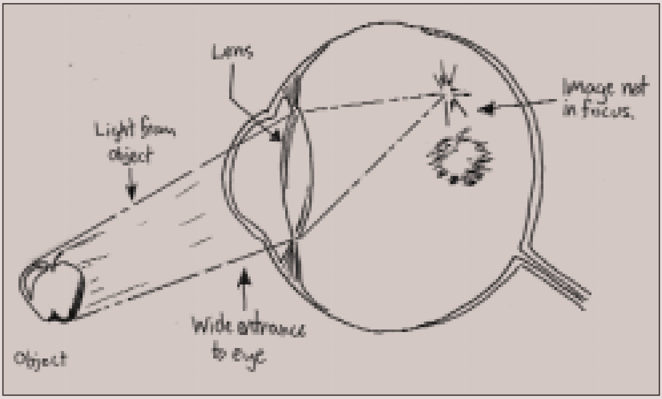
The retina is the layer of cells in the eye that are sensitive to light, including the rods (black-and-white vision) and the cones (colour vision). The fovea is the place on the retina where the cones are concentrated and where the image is focused for the best vision when you look directly at something. The brain also plays a vital role in the amazing sense of vision.

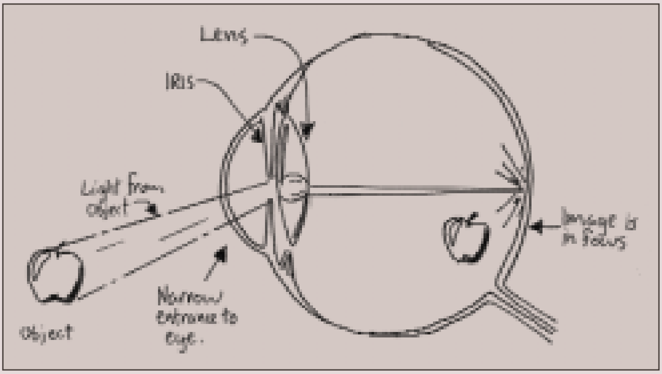
How the eye works, continued...

Pupil: why have a narrow entrance to the eye?

Follow these steps

1 Make a small pinhole at the centre of the card.
2 Without the card, focus on an object at the front of the room and hold the pin in front of you at arm's length.
3 Still focusing on the distant object, bring the pin closer and closer until it goes out of focus.
4 Note how far away the pin is when this happens.
5 Now focus on the same distant object as before but view it through the hole in the card.
6 Move the pin closer and closer as before, noting the distance at which it becomes out of focus.



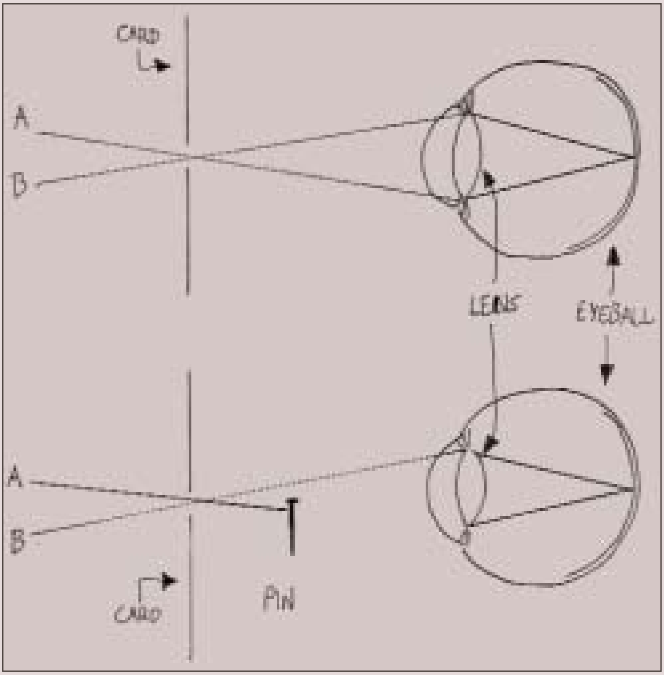


So what happened?

The pin remains in focus much closer to the eye when you look through a small hole. A much greater depth of field is in focus when the entrance to the eye is smaller. The small entrance to the eye means that the light coming from both objects (the distant object and the pin) is much more similar, so the depth of focus is greater (see figure).

How the eye works, continued...

Lens: what kind is it?



Follow these steps

1 Look through the pinhole in the card at the brightly lit screen in front of the overhead projector.
2 Hold the pin between one eye and the card.
3 Move the pin around until you can see the shadow (image) of the pin.
4 Move it up and down slightly and record what you notice.

So what happened?

The shadow of the pin is inverted. This can only be explained if the lens in the eye is a convex lens and the pin is blocking some of the rays of light entering the eye (see figure). Images on the retina are normally inverted and the brain turns them upright. The shadow of the pin is really the same way up as the pin, so it looks inverted.

Aqueous humour: is the eye full of fluid?

Follow these steps

1 Illuminate the screen with the overhead projector.
2 Use the pin to make a small hole in the centre of the card.
3 Hold the card in front of one eye and look through the hole at the brightly lit screen.
4 Keep looking for at least 1 min.
5 Describe what you see.

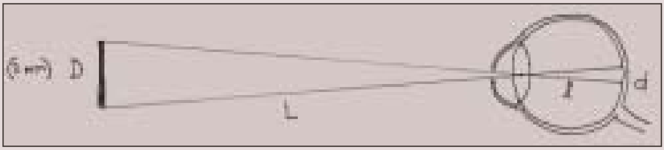
So what happened?

You will see "floaters" – strands and particles moving around in the fluid of the aqueous humour. This fluid plays an important role in maintaining the shape of the eyeball, which is essential if the image is to be focused precisely by the lens onto the retina.

The pressure of the fluid is accurately maintained by a duct, but it is important in middle age to get this pressure checked to screen for a condition called glaucoma, which can do permanent damage to sight if left untreated.

How the eye works, continued...

Retina: how far apart are the rods and cones?



Follow these steps

1 Place a sheet with two parallel black lines 2 mm apart at the front of the room

2 Ask who can distinguish the two separate lines.

3 Measure the distance from the sheet to the farthest students who can distinguish the two lines.

4 Take eyeball length to be approximately 20 mm and use geometry (see diagram and formula) to determine the distance between the light-sensitive cells.

$$\frac{L}{D} = \frac{l}{d}$$

where $l = 20$ mm, $D = 2$ mm and L = distance measured.

So what happened?

You should calculate the distance between the light-sensitive cells to be approximately 8–10 µm.

This simple activity involving the whole class has the added bonus of showing that geometry does actually have its uses.

What next?

If you can get hold of an optician's Snellan chart, the students can measure their own visual acuity, which they always enjoy.

Retina: where are the blood vessels?

Follow these steps

1 Hold the card in front of one eye with the other eye closed.

2 Look through the hole at the brightly lit screen.

3 Vibrate the card quickly while still looking through the hole.

4 Note what you see.

So what happened?

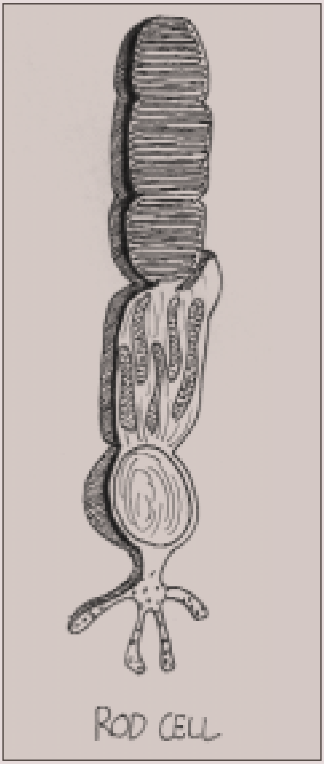
The retina is made of living cells, so it has blood vessels to supply these cells with the food and oxygen that they need to survive. Normally the image of these blood vessels is there all of the time and the brain ignores it, but in this experiment the messages are so confused that this does not occur and you can see them.

How the eye works, continued...

Rods: how do they work?

Follow these steps

1 View the Internet image on the screen for 1 min (see www.eyetricks.com/jesus.htm).
2 Remove the image and stare at the white screen.
3 Note what you see (try blinking).



So what happened?

You will clearly see an after-image of Jesus Christ.

The rods – the most numerous of the light-sensitive cells in the retina – contain a pigment, rhodopsin, which is sensitive to light. When the pigment is exposed to light it breaks down, causing an impulse to pass along the optic nerve to the brain.

When you stare at the original image, the bright parts cause the rhodopsin in the corresponding cones in your retina to break down and send messages to the brain. The dark parts of the image emit no light, so the corresponding rods send no messages.

When the image is removed, the rods that were receiving no light (corresponding to the dark areas of the original image) start receiving light, causing rhodopsin to break down and messages to be sent to the brain, so these areas look bright.

However, the rhodopsin in the rods that were originally receiving light has been broken down and has to be reformed before it can be broken down again and messages can be sent to the brain. When the image is removed, these areas thus appear darker. The result is an after-image of the original.

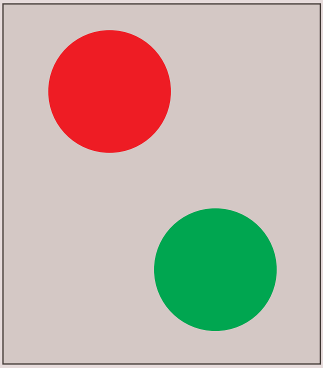
How the eye works, continued…

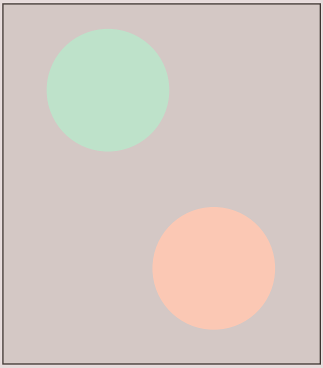
Cones: how do they work?

Follow these steps

1 Project two small circles of red and green filter placed side by side.
2 View the screen for 1 min.
3 Remove the colours.
4 Record what you see.

Note: If filters are not available, this also works with squares of vividly coloured paper held in strong light for 30–60 s.



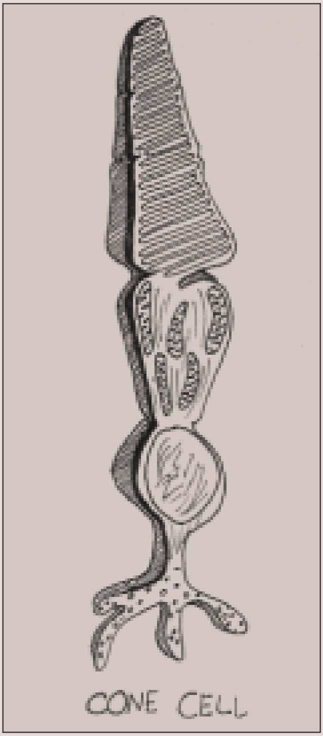


So what happened?

Most people see red where it was green and green where it was red.

There are three types of cone in the retina – sensitive to each of the three primary colours. After staring at red for a while, the red-sensitive cones are less sensitive because some of the pigments in them have been broken down, so when the colour is removed and the retina is bombarded with white light (containing all three primary colours), the messages sent from the green- and blue-sensitive cones are stronger for a while. Similarly, after staring at green, it is the red and blue cones that send most messages.

Some people claim instead that they see the complementary colours (i.e. cyan where there was red and magenta where there was green), but they may have been physics teachers used to looking at their results with the eye of faith. There is also likely to be some individual variation, depending on which part of the retina the image was focused on.

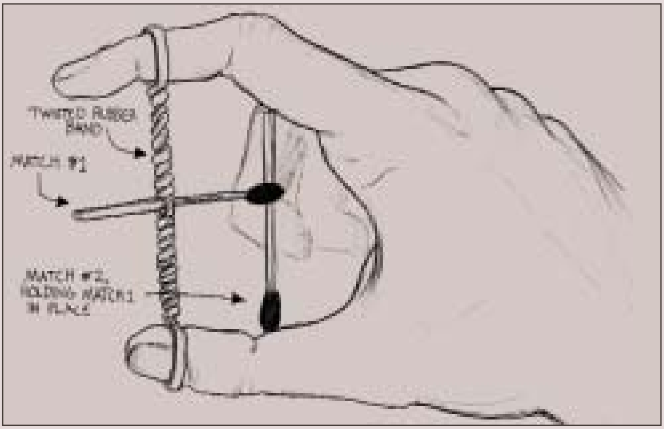


How the eye works, continued...

The brain: what is its role in vision?

Follow these steps

1 Place a rubber band over the thumb and first finger of one hand in a "C" shape.
2 Place a match between the strands of the band and twist it round many times.
3 Place a second match between the thumb and forefinger so that it holds the first match in place and prevents it from turning.
4 Half rotate the first match and then let go.



So what happened?

It appears as if you are rotating one match through the other even when you watch quite closely. The wound-up elastic in fact rotates the match back to its original position each time it is let go, but this movement is too quick for the eye to respond to, so the brain makes the logical interpretation that the match is being rotated in a circle.

Fovea: what is it for?

Follow these steps

1 Repeat the experiment on p42 but look more carefully.
2 Look for a clear area in the centre of the retina with no blood vessels – the fovea.
3 View the letters projected onto the screen from an OHP.
4 Stare at the centre letter.
4 Note which letters either side of the centre letter is out of focus.

E M C L I A G D F H J K B N F X R

So what happened?

The fovea is at the centre of the retina where there is the highest concentration of light-sensitive cells, especially the cones for colour vision. This is why the best vision is at the centre of the field of view (the central letter) while vision deteriorates farther from the centre as the image lies farther and farther from the fovea.