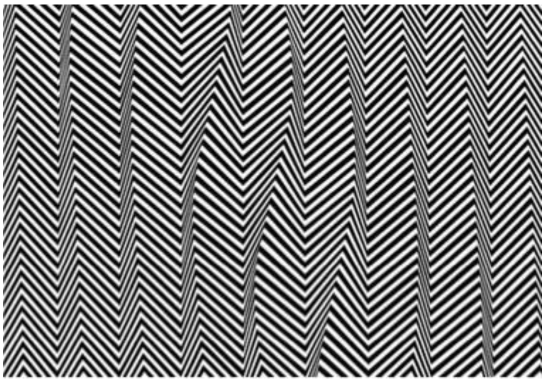
Exploring Light and Colour: A Masterclass

Working with light boxes.

Students look at some 'art with straight lines' (e.g. Bridget Riley) and the caustic curve light pattern.

Elicit comments about what students see in the artwork. Movement, colour, 3D effects were amongst the things they mentioned. Point out that these are created by the artist's use of straight black lines. Mention that the caustic curve is a beautiful curved pattern formed by light reflecting from the inside of a ring. Light travels in straight lines. Again straight lines can produce a surprising pattern.

Prompt them to think about questions that this raises for them.



Main task 8 min. Students work in groups of four with a light box and a mixture of straight and curved mirrors, lenses, prisms, single and multiple slits and colour filters.

Ask them to use the kit to make their own interesting ray patterns by using whatever combinations of ray box settings and other equipment that they like.

They are encouraged to 'play' and to make a record of their patterns for their own use, perhaps using mobile phone cameras.

B1 Refraction- Bending Light

How can you flip the direction of the arrow using only a glass and some water?

How do you make the coin disappear?

How can you make it easier to see the image underneath the glass of water beads?

What does light do as it passes through water and as it passes through vegetable oil?

How does a spherical container of water affect light?

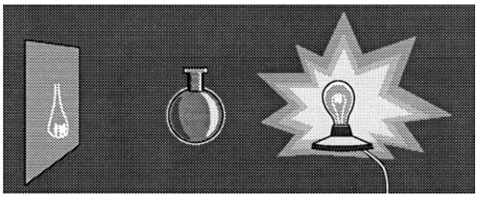
- **Arrow flipping-** Using a water glass, encourage the children to hold up the empty glass with the arrow behind it then move the arrow from side to side- nothing should change. Then fill the glass with water- the arrow should flip direction.

- **Coin trick-**
  - Set a penny on a flat surface.
  - Place the base of a clear drinking glass over the penny.
  - Cover the mouth of the glass with a piece of black card. Looking in through the side of the glass, you can still see the penny.
  - Now, tilt the saucer back and fill the glass with water.
  - Once you've filled the glass, replace the saucer. You should no longer be able to see the penny.
  - Take the saucer off of the mouth of the glass. Peer straight to the bottom of the glass through the water, the coin should reappear.
  - Equipment:
    - Jug
    - Penny
    - Water glass
    - Black card
- **Water beads-**
  - Fill a glass with water beads (drain off the water using sieve)
  - Place the glass over an image- it should be blurry
  - Ask the children what they might do to make the image clear.
  - Fill the glass with water and the beads have the same refractive index as water so it should now appear that the glass is only full of water and the beads are now invisible.
  - **Equipment:**
    - Jug
    - Glass
    - Water beads
    - Laminated image
    - Sieve

- **Spherical water-filled lenses**

Based on https://www.exploratorium.edu/snacks/water-sphere-lens

  - Fill spherical lens with water and clamp it just above the table.
  - Place the lightbulb or candle more than 30 cm from the water-sphere lens. Hold the white card against the side of the lens opposite the light source.
  - Move the card away from the sphere until you see an image of the filament (or flame) on the card. Notice that the image is inverted.



  - Move the light source up and notice that its image moves down.
  - Move the light very close to the water sphere, and notice that you cannot find an image on the card at any distance.
  - Look through the water-sphere lens at a newspaper held close to the other side of the sphere. Notice that the sphere acts as a magnifying glass. Vary the light-to-lens distance and notice how the image-to-lens distance changes. Also notice how the image changes size.
  - The image you see may be fuzzy and distorted, but should be recognizable. It also may show colour distortion. The fuzziness is due to spherical aberration—a sphere is not the perfect shape for a lens; the colours are due to chromatic aberration—each different colour of light bends by a different amount as it enters or leaves the lens.
  - *Round bottles of water, left in an open window, have been known to start fires by focusing sunlight into an intense "hot spot." In the 1700s, spherical glass bottles filled with water were used to focus candlelight for fine work such as lace making. In 2008, Joshua Silver, a former physics professor, designed eyeglasses with fluid-filled plastic lenses. The lenses are each connected to a small syringe so the eyeglass wearer can vary the amount of fluid, changing the power of the lens, until the images are as clear as possible. Silver's invention is benefiting people around the world who do not have access to eye-care professionals.*
  - **Equipment:**
    - Clamp and stand
    - Spherical glass jars
    - Water jug
    - Newspaper
    - White card
    - 2 bulldog clips to hold screen

- **Oil and pyrex**:
  - Fill one conical flask with water and the other with vegetable oil.
  - Place a pyrex rod in both and get the students to note the difference.
  - Pyrex and vegetable oil have the same refractive index so the pyrex rod should be invisible in the oil.
  - Get the students to discuss what they think is going on.
  - **Equipment:**
    - 2 x conical flasks

- Vegetable oil
- Kitchen roll (for spillages)
- Jug of water
- 2 x pyrex rods

B2 Interference- light waves interacting

Drop droplets of water onto the surface to produce waves

Use the ripple tank to explore how waves interact with each other

- **Interference in a ripple tank-**
    - Set up the ripple tank without the viewing screen initially.
    - Get the students to use a pipette to drop water droplets on the water and see the waves.
    - Let the students adjust the different settings to try and get the waves to interfere with each other (as discussed by Pete in his lecture)
    - Use 2 vibrating heads and try obstacles
    - Equipment:
        - Ripple tank
        - Jug
        - Pipette x 2

B3 Structural Colour

Some colour comes from pigments but why are bubbles colourful when bubble solution isn't?

What is happening in the soap film

- Let the students blow bubbles and think about where the colour comes from.
- Make up soap solution with 1 part dish soap solution and 10 parts water.
- Dip the hollow end of black film tubes (pieces of black pipe can be used with the end covered) in the solution and place sideways on a piece of white paper.
- Observe the changes in colour- where the solution is slightly thicker bands of colour should appear (wavelength matching). Where the solution is thinner at the top it will go from silver to black as it is too thin for interference to work.
- Ask the students:
  a) Do you see the fringes? What do they look like?
  b) Why do you think there are many colours? What makes the dark bands?
  c) Can you see evidence of constructive interference? Destructive interference?
  d) What are the fringes doing?
  e) What determines what the fringes look like?
  f) What happens when the bubble gets old (before it pops)?
  g) Do you think this interference is useful for anything?
- As students experiment, share that the colours we see on the bubble are the reflection of white light shining on the bubble film. White light has many colours—each colour has a different wavelength.
- If the crests of two sets of waves meet, the colours will intensify and we see evidence of constructive interference
- When the crests of one wave meets the trough of another wave, the waves cancel each other out and we see destructive interference.
- As a bubble film thins out, the colours cancel each other out until all we see is a black dot in the middle of the bubble.

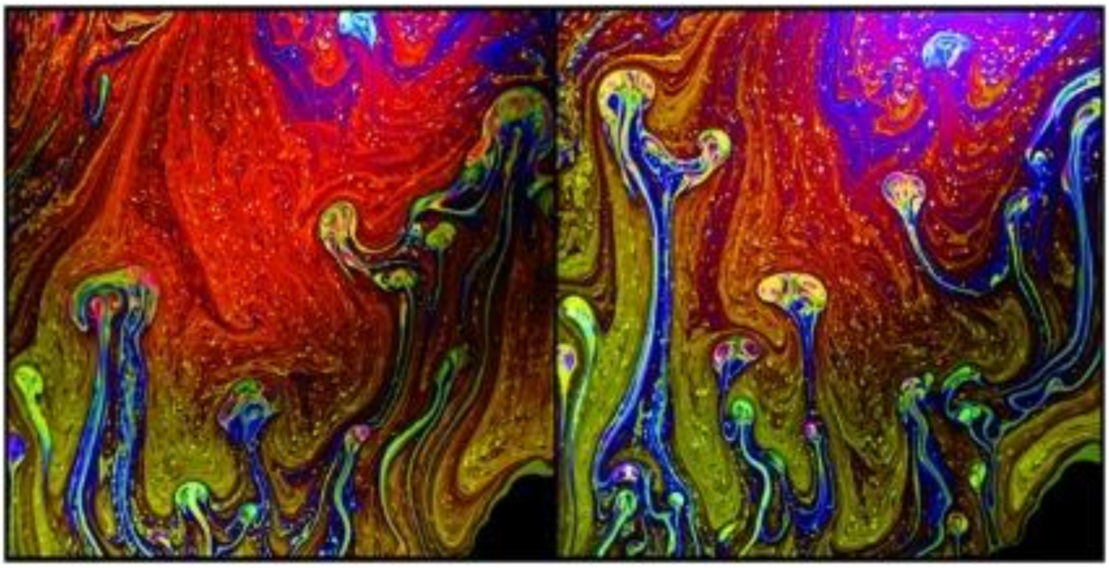
Discussion

The bubble's thickness is not uniform, that is why you see fringes or bands of different colours, and dark bands where the light interferes destructively. Over time, the thickness of the bubble changes, leading to a changing and swirling of the colours. As the bubble ages, it gets thinner on top and thicker on the bottom. Eventually the top gets so thin that light interferes only destructively, all the colour waves cancel each other out, and we get a dark spot.

How is this thin film interference useful? Well, since the colour of the fringes (and also their spacing) is related to the thickness of the film, we can use this to measure the thickness of films, which are too thin to measure with, say, a ruler. Scientists actually use this to measure very thin objects! Also, you can use this property to create light filters that only let through certain colours of light (the other colours interfere destructively).

- [Show images of Pery Burge's work on screen- artist who did some beautiful photography of soap film surfaces. (see example below)]

- **Equipment:**
    - Bubble kits
    - Bubble solution
    - Petri dishes
    - White paper
    - Film tubes



An example of Pery Burge's work: 'Sci-fi garden growing' depicts two stages in the developments of soap film, separated by less than a second.
See http://emps.exeter.ac.uk/about/artist/

This is based on http://www.reachoutmichigan.org/funexperiments/agesubject/lessons/bubbles.html
and https://www.exploratorium.edu/snacks/soap-film-on-can

B4 Colour Mixing

How do you make white light from the three colours of light here?

What other colours can you make?

How does your eye see these different colours?

Where is magenta in the spectrum of light? How can you see it?

How do colour filters work?

- SPIE colour mixing kit with variable brightness- let the children use it to try and make white.
- Ray boxes with coloured lamps can also be used to combine the colours.
- Set up discussion on how the other colours are formed (yellow lies between red and green in the spectrum, cyan lies between green and blue in the spectrum but magenta does not exist in the spectrum and results from the your brain inferring a colour that combines red and blue)
- Use red filter to look at image of red playing card- why does it disappear? Only fully works with exact colour match.
- How does the eye work? Is this the same for all animals or do some animals see different colours?
- **Equipment:**
    - Light mixing kit and screen
    - Ray boxes
    - Colour filters
    - Playing card print out

Questions created by the students – to be followed up in school if possible

Why do optical illusions trick our minds?

> Why do optical illusions change the more you look at them? Why do they seem to change colour? Do different people see them differently?

Why does light bend?

> Why does light bend when it is seen through a liquid?

Does light of differ colours bend in different ways?

Why can you not see clear objects in water?

> Can water make anything disappear looking from the side?
> Could you make an invisible suit or make someone invisible using refraction?

Why does light travel?

What can refraction be used for in everyday life?

Can other animals have infra-red sight?

Does anyone see in just black and white?

What causes colour blindness?

How does the paper for the pinhole camera work?

Why can't we see infra-red?

> Why cant we see infra-red or ultra-violet; is it because the wavelength is too low/high?
> Would it be possible to see radio waves?

..and some bigger issues:

How was the earth created?
What is life?
What is beyond the universe – if you go past the point where it is still expanding?
If the sun turns into a black hole will we experience the pull of gravity or the loss of light first?

Rationale for the workshop

The workshop was inspired, in part, by the concept of "conversive trauma" (Hargreaves 1983) which suggests that the affective reaction to a work of art can be the stimulus to find out about the processes involved in its creation, rather than understanding of those processes being the basis on which the affective response is based. This is consistent with Woolnough and Alsop's (1985) notion that one purpose of science practical work in schools is to give students a 'feel for the phenomena'. (Pushing a balloon into water is great way of getting a feel for the phenomenon of upthrust.) Once this "feel" is established, detailed exploration of the phenomenon can be undertaken with meaning (and enthusiasm).

The workshop produced some 'wow –that's cool' responses from the youngsters suggesting that some element of conversive trauma was taking place; it then gave them opportunities to explore the ideas practically and discuss with experts aspects of the science tasks and demonstrations that they were experiencing

References

Hargreaves, D. (1983) The teaching of art and the art of teaching: towards an alternative view of aesthetic learning, in: M. Hammersley & A. Hargreaves (Eds) Curriculum Practice: Some Sociological Case Studies (London, Falmer)

Woolnough B and Alsop T (1985) Practical work in Science Cambridge: Cambridge University Press