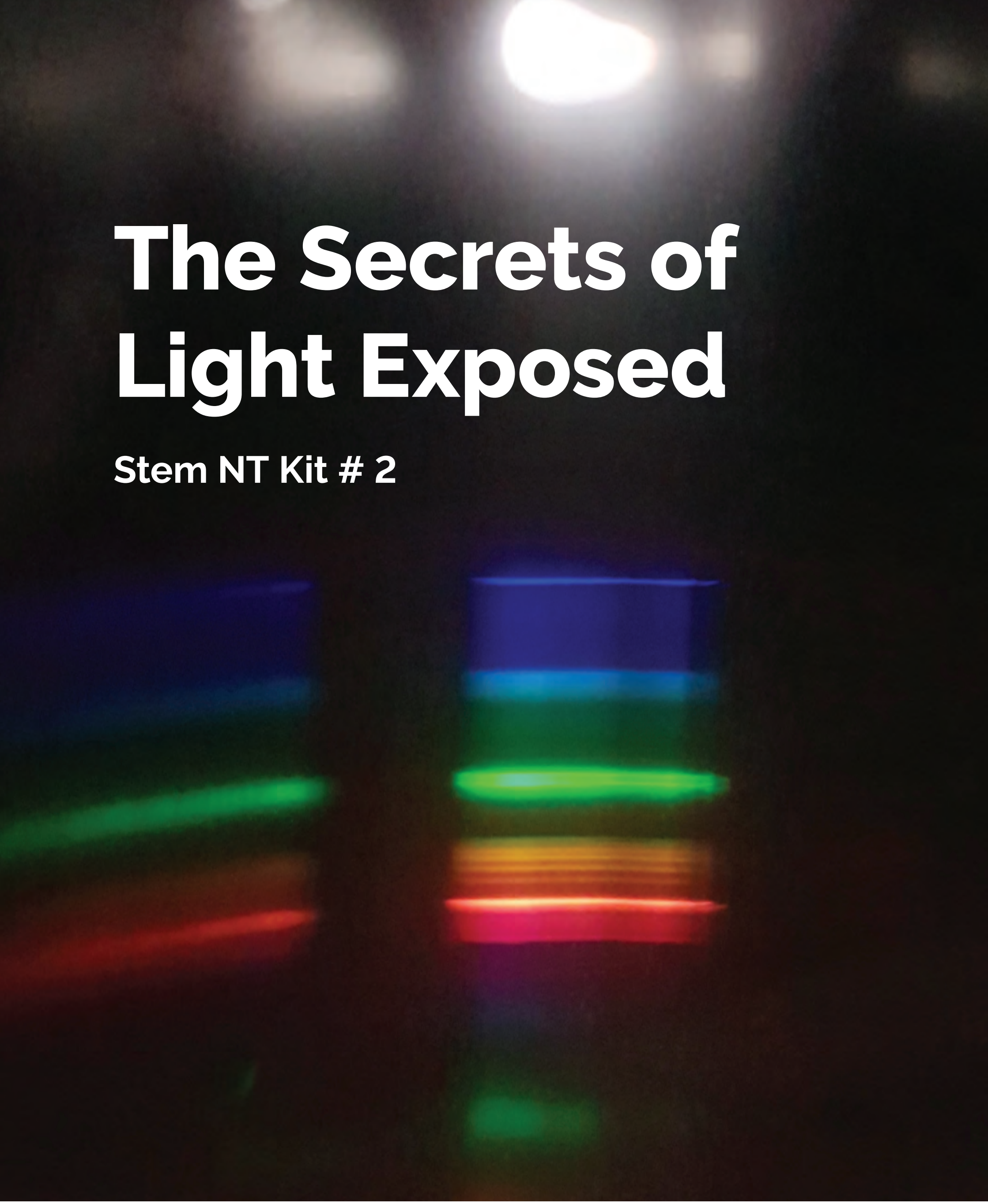
The Secrets of Light Exposed

Stem NT Kit # 2



An Australian Government Initiative
Inspiring Australia
INSPIRED NT
CITY OF DARWIN LIBRARIES
CHARLES DARWIN UNIVERSITY AUSTRALIA

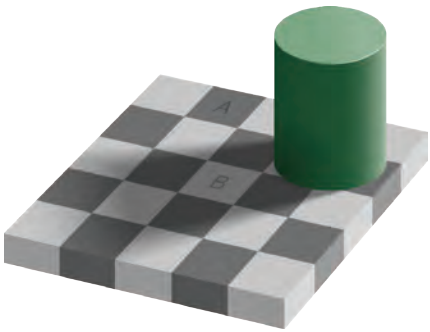
STEM NT KIT # 2
The Secrets of Light Exposed

Welcome to wonderful world of light!

From the day we first opened our eyes to this moment right now we have relied on light to tell us about the world we live in. It shows us where we are going. It brings us joy as we look at a beautiful rainbow. It helps us to learn and play and it is essential to the functioning of life for many, many species.

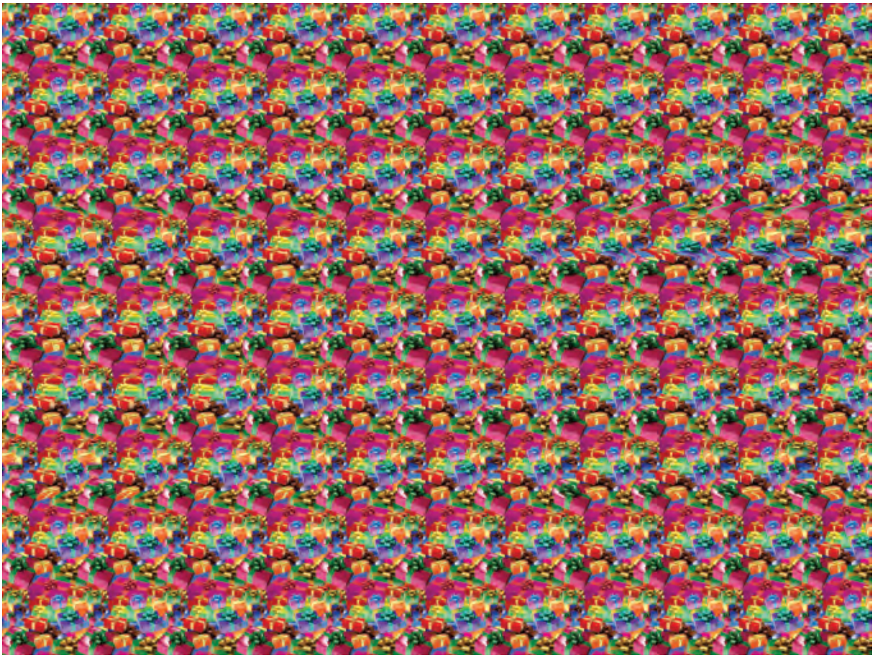
The thing is though, most people go through life without shedding any light on light. We experience the world through our senses, our eyes, our ears, our noses, our taste buds, and through touch and it is the brain that makes sense of all of this. However, the very senses that make our brains powerful also limit our ability to experience the world around us.

Take a look at this chess image; it looks like square B is lighter than square A.



In reality though, they are the same colour. It is possible to trick the brain and this is the source of optical illusions. If you get a piece of paper and use a pencil to push a hole through where square A and B are you will see they are the same colour. This shows you that the brain has limitations and so do the eyes.

Now try this magic eye image - go cross-eyed and see if you can ready the 3D message hidden inside.

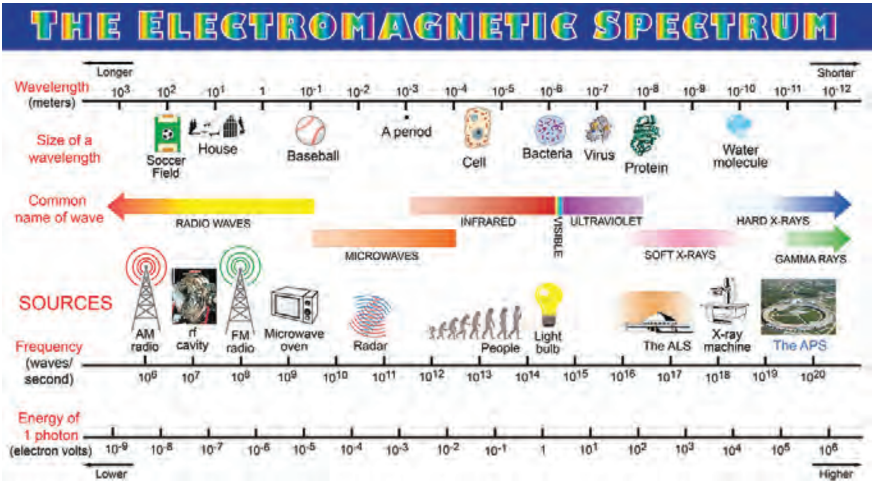


Can you read NT o the magic eye figure above? You can also create your own 3D hidden message using this website:
http://www.sarahpiercegames.com/makeastereogram/

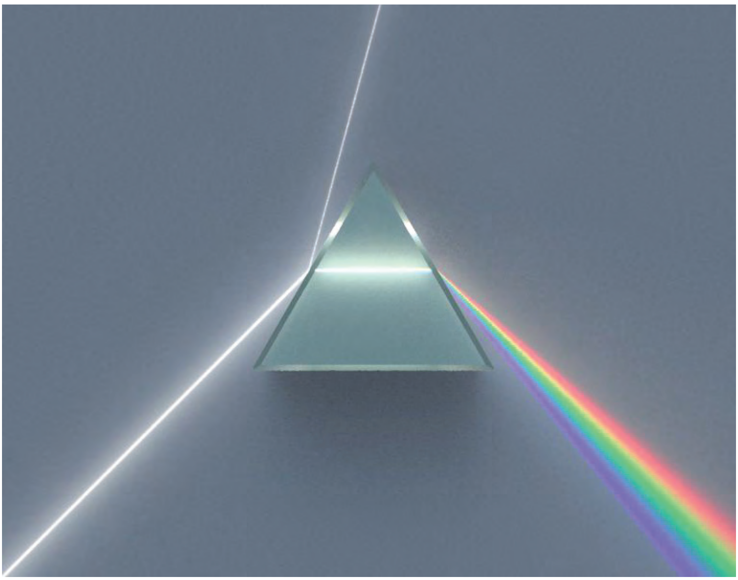
What is light?

Light is part of the electromagnetic spectrum, which also includes radio waves, microwaves, and x-rays. Human eyes can only see in the visible spectrum. Yet, it is only one tiny part of the full electromagnetic spectrum that stretches from radio waves thousands of kilometres long to tiny x-rays and gamma rays that have so much energy that they are dangerous to be around for too long.

Look at the electromagnetic spectrum figure, notice how small the visible light region of the Electromagnetic spectrum is - wedged in between infrared and UV light.



It is common knowledge that if you use a glass prism you can separate sunlight into its separate colours (separate wavelengths of visible light).



This was famously discovered by Isaac Newton in the late 1660s and published by him in 1672. Light can tell you a lot of things; for instance, when we look at grass, we can see it is green.

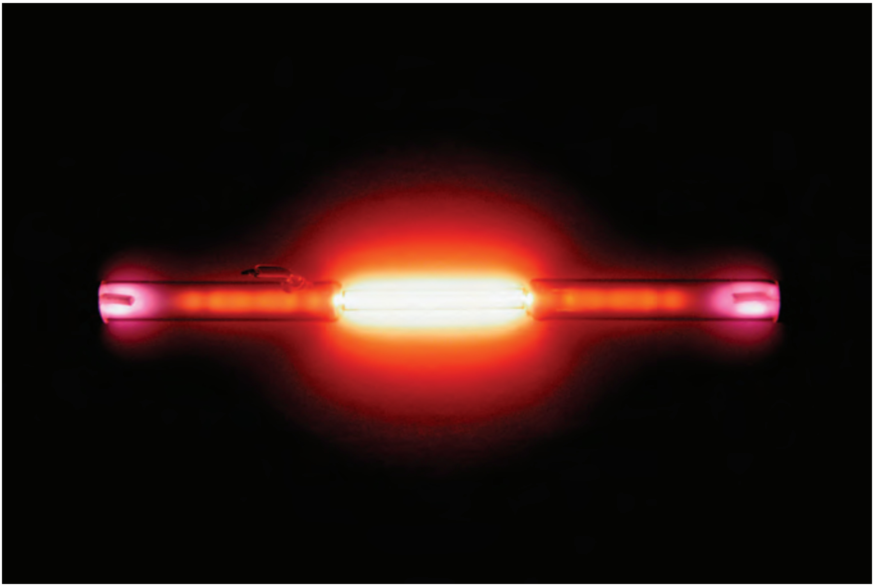
The reason the grass looks green is due to the chlorophyll in the grass cells. The grass absorbs all other colours of white light from the sun but reflects green into our eyes and so we see the grass as green.

Have you ever wondered what the colour of grass is when all the light has gone away? Say for example you put the grass into a box and tape it shut so all the light cannot get in; what colour is the grass now?

Light is a very useful thing. It can tell us many more things than simply what colour an object is. It is linked to the elements something is made of. We can use light to see what things are made of. Every element has what is known as a 'spectral fingerprint'. Just like you and I have unique fingerprints, different elements are able to release different colours of light.

We can measure these colours of light and determine what element we are looking at. This process is called spectroscopy, which allows us to look at starlight from a distance star and determine the elements that make that star up.

An instrument which divides light up into its separate wavelengths is known as a spectroscope. You need a special instrument to do this because the human eye cannot separate out all the colours independently. Take for example a helium gas discharge tube – it is a tube filled with the noble gas element helium. When an electric current is passed across the tube, just like a fluorescent globe, the helium tube lights up and we see its colour:



The helium tube has a lovely orange glow. The thing is though, there is not one colour coming out of that tube – it is quite a few.

With the help of a spectroscope, the instrument which splits light into all its different colours, we see all the different lines of helium's spectral fingerprint:

But you do not need an expensive scientific instrument though! You can make your own spectrometer at home and that is what is in this kit.

Foldable Mini Spectrometer

You will make your own Public Labs Foldable Mini Spectrometer from https://publiclab.org/

The Inspired NT "The Secrets of Light Exposed" kit has:

(1) Instructions for assembling the foldable mini spectrometer

(2) A cardboard mini spectrometer ready to cut out

(3) A piece of cut-up DVD (used to split the light)

(4) A foldable Inspired NT optical illusion character to cut out and assemble

(5) A card with QR links for a video on how to assemble the spectrometer, how to use the spectrometer and how to assemble the optical illusion character

You will need:

(1) A pair of scissors

(2) A sharp knife

(3) An adult to help you (if you're a kid 😀)

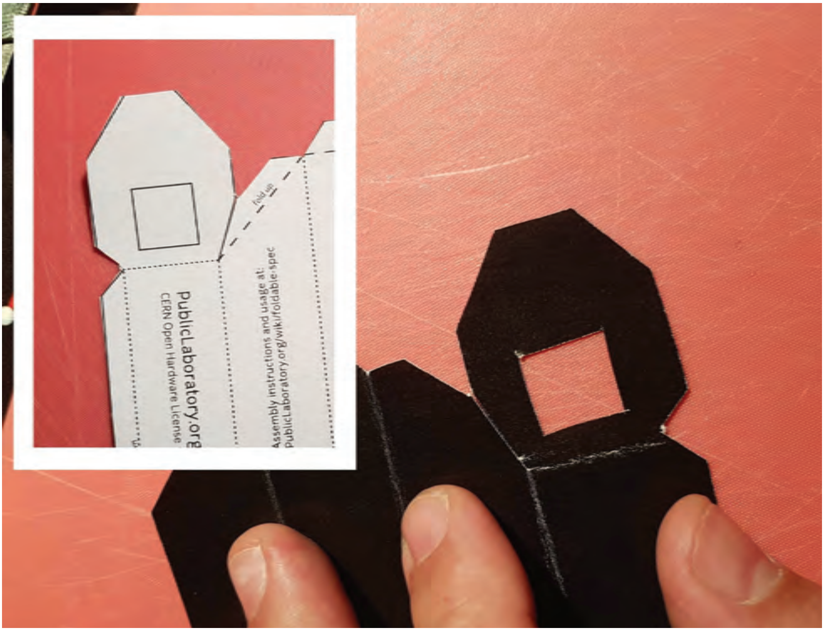
(4) Tape or a hot glue gun <u>(Caution – hot glue is hot!)</u>

Now you are ready to start! For the foldable mini spectrometer to work, you should follow the step by step instructions below:

In addition to the Public Labs instructions or the video, you can follow the step by step instructions below:

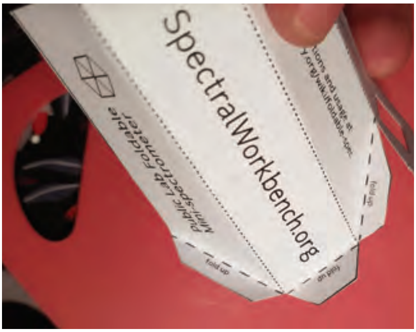
1. Cut out around the outside of the spectrometer. The bold lines need to be cut, and the dotted ones are for folding. Do not cut the dotted lines.
2. Be sure to cut along the solid line near the square window.

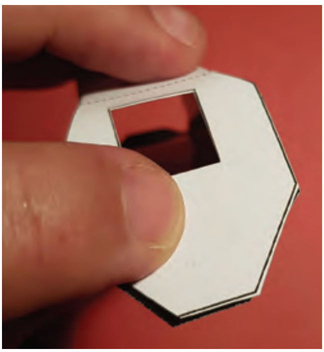
3. Cut out the square window.

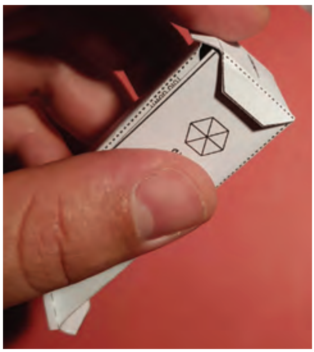


4. Cut a slit - make sure it is nice and thin. You might need to make the slit bigger, but for now, keep it small. It is easier to make a small slit bigger, but very hard to make a big slit smaller.

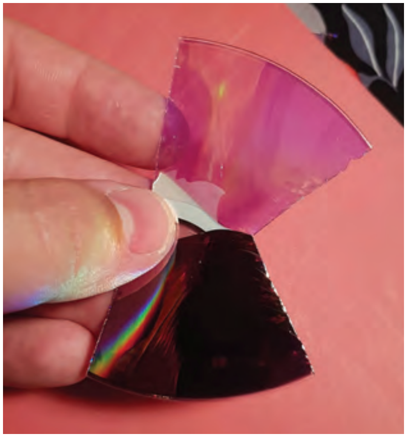
5. Fold the spectrometer along all the dotted lines.

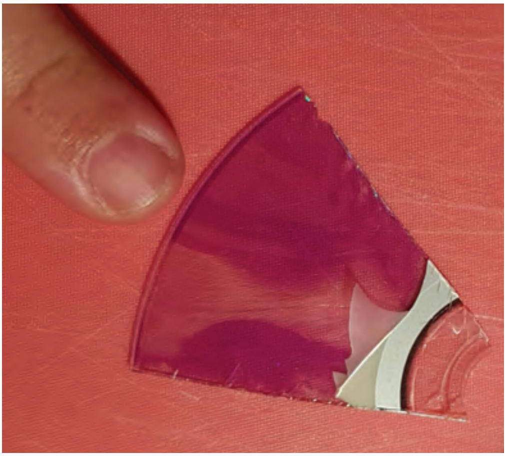


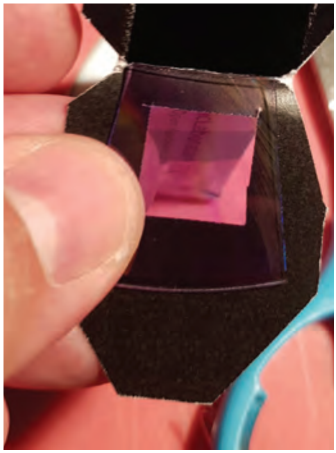




6. Cut the DVD to size and stick it onto the window.

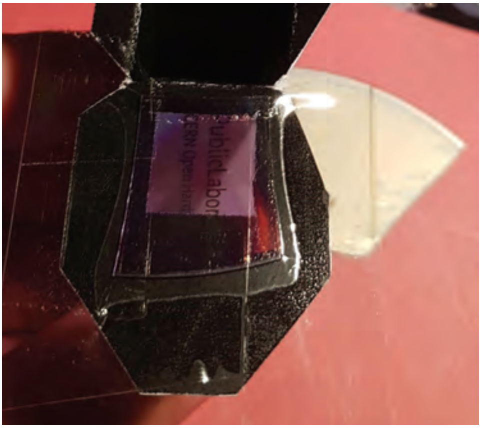




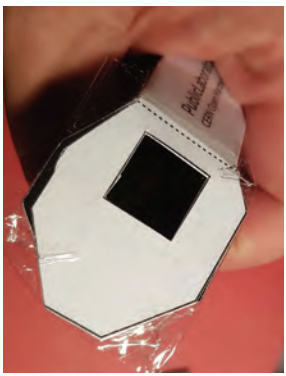


Note: It's important the DVD is cut and placed the right way. The curvy part of the DVD should face towards the bottom of the 'window' slit (see below). If the DVD faces the wrong way the colour lines will not show up in the right place.

Make sure the tape does not cover over the DVD window – it should only stick to the sides. You want the window to have as much clear DVD as possible.

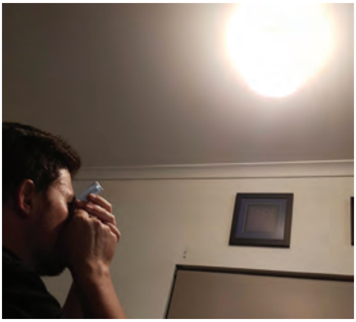


7. Secure the body, slit end, and window end of the spectrometer.

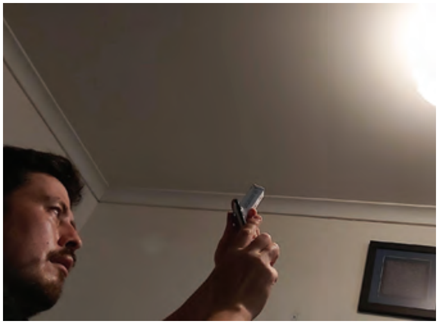


8. Go do some spectral photography! Look through the DVD window and hold up the slit to the light. If you cannot see anything make the slit a little bigger. Hold the spectrometer to your eye like in the picture:

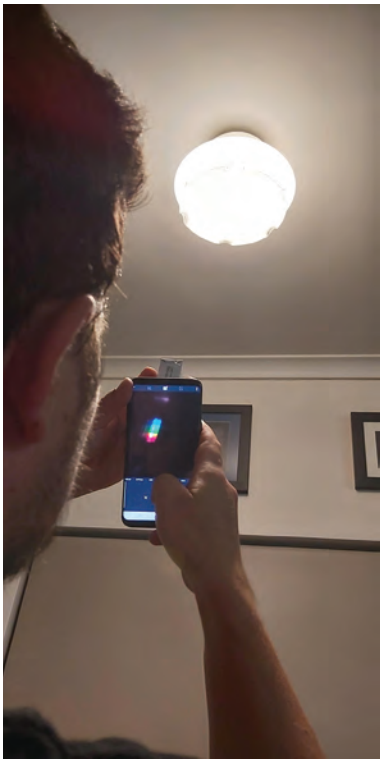
With my eye:



With my phone:



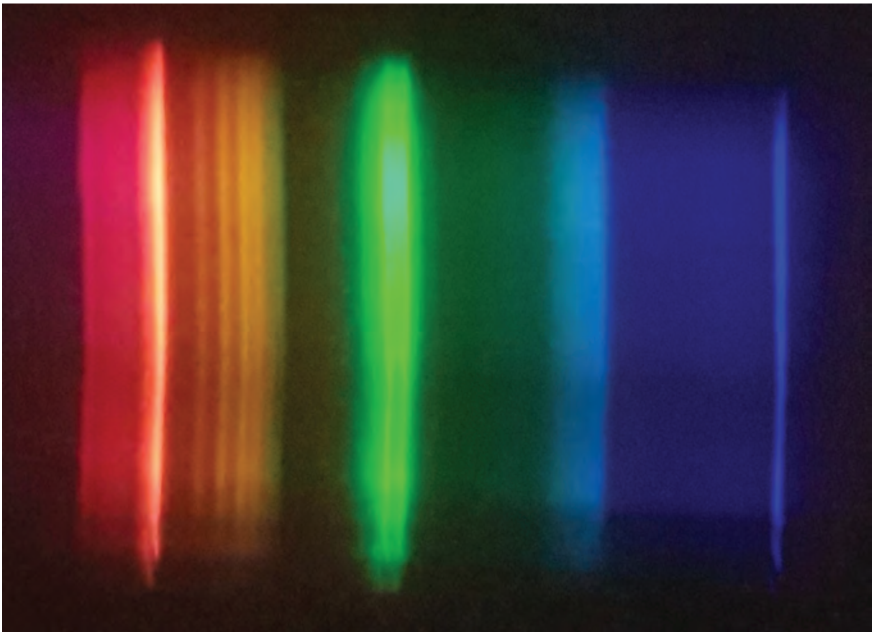
Use the phone's camera and make sure you turn the flash off. Wait till you get a good pic then take it - you can always crop the image later.



Now you are ready to start using your spectrometer!

The first and best thing to do is look through the spectrometer with your eye at a fluorescent light bulb or fluorescent tube. If you look at a fluorescent tube you will see lines which are the elemental spectral fingerprint of the gas elements in the fluorescent tube. If you look at an ordinary light bulb or a LED light bulb you will see a rainbow.

The first thing you should notice, especially if you look at a fluorescent bulb, is that the white light you see is not white at all. Look at the lines of colour and the black space between them.



The fluorescent tube is only releasing those colours of light you see in the picture; and yet you see them all at once as white light. What looks white to our eyes is not white at all – it is an array of beautiful bright colours; red, yellow, bright green and two shades of blue. These colours combine to make white.

You must make sure to use a light which has a gas in it, like a baton tube or low power fluorescent globe (kids, ask your mum or dad to help if you need to).

You can also look at the sun with the spectrometer, but you should not do this with your eye. Use a mobile phone to get a photo of the spectra of the sun. It will be very intense, but you will see a bright rainbow - that is all the colours of the sun coming out and being separated.

What am I looking at?

First, we need to understand a little bit more about atoms. Most of us know that all of the matter around us, the solids, liquids and gasses that make up the world around us, is made up of atoms.

Atoms, these building blocks have two parts: electrons and a nucleus. For light, we will only talk about the electrons. Electrons are tiny particles that whiz around the outside of the atom. However, they cannot just move around freely. Like cars on a multi-lane highway, they have to stay in their lanes. We call these lanes “energy states”.

One way to visualise these Energy States is a ladder. You can only stand on certain rungs of a ladder - you cannot float half-way between two rungs. If you want to move up a rung, you need to put in some effort - some energy - to move up. Moving down is much easier, because you are releasing some of the energy you used on the way up.

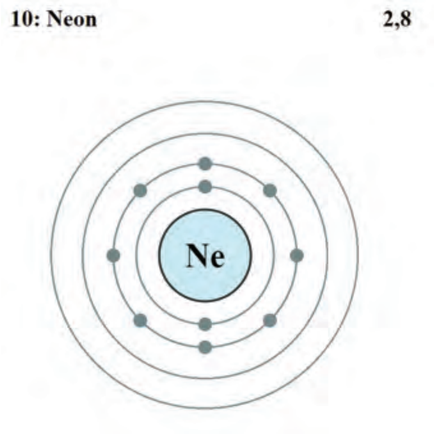
But electrons are not people and energy states are not rungs. An electron cannot drink a sports drink to get energy - it gets it from light.

We are learning here the basics of Quantum Mechanics. To learn more you can use this QR code or the link below to see the video "Quantum Mechanics for Babies" by Chris Ferrie.

https://www.youtube.com/watch?v=IBBO0ypubCc

Let's look at a real example - a neon atom. In the diagram below you can see the nucleus in the centre and the grey electrons circling it. The grey rings represent the different energy states - the rungs on our ladder. For an electron to move from one ring to the next, it needs to absorb energy. But if an electron drops from one ring towards the centre, it will give of some light.

We can add power to a neon atom, for example, by turning the power on for a Neon sign. This will move some of the electrons up the ladder, and after a time, they will drop down again, emitting a photon of light.



Since the distance between the energy states does not change, the photon emitted will have the same energy, every time. A neat thing about photons is that their energy relates directly to their colour If we know which colour (wavelength) we are seeing, we know how much energy the electron lost moving from one energy state to the next.

Just like with our ladder, an electron does not have to move one rung at a time. It can drop a few levels at once, giving off yet another coloured photon. That is why you will see many coloured bands when you look at your fluorescent light.

Since each atom is slightly different, you get a slightly different set of colours emitted by each - a light “fingerprint” for every atom. We can then use this to identify the atoms that are in an object - a study called spectroscopy. We call these “fingerprints”: elemental spectra.

This also proves that elements have set energy levels for electrons. If elements had random energy levels electrons would jump up all over the place and release all kinds of colours and you would get a rainbow of colours.

When we look at the spectra of neon, or the fluorescent tube, we see specific colours with dark gaps in between. Those specific colours show the energy rungs of the neon elemental ladder.

To see down to the individual energy level of electrons all you need is a bit of cardboard, some cut up DVD and a basic level of quantum mechanics knowledge!

Congratulations. You now know the secret of light. Take spectral photographs of as many things as you can! Always remember that things are never really as they seem and sometimes all it takes is a bit of cardboard and plastic to change your perspective on the world.

The candlelight experiment

Take a photo of the spectrum from a candlelight (Caution – hot and fire risk!). You will notice you will get a rainbow and not the straight lines of colour with the dark space between them, like the fluorescent tube. Why is this?

Well, light can be made in two ways. One is the method we mentioned above for the fluorescent tube - the electrons jump up and down between rungs and release light in the process. In that case the only place the electrons can go is up and down the specific rungs of the energy ladder. They will only release light with a single colour - hence the strong lines in the spectrum.

The second way to create light is through heat. For a candle flame, it comes from burning the candle wax. Temperature is really the measurement of how much the atoms in an object (or the air around you) are moving. If you think of the temperature in the room right now, every air molecule in the room will not be moving at the same speed, so they will not be at exactly the same temperature.

When you read a thermometer, it gives you an average temperature of all the air molecules hitting it. You can think of the air as having ‘a range of temperatures’.

If you were to graph the speed (or temperature) of each air molecule you would get a ‘bell curve’ - this is a curve where most of the molecules will be around the room temperature (say, 25°C) - roughly half of them will be within 24 to 26°C, but some will be 23°C, and others closer to 27°C.

To see a bell curve in action, use this QR code or link below to go to this video demonstration from the UK Institute of Mathematics and its Applications.

https://youtu.be/6YDHBFVIvIs

It is the same for any source of light that comes from heat generation. Every single atom in a candle flame is not at the same temperature and so it releases a whole bunch of different colours (wavelengths) of light at random wavelengths. Consequently, it gives off a smooth rainbow.

The same applies to the sun. The sun generate light through heat and because every atom involved in the sun is at different temperatures, they give off a range of colours; and hence you see a rainbow (Caution - do not look directly at the sun with your eyes!)

Try and take photos of anything which gives off light. Use the spectrometer to see the true colours it is made up of.

Nature's spectrometer

Water droplets in the air can take the place of the spectrometer and split up the light of the sun into its different colours, forming a rainbow. Just looking at a rainbow shows you white light is not a colour – it is all the colours of the rainbow.

The effect on the photo below is called the double rainbow. Note how the colours are reversed in the second rainbow (which is harder to see).

For a bit of added fun with optical illusions try this video:

https://youtu.be/Z0aLjw52ip4

Information about the STEM Kit developer:

Adam Turley

Adam is a Stage 1 and 2 Chemistry and Physics teacher at The Essington School Darwin. Adam went into the Army at age 17 and completed a Bachelor of Science with Honours in Chemistry at the Australian Defence Force Academy. In 2010, he was posted to RAAF Darwin with Joint Logistics Unit (North), met Hannah and decided to discharge and stay. He completed his teacher training at CDU and final placement at Taminmin College. Science is Adam's passion and sharing the story of science with his students continues to be his focus; as well as his two young kids and partner. Adam does science outreach on occasion and facilitates model rocket building workshops and liquid nitrogen and dry ice cream experiences. The best part of being on site at CDU for Adam is the chance to catch up with some of his ex-students and see how they are all progressing in their tertiary training.

ESSINGTON

This STEM NT KIT was proudly sponsored by:

An Australian Government Initiative

Inspiring Australia

INSPIRED NT

CITY OF DARWIN LIBRARIES

CHARLES DARWIN UNIVERSITY AUSTRALIA

cdu.edu.au

inspirednt.com.au