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Light and colour

On a recent visit to the beach, I was asked by the older of my two grandchildren why the sky was blue. Not to be outdone, the younger one then asked why the sea was blue? How do you answer these questions in a way that an eight and six year old will understand? One way is to say that when the light from the Sun, which contains all the colours of the rainbow, hits the Earth's air it is scattered, and it is mainly blue light that is scattered out of the sky. Experience should have warned me of the question and answer session that would follow such an explanation. These questions are answered a little more fully in this Newsletter and a number of tried and tested experiments are described.

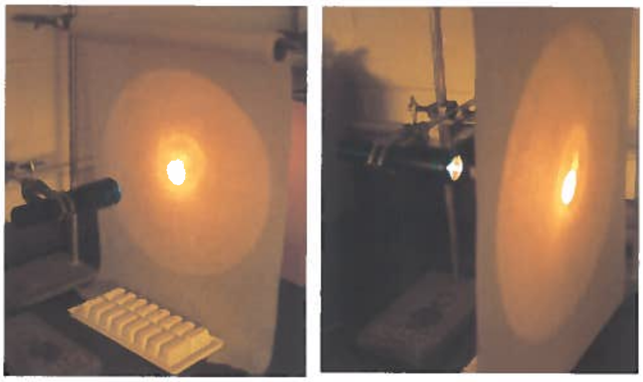
Ian Buchanan, Senior Associate

Why is the sky blue?

Sunlight is made up the colours of the rainbow (Fig. 1) plus a few that we can't see (infrared and ultraviolet). We can sense infrared when we feel the warmth of the sun and experience the burning or tanning effect of ultraviolet. Light can be described as being like waves – like those you see on water but much, much smaller. So why is the sky blue? When sunlight shines through the Earth's atmosphere the blue light is scattered sideways by air particles. When you look up at the sky, you see this blue light everywhere. Therefore the sky is blue.

Figure 1 - *Rainbow over Fife*

The scattering of light can be demonstrated in the classroom by shining white light from a torch at a sheet of greaseproof paper. From the front or the back the greaseproof paper emits light (Figs. 2 & 3).



Figs. 2 &3 *Demonstration of scattering of light*
Light emitted from front and back of paper

This happens because the rough surface of the paper scatters light in all directions. In nature, the scattering of light can be observed when a shaft of sunlight breaks through clouds (crepuscular rays). We can see these shafts of light because a column of air is lit by the sun and a small portion of the sun's light is scattered towards us by air particles (Fig. 4).

Figure 4 - *The sun's light is scattered towards us by air particles*

Why is the sun red at sunset?

At sunset, the sun appears red or orange rather than yellow (Fig. 5). Why is this the case? Again, the explanation comes down to the scattering of light by air particles.

***Figure 5** - Sun appears red/orange in some sunsets*

In the summer at midday, the sun's rays only have to travel through about 100 km of atmosphere to reach the observer. However, when the sun is setting, the rays of light from it have to travel through about 1000 km of the earth's atmosphere to reach the observer (Fig. 6). As the sunlight travels through this great thickness of atmosphere, blue light and to a lesser extent green and yellow light is scattered out of the rays by air particles. By the time the beam of light reaches the observer it is depleted in blue, green and yellow and the sun appears red/orange.

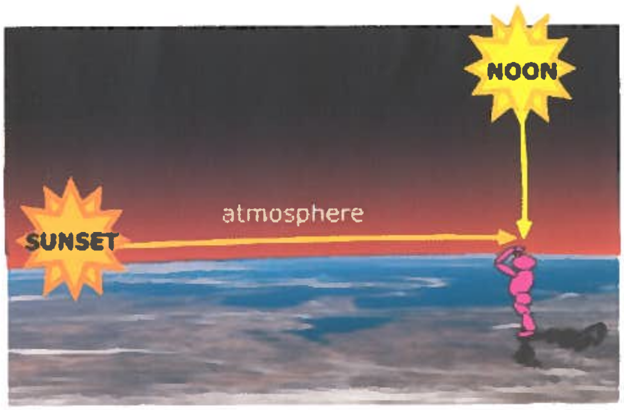


***Figure 6** - When the sun is setting, the rays of light from it have to travel through about 1000 km*

Sunset in a glass

For this demonstration, you'll need a large clear and colourless glass filled with water, a torch, a piece of white card or paper and a little semi-skimmed or skimmed milk.

In the darkest corner of the classroom, place the glass of water on a table and put the piece of card approximately 10 cm behind it. Shine the torch beam through the glass so that it hits the card (Fig. 7). This demonstrates white light travelling through a substance with no scattering (or more accurately very little scattering). Slowly stir in a little semi-skimmed or skimmed milk. The light projected onto the card should slowly turn pink/red (Fig. 8). This happens because the fraction of light that is blue is preferentially scattered out of the beam by the particles in the milk. Hence the beam becomes depleted in blue light causing it to appear pink or red.

***Figure 7** - Torch beam shone through glass of water*

***Figure 8** - Some semi-skimmed milk added*

If the students are then asked to look at the glass containing the milk solution they should notice a slight bluish tinge to it (Fig. 9). This occurs because the observers are seeing the scattered blue light.

If you add too much milk all the light gets scattered and the beam does not reach the screen. Make sure you try this demonstration before showing it to your class so as to find out how much milk to add.

***Figure 9** - Scattered light to side has bluish tinge*

Milk is used in this demonstration because, like the atmosphere, it has tiny particles suspended in it. Just as light is scattered when it hits particles in the milk so also is it scattered on hitting air particles in the atmosphere.

Why is the sea blue?

When the sky is clear of clouds and blue the sea is also blue. Not the most common occurrence in Scotland but it can occasionally be seen. In these unusual weather conditions, the sea appears blue because it is reflecting the blue of the sky (Fig. 10). The sea only looks blue when the sky is blue. Everyone knows that water reflects light. We have all looked into a pool, puddle or toilet bowl and observed our own reflection! Be careful and don't gaze too long or you may become like Narcissus. In Greek mythology he fell in love with his own reflection in a stream. The gods thought he would die of starvation so they changed him into a flower to stay there forever.

Figure 10 - *Sea appears blue because it is reflecting the blue of the sky. Why is the surf in the sunshine white and blue in the shadow?*

Mixing colours

Ask anyone to name the primary colours and they generally answer red, yellow and blue. Some may also suggest that you can produce different colours, even white, by mixing red, blue and yellow paint or ink. Like most of life, in practice it is not quite so straightforward.

We have all seen rainbows and understand to some extent that it is the sunlight ('white light' – Newton's description) being split up into red, orange, yellow, green, blue, indigo and violet (ROYGBIV). However, all of us having dabbled with painting at some time in our lives know that there is no way you are going to get white if you mix all the colours in the paint palette together. The water pot you use to clean your brushes usually ends up a yucky brown colour.

To understand why this happens you need to know the difference between the light emitted by a source and the coloration of a surface.

The coloration of a surface (Fig. 11) is reflected light and is due to the colour of the light shining on the surface and the optical properties of the surface.

Figure 11 - *Colours reflected from a car's surfaces*

When light shines on a surface some of the light is absorbed and the rest is reflected. The colour seen is the colour of the reflected light.

Try this simple, fun colour mixing process using coloured acetate strips (gels) placed on an overhead projector. All you need is an A4 piece of white paper, strips of coloured acetate and an overhead projector.

Figure 12 - *Acetate film patchwork*

Lay different coloured strips on top of each other and observe the 'new' colours produced. We took this a stage further by laying strips in rows to produce a patchwork effect (Fig. 12).

In this instance, the colours seen result from the removal of colours from white using the coloured gels.

Paints and ink

What happens when you mix red, green and blue paint or ink – do you get white? No, you get black. This is because the red part of the mixture absorbs the non-red colours in the spectrum. The green absorbs the non-green colours and the blue takes out the non-blue colours. Therefore no light is reflected because all of the colours have been absorbed and the surface coloration is black. In practice, you may get the familiar yucky brown because not quite all of the light is absorbed (Fig. 13).

Figure 13 - *Mixing inks*

Light sources

Mixing red, green & blue from coloured light sources is an additive process and this can produce all other colours. A computer monitor or the TV screen is made up of lots of tiny dots emitting varying amounts of red, green and blue light. If they are mixed in the right amount we get white light. If red is mixed with green the result is yellow and so on. Fig. 14 shows the projected light from coloured LEDs onto a dark background. Where the coloured discs overlap and all colours mix, there is an area of white light.

Anyone wanting to try this particular demo should contact Jim Jamieson at SSERC - jim.jamieson@sserc.org.uk

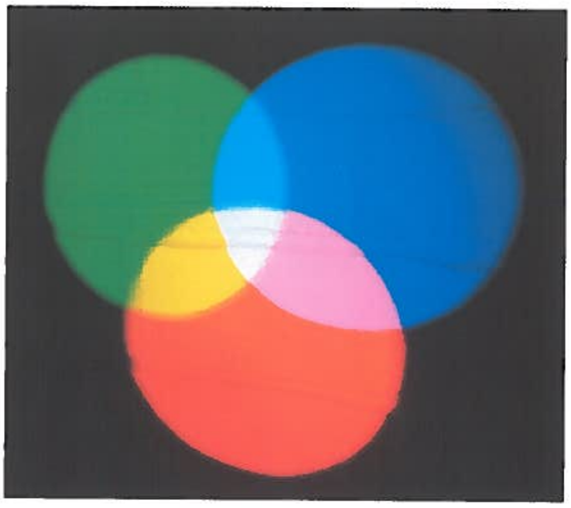


Figure 14 - *Colour mixing with LEDs - almost white!*

Black and white

'White light' is an idea used by Newton to describe sunlight (Fig. 15). From his experiments with prisms, Newton had shown that sunlight is composed of all the colours of the spectrum. White light is now the term used to describe the mixture of colours found in sunlight.

Figure 15 *- White light*

Why are the unprinted parts of a magazine white? This is for two reasons. Firstly you are reading it in sunlight or artificial lighting equivalent to sunlight in its mixture of colours and secondly all these colours are reflected and scattered equally well off the surface of the paper. Why is snow white? Because it reflects and scatters all colours of daylight equally well (Fig. 16).

Figure 16 *- Snow scatters all colours of daylight equally well*

Black is the opposite to white. Blackness is an absence of light. A black surface emits no light, or so little light that you are unaware of any because of contrast effects.

Here's something else to try. The mug in the illustration has a white interior when seen in daylight (Fig. 17). You will need a mug similar to this and a piece of card through which a pencil has been poked to make a hole.

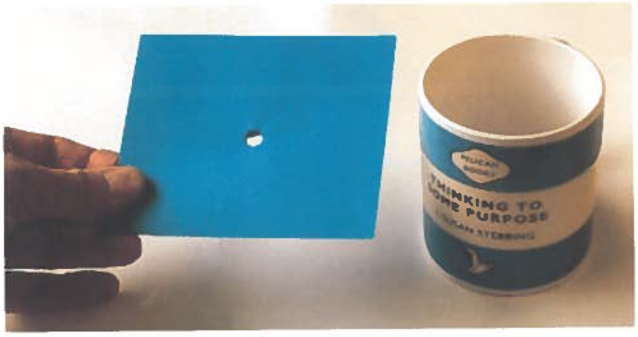


Figure 17 *- Mug with white interior*

Sit the card over the mug (Fig. 18). What colour is the interior? It is now black. There is almost no light getting into it. Therefore there is almost none getting out. Therefore when you look at the hole it is black and when you peer inside it is also black.

Figure 18 *- Same mug with black interior*

This Newsletter and previous issues can also to be found in web

page format on the Improving Science Education 5-14 website at:

http://www.ise5-14.org.uk/prim3/New_Guidelines/Newsletters/menu.htm

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