Capturing curiosity through physics

Figure 1 The 'invisible balls'

Alexander Odeneal explores physics activities that can be used within the classroom to engage children and explore curious phenomena

There is a cat that needs to be let out of the bag before I write any more: I am a secondary school teacher. I am recently qualified and have taken forward from my PGCE the emphasis that was placed upon making more meaningful links with primary school science. I am trying to build upon this as a newly qualified teacher (NQT) and felt it might be worth sharing some ideas that primary teachers could use to capture pupils' interest and support scientific discussions. On a selfish level, I want those children transferring from primary school to come to me already having a love of physics!

This article offers four different activities and an explanation of why they do what they do to support the non-specialist teacher leading the lesson. I am not claiming any are ground-breaking in nature but they all connect with key science in key stage 2 (ages 7–11), promote questioning and discussion, and are fun.

Invisible balls

The first phenomenon I would like to suggest is known as 'invisible balls'. As Figure 1 shows, these are a collection of transparent balls made of an extremely porous polymer. These balls, when placed in water, will seem to 'disappear' (and if they are left for any prolonged period of time, they will absorb a lot of that water).

When light enters water, the light will *refract*. This means that the light waves change their speed and, depending on the angle at which light enters the water, they will change direction too. (Refraction is also the reason a pencil appears to be 'bent' when we put it in water at an angle.)

Every material that allows light to pass through it, including both water and the disappearing balls, has a *refractive index*, which is essentially a property of that material (given as a single number) that determines how much light will change direction when it enters that material.

As mentioned, when these balls are placed into a body of water (as in the bowl in the picture), they seem to disappear. This is because the refractive index of the balls is exactly the same as the water, so the light does not refract when it moves from the water into a ball or from a ball to the water.

Despite being significantly older than a primary pupil, I am still extremely excited by the chance to play around with this particular investigation. It is perfectly safe for children to put their hands into the water and feel, and even remove the balls from the water. When they put them back they will disappear again.

Points for discussion

- Ask the children to predict what they think will happen when the balls are placed in the water and why. What do they observe happening? What explanations can they offer for this?
- Show them a pencil partly immersed in water and ask them to try to explain its appearance.
- What links can be made between the pencil and the disappearance of the balls?

Put simply, this investigation helps to show how light interacts with different substances (in this case the activity is considering specifically water and the superabsorbent polymer the balls are made of). The concept behind it, *refraction*, can be applied to lots of different materials in everyday life.

This also leads nicely into the second activity.

Key words: Curiosity Physics

Refraction rainbow

This investigation is likely to be easier to conduct with equipment that can ordinarily be found within a school: a light box with a slit plate and a glass prism, though if you happen to have a crystal chandelier in your classroom, that will work too!

The principle behind this activity is very similar to the invisible balls one: both are based on *refraction*. However, what happens to the light in this case is obviously a bit different: the aim here is to produce a small 'rainbow' of light using the prism. The darker the classroom, the easier it is to see the rainbow.

Figure 2 shows a light box (silver, on the left) producing a ray of light. This light travels through the slit plate as a single, thinner ray. The ray then hits the prism at an angle, meaning that the ray refracts. The now-separated rays refract again and separate further when they leave the prism, producing the small rainbow on the mirror shown on the right-hand side of the photo. (You don't have to use a mirror – any plain surface (including a sheet of paper) will do.)

Pupils may or may not know that light from the Sun or a light bulb is made up of all the colours of the rainbow; this is known as 'white light'. When the white light travels into the prism at an angle, each of the different colours travels at a different speed, and so they start to separate out. Because of the shape of the prism the colours are separated out more when they leave the prism on the other side, showing a little rainbow on the mirror.

There are several reasons I suggest this investigation for primary pupils. The main one is that it produces a result that is easy to see, with relatively little work. It is simple enough for pupils to do themselves if the equipment is available. The explanation does not have to go beyond '*the shape of the glass splits the light into the colours of the rainbow*', but it is possible to add more detail if the pupils are interested. The fact that this is easy to tailor to the age and ability of the pupils means it could be used for pupils throughout the primary age range.

It is easy to choose how involved the pupils are in setting up the investigation: they can have a go themselves in pairs or just watch as the teacher sets it up. To involve the pupils a bit, but without having them handling the hot light box, set up the light box yourself, and have the pupils place the prism in varying positions to work out how to find the 'best' rainbow.

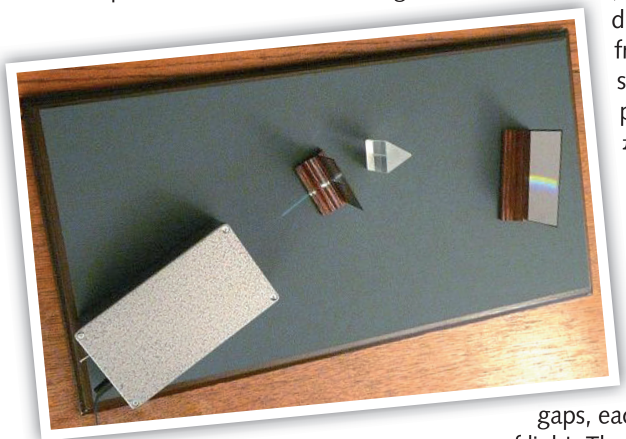

Figure 2 Refraction of light within a prism

Points for discussion

- How many colours are there in a rainbow?
- Where does the rainbow come from?
- Can we recreate a rainbow in the classroom?

This particular investigation is part of the GCSE science course so primary pupils will feel particularly impressed that they are learning such in-depth physics! But it also acts as a great starting point for children to learn about light, stimulated by something they are very familiar with – a rainbow.

Diffraction patterns

(Warning! There is some serious science coming up!) This activity is slightly different, and is more complicated to explain. However, the patterns produced are more impressive than those mentioned already. The activity demonstrates the phenomenon called *diffraction*, in which light 'bends', or changes direction, as it meets the corner of an object or goes through a small aperture (or just 'hole'). This is shown in Figure 3.

You will need a laser of some sort (e.g. a red laser pen) and a diffraction grating (borrowed from your local secondary school, made yourself or purchased online for around £1 each). As the light from the laser passes through the gaps in the grating, it starts to 'spread out' or 'bend' as in Figure 3, but in this case through each and every gap.

Once the light has travelled through the gaps, each gap is acting as a source of light. Therefore, the light from one gap will interact with the light from the other gaps. In some places the light waves will undergo *constructive interference*, which means they join together and become twice as bright. In other places the light waves will undergo *destructive interference*, where the light from the two slits cancels out, and it appears dark. This produces a pattern, like the one shown in Figure 4 (note that this diagram is based on a red source of light being used initially).

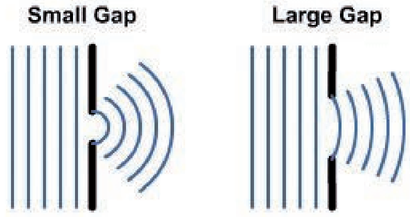

Figure 3 Diffraction in action!

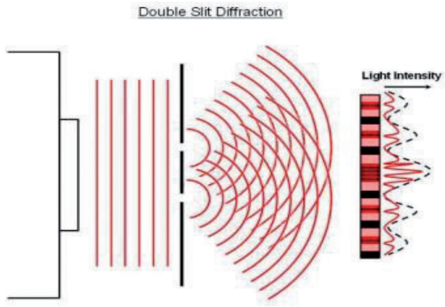

Figure 4 Diffraction patterns with light passing through two slits and using a laser as a source

In this particular diagram, there are only two slits ('double slit diffraction'). On the right-hand side of the diagram is a piece of white card or a plain background – you can see that there are parts where the red light has intensified (like in the very centre), but there are other parts where it is black and the light waves have cancelled out to form a dark patch.

Figure 5 shows the kind of pattern that can be produced if the initial light source is made of white light (rather

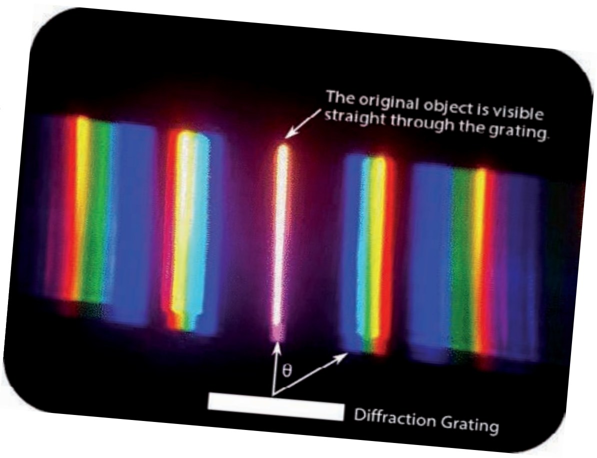

Figure 5 Using a white light source to demonstrate diffraction

than a red laser pen). This picture shows that the very centre has allowed the white light to travel straight through. As you move further from the centre (in both directions) there are dark patches, and it is possible to see two rainbows of decreasing brightness on each side of the centre.

While this activity is undoubtedly more difficult (it is part of the A-level physics curriculum), it produces a much cooler effect.

To explain this to primary pupils, for a *monochromatic light source* (i.e. a single colour, like a red laser pen), consider using a simple explanation: the light splits into two different lights, and then it adds together in some places to make the bright parts, and cancels out in other parts to make the dark parts. When looking at the white light source, the different colours are separated when they go through the slits, and then add together or cancel out in the same way as with a single colour.

Points for discussion

- Where are lasers used?
- Look at laser beams through talcum powder to demonstrate the straight line it travels in.
- What language are the children aware of in relation to outside the visible spectrum: ultraviolet? infrared?

Safety: To ensure safe practice during this activity, it is important that the users never look directly at a laser or point a laser at someone else's eye. This is a teacher demonstration activity.

Structure of the atom

This practical activity will help pupils to understand that the atom, commonly thought among younger children to be the smallest particle that exists in the universe, is actually made up of even smaller particles.

In the years leading up to 1911, scientists thought that the atom was structured a bit like a plum pudding, with the 'cakey' part being positive and the plums being lots of little negative bits (Figure 6). In 1911, British scientist Ernest Rutherford did an experiment known as *Rutherford's scattering experiment*. He thought that if the atom was structured like a plum pudding, then positive (alpha) particles fired at gold foil would be deflected (since positive charges repel – if pupils aren't sure about what charge is then it is possible to use the north and south poles of a magnet as an example; magnetism and electrical charges are not the same thing but the analogy would work). However, the way that each of these positive alpha particles changed direction (or not) when going through the atom showed that the nucleus of the atom (the middle part) must be small, leaving a lot of the atom empty. It also showed that the nucleus must be positive too.

To engage pupils in this investigation, you will need a Nerf gun and the accompanying 'darts', and some pupil volunteers. One pupil stands in the centre of a large circle to represent the nucleus in the centre of an atom; the remainder of the class stand in a line and fire the Nerf gun straight ahead through the whole circle. Some of the darts will hit the pupil nucleus and bounce off, but most of the darts will miss and go completely straight – this won't of course be the case if all the darts are fired directly at the pupil in the centre.

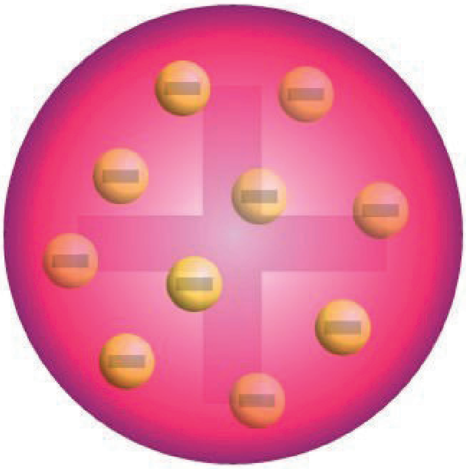

Figure 6 The 'plum pudding' model of the atom

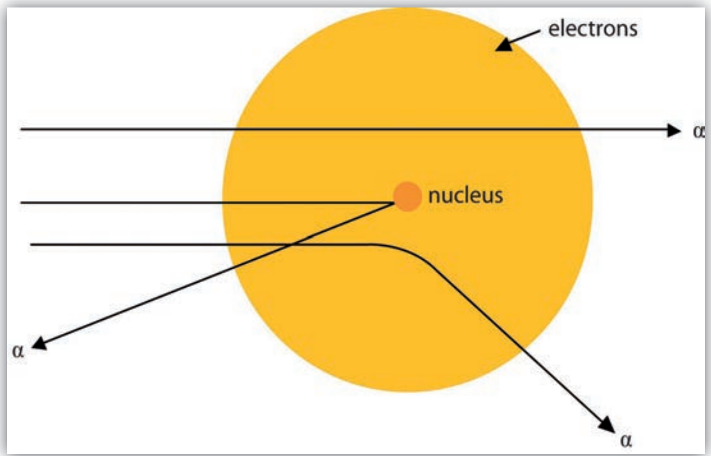

Figure 7 Replicating Rutherford's scattering experiment

Figure 7 shows how it works. The yellow circle represents the atom as a whole (electrons are too small to be seen) and can be represented with a chalk line on the ground or some tape; the nucleus is a pupil volunteer. Looking at where the darts land can show the direction of the alpha particles. Most will go straight through (since the circle is mostly empty), and some will hit the pupil nucleus and be deflected.

Points for discussion

- If an atom is mostly 'space' how is a table (or chair, or anything else!) solid?
- How does this link with the research of CERN and other bodies?

Safety: To ensure that the pupil nucleus volunteer is safe, make sure the pupils firing are a safe distance away so that the darts won't hurt. They should also wear eye protection.

Conclusion

I am not naive enough to suggest that these activities are accessible to all in terms of the science that explains and underpins them. However, along with a whole plethora of other investigations, these are simple enough to conduct, explain a key idea in physics and hopefully excite primary pupils about physics. Pricking their curiosity in primary school may go some way towards stimulating an interest in science and supporting their subject choices post-16.

Figure sources/Websites

Figure 1: www.youtube.com/watch?v=Rgl6srsZGoo
Figure 2: www.creative-science.org.uk/prism.html
Figure 3: www.s-cool.co.uk/a-level/physics/diffraction/revise-it/diffraction-interference-and-superposition
Figure 4: https://thiscondensedlife.wordpress.com/2016/05/21/diffraction-babinet-and-optical-transforms
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Figure 6: www.universetoday.com/38326/plum-pudding-model
Figure 7: www.atulranatutors.co.uk/physics/rutherfords-gold-scattering-experiment-for-gcse-science

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