LightWorks

Teacher's exhibition notes

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ScienceWorks and The Observatory Science Centre are part of Science Projects, an educational charity specialising in the communication of science through hands-on exhibits.

FROZEN SHADOWS

Light travels in straight lines
Light can affect surfaces it falls on

DESCRIPTION
This exhibit has a photoluminescent screen, which reacts to light falling on it by emitting yellow light for a short time afterwards. When the switch is pressed a bright light shines on the screen for about two seconds. Placing a hand or other object in the way of the light falling on part of the screen prevents it from glowing, creating a shadow.

CURRICULUM LINKS
Key stage 1
"Pupils should have opportunities to explore light sources and the effects related to shadow..."
Key stage 2
"Pupils should investigate the formation of shadows..."
Key stage 3
"Pupils should study the behaviour of light, particularly its transmission, absorption... They should learn how light is...used in a range of common optical devices, for example,…simple camera..."

RELATED EXHIBITS
Laser amazer
Demonstrates that light travels in straight lines.
Pin-hole camera
Shows the formation of an image by allowing only a portion of light to pass.

WHAT TO DO
Put your hand or other object between the light and the yellow screen. Press the switch. After the flash of light move your hand away.

Q: What do you see on the screen?
(A: A shadow of your hand.)

(NB. There is a short delay before the light can come on again.)

MORE THINGS TO DO
Repeat, putting your hand or object at different distances from the screen.

Q: How does this affect the size and sharpness of the shadow?
(A: The shadow is larger but less clear if your hand is nearer to the lamp.)

Turn your hand or object round a bit and try again.

Q: How does it affect the shadow?
(A: It can change its shape.)

Q: Why?
(A: The amount of light blocked by many objects depends on which way the object is facing.)

Try moving your hand slowly while the lamp is on.

Q: What happens to the shadow?
(A: It becomes blurred - more if the movement is fast, less if the movement is slow.)

Q: What does this remind you of?
(A: Photography - this exhibit is a very simple form of photography.)

Try using materials such as loose knitting or your hair.

FROZEN SHADOWS: FURTHER INFORMATION

Light travels in straight lines
Light travels in straight lines away from a light source until it hits an object.

Light which just passes the edge of an object will continue in a straight line, striking a surface beyond, which we would see as being a 'lit' area. Light which strikes the object is stopped, and all the areas which it would have reached on the surface are not 'lit' Ð we call this area a shadow.

How shadows can change
The shape of a shadow depends on the position and angle of the object.

Photoluminescence
The screen is photoluminescent. It absorbs the energy of light and stores it for a short time, slowly emitting it as the yellow light you see. Eventually the glowing area fades and becomes indistinguishable from the shadow. Emergency exits signs use this material so they will glow for a time in the event of a power cut. It is also used on the edges of steps for similar reasons.

MIRROR DRAWING

Light travels in straight lines
Sight, and how our brains act on what we see, can be important in controlling what we do

DESCRIPTION
A piece of paper with designs on it can be placed under a small screen where it cannot be seen, but can be drawn on. A mirror behind the screen shows a reflection of the paper. The sample paper in this booklet has some simple designs printed on it, which you should photocopy. You can try to draw round the shapes with a pencil while watching what you are doing via the reflection in the mirror.

CURRICULUM LINKS
Key stage 1
“Pupils should have opportunities to explore...effects related to...reflection...”
Key stage 2
“Pupils should learn about the reflection of light...and relate this to everyday effects.”
Key stage 3
“Pupils should explore the nature of vision, leading to an appreciation that vision occurs because light enters the eye and signals are interpreted by the brain.”

RELATED EXHIBITS
Mirror maze
Flat mirror placed at different angles show single and multiple reflections.
Laser amazer
By observing narrow beams of light, you can clearly see the way light reflects off a mirror.
Anamorphs
Here a mirror is used to produce a distortion of what you are drawing.

WHAT TO DO
Try drawing around the shapes on the sheets of paper provided.

Q: What happens?
(A: It is very difficult.)

Q: Are some shapes more difficult than others?
(A: Curved shapes are more difficult.)

Q: Do you get better at it?
(A: With a lot of concentration an improvement within a minute or so is quite possible.)

MORE THINGS TO DO
Have another go at this exhibit after an interval of approximately 10 minutes.

Q: Are you better at it now than before?
(A: Many people are better the second time if they have had a break from it for a while.)

Q: How can you do it better?
(A: Either by simple trial and error or by thinking carefully about how the reflection is making directions appear reversed and trying to predict the correct way to move the pencil.)

OTHER THINGS TO DO
Try combing the back of your hair while looking in a mirror in front of you, at a reflection of your head in a mirror behind you.

MIRROR DRAWING: FURTHER INFORMATION

Reflection

Light in the room is scattered in all directions from the surface of the paper. Some of this light from the paper strikes the mirror and reflects towards you. This is why you see the paper. Because the image of the paper and your hand seen in the mirror look just like the real thing, and are in generally the correct position, the brain interprets this image entering the eye to be your actual hand.

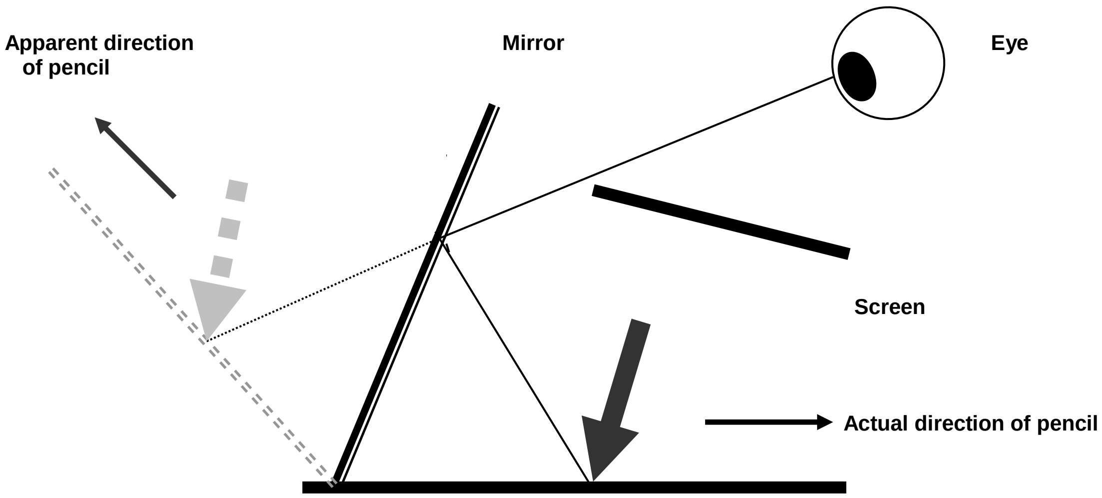
Hand-eye co-ordination

The fine movements we make with our hands are controlled by our brain. Our brain relies on our eyes to tell it what hand movements it has just made. Without being aware of it our brain uses a lot of trial and error to control our movements. For example, by guessing what direction to move then looking to see what further movement is necessary, and repeating this, the desired movement is completed. This happens rapidly enough to give smooth movement.

This system is very effective if the eyes are able to see movements correctly. If what they see is reversed (by the mirror) our brain still tries to predict the correct movement, but quickly stops the movement when it finds it is completely wrong. This can cause the brain to become confused and almost unable to control movement at all.

For example, with the mirror drawing it might look as if you should move the pencil away from you to follow the lines. The brain sends a message to your hand to start doing this. Because of the mirror your eyes get the confusing information that the pencil is coming towards you so the brain sends a message to stop.

After a time the brain learns to predict the correct direction in which to move the hand by taking into account the back to front information from the eyes and the mirror drawing becomes much easier. After practising a lot, it may be difficult to draw normally again for a while.



OPTICAL FIBRES

Optical fibres channel light along their length
Light travels away from light sources
Light reflects from surfaces

DESCRIPTION
An optical fibre bundle which consists of 100 plastic coated stands is fused together at one end, the fat end. Either end can be pointed towards a lamp or other objects, causing light to travel from that object along the fibres and emerge at the opposite end.

Coloured sheets can be placed in a position where the light illuminates them. The optical fibres can be held up to the sheets so that light which is transmitted or reflected travels into and along the fibres.

CURRICULUM LINKS
Key stage 1
“Pupils should have opportunities to explore light sources...”
Key stage 2
“Pupils should explore the effects produced by shining light through...objects...”
Key stage 3
“Pupils should study the behaviour of light, particularly its transmission...They should learn how light is...used in a range of common optical devices, for example...fibre optics...”

RELATED EXHIBITS
Laser amazer
This exhibit includes a pair of curved mirrors which cause light to travel around the curve between them in a series of short straight lines. This is useful in appreciating how light travels through an optical fibre.

WHAT TO DO
Put the fat end of the fibre bundle pointing to the bright light. Look at the other end of the fibres.

Q: What do you see?
(A: Bright light comes from each one.)

Q: Can you make some of the fibres light up while others remain dark?
(A: Put your hand over part of the fat end to block the light going into some of the fibres.)

Q: If you put your finger in front of the light, what do you see?
(A: Red. Fingers are translucent - the colour is that of your blood.)

MORE THINGS TO DO
Turn the bundle round, holding the thin ends up to the light source.

Q: What do you see at the fat end?
(A: Light shows at the fat end. Each fibre brings light to a different section.)

Hold the bundle up to the window or overhead light.

Q: What happens?
(A: It works as before but not as brightly.)

Put one of the coloured sheets in front of the bundle.

Q: What do you see?
(A: The same colour as the sheet - light passes through it.)

Hold a coloured sheet so light is reflected off it and point the bundle at its surface.

Q: What do you see?
(A: Light of the same colour as the surface is reflected along the fibres.)

OPTICAL FIBRES: FURTHER INFORMATION

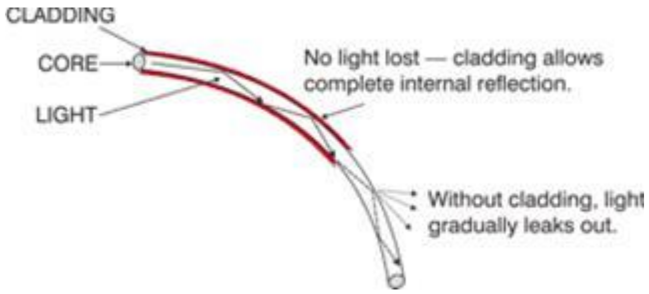
Optical fibres
Each of the 100 strands of the optical fibre bundle in this exhibit consists of many very thin fibres of glass. Each fibre is thinner than a human hair and runs all the way along its strand, covered by a protective black plastic sheathing.

Very thin fibres of glass are flexible and can be bent without breaking. The glass is also transparent - light travelling down these fibres passes through one metre of solid glass and emerges virtually undiminished in brightness. Normal window glass would not be as transparent as this if it were one metre thick.

At the 'fat' end all the fibres in all the strands are amalgamated into one block, protected by a metal ferrule. Because of the way it is made, the fibres in each strand end up in a particular sector of the block, which can be identified by letting light pass through only one strand at a time.

The colour of light is not affected as it passes along the fibres.

How light can travel round corners
Although the light appears to be able to bend when shining through the optical fibres, in fact it gets round the corners in a series of straight lines. It can do this because if the light collides with the sides of the fibre it reflects internally, glancing off the inside surface of the fibre. This internal reflection is better if there is cladding round the fibre.



Optical fibre

Light reflecting from objects
Light travelling towards any object will strike it. Some of the light bounces off, while some of the light is absorbed. The light which is absorbed is usually of particular colours, leaving the reflected light missing those colours. When we look at the object we see the remaining blend of colour and we interpret this as being the colour of the object itself. Thus leaves appear green because the other parts of white light are absorbed by the pigment chlorophyll for the process of photosynthesis.

MODEL EYES

Light travels in straight lines
Light can form images

DESCRIPTION
Two plastic models of human eyes are provided. They are enlarged six times. Each eye can be dismantled into five parts and reassembled.

CURRICULUM LINKS
Key stage 2
"Pupils should explore the effects produced by shining light through such objects as lenses..."
Key stage 3
"Pupils should explore the nature of vision, leading to an appreciation that vision occurs because light enters the eye...They should study the function of the eye."

RELATED EXHIBITS
Pin-hole camera
Shows the images formed when light passes through a small aperture and the effect of lenses and light intensity on them.
Laser amazer
Demonstrates that light travels in straight lines and shows the effect of a convex lens on light.
Frozen shadows
Demonstrates that because light travels in straight lines simple images (shadows) can be formed.
Mixing coloured light
Shows the primary colours we detect with our retinas.

WHAT TO DO
Dismantle the eye. Reassemble the parts in the correct order.

Q: Can you find: the lens, the retina, the optic nerve?
(A: Yes.)

Try to identify the pupil.

Q: The pupil of an eye is black. Take the eye apart - can you find where this black part is?
(A: No - the pupil is a hole to the inside of the eye. The inside is dark because little light gets through the pupil. From the outside it looks black.)

Look at your own eye in a mirror.

Q: What parts from the model can you see in your own eye?
(A: The white outside, the transparent cornea, the iris and the pupil in the middle of it.)

MORE THINGS TO DO
LEFT: Look at the picture.

Q: Can you see a number?
(A: If you see 29, then you have standard colour vision. If you see 70, then you are partially colour blind (red-green). If you can see no number at all, you have total colour blindness.)

RIGHT: Look at the creature. Then put on the spectacles.

Q: What do you see?
(A: The creature appears as 3-D and coming out of the picture towards you, provided you have the spectacles with red side to your left eye.)

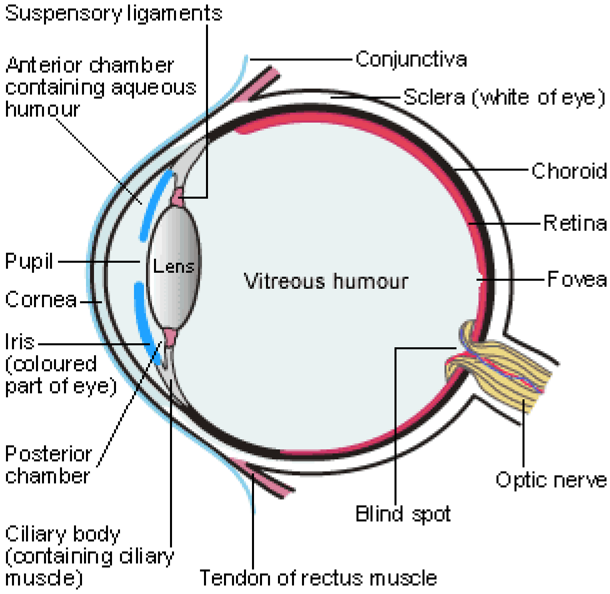
MODEL EYES: FURTHER INFORMATION

The pupil

When we look at an object reflected light from it enters our eyes. Light first passes through the pupil - a circular hole in the middle of a ring of muscle (the iris). The iris can alter the size of the pupil to allow more light into the eye when dark, and less if it is too bright.

Accommodation

Just behind the pupil is the lens. Changing the shape of the lens, using the circular ciliary muscle, bends the light more (for near objects) or less (for distant ones). The light passes to the back of the eye – the retina - focused on a small area - the fovea or macula - where the colour receptors - the cones - are concentrated. These are special cells which detect light falling on them and send signals to the brain along the optic nerve.



Cross-section of an eye

Forming an image

The pupil and lens form an image of the object we are looking at on the retina. Like the pin-hole camera, the image is actually upside down - but our brains reinterpret it the right way up. Short-sightedness or long-sightedness occurs when the lens forms an out of focus image on the retina. These conditions can be corrected by glasses.

Judging distance by stereo vision

Our left eye receives light travelling from an object in one direction; our right eye receives light travelling from the object in a slightly different direction. The difference between the two directions depends on how far away the object is. Our brain is able to judge accurately this distance from the images formed in our left and right eyes.

In the right picture in this exhibit two images of the insect, one in red, the other in green are positioned next to one another. The spectacles contain green and red filters. Each will allow you to see only one of the images. The effect of the positions of your eyes and the images is that they appear as a single three dimensional image.

Colour vision

The picture on the left is a test for colour-blindness. This is quite common in society but many with the condition are unaware of it. There are three types of light receptors for colour, the cones – red, blue and green. Those with colour blindness have less than three. The red-green variety is quite common, but the total condition is rare. Whereas we have three colour receptors many mammals have only two or even none. But other creatures like the goldfish have four, while insects and some birds can see ultra-violet and some snakes, infra-red.

PINHOLE CAMERAS

Light can form images
Altering the distance between a lens and a screen can focus images

DESCRIPTION

Three 'cameras' are provided. At the front of each is a hole. One camera has a small hole, one a larger hole, and the third a large hole with a lens. The cameras can be pointed at any bright object, perhaps out of the window. The inner tube has a large viewing hole at the back and a screen inside the camera. The screen can be moved in and out to focus the image.

CURRICULUM LINKS

Key stage 1

“Pupils should have opportunities to explore light sources...and the effects related to shadow...and colour.”

Key stage 2

“Pupils should explore the effects produced by shining light through such objects as lenses...”

Key stage 3

“Pupils should explore the nature of vision...They should learn how light is controlled and used in a range of common optical devices, e.g. the simple camera. They should study the function of the eye.”

RELATED EXHIBITS

Model eyes

Show the shape and relation of the parts of the eye.

Laser amazer

Demonstrates that light travels in straight lines and shows the effect of a convex lens.

Frozen shadows

Demonstrates that because light travels in straight lines, simple shadows can be formed.

WHAT TO DO

Looking through the view hole, point the camera with the smallest hole out of the window or at a light bulb. Move the inner tube in and out to see the effect.

Q: What do you see?

(A: A slightly blurred, faint, upside- down image of what the camera is pointing at. This is a pin-hole camera.)

Use the one with the slightly bigger hole.

Q: What do you see?

(A: A fairly bright but very blurred image of what the camera is pointing at.)

Try using the one with the lens in a large hole.

Q: What do you see?

(A: When the screen is in the right place, an upside-down image of what the camera is pointing at. This is a camera obscura.)

MORE THINGS TO DO

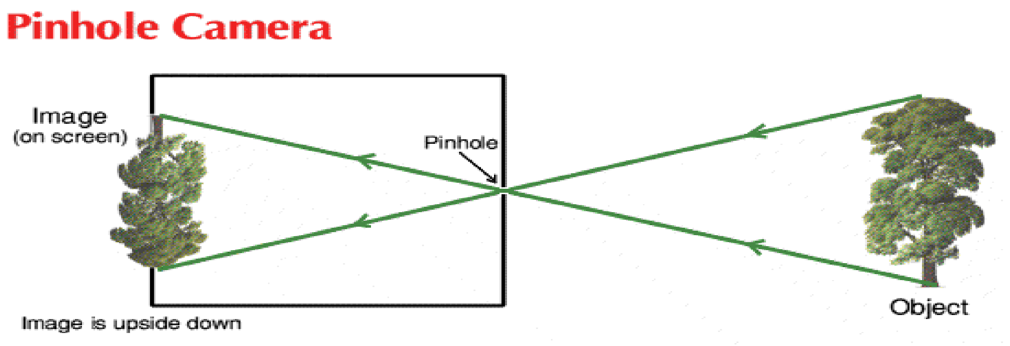
Look inside the camera - especially the one with the lens, while it is pointing at a bright object.

Q: What do you see?

(A: A screen which is fixed at the far end of the inner tube. The picture seen inside the camera is on the screen. In a real camera the film would be in the position of the screen.)

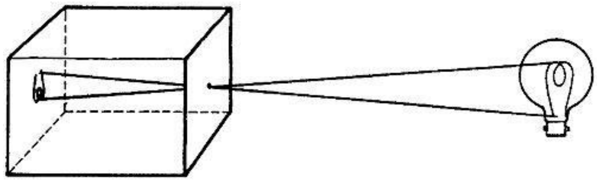
PINHOLE CAMERAS: FURTHER INFORMATION

Light travels in straight lines
Light travels in straight lines away from a light source or a lit object in all directions. This means that some of it enters the hole at the front of the camera when it is pointing towards it. Light from each part of the object enters the hole. The rays cross over as they go through the hole, forming an image which is upside-down and reversed from side to side. The brightness of the image depends on how much light gets into the camera. This depends on the size of the hole and how bright the subject is.

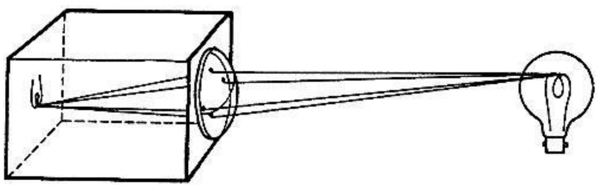


Sharpness of the image
Consider the light travelling from one particular spot on the subject, outward in all directions. A large hole will allow a number of rays of slightly different directions to pass through and fall on slightly different parts of the screen. This means that the image of that particular spot on the subject appears spread out. When the part of the image corresponding to each part of the subject is spread out and overlapping, we see the image as blurred. Even the image from a small hole is blurred, but if the blurring is not very great the image of the subject is easily recognisable.

The effect of a lens
Light passing through the lens changes its direction. A convex lens bends all the light passing through it back towards its centre line, and light from a particular spot on a subject gets closer together rather than getting further apart. When a camera with a large hole is used - to make the image brighter - the lens can counteract the blurring effect otherwise caused by the large hole (or aperture). This was first used in the sixteenth century to form images on a large screen. It was called a Camera Obscura. Placing light sensitive material at the focal point creates a modern camera.



Pinhole camera



Camera obscura with lens

MIRROR MAZE

Light travels in straight lines
We see things because light travels from an object to our eyes

DESCRIPTION
LEFT: This is a mirror table on which separate movable mirrors which can be positioned.

RIGHT: A box with partitions is arranged like a maze. In one corner is a transparent panel and in the opposite one a viewing window. The mirrors can be placed in the box to direct the light from the panel around the obstacles. If this is done successfully the picture on the panel can be seen through the viewing hole when the box lid is down.

CURRICULUM LINKS
Key stage 1
"Pupils should have opportunities to explore...effects related to...reflection..."
Key stage 2
"Pupils should learn about the reflection of light...and relate this to everyday effects (mirrors...)"
Key stage 3
"Pupils should explore the nature of vision, leading to an appreciation that vision occurs because light enters the eye.... Pupils should study the behaviour of light, particularly its...reflection..."

RELATED EXHIBITS
Mirror drawing
This shows the difficulty of hand-eye co-ordination when watching your hand moving only in reflection.
Optical fibres
Blocking one end of the fibres shows that light travels in a certain direction.
Laser amazer
Light beams travelling in straight lines can be clearly seen and investigated.
Anamorphs
A curved mirror is used to produce a distortion of what you are drawing.

WHAT TO DO
LEFT: Arrange the mirrors in various ways. What you will see reflected? Check to see if you were right.

Arrange two long mirrors parallel at right angles to your line of vision. Looking at the rear mirror from the right side, place an object on the left and behind the near mirror so that you can see its reflection.

Q: Can you still see the object if you put a hand over the middle of the near mirror?
(A: No. Your hand blocks the view, because the image is reflected three times before it reaches your eye.)

Q: What do you see if you arrange three small mirrors in a triangle?
(A: With three mirrors in a triangle you see an endless pattern of triangles as in a kaleidoscope.)

RIGHT: There is a figure on a transparent panel in one corner. Arrange the mirrors inside the box so that you can see it, looking through the viewing window at the front.

Q: What is the smallest number of mirrors required?
(A: You can do it with three.)

Q: What happens to the image if you use this number?
(A: It's reversed. It is only the right way round with even numbers of mirrors.)

Q: What happens if you place the white panel behind the image?
(A: It is easier to see. The white panel reflects more light into the back window and provides a greater contrast behind the figure.)

MIRROR MAZE: FURTHER INFORMATION

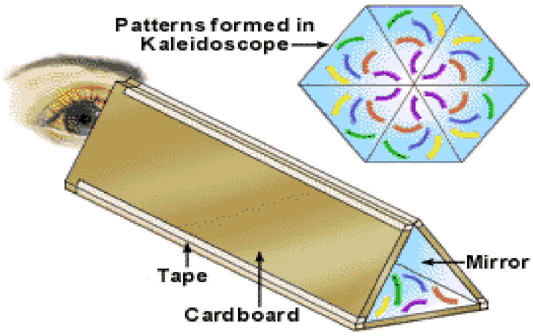
Reflection
Light bounces off a mirror in the same sort of way as a rubber ball bounces off a wall - the angle it hits the mirror is the same as the angle it leaves.

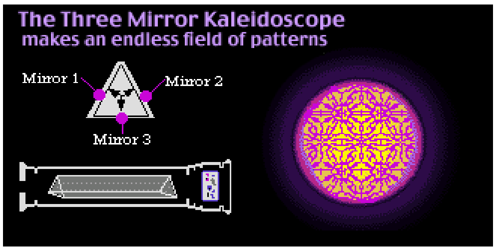
Light travels from an object to our eyes. The mirror maze can demonstrate that we see the transparent panel because light travels through it to our eyes. A common misconception is that the light travels from our eyes to the object.

Multiple reflections
Light will bounce off any number of mirrors, changing its direction in the same way each time. If at any point the light enters someone’s eye, they will see several images of the object from which the light originally came.

Some arrangements of mirrors give special results. For example mirrors set at right angles always reflect light back in exactly the same direction from which it came. If you look at such an arrangement of mirrors, the reflection of your eye will always appear at the join between the mirrors.

Kaleidoscope
A use of multiple reflections is in kaleidoscopes. These usually comprise three mirrors arranged in a triangle with small coloured shapes at the end closed with a translucent screen. Viewing through the other, open end, you can see a series of changing images repeated in six triangles as you turn the tube. They can be made with four mirrors angled to an object which will appear as an orb.





ANAMORPHS

Light travels in straight lines
Mirrors fool the brain
Curved mirrors produce distorted images

DESCRIPTION
A curved mirror sits on a whiteboard. Pupils can draw on it using the water-based pens provided, observing the reflection in the mirror which distorts the images in front. (Pieces of plastic are provided which on reflection appear as geometric shapes.)

A distorted picture is also present which can only be seen properly using the small cylindrical mirror.

CURRICULUM LINKS
Key stage 1
"Pupils should have opportunities to explore...effects related to...reflection..."
Key stage 2
"Pupils should learn about the reflection of light...and relate this to everyday effects (mirrors...)"
Key stage 3
"Pupils should study the behaviour of light, particularly its...reflection..."

RELATED EXHIBITS
Mirror maze
This exhibit provides a number of flat mirrors which can be placed at different angles to observe single and multiple reflections.
Laser amazer
Narrow beams of light show that light travels in straight lines.
Mirror drawing
This exhibit shows the difficulties of hand-eye co-ordination when looking in a mirror, even a flat one.

WHAT TO DO
Place the small plastic shapes in front of the mirror.
Q: What shapes do you see?
(A: They are a circle, a square and a triangle.)

Try to draw similar shapes.

Draw a line from right to left across the front of the mirror. Draw six blobs on the line, spread out from right to left.
Q: What does the line look like in the mirror?
(A: It looks bent; the ends bend round, away from the mirror.)

Q: Can you draw a line which looks to be a straight line when viewed in the mirror?
(A: Yes - hint - try making a straight line of blobs first, then join them up.)

Try to draw a grid on the board that looks square in the mirror. Does a grid help in drawing a more complicated shape like a face?

MORE THINGS TO DO
RIGHT: Can you make out the picture? Move the small cylindrical mirror until the picture looks right in the reflection.

ANAMORPHS: FURTHER INFORMATION

Reflection
We see the reflection of a point on the board in the mirror because light travelling from it bounces off the mirror into our eye.

When we look at the reflection of an object in a flat mirror our brain, which interprets what we see, makes a mistake because it cannot take account of the reflection of the light. Thus the image of the reflected object looks as if it is behind the mirror. The part of our brain that interprets the image entering our eye, persistently assumes that there is no mirror. However we know from experience that the mirror is there and that what we see is not correct. Because we learn this at an early age we do not find it strange.

A curved mirror
The brain finds the distorted images from curved mirrors even harder to understand. It assumes that if the light from the object entered the eye in a particular direction, that must be the direction in which the object is actually located.

The result of the change in direction of the reflected light caused by the curved surface of the mirror is to alter the apparent direction of the various parts of the reflected image. Our brain interprets this as a distortion of the object's shape.

Anamorphs
These are pictures which can only be seen correctly when observed in a particular way The kind found on the right of the exhibit was a common parlour game in the Victorian Era, but they had been used for sending secret messages by the Jacobites plotting the rebellions of 18th century. The most famous anamorph is in the painting "The Ambassadors" by Holbein in the National Gallery where the strange shape in the foreground can only be seen to be a skull when viewed at an extremely acute angle.

→

The Ambassadors by Holbein

LIGHT TABLE

White light is a mixture of different colours
Some materials let particular colours of light through but absorb the rest

DESCRIPTION
A number of sheets of material are provided which can be laid on a light table to see the effect on the light passing through it. Most of the sheets are colour filters. The sheets can also be overlapped.

CURRICULUM LINKS
Key stage 1
"Pupils should have opportunities to explore light sources...and the effects related to...colour."
Key stage 2
"Pupils should explore the effects produced by shining light through such objects as...colour filters..."
Key stage 3
"Pupils should study the behaviour of light, particularly its transmission, absorption...They should learn how light is controlled and used..."

RELATED EXHIBITS
Mixing coloured light
This exhibit is the opposite of the **Light table.** It allows investigation of additive colour mixing – i.e. where light coming from a source shining on a screen is superimposed over light from a second source.

WHAT TO DO
Pick up a sheet and say what you will see when you put it on the light table. Put it on to see if you're right.

Q: What happens to the brightness of the light?
(A: Light going in one side of any material will always come out the other side less bright, although with very transparent materials it may be almost as bright.)

Q: How would you describe the three non-coloured sheets?
(A: Transparent, translucent and opaque.)

Put a blue filter on the light table.

Q: Where is the blue light coming from?
(A: The blue light is coming from the light table. The filter is removing the other colours of the spectrum from the white light.)

MORE THINGS TO DO
Predict what will happen if you overlap sheets of material.

Q: What happens if you overlap all three primary colours: red, blue and green?
(A: You see black - the filters between them have stopped all the different parts of the originally white light. Compare with the combination of lights in **Mixing coloured light** which produces white.)

Q: What colours do you get when you overlap two of the primary filters?
(A: Blue and red make purple, green and red make brown, green and blue make turquoise.)

Q: What do you see if you overlap pairs of the secondary colours: magenta and yellow; yellow and cyan; cyan and magenta?
(A: The primary colours red, green and blue.)

LIGHT TABLE: FURTHER INFORMATION

White light

White light is really a mixture of different colours of light, all travelling in the same direction together. A rainbow shows us what all these colours look like if they are spread out separately for us to see.

Opaque objects and grey filters

Opaque objects stop all light passing through them. Grey filters stop a proportion of all the parts of light going through them equally. An opaque object on the light table does not look completely black because light from elsewhere in the room is falling on it and being scattered, with the result that some light from the object reaches our eyes.

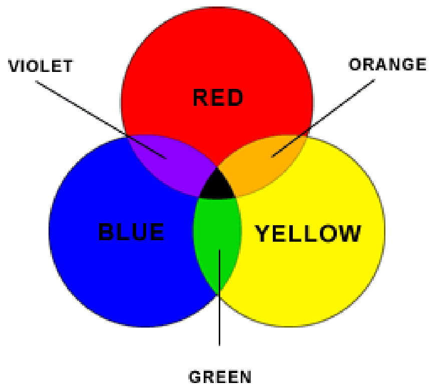
Subtractive colours

A colour filter placed on the light table has the effect of stopping some parts of the white light but letting other parts through. The light which is stopped is actually absorbed by the filter. When the mix of colours of light is changed by some of them being absorbed - this is called a subtractive process.

A primary red filter STOPS blue and green colours.
A primary blue filter STOPS red and green.
A primary green filter STOPS blue and red.

Other filters have other effects:
A magenta (pink) filter STOPS primary green.
A cyan (greeny-blue) filter STOPS primary red.
A yellow filter STOPS primary blue only.

All the filters together STOPS all light - producing black.



Paint and pigments produce specific colours by a subtractive process also. In this case the paint absorbs some particular colours (for example red paint absorbs blue and green light) and reflects the rest (red). Leaves absorb the red and some of the blue ends of the spectrum to provide the energy for photosynthesis; they reflect the rest of the spectrum and thus look green.

Additive colours

In **Mixing coloured light** red and green makes yellow light. Mixing yellow and blue light makes white light (because red and green plus blue = white). These are examples of additive mixing. (Mixing yellow and blue paint makes green paint, as this is an example of subtractive mixing.)

ZOETROPE

A rapid sequence of images gives the illusion of movement
Persistence of vision affects how we see

DESCRIPTION
A round drum can be spun round. It has vertical slots in the sides at intervals around the circumference. Inside the drum is a series of panels, each with a drawing on it. The drawing on each panel differs slightly from its neighbour in a sequence of movement.

CURRICULUM LINKS
Key stage 2
"Pupils should explore the effects produced by shining light through...objects."
Key stage 3
"Pupils should explore the nature of vision, leading to an appreciation that vision occurs because light enters the eye and signals are interpreted by the brain."

RELATED EXHIBITS
No other exhibits relate directly to this. A television set creates the impression of continuously moving action in the same way.

WHAT TO DO
Spin the drum while looking in over the top.

Q: What do you see?
(A: The inside of the drum, and all the pictures turning round).

Spin the drum round whilst looking into it through the slots in the side.

Q: What do you see?
(A: Each panel appears to stay still but the drawings on the panels appear to be moving about.)

MORE THINGS TO DO
Spin the drum at different speeds.

Q: What happens when the drum slows down or when it speeds up?
(A: Slowing down the drum slows down the movement of the drawings; speeding up the drum quickens the movements.)

Spin the drum the other way.

Q: What is different?
(A: They move in reverse.)

Shut one eye, and look through the slots. Turn the drum very slowly.

Q: What exactly do you see as the drum turns?
(A: You see the outside of the drum most of the time. As each slot comes past you see the drawings inside the drum. While you cannot see through a slot, the pictures move round one place.)

Q: Now spin the drum fast. What is the difference in what you see?
(A: It appears as though you do not see the outside of the drum at all.)

ZOETROPE: FURTHER INFORMATION

What are you looking at?
The spaces between the slots are much wider than the slots themselves. When the drum spins very slowly you see the slots and drum alternately. As the drum is speeded up you become more conscious of what you see through the slots and less conscious of the outside of the drum.

When the drum spins fast you see each of the different panels one after the other through the slots. Parts of the drawings on each panel have been copied and so look the same, but other parts have been changed to slightly different positions.

The slots are at same intervals around the drum as the panels. As you look through each slot, the panels are always in more or less the same positions on the opposite side of the drum.

Persistence of vision
The brain, while it interprets the images in each eye, is able to ignore parts of what we see in order to concentrate on the interesting parts. With the zoetrope spinning fast the brain ignores the view of the outside of the drum, and the picture seen through each previous slot 'persists' until the next slot comes into view. We are not aware that we are really looking at the outside of the drum most of the time.

Our brain is also able to 'smooth' out the jerky changes between the drawings when it sees them in quick succession. Most of the time the real objects and things we look at, move in a fairly steady way. If the brain receives an unusual set of images from the eyes, as with the jerky images from the zoetrope, it usually interprets them as being like something it is more used to.

Zoetropes, etc
The zoetrope ('wheel of life') was re-invented in 1834. (It had first been developed in China in the second century CE.) Similar devices were also developed such as the phenakistoscope, the praxinoscope and the thaumatrope which all relied on the principle of persistence of vision. As cameras improved over the nineteenth century it became possible to rely on photographs rather than drawings. The pioneer in this field was Eadweard Muybridge who produced many sequences of animal movement, in particular solving the question of whether all of a horse's feet are off the ground at any time when trotting (they are).

Cinema
Film works in the same way as a zoetrope, presenting a series of still pictures separated by bands of darkness.

Television
A television also presents our eyes with a rapid sequence of still pictures, but it does so by a different arrangement. There are no completely black sections between the pictures, as with the zoetrope. Each picture is slightly different from the next, and our brain ignores this jerkiness, interpreting it as smooth movement.

LASER AMAZER

Light travels in straight lines
Light can change direction by being reflected
Light can change direction by being refracted

DESCRIPTION
A pair of lasers produces bright narrow parallel beams of light which shine across a box. In the path of the beams is a double sided mirror which can be turned to aim the beams in various directions at lenses, mirrors, etc. some of which can also be rotated.

Fine smoke created by joss-sticks inside the box makes the beams visible.
(Open the lid on the right near side of the box by putting a finger into the hole and pushing up. Inside is an aluminium box with a drawer. Push short, smouldering joss-sticks into the plasticine in the drawer.)

CURRICULUM LINKS
Key stage 1
“Pupils should have opportunities to explore light sources and the effects related to...reflection...”
Key stage 2
“Pupils should learn about the reflection of...light and relate this to everyday effects (mirrors...). Pupils should explore the effects produced by shining light through such objects as lenses...prisms.”
Key stage 3
“Pupils should study the behaviour of light, particularly its reflection and refraction ..."

RELATED EXHIBITS
Frozen shadows
Shows that light travels in straight lines.
Mirror drawing/Mirror maze/
Bendy mirrors/Anamorphs
About the reflection of light.
Pin hole cameras/Eye models
Involve the effect of lenses on light.
Optical fibres
Involves light making a series of internal reflections

WHAT TO DO
Turn the central mirror to direct the beams to the other shapes to see the effect it has on the beams.

Q: What happens with the convex lens?
(A: The beams bend in towards each other.)

Q: What happens with the concave lens?
(A: The beams bend outwards.)

Q: What happens with the rectangular block?
(A: The beams bend slightly as they go into the block, and bend again in the opposite direction as they emerge from the other side.)

Q: What happens with the concave mirror?
(A: The beams bend in towards each other after having been reflected.)

Q: What happens with the convex mirror?
(A: The beams bend outwards after reflection.)

MORE THINGS TO DO
Bend down and look 'along' the line of the beams both from the left and from the right hand direction. (You won’t be able to look directly into the laser.)

Q: What do you notice about the beams themselves?
(A: In the direction from the lasers, right to left, the beams look less bright than when looking towards the lasers.)

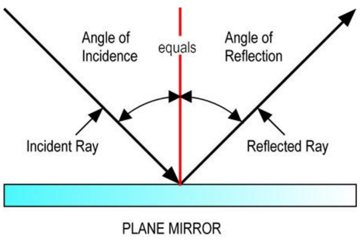
Q: Can you think why this happens?
(A: The light is travelling from right to left like a stream of bullets. We see the beams when some of the light 'bounces' off the smoke particles up towards our eyes. More deflected light comes off in the forward direction of the light than in the reverse.)

LASER AMAZER: FURTHER INFORMATION

Laser light
Laser light is basically the same as ordinary light. Lasers are used in this exhibit because they can produce very narrow beams of light which do not spread out - this helps to show the path of the beams clearly. This laser only produces red light. Light beams are not normally visible. Light from the beams is visible because tiny smoke particles in the box cause the light to be scattered in all directions, some of which enters our eyes, letting us see the beams' paths.

Light travels in straight lines
Light always travels in straight lines. Its direction can only be changed by reflection or refraction. (Scattering of light is a special case of multiple reflections.) If a beam of light is not reflected or refracted, it will continue in the same direction indefinitely. Light from distant stars travels for millions of miles across space in a straight line.

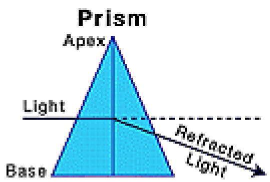
Reflection
Reflected light always leaves the reflecting surface at the same angle as it strikes the surface.

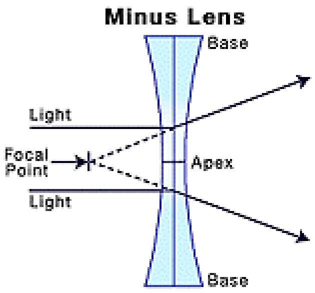


Refraction
Refraction occurs when light passes between two materials, for example, from air into transparent plastic like the lenses here. As it crosses the boundary a change in direction of the light beam occurs.

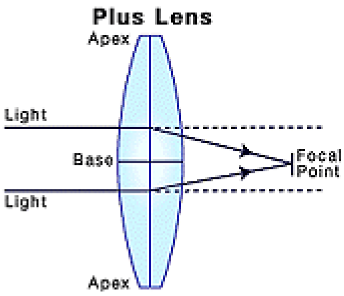
The change in direction depends on how fast light travels through each of the materials. For instance, it travels more slowly through plastic than through air. If two materials transmit light at the same speed no refraction will occur at their boundary. The amount of refraction depends also on the angle between the boundary and the light beam. If a light beam approaches a boundary at right angles there is no refraction. The sharper the angle at which it approaches, the greater the angle of the refraction will be until a limit is reached when total internal reflection occurs, as in optical fibres.

Refraction is very useful as it can be used to focus light in a way which helps us to see, as in the lenses of spectacles, microscopes and telescopes etc.





Concave lens



Convex lens

MIXING COLOURED LIGHT

Different coloured light sources can mix to make a third colour
White light is a mixture of different colours

DESCRIPTION

Three lamps with coloured filters produce primary blue, primary red and primary green light which can be aimed at a screen to produce spots of light. They can be overlapped to make secondary colours. If all three spots of light are superimposed, white is produced.

By placing your hand between the light tubes and the screen you can see various coloured shadows.

CURRICULUM LINKS

Key stage 1
"Pupils should have opportunities to explore light sources...and the effects related to...colour."
Key stage 2
"Pupils should explore the effects produced by shining light through such objects as...colour filters...they should also investigate the formation of shadows..."
Key stage 3
"Pupils should learn about the visible region of the electromagnetic spectrum...they should study the behaviour of light."

RELATED EXHIBITS

Light table
This exhibit shows subtractive colour mixing by providing a large white light source and coloured filters and other materials which absorb some of the light
Model eyes
Shows how light passes through the lens to the retina, where the cones are situated. There is also a test for colour blindness.

WHAT TO DO

Direct the three lights, so that the colours on the screen overlap.

Q: What do you see when red and green overlap?
(A: Yellow.)

Q: What do you see when red and blue overlap?
(A: Magenta or pink.)

Q: What do you see when blue and green overlap?
(A: Cyan, a greeny-blue.)

Q: What do you see when red, blue and green overlap?
(A: The light is almost colourless/white.)

MORE THINGS TO DO

Make colourless/white light by overlapping the three colours, then put your fingers in the way of the light.

Q: What do you see on the screen?
(A: Three sets of overlapping shadows of your fingers, parts of which are yellow, magenta and cyan.)

Shine just one light at a time at coloured objects.

Q: What does a red object look like in red light?
(A: It will look very dark, maybe black.)

Try this with other coloured objects and lights - saying what you expect each time.

OTHER THINGS TO DO

Look at a TV screen through a strong magnifying lens - a 'balloon' glass full of water makes a good one. You will see the primary colours as stripes or dots.

MIXING COLOURED LIGHT: FURTHER INFORMATION

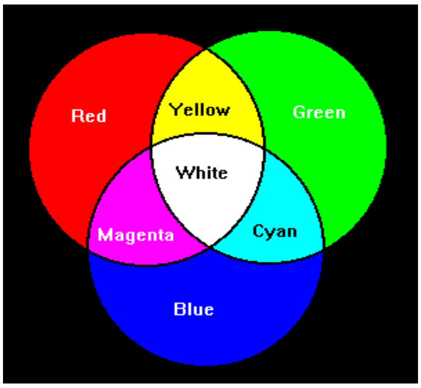
White light
White light is really a mixture of different colours of light all travelling together. A rainbow shows us what all these colours look like if they are spread out separately.

Filters
A colour filter is one which blocks out all other colours of light. For instance, a red filter only allows red light to pass through it, while absorbing blue and green.

Primary colours
If particular shades of blue, red and green light are mixed then white light is produced. They are known as primary colours. This is additive light mixing.

Additive light mixing
Additive colour mixing can only be done with different light sources. When the light from two coloured lamps is superimposed we see one new colour - a mixture of the two:

Red + Green = Yellow
Red + Blue = Magenta (pink)
Blue + Green = Cyan (greeny-blue)
Red + Blue + Green = White



It is possible to separate them again - using a colour filter to remove one of them.

Coloured shadows
If three lights are coming from different directions, shadows made by each one of the same object will fall in different places.

Use two lights only, say red and green, and look at the shadow of one finger. One shadow will be made by the finger blocking red light, so here you will see just green coming direct from its light source. The other shadow is the one made by the finger blocking the green light, leaving the red light to fall on the screen. So what you see is a red and a green shadow against a yellow background where the two colours are mixing.

Vision
The primary colours are detected in the retinas of our eyes by three different receptors called cones. The same colours are used to make up television pictures.

If we had four types of cone in our eyes like goldfish there would be four primary colours. Some people who are said to be colour blind have only two types of cone, like most mammals. Only primates like monkeys and apes have colour vision like us. It evolved so they/we could see things like fruit amongst the green vegetation of the forest.

BENDY MIRRORS

Light travels in straight lines
Mirrors fool the brain
Curved mirrors produce distorted images

DESCRIPTION
A frame contains two large curved mirrors facing in opposite directions. Both mirrors are convex (curved outwards) but one curves vertically and the other curves horizontally. The images seen in the mirrors are distorted and can be seen from some distance away.

CURRICULUM LINKS
Key stage 1
"Pupils should have opportunities to explore...effects related to...reflection..."
Key stage 2
"Pupils should learn about the reflection of light...and relate this to everyday effects (mirrors...)"
Key stage 3
"Pupils should study the behaviour of light, particularly its...reflection..."

RELATED EXHIBITS
Mirror maze
A number of flat mirror surfaces can be placed at different angles to observe single and multiple reflections.
Laser amazer
Narrow beams of light demonstrate that light travels in straight lines.
Anamorphs
Here a curved mirror distorts what you are drawing.

WHAT TO DO
Look at your reflection in either side of the mirror.

Q: **How do you look**
(A: In one mirror you look fat; in the other mirror you look thin.)

Q: **In the mirror that makes you look fat, do you look shorter in height as well**
(A: Yes, in fact your 'width' has not changed - you look fat simply because you look shorter.)

Q: **In the mirror which makes you look thin, do you look taller as well?**
(A: No, in fact the mirror makes you look thinner, but your height appears unchanged.)

MORE THINGS TO DO
Stand at some distance from the mirrors. Hold your arms out straight sideways and watch your reflection as you raise and lower your arms.

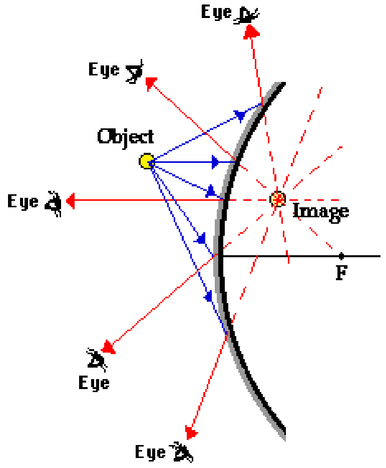
Q: **What happens to the length of your arms**
(A: Your arms appear to change length as you move them from the horizontal to the vertical. Which way round this happens, depends on which mirror you are looking in.)

BENDY MIRRORS: FURTHER INFORMATION

Seeing our own reflection
Light bounces off our body and is scattered in all directions. Some of this light travels to the mirror, where some of it is reflected into our eyes. Our brain interprets the image coming into our eyes as having come from an object - even if it is our own body - which is beyond the mirror.

Curved mirrors
When a mirror is curved the light reflects in different directions depending on where it strikes the mirror. Compared to a flat mirror some of the light gets closer together after having been reflected, some further apart. These distortions cause the final image we see in these curved, convex mirrors to be altered. The effects are traditionally produced in a Hall of Mirrors at a funfair, where multiple curves in a mirror produce grotesque reflections.

Convex mirrors



Concave mirrors
A concave mirror also has a distorting effect on an image, but at anything other than close range the image is too distorted to be meaningful.