Creating Science – Incendiary Sunlight

How much energy does the sun produce? Enough to start a fire? ***#CreatingScienceSunlight***

DANGERS!

This section cannot explain every possible danger in this activity. Adult care and surveillance is required at all times. Please exercise all appropriate caution at all times.

1. *We will be using light! MAKE SURE you wear* ***<u>good sunglasses</u>*** *as the bright spot can hurt your retina, though rarely permanently unless you direct the sunlight directly into your eyes using a mirror or shining it directly into your eye. So DON'T DO THAT!*
2. *We will be using enough heat to make* ***FIRE****! Be sure to have water nearby for little burns or conflagrations. Use the LENS carefully, on a bright day with the right combination of bad luck, it can start a fire in <u>seconds</u>. DO NOT do this activity on a day of total fire ban, it will possibly get you arrested and facing a hefty fine.*
3. *We are POPPING BALLOONS.* ***Do not*** *let balloon shrapnel get into drains and sinks. Please dispose of appropriately. Make sure you WARN STUDENTS, and have ear plugs or enough distance for sensitive children.*

Suggested Outcomes

(NOTE: This is by no means an exhaustive list of possible outcomes, neither is it intended that ONLY these outcomes can or should be met. Science is a deeply interrelated activity, and you may find cross curriculum links you can and should use.)

Science understanding

As we use sunlight to heat things up, we can learn that;

- Earth and space sciences 3: Earth's resources, including water, are used in a variety of ways
- Physical Sciences 5: Light from a source forms shadows and can be absorbed, reflected and refracted

Also

- Physical Sciences 1: Light and sound are produced by a range of sources and can be sensed
- Physical Sciences 3: Heat can be produced in many ways and can move from one object to another

Science inquiry skills

As we make scientific predictions and carefully record our results, we have the chance to;

- Questioning and predicting 1-2: Respond to and pose questions, and make predictions about familiar objects and events – as we try and see what balloon colours heat up best.
- Planning and conducting 1-2: Participate in different types of guided investigations to explore and answer questions, such as manipulating materials, testing ideas, and accessing information sources – by using the lenses to heat up balloons and other objects.
- Processing and analysing data and information 1-2: Use a range of methods to sort information, including drawings and provided tables and Evaluating 1-2: Compare observations with those of others – as we carefully record our results and compare them with other.
- Communicating 2-3: Represent and communicate observations and ideas in a variety of ways such as oral and written language, drawing and role play – as we write up a report about what we have learned.

Science as a human endeavour

As we learn that light can be a dangerous way to start fires, we learn that;

- Nature and development of science 3-4: Science involves making predictions and describing patterns and relationships
- **Use and influence of science 3-4: Science knowledge helps people to understand the effect of their actions**

Science vocabulary words

Tier 1 (Everyday words) Sun, light, fire, danger.

Tier 2 (Dual meaning)

Tier 3 (Specialised vocabulary)

- Incendiary – able to start a fire (often used colloquially to mean 'able to start a very big fire very quickly, such as a bomb.')
- Infrared – a colour of light that we cannot see, but that carries the most heat energy of any form of light, thus we can often feel it with our skin. It was discovered and described in 1800 by the German astronomer and musical composer William Hershel, who learnt he could bounce it off mirrors and focus it with lenses, even though he could not see it at all! (He called it 'caloric rays' at the time).

- Fresnel lens. A special kind of lens that was developed by French physicist Augustin-Jean Fresnel for use in lighthouses in the 1700's. It is just as wide, but very flat. They are nowadays often flexible plastic, made up of concentric circles that focus light.

Preparation

- You will need a set of Fresnel lenses; one for each student is ideal, usually fairly cheaply online.
- Balloons. Lots of balloons. At least three per colour per student, and enough water balloons for everyone. *Be sure to dispose of carefully.*
- You will do well to have a set up like William Hershel – triangular prism, an old thermometer, and a little stream of sunlight coming through the window.
- Other related infrared equipment, such as a night vision camera, an ordinary remote control and smart phone camera.

Learning Intent (student friendly)

'We are learning to' (WALT) – pop balloons. No, seriously, we are learning about the immense power of the sun, and thinking of ways to put that power to better use in society.

Success criteria

'What I'm looking for' (WILF) – clear tables which indicate students have been thorough in their creation of scientific knowledge. Also, the activity encourages students to form conclusions about their data and make suggestions of how to put the sunlight to better use, thus, a poster or even oral conversations about the meaning of their data can be very valuable.

Student learning goals

Help students make a self-monitored learning goal for this lesson.

Evidence of learning

What EVIDENCE do you have that your students have met or exceeded the learning expectations?

Suggestions for other year levels

As always, more material is presented here than can be used by the average class during the average lesson time. However, since the students questions can and should guide student learning, more material is presented for you convenience. Remember, it is not uncommon for students to only remember those points which answered their personal questions.

Younger:

All children need sunglasses, not just those holding the lens.

You may want to put the lens in the steadier hand of an older child or adult, but only if necessary.

You may want to take the lens off younger / certain children with pyromaniac tendencies. The temptation to test the incendiary temperature of various materials unsupervised can be ***extremely regrettable!!***

Children at this age can have difficulty with focus. Avoid tangents into interesting side tracts if you're attempting to make a key point.

Middle:

This activity is well suited to this age group, but, again, be cautious.

Teen:

Can students find ways to more accurately measure the energy coming from the sun? Aside from using a purchased photometer, students can try heating up small amounts of water and calculating the energy taken to bring it to boil. This is the very basis of many solar electricity generators.

Try building a solar BBQ using aluminium foil and a parabola shaped 'oven', see extension activities.

Engage

- ⇨ Note the Learning Intention of this lesson for students.
- ⇨ Make sure all students write down any questions they may have generated during this phase regarding the topic for today.

Allow students to play with the Fresnel lenses. If you wish, explain their history and origin. Use them to focus on small items in the room, such as the back of their hands. (You may want to discourage looking into other people eyes because, as fascinating as it is, students might want to try and focus sunlight into each other's eyes later on, and that would be deeply regrettable).

Ask: How hot is the sun? How much energy does it produce (a lot)? How can we put that energy to better use in society?

The hottest colour

Ask: What is the hottest colour? How can we find out?

In 1800 William Herschel, British astronomer of German and Czech-Jewish origin, stuck a thermometer in a rainbow he'd made on his desk. He was astonished to find the hottest colour of all was one he could not see, but Herschel figured out he could ***bounce this light off mirrors*** and ***refract it with lenses*** just like normal light. He took to calling them 'calorific rays', though we now call them **infrared light**. Infrared light is the way heat usually radiates, and just about all objects with a temperature above 0 degrees Kelvin emit it.

Thus, the hottest colour ***is a colour you cannot see!***

So, usually, if you want to make a hot light using the sun, you have to move the lens outwards until it makes the tiniest spot you can, and then go just a little bit beyond that (where the light actually looks a little larger). This is to help concentrate the brightest colour of all – the infrared light.

Explore

- ⇨ Encourage and validate student explanations of this phenomenon. You may like to ask students to write or draw their explanation personally to avoid embarrassment to students unfamiliar with this material. Remember, 'I don't know' is a valid explanation in science – it is the beginning of learning new things!

Experiment: Perform the activities at the end of this document 'a worksheet for incendiary light';

Melt a hole in a balloon – colour matters!

When you shine the light on the balloon, the light can heat up the balloon. Once it gets hot enough it can melt the latex. And because balloons are stretched out wide the hole can rapidly tare the balloon apart in less than a second!

But different colours will absorb heat at different rates. Typically darker colours will heat up faster, but they might also be thicker! Also, since red and infrared are the hottest colours, usually green will heat up fastest (being the opposite of red). Find out for yourself, what did you discover?

This means that if you want to start a fire using a lens, you need to use brown or black wood shavings or paper – white paper will reflect too much light and can take ages to heat up!

Explain

The sun produces a LOT of energy. While every kind of electromagnetic radiation comes from the sun, the energy that it produces the most of is visible light[1]

This energy can be used to do work: It can heat things up. The amount of energy coming from the sun is almost *incomprehensible*. Such a tiny, tiny amount of that energy hits the earth, yet it is so powerful that a meter square of light produces about 1,000 watts of energy, which is a lot if we can harness it all!

Once you concentrate even a small amount of light, it can be enough to melt a hole in a balloon. How much heat energy do you think we need exactly, in joules, to melt a balloon?

Elaborate

Unmeltable balloon – why can't I melt a hole in a water balloon?

Not only does water have a much higher ability to absorb heat than wood or latex, it can also carry that heat away much more effectively than the air.

When you heat up the balloon, the water behind it heats up as well, cooling the balloon back down enough so that it does not melt. But, as you know, hot water rises! So newer, cooler water is always taking the place of the warmed-up water. You won't get to melt a hole in a balloon with water until ALL the water is hot enough!

[1] And the most common colour is the one right in the middle of the rainbow – green.

Writing names

The light from the sun is so hot it can quite easily start a fire! You can use it to write your name in a piece of wood – but watch out!! It can get so hot that you accidentally start a fire, or if you put the light on your fingers, it will burn your hands!! So be careful!

Set up and use a nice inferred camera.

Available cheaply online. You might need a dark space to have the IR lights light up though.

Using Fresnel lenses for Solar power

(From Wikipedia, 31 jan 2020)

Since plastic Fresnel lenses can be made larger than glass lenses, as well as being much cheaper and lighter, they are used to concentrate sunlight for heating in solar cookers, in solar forges, and in solar collectors used to heat water for domestic use. They can also be used to generate steam or to power a Stirling engine.

Fresnel lenses can concentrate sunlight onto solar cells with a ratio of almost 500:1.[21] This allows the active solar-cell surface to be reduced, lowering cost and allowing the use of more efficient cells that would otherwise be too expensive.[22] In the early 21st century, Fresnel reflectors began to be used in concentrating solar power (CSP) plants to concentrate solar energy. One application was to preheat water at the coal-fired Liddell Power Station, in Hunter Valley Australia.

Evaluate

- Review with students what they felt they learnt from this lesson. Did they have any questions at the start that they feel were answered? Can they tell you the name of the 'hottest colour', and who discovered it?

Success criteria

- Review the Learning Intentions of this lesson with students. Was it met?

At the end of each class, review the learning objective and see how we did. Ask:

- What did you learn?
- (If needed) where can you go for extra help or information?

Assessment

Prior learning:

Make sure you take time to ask students what they think will happen before each step is taken in the experiments and activities below.

Be sure to watch out for the following common alternative conceptions:

- Only objects in motion have energy – actually even completely still objects can heat things up.
- Energy gets 'used up'. This is incorrect; energy *sources* can get used up, but the energy itself is always present in the universe, it cannot be created or destroyed.

Formative:

As students are learning, help them self-monitor their own learning and achievements.

Make sure they WRITE DOWN what they are doing, and even more effectively, WRITE DOWN what they think are the underlying reasons for what they observe. This is the very basic of real scientific thinking.

Summative:

Help students consider ways they can communicate their new understanding to others, just as scientists need to do. They could teach a younger sibling perhaps? (One with less access to incendiary objects, for instance). Alternatively they could present their results to the class in an oral presentation, including their predictions and results, just like real scientists will often do.

So what?

The hottest colour is invisible.

We can start fires with light.

Tips from the Masters to make it work:

Wear sunglasses!!!

Try to do it closer to the middle of the day, it works much better. We did get it to work at 4pm, but then again it was in Queensland…

Keep the sun, the lens, and the target all in one straight line!

Try to make a shape on your target the same shape as your lens, then move the lens slowly forwards or backwards until you get the brightest single spot of light.

If you're really spot on, you actually can see the image of the sun and nearby clouds in reverse on your target!

Don't give up; this activity is HARD and it take TIME.

Sit comfortably and place the target on the ground or at your feet where it is directly facing the sunlight. That way you only have to move the lens (I call this the Jeeves' technique, after its inventor):

Fresnel Lenses: "The invention that saved a million ships!"

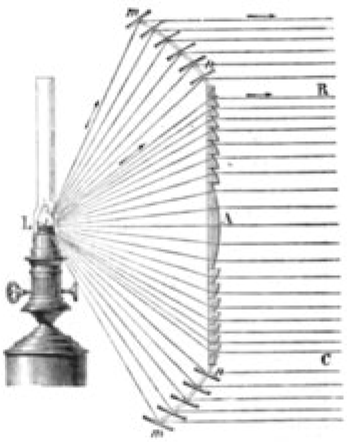
From Wikipedia, 31 jan 2020

History[edit]

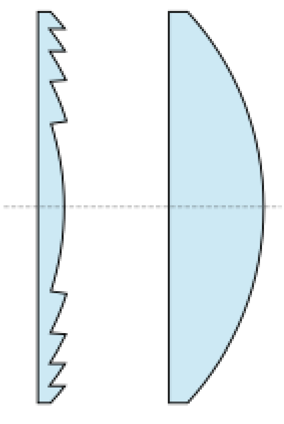
Further information: Augustin-Jean Fresnel § Lighthouses and the Fresnel lens

The idea of creating a thinner, lighter lens in the form of a series of annular steps is often attributed to Georges-Louis Leclerc, Comte de Buffon.[4] Whereas Buffon proposed grinding such a lens from a single piece of glass, the Marquis de Condorcet (1743–1794) proposed making it with separate sections mounted in a frame.[5] French physicist and engineer Augustin-Jean Fresnel is most often given credit for the development of the multi-part lens for use in lighthouses. According to *Smithsonian* magazine, the first Fresnel lens was used in 1823 in the Cordouan lighthouse at the mouth of the Gironde estuary; its light could be seen from more than 20 miles (32 km) out.[6] Scottish physicist Sir David Brewster is credited with convincing the United Kingdom to adopt these lenses in their lighthouses.[7][8]

Description[edit]



How a spherical Fresnel lens collimates light



1: Cross section of a spherical Fresnel lens
2: Cross section of a conventional spherical plano-convex lens of equivalent power

Close-up view of a flat Fresnel lens shows concentric circles on the surface

The Fresnel lens reduces the amount of material required compared to a conventional lens by dividing the lens into a set of concentric annular sections. An ideal Fresnel lens would have an infinite number of sections. In each section, the overall thickness is decreased compared to an equivalent simple lens. This effectively divides the continuous surface of a standard lens into a set of surfaces of the same curvature, with stepwise discontinuities between them.

In some lenses, the curved surfaces are replaced with flat surfaces, with a different angle in each section. Such a lens can be regarded as an array of prisms arranged in a circular fashion, with steeper prisms on the edges, and a flat or slightly convex center. In the first (and largest) Fresnel lenses, each section was actually a separate prism. 'Single-piece' Fresnel lenses were later produced, being used for automobile headlamps, brake, parking, and turn signal lenses, and so on. In modern times, computer-controlled milling equipment (CNC) might be used to manufacture more complex lenses.

Fresnel lens design allows a substantial reduction in thickness (and thus mass and volume of material), at the expense of reducing the imaging quality of the lens, which is why precise imaging applications such as photography usually still use larger conventional lenses.

Fresnel lenses are usually made of glass or plastic; their size varies from large (old historical lighthouses, meter size) to medium (book-reading aids, OHP viewgraph projectors) to small (TLR/SLR camera screens, micro-optics). In many cases they are very thin and flat, almost flexible, with thicknesses in the 1 to 5 mm (0.04 to 0.2 in) range.

Modern Fresnel lenses usually consist of all refractive elements. However many of the lighthouses have both refracting and reflecting elements, as shown in the photographs and diagram. That is, the outer elements are sections of reflectors while the inner elements are sections of refractive lenses. Total internal reflection was often used to avoid the light loss in reflection from a silvered mirror.

Scientist's Name
Date of Experiments

A worksheet for Incendiary Light

At any one moment, the SUN produces about 3.86 x 10^{26} watts of energy, and only a *teeny, tiny* fraction of that hits Earth (around 1.74 x 10^{17} watts, or 174 quadrillion watts). In the middle of the day, a circle as wide as you can reach receives around 1,361 Watts (xM^2), which is more than enough to power the average home! So just what kinds of work can we put all that light to?

We will need to go outside for these activities. Please bring;
Your Fresnel lens, stopwatch, 3 balloons of different colours, and your SUNGLASSES!

Melt a hole in a balloon

1. Inflate one balloon.
2. Hold your lens up against the balloon.
3. Slowly move the lens backwards, directly towards the sun (i.e., perpendicular to the surface of the balloon.)
4. Notice how the light collects towards a small point. Pause when you get just *after* the smallest point of light (infrared light).
5. Time how long it takes the light to melt a hole in the balloon and make it pop.
6. Try two different colour balloons, is there a difference in the time it takes to pop?
7. Now we never create science with only one or two tests if we can help it! Repeat your experiment at least three times and average the results. Which balloon colour do you think melts in the sun the fastest?

	Colour 1 -	Colour 2 -	Colour 3 –
Test 1			
Test 2			
Test 3			
More tests?			
Average results			

Conclusion – the colour which melts fastest is:

Theory – The colour which absorbs the most light energy from the sun and therefore pops the fastest will always be:

What this means – can you put this knowledge to work? What colour should we make our cars? Or our solar panels?

Melt a hole in a water balloon!?

Perform the previous experiment again, only this time use a water balloon filled with water – though make sure there's a little air bubble at the top!

1. Try to melt the side of the balloon next to the water, did it pop?
2. Try to melt the top of the balloon next to the air bubble, did it work?
3. Can you hypothesise why?

Starting fires

Using these skills you can start a fire without matches! But what materials are the best to use? Time how long it takes to set fire to each of the following materials. (Never test just once!)

	Time to smoulder	Official ignition temp
White paper		
Black paper		
Green leaf		
Brown bark		
Match head		
Sparkler		
Liquid fuel?		

Writing names

Can you CAREFULLY burn your name into a piece of wood using the skills and technology you have gained in these experiments?

What other practical uses could there possibly be for this knowledge? Can you test your ideas?

