Light and colour

Colourful lighting at a Duke Special concert.

Television studios, sports stadiums, theatres, roads ... just some of the places that need special lighting. It is the responsibility of lighting engineers and technicians to design, test and develop appropriate lighting systems.

Have you ever been to a theatre or pop concert and noticed the huge number of lights? They come in many different sizes and colours. Some focus light on small areas, some flood a large area with light. Some stay still, others move around. Lighting technicians have to work out how to provide lighting effects for pop concerts and other events. They need to know how lights and colour combine.

Imagine you're a lighting technician at a theatre. Your favourite band is coming to town. You've got to set up the stage lighting and make sure it adds to the atmosphere. You don't want to make any mistakes!

You need to check how you'll use your coloured filters.

your task

You are going to investigate light and how to make different colours.

Read all the instructions carefully before beginning.

what you will need

- light box
- 12 V power supply
- triangular prism
- 3 x primary coloured filters (red, green and blue) in frames
- whiteboard and stand
- coloured pencils or crayons

safety

Take care – light boxes may get hot.

what you need to do

1. Connect the light box to a power supply and turn it on.
2. Place the prism about 2 cm in front of the light box with one edge facing the box.
3. Place the whiteboard about 20 cm in front of the light box, slightly to one side.
4. If you can't see a clear spectrum on the whiteboard, move the prism slightly until you can.
5. Identify the seven main colours of the spectrum.
6. Draw this spectrum under '**results**' below.
7. Colour in the 'no filter' row of the results table to show the seven colours – one in each box.
8. Place the red filter in front of the light box. Observe what happens to the spectrum.
9. Colour in the 'red' row of the table to show what the spectrum looks like now.
10. Repeat step 6 for the green filter, and then the blue. Colour in the results in the table.
11. Try combining two filters to see what happens to the spectrum. Record the results in the table.
12. Clean the whiteboard.
13. Turn the light box around so that the hinged mirror end is facing the whiteboard.
14. Place each filter in a different slot – one at the front and one either side (you may need to open the hinged mirrors to reveal the side slots).
15. Open the mirrors so that three rectangular, primary-coloured light beams shine onto the whiteboard.
16. Adjust the mirrors so that the pools of light overlap.
17. Place a further filter (or a piece of black card) in the front slot. This will block the central light beam and allow you to observe what happens when only the 'left' and 'right' pools of light overlap.
18. Use your observations to colour in the overlapping-circles diagram.

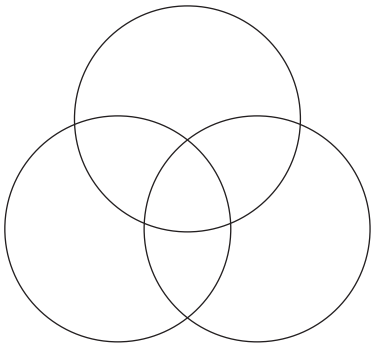
results

- Draw a spectrum using coloured pencils. Label the seven main colours.

- Complete this table:

colour of filter(s)	spectrum colours visible						
no filter							
red							
green							
blue							
red and green							
red and blue							
green and blue							

- Colour this diagram of overlapping primary colour lights:



questions

- Explain a spectrum using the terms refraction and dispersion.
- How can you remember the colours (and order) in a spectrum?
- There aren't really any sharp dividing lines between the colours. Describe what the spectrum *really* looks like.
- Explain how colours can change, using the terms 'absorb' and 'reflect'.
- What are secondary colours and what are their names?
- In terms of coloured light, how can we explain black and white?
- Share your findings with the rest of the class. Are they the same?
- How could you improve your investigation?
- What further investigations about light and colour could you carry out?
- How is mixing light different from your experience of mixing paints in art?

extension

- Investigate how objects of different colours appear in different coloured lights. The 'objects' could simply be pieces of card of different colours.

engineers

- There are four engineers shown on the poster. What other engineers do you think might be needed to help put on a live music performance?
- As well as working at music concerts, where else might you find a lighting technician? Try to think of at least three areas of work.

Light and colour

Curriculum links

England and Wales (Key Stage 3 Science Programme of Study)	
key concepts	1.1a, 1.2a, 1.3a
key processes	2.1a-c, 2.2a and b, 2.3a
range and content	3.1a
curriculum opportunities	4a-c
Northern Ireland (Science Statutory Requirements)	
knowledge, understanding and skills	develop: enquiry skills; critical thinking; practical skills research information learn about: light
objective 1 – develop as individuals	mutual understanding: team work
objective 3 – as contributors to the economy/environment	identify skills used in: the lighting industry; technical aspects of entertainment
Scotland (SQA Science Outcomes)	
third level	SCN 322T, 323U

Introducing the activity

You may wish to start by discussing what the pupils already know about light. They should, at least, be able to state:

- some examples of different sources of light
- that objects reflect light
- that light travels in a straight line
- how we see (light source → object → eye)
- how shadows are formed (and use the terms transparent and opaque)

The pupils may also be able to explain that light reflects back at the same angle. However, they are unlikely to have encountered different types of reflection (plane and diffusion). Pupils are also unlikely to have worked on colour. Spectrum, refraction, dispersion, absorption and so on, are terms with which they will be unfamiliar. You will need to decide which of these, if any, need to be explained before the investigation. The pupils will need enough information to be able to explain their results.

Discuss the different places that pupils have seen coloured light being used.

Ask the pupils how they could produce coloured light. Establish that the easiest way is to shine white light (from a torch, for example) through a transparent, coloured object. Introduce the idea of filters. Explain that in television and theatre lighting, different coloured filter 'gels' are used to produce light of different colours.

You may want to ask the pupils if they have ever noticed the colour of cars under yellow street lamps. How coloured objects appear under different coloured light is something the pupils can investigate as an extension.

Explain that they are going to investigate what happens when coloured light is passed through different coloured filters, and what happens when different coloured lights combine.

The practical activity

It is suggested that this activity is completed in small groups. With less equipment, rotation with other activities may be required. It is your decision as to how much of the activity you need to discuss with the pupils before they are confident, and you are confident in them, of carrying out the experiment correctly and safely.

They should be able to divide the spectrum produced into seven main colours (red, orange, yellow, green, blue, indigo, violet). This can be remembered using the following mnemonic: **R**ichard **O**f **Y**ork **G**ave **B**attle **I**n **V**ain. However, encourage them to look more carefully. Do they see sharp, sudden changes in colour? The answer should, of course, be "No". The white light spectrum is continuous, with gradual changes merging one colour into the next. The spectrum produced will be small and narrow so the pupils will need to look *very* carefully!

Since the spectrum is continuous, some pupils may ask why we divide it up. Though they do not need to know this, you could challenge them to find out why seven colours. [Answer: It is said that Isaac Newton originally noted five colours (R, Y, G, B, V) and later added orange and indigo to make seven, to match the number of days in a week, notes in a musical scale, and planets known at that time.]

When a filter is placed in the light box, it will absorb all colours except for its own. In other words, the red filter will let only red light through. That is why it appears red. Similarly, the blue filter allows through only blue light, and the green filter passes only green light. In each case the rest of the spectrum disappears.

When two or more filters are combined, theoretically, all colours will be absorbed and no light will be projected onto the whiteboard. That is, in the absence of any other illumination, the board would be not be visible. In practice, the filters may not completely absorb each other's wavelengths, so a little light gets through both. Stray light from the light box and other extraneous sources will also provide some background illumination.

In the colour mixing activity, where two primary colour light beams are overlapped, they produce secondary colours (red + green = yellow; green + blue = cyan; blue + red = magenta). Where all three lights overlap, the result is white – though probably tinged with orange.

Note: For best results use true primary red, green and blue filters, rather than paler colours or other shades that transmit a broader range of red, blue or green wavelengths. Even with these it may be difficult to get true white, because the hot lamp filament is emitting much more red/yellow light than blue. So the intensity of the beam passing through the red filter is higher than through the blue, giving the resulting mix a red/yellow tinge.

If the spectrum produced is not very 'sharp', the pupils could try placing a narrow slit in the front of the light box. This will allow a narrow beam of light to be shone into the prism.

Any light or ray box (with a 24 W lamp) can be used to produce a spectrum. However, if you do not have a light box with hinged mirrors then you would have to use three separate light boxes (or light sources of appropriate power) to produce three separate light beams. The boxes could then be moved to overlap the pools of light.

Remember to turn off the main room lights so pupils can see the light produced by the light box more clearly.

Equipment

(Per group)

- light box (white light) with hinged mirrors along both sides at one end of the box and 12 V, 24 W filament lamp
- 12 V power supply
- triangular prism
- 3 x primary coloured filters (red, green and blue) in frames
- whiteboard and stand
- coloured pencils or crayons

Possible extension activities

- Suggest ways in which different coloured filters could be used to create appropriate 'tones' for different types of events in the same venue, such as:

  a concert | an ice hockey match | a conference | an exhibition.
- Use secondary sources to research the use of coloured lenses in sport, such as cricket.
- Use secondary sources to investigate the Chinese spectrum. Do they define the colours in the same way as we do?