

# Square Kilometre Array

## Years 7 & 8

### Activities 1–7

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[www.anzska.govt.nz](http://www.anzska.govt.nz)

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**This resource has seven student science activities reinforcing the ‘big idea’ in astronomy: that everything we know about the universe is from “messages” in the light we receive from beyond planet Earth.**

The activities are a good foundation for the ‘Planet Earth and Beyond’ curriculum area in science.

Humankind has been interested in the night sky for millennia, astronomy probably being the oldest science. Observations from Earth can be carried out only in the light that is not blocked by the atmosphere: visible light and radio. Optical telescopes have been in use for the past 400 years and radio telescopes for about 70 years. Space-borne observatories have been in use for around 40 years, observing the universe especially at wavelengths partly or wholly blocked by the Earth’s atmosphere, such as x-rays, UV and infrared, as well as in visible light. Observations in each wavelength provides different information.

## Student activities

Each of the activities introduces one everyday aspect of how light can carry messages or information. They complement science activities that may already be part of the science programme about the behaviour of light: reflection, refraction, dispersion (splitting white light into its colours), scattering (when light is reflected at random angles by a rough surface, or diverted by particles in the medium), and absorption.

**The seven ‘messages in light’ activities are:**

1. We use the colour of visible light to carry messages.
2. We use flashes of visible light to carry messages in code.
3. The structure of the light and its intensity also carries messages.
4. Messages can be carried by ‘light’ we cannot see – an investigation of devices we use every day which utilise infrared light.
5. Further investigation into messages carried by light we cannot see, in this instance radio waves.
6. Investigation into the properties and behaviour of radiation we cannot see.
7. That more intense radiation of the same type can overwhelm messages carried by radiation.

Most activities take about an hour, with students in groups of 3–4, but some will take longer where equipment is to be made as part of the activity.

## Starting with the familiar

In everyday life we encode many messages in visible light, in light frequencies we may be able to feel but cannot see, and in radio frequencies.

The intention is to use everyday examples to show several of the ways that astronomers gain information about the universe. The strength of the linkage between these common examples and astronomy will depend on particular objectives a teacher may have in this area. While the concepts are not difficult, their practical realisation in astronomy can be complex and beyond the level of understanding required at this level. These resources are part of a series up to Year 13.

## Prior knowledge and skills required

Little or no specific prior knowledge is assumed for each activity.

Most URLs provided are to Wikipedia, which is reliable in these topics and have some public domain diagrams which could be used. As a teacher’s time is limited, these resources attempt to provide the essential information.

## Assessment

Assessment examples have not been included.

## Radio telescopes

This resource is part of the **Square Kilometre Array (SKA) Project**, the largest international science project so far attempted. It would consist of an extensive array of radio telescopes providing a total collecting area of about one square kilometre, hence the project name. Australia has been short-listed as a location and it would also involve New Zealand to give a 5,500 km baseline – the longer the baseline the higher the resolution. The sensitivity and resolution of this array would enable it to see further into the universe, almost as far back in time as when it was formed.

From an educational perspective, the SKA project provides a context for several curriculum areas at different levels. It may also be where some of your students could work in the future.

**For details of the whole SKA project see:**

<http://www.skatelescope.org/>

**For the Australian and NZ part of it:**

<http://www.ska.gov.au/Pages/default.aspx>

**For the NZ part of the project see:**

<http://www.ska.ac.nz/news>

**For an overview:**

[http://en.wikipedia.org/wiki/Square\\_Kilometre\\_Array](http://en.wikipedia.org/wiki/Square_Kilometre_Array)

**AV material (starter loops) and other resources available online for free download:**

<http://www.ska.gov.au/media/audioandvisual/Pages/default.aspx>

## Messages In Colour

### Rationale

In astronomy the colour of visible light from stars provides some information about them. This idea of colour carrying information is reinforced by identifying the everyday examples of messages carried by colour.

### Equipment

No special equipment is required.

### References

Wikipedia is useful and reliable in this topic. Suggest search Google or Wikipedia for: navigation lights (e.g. use of coloured lights to mark the port and starboard sides of boats and aircraft, lights on harbour buoys), signal lights, additive and subtractive colour.

### Outcomes

At the end of this activity students should be able to discuss many of the ways we use colour to carry messages.

### Background information

#### PART ONE

Colour is a human perception in response to different wavelengths of visible light. Longer wavelengths are perceived as red, shorter wavelengths perceived as blue. White is perceived as a mixture of all wavelengths or, as in computer and television screens, from adding equal proportions of red, green, and blue light only (the 'primary' additive colours of light); other colours are obtained by varying the proportions of each primary, as each primary stimulates each of the three types of cone cells in the retina differently.

**Colour carries many messages; some examples are:**

**Food and health:** Red may indicate ripeness of fruits; red meat turning green indicates decay; skin turning red indicates sunburn.

**Transport and traffic:** Vehicles have constant coloured lights to indicate front and rear and/or left and right sides at night, e.g. road vehicles have a red light at the rear, white at the front; boats and aircraft have red on the left side or left wing to indicate its port side, green on the starboard side.

**Distress signals** use bright coloured flares or lights.

**Some animals produce light:** some deep-sea fish use light to attract prey, as do some insects, like glow worms.

**Colour codes** are used in electrical wiring and electronic circuits (e.g. mains wiring colours, resistor and capacitor codes), and may be used in technical diagrams (e.g. blue for air/water, green for plants), etc.

#### PART TWO

Part Two of the activity is about how the colour is actually made. Colour can be produced by a single colour source (e.g. lasers, LEDs, gas discharge lamps), or by adding together light from different coloured sources (additive colour: red/green/blue), or

by colours being selectively absorbed (subtractive colour) from light transmitted, reflected or scattered by an object. This section could be extended into how colour on a TV or computer monitor is produced in comparison to colour on a printed page. Look at a computer monitor with a magnifier (to see the red, green and blue pixels) and then at a colour illustration in a book to see the rosettes of cyan, magenta, yellow, and black dots. Note that the black (K) is needed only to overcome the limitations of the C, M and Y inks and to reduce the amount of ink required.

### Extension

1. Colour is also used in defining a mood, and in language; this website provides a comprehensive list and links to individual colour meanings and uses:  
<http://desktoppub.about.com/cs/color/a/symbolism.htm?nl=1>

### Curriculum Links

#### SOCIAL SCIENCES

- Understand how cultural practices vary but reflect similar purposes.

Research how the colours red and black are used in Maori culture, and what 'messages' they might be intended to project. Create a poster to show your findings.

#### TECHNOLOGY

- Describe the nature of an intended outcome, explaining how it addresses the need or opportunity.

Select an item of safety clothing that uses colour as an important part of its design. What is the purpose of the colour choices? Do they achieve the intended outcome? How would you improve the design in relation to colour?

#### MATHS

- Evaluate the effectiveness of different displays in representing the findings of a statistical investigation.

When you look at stars in the night sky, they all appear to be white. But did you know that stars actually can be blue, yellow, red, green, orange, violet or white? Research why stars are different colours and what this has to do with their temperature. Go to [www.ask.com](http://www.ask.com) and type in the question "Why are stars different colours?" You will get a list of web site references that you can use for your research. Find different ways in which temperature can be measured and displayed through graphs, charts, scales etc. and how colour is used as part of this measurement and display. Draw some conclusions on how effective these different options are. Do you think some are better than others? Justify your answer. Can you come up with your own method of displaying temperature using different colours?

## Messages In Colour

We see the world around us in visible light. The 'white' light from the sun is a mixture of different 'lights' or wavelengths that we perceive as colours. We use colour to send messages, and colour in nature often carries messages. This activity aims to identify examples of messages in colour.

- Brainstorm examples of how we use colour to send messages. Classify them into categories and list them in the table below. Some examples of categories and messages are included to help you.
- How was each example of colour actually made? Was it made:
  - by a light making only that colour, or
  - from the colour reflected after other colours were absorbed from the white light shining onto it?

Category	Example	Message, and how the colour was produced
Food	Fruit red when ripe	Indicates the fruit is ripe and ready to eat. Red colour produced by other colours being subtracted from white light (sunlight) leaving red reflected to my eyes.
Health	Redness Skin turning blue	May indicate an injury or an infection to a part of the body.
Transport	Traffic lights Navigation lights: • boats • aircraft Vehicle colours	
Colour codes for identification	Household electrical wiring is colour coded	
Uniforms		

## Messages In Code

### Rationale

The universe has many sources of pulsating radiation of several kinds. The challenge for astronomers is to decipher the message. For example, brief changes of a star's brightness may be one indicator that it has planets. A large planet orbiting between its star and our viewpoint would briefly eclipse some of its light. See:

[http://en.wikipedia.org/wiki/Variable\\_stars](http://en.wikipedia.org/wiki/Variable_stars)

We use pulses of light to send information. A simple everyday example is the flashing turn indicators on road vehicles. The flashing signals an intended turn, and the position of the indicator light signals the direction. A more complex but less obvious everyday example is using rapid pulses of light along fibre-optic cables to carry our phone conversations and internet traffic.

### Equipment

No special equipment is required.

### Outcomes

At the end of this activity students should be able to discuss how light can be used to carry messages in code and the advantages and disadvantages of using light.

### Background information

The most common everyday example is probably vehicle lighting. In the daytime indicator lights provide information about a driver's intentions. At night, the required lighting provides information about vehicle orientation. See:

[http://en.wikipedia.org/wiki/Navigation\\_light](http://en.wikipedia.org/wiki/Navigation_light)

Emergency situations have their own flashing light codes depending on whether it is an 'ordinary' vehicle or an emergency services vehicle.

[http://en.wikipedia.org/wiki/Automotive\\_lighting](http://en.wikipedia.org/wiki/Automotive_lighting)

[http://en.wikipedia.org/wiki/Emergency\\_vehicle\\_lighting](http://en.wikipedia.org/wiki/Emergency_vehicle_lighting)

*(useful in comparing regulations in different countries and a good summary of NZ regulations on the use of coloured lights by emergency vehicles)*

Hazards are often marked with flashing lights. Lighthouses have specific flashing codes so mariners can readily identify them and so they are not confused with other fixed lights. Lighthouses are still important, as even though ships may have a satellite navigation system, a situation could arise when it is faulty. Lighthouses are a topic in themselves, being both an ancient technology and often very impressive. For example, the lighthouse at Alexandria was regarded as one of the Seven Wonders of the Ancient World. Two references are:

[http://en.wikipedia.org/wiki/Lighthouse\\_of\\_Alexandria](http://en.wikipedia.org/wiki/Lighthouse_of_Alexandria)

<http://www.unmuseum.org/pharos.htm>

A heliograph is a signalling mirror, usually with a hole in the centre, used mostly in the 1800s to early 1900s, but with a history back to the ancient Greeks. To ensure accurate signalling the mirrors were mounted on stands, with aiming aids, and equipped with shutters rather than relying on the tiny mirror movements required. To signal in the same direction as the sun two mirrors would be used. Radio made heliographs obsolete, but they are still an essential item in an outdoor emergency kit.

### Extension

1. Use a small ordinary mirror and an aiming stick to send your initials in Morse code to someone 100 m or more away. Do not use SOS, it must only be used for real emergencies.
2. Research the improvements that have been made with regards light sources and lenses in lighthouses over the years, from the very first lighthouses to use lenses (early 19th Century) right through to modern day automated lighthouses. Create an A3 poster to display your findings.

### Curriculum Links

#### SOCIAL SCIENCES

- Understand how groups make and implement rules and laws.

We've all been in the situation of waiting at a red light when there's no vehicles coming. Very frustrating! But road rules are there for good reasons. What would happen on our roads if there were no traffic lights, or vehicles didn't have indicators? Are there any road rules that you think should be changed? How would you go about trying to get those road rules changed?

#### TECHNOLOGY

- Undertake planning to identify the key stages and resources required to develop an outcome.

In keeping with New Zealand's green image, you have been asked by the government to develop an alternative to traffic lights using only renewable resources, but still using a colour coding system. Develop a design plan for an alternative, identifying the key stages and resources required.

#### MATHS

- Classify plane shapes and prisms by their spatial features. Represent objects with drawings and models.

There are many different plane shapes used to display road rules. We see these road signs all the time as we travel. Research different plane shapes used. Create an A3 poster of road signs with a minimum of five different plane shapes.

## Messages In Code

Coloured light gives us information about an object, or may contain specific messages or instructions, as you may have investigated in the previous activity. Other aspects may be included by the position of the light, by having it on constantly or switching on and off at particular rates, or by all three characteristics (colour, position and duration).

If a code of flashing lights is used, both the sender and the intended receiver need to understand the code in order to correctly send and interpret the message. Making an error in sending or receiving a message may be dangerous!

1. In the table below, add examples of how flashing lights are used to transmit information. For example, road vehicles use flashing lights, but emergency situations or emergency vehicles have their own codes. Consider land, water and air vehicles. To your table add the requirements, if you can find them, of the rate of flashing and the pattern of flashes.
2. On the table show the patterns of your examples of flashing lights by a diagram.

Example of use of flashing lights	Requirements for colours and frequency of flashing	Flashing pattern

3. Some producers of flashing lights may be stationary, such as tall structures and lighthouses. What is the purpose of their lights?
4. Morse code is still useful, especially the internationally recognised SOS. A useful emergency item for daylight use is a mirror, as a flash of sunlight can be seen from a long way away. The problem is to direct the flash from the mirror. A heliograph is a mirror designed for signalling. The simplest form is a mirror with a hole in the centre which helps to aim it. A modern heliograph for emergency use is of metal-coated plastic with a special insert in the hole to make it easier to aim.
  - Find the Morse code for SOS and write it down in diagram form.
  - What are advantages and disadvantages of a heliograph?

## Messages Hidden In Light

### Rationale

While light may appear in different colours, the structure of those colours can tell us much about the way the light is produced. Astronomers split the faint light from stars into its wavelengths so the spectrum of each star can be examined. A star's spectrum is rather like a fingerprint.

The activity is to make a spectroscope from pieces of an old CD or DVD. There are different models of spectroscope. The best one suggested for use is in a PDF file downloaded from:

<https://pantherfile.uwm.edu/awschwab/www/specweb.htm>

There are two versions (the 3-per-page version is better with its smaller viewing port), and note the construction notes at the bottom of the page. The CD cutting hint is worthwhile.

### Equipment

Old CDs to be cut into pieces (or CD-R disks), black cartridge paper, glue or sticky tape, scissors, and a trimming knife and metal ruler to cut the slit or sharp-edged strips.

### Outcomes

At the end of this activity students should be aware that light is often made up of distinct colours, the relative proportions of each colour providing a 'fingerprint' of that light source.

### Background information

#### MAKING A CD SPECTROSCOPE

In addition to the spectroscope recommended above, the other CD spectroscope commonly described is the "cereal box" reflection spectroscope, although they do not perform as well as the one above. There are many websites with such designs; for examples see:

<http://www.cs.cmu.edu/~zhuxj/astro/html/spectrometer.html>

[http://coolcosmos.ipac.caltech.edu/cosmic\\_games/spectra/makeGrating.htm](http://coolcosmos.ipac.caltech.edu/cosmic_games/spectra/makeGrating.htm)

Another variation is the CD transmission spectroscope. In this type the label side of a CD is removed and light is shone through the now clear CD. To remove the coating, first cut a CD into the sized pieces you want, then stick some masking tape or duct tape on the label side starting on a cut edge and pull off the label and aluminium coating. The aluminium layer is easy to pull off the type of CD designed for printing labels onto it with an inkjet.

A 110 g or 120 g toothpaste box is a good size for this type of spectroscope as it is small in cross-section and long enough to produce clearly separated spectra. It has been included in the student activity as an alternative to the reflection model. It is slightly harder to use but gives a greater spectrum spread.

The slit is to produce a parallel beam of light. Too wide a slit will produce a blurred spectrum, a very narrow slit produces a spectrum with more defined lines but will be much less bright. Aim for a slit 0.4–1 mm, but it is difficult to cut. One suggestion is to cut

strips of black card cleanly with a sharp trimming knife and metal ruler, which students can then cut to length and tape over a larger opening at the front of the box to make the slit.

The slit is to produce a parallel beam of light. Too wide a slit will produce a blurred spectrum, a very narrow slit produces a spectrum with more defined lines but will be much less bright. To cut-out the recommended spectroscope an easy way is to photocopy the outline onto paper, tape it to black cartridge paper, score the fold lines, and cut through both layers.

Students can use their spectroscope to examine different sources of light: daylight (but don't look directly at the sun), incandescent lamps, fluorescent lamps, LEDs, computers screens, etc. Note that colour-blind students will need additional assistance.

### Extension

Suggest that students take their spectroscopes home and look at the spectra of objects producing light.

### Curriculum Links

#### SOCIAL SCIENCES

- Understand how cultural practices vary but reflect similar purposes.

Rainbows have always played an important part in ancient beliefs. When a rainbow appeared, it was seen as a mystical, magical gift from God. Rainbows were symbols of hope and light after the darkness of the storm. Even in the world of today, a rainbow lifts the spirit and fills the heart with joy. Why do you think so many different cultures through history have revered rainbows in this way? How do you feel when you see a rainbow?

#### TECHNOLOGY

- Undertake planning to identify the key stages and resources required to develop an outcome.

When we design something, we need to consider its "fitness for purpose". In other words, does it actually do what it was designed to do? Consider the spectroscope you have made. What conclusions do you draw about its "fitness for purpose"? What are the strengths and weaknesses of this design with regards its "fitness for purpose"?

#### MATHS

- Use linear scales and whole numbers of metric units for length, area, volume and capacity, weight (mass), angle, temperature, and time.

Your spectroscope will contain a number of different plane surfaces. How many plane surfaces are there? Calculate the area of each. Graph your results using either a pie chart or a bar graph.

## Messages Hidden In Light

Light can contain messages by colour, by flashing on and off, and also by the structure of the colours in light. Each source of light has its own light 'signature' (think of it as a kind of fingerprint). This activity investigates the 'signature' of different sources of light.

- The first step is to make a device called a *spectroscope*. It splits visible light into its individual colours. You may have noticed that a CD produces rainbow colours when light is reflected off its shiny side. Use a piece of an old CD for your spectroscope. There are two different kinds of spectroscope: one reflects light off a piece of CD, the other requires the removal of the silver layer on the label side so you look through the now transparent CD.

This version reflects light off a piece of CD. Your teacher will have a template, or you can find it on this website:

<https://pantherfile.uwm.edu/awschwab/www/specweb.htm>

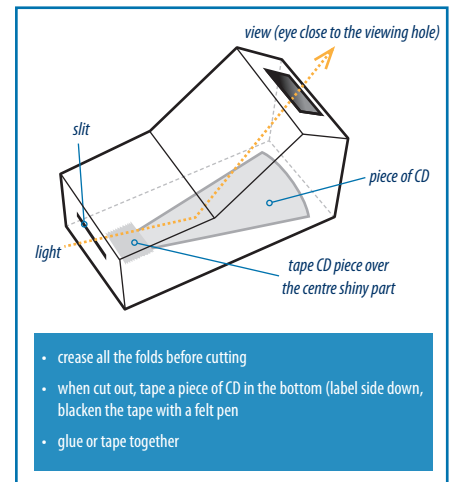
If you want to make the second type you would need the box that 110 g or 120 g tubes of toothpaste come in. It is best with bright sources of light. Scientists sometimes have to design and make their own equipment!

- Cut an old CD in half and cut a piece about  $4 \times 3$  cm (or the size of the end of your box) from near the outer part of the CD. Press masking tape onto the label side of this piece and then pull it off so it takes off some of the silver layer. Continue until it is completely transparent.
  - With a sharp trimming knife and metal ruler cut a strip of black card about 1.5 cm wide. Cut into two pieces about 3.5 cm long.
  - Remove one end of the box and attach one of the black card strips with tape. Tape the second piece in place but have a piece of thick paper (or lightweight card) between it and the first to provide the spacing for the slit.
- The second step is to use it! Aim the slit of your spectroscope at any source of light and look at the spectrum of colours displayed. Do not aim it or look directly at the sun, instead aim at the sky or at a piece of white paper in sunlight. You may need to look at different angles to see the spectrum, and you are also likely to see a second spectrum. Each colour of light is bent differently when it is reflected off (or goes through) the tiny tracks on the CD, so the light becomes spread into its colours.

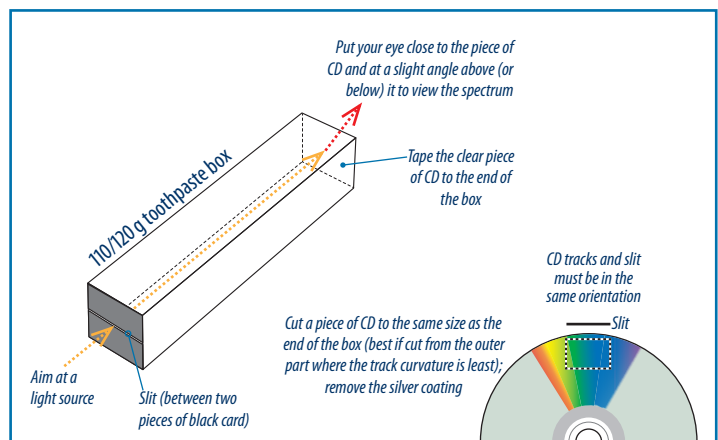
Look at an 'ordinary' light bulb, an 'energy-saver' compact fluorescent light, an LED, a TV or computer screen (white and coloured parts), different kinds of street lights, etc. You may be asked to complete this for homework.

The main differences to look for are whether the transition from one colour to another is continuous and smooth, or whether some colours appear in distinct bands. Some lights (e.g. LED indicators) which seem to be only one colour may be made of two colours. In the table, list the light sources you examined and make a coloured drawing of the spectrum.

Spectroscope (Type One)



Spectroscope (Type Two)



Light Source	Spectrum

## Messages In Light We Cannot See

### Rationale

Objects in the universe produce radiation in all parts of the electromagnetic spectrum (for more go to [http://en.wikipedia.org/wiki/Electromagnetic\\_spectrum](http://en.wikipedia.org/wiki/Electromagnetic_spectrum)). So far the activities in this resource have considered aspects of visible light, only a tiny part of the spectrum of electromagnetic radiation. Household remote control devices utilise infrared (IR) and are a convenient example of information encoded in radiation we cannot see.

This activity aims to develop a greater understanding of 'light' by having to infer some properties from the behaviour of 'light' we cannot see. Most objects in the universe appear as indistinguishable dots of light, some very faint indeed. Being able to 'see' objects in other wavelengths of light yields more information about them. In astronomy, IR telescopes on mountains, in high-flying aircraft or orbiting above the Earth can see stars behind clouds of dust that cannot be seen by optical telescopes.

### Equipment

- One or more devices controlled by an IR remote, such as a TV set, a remotely controlled toy (ensure it is IR, not radio), a stereo, video recorder/DVD player, etc. Note: most video game controllers and garage door remotes use radio, not IR. Infrared remote control devices require line of sight operation and have a maximum range of around 10 m.
- A digital camera or a mobile phone with a camera.
- Samples of materials such as paper (white and black), aluminium foil, cloth, etc.

### Outcomes

At the end of this activity students should know some of the properties of IR light and that it can carry information.

### Background information

This activity would work well as an individual or group project, as much of it can be carried out at home without the need for specialist equipment or guidance.

Digital camera sensors are very sensitive to IR light (hence their use in security cameras), but have an infrared-blocking filter to avoid IR blurring the picture. However, the blocking filter does not block all IR close to visible red light, especially in cheap cameras. A digital camera will show the infrared light produced by an IR remote control unit, although it usually shows as purple to white (to a camera it is very bright).

This activity is the first part of a two-part series investigating some properties common to all parts of the electromagnetic radiation spectrum: absorption, transmission, scattering, reflection. It investigates mostly absorption and transmission.

An IR remote control unit encodes 'commands' as chunks of rapid binary (on-off) pulses. Where repetitive chunks of commands are sent (volume changes for example) the IR LED of the remote will

flicker when viewed with a digital camera. To reduce interference, as IR is produced by heaters, lights, human bodies and, of course, the sun, the receiving device may have a filter to allow only the narrow band of IR used to be received. It is also usually programmed to ignore IR not received as pulses. However, at times the strength of other IR sources can overwhelm the remote control signal.

### Extension

Hold your hand above a stove element (but not touching it!) after it has been turned off and is warm but no longer glowing. How is heat being transmitted to your hand? [By IR radiation]

Place a piece of aluminium foil over one knee, and a piece of black plastic over the other. Sit for a few minutes in direct sunlight. Describe the difference between what you feel in each knee. Explain what happened.

### Curriculum Links

#### SOCIAL SCIENCES

- Understand how groups make and implement rules and laws.

Police and other government organisations such as the Security Intelligence Service can use technologies like this to 'spy' on people, secretly listen to conversations, etc. For example, they can listen to phone conversations using radio frequency (RF) transmitters. These transmitters convert the electric pulses from voice on the phone line into radio waves that can be received by any device listening to the same frequency. Is this fair? Could these technologies be abused? Have a class discussion on the rights to 'spy' on people in this way, versus individual rights to privacy.

#### TECHNOLOGY

- Understand the relationship between the materials used and their performance properties in technological products.

Consider the results you generated from your analysis of different materials, and whether or not they transmitted infrared. What recommendations would you make to manufacturers of technological products that use transmitted infrared?

#### MATHS

- Evaluate the effectiveness of different displays in representing the findings of a statistical investigation or probability activity undertaken by others.

Consider the results you generated from your analysis of different materials, and whether or not they transmitted infrared. What are some different ways that you could present these results? Which way do you think best demonstrates the results? Explain your answer.

## Messages In Light We Cannot See

Visible light is only a very small part of what we call electromagnetic radiation. Some other parts of this very wide range or spectrum of radiation are x-rays, ultraviolet, infrared, microwaves, radar, TV, radio.

1. First, how could we know that a remote controller uses infrared and not radio (also invisible to us)?

One clue is to look at a remote control unit and see if it has a clear 'button' of its LED on the front or a red plastic panel. Radio units don't. A reliable test is to look at the transmitting end of the remote control through a simple digital camera or phone camera. These can 'see' infrared, but not radio. Press the remote button and see if it shows in the camera screen. What colour is it? What could explain this colour? (Hint: it would appear very bright to something which could see infrared.) It is safe to look at an infrared remote as they are low-power devices.

What evidence do you have for deciding whether the remote you examined and tested used infrared light or radio?

Transparent materials transmit visible light – they allow light to pass through them. Other materials totally absorb light and are opaque. Even highly transparent materials still absorb a small amount of it, shown by increasing the thickness and seeing how its transmission is affected.

Are there some materials which transmit infrared but not visible light? Use an infrared remote control unit to test materials for their ability to transmit or to totally absorb infrared. Use paper, cloth, foil, plastic, thin wood, etc.

If possible, fold each material over the front of the remote (so that no infrared can escape by being reflected) and see if it still controls the device.

Increase the number of layers or the thickness of transparent materials until the remote no longer controls the device. If you try your finger, then try the palm of your hand which is thicker.



Material	Thickness or number of layers until no transmission	Transmits visible light (Y/N)	Transmits IR (Y/N)

2. Were any of the materials totally transparent to infrared? Explain the evidence you gained from the investigation above that supports your yes or no answer.
3. When testing your materials to see whether they could transmit or block infrared, what precautions did you take to ensure that the infrared from the remote was not reflected off the material to reach the device by another route?
4. Some of the materials were opaque to infrared not because they absorbed it, but because they reflected it. Test your materials again to distinguish between those that absorb infrared and those that reflect it. Describe your results and include the evidence you have.

## Messages In Light We Cannot See

### Rationale

This is the second of the activities investigating 'light' (or more correctly, electromagnetic radiation) that we cannot see. The focus is on radio waves, investigating some properties of radio in relation to such common devices as portable radios, mobile phones, garage door openers, video game controllers and radio-controlled toys.

An increasingly important tool in astronomy is the radio telescope. It is used either singly, or more usefully, in large arrays where together they can be made to act as though they are one giant telescope. The bigger a radio telescope the more clearly it can resolve celestial objects and better it can collect faint signals from very distant objects. Radio waves easily penetrate the atmosphere.

### Equipment

A small broadcast (transistor) radio receiver is the best, but a mobile phone could be used. Because some of the test materials are opaque to light (e.g. foil) a radio receiver is best as it can be heard, whereas the signal strength indicator on a mobile phone couldn't be seen.

Materials required are metal mesh of the type used for insect screens or whitebait nets (this is essential) and paper, cardboard, aluminium foil, plastic, metal can with lid, fibreglass screen mesh, etc. The metal and fibreglass mesh are usually available at hardware stores and are not expensive. They can be cut with snips and a piece about 30 cm square per group should be sufficient. The piece needs to be large enough to be folded around and completely enclose the radio used. Students may need gloves when handling the metal mesh.

### Outcomes

At the end of this activity students should have an understanding of the role of diffuse reflection of electromagnetic radiation in everyday life.

### Background information

This activity investigates some properties of radio waves, in particular the materials which are transparent to radio and those which are opaque and block the radio waves.

Generally, materials which readily conduct electricity will block radio waves. The most surprising material is likely to be the metal mesh. Where holes in the mesh are less than  $\frac{1}{100}$  the wavelength of most of the radio signal is reflected. Where holes are larger than that increasing amounts of signal are transmitted, and when holes are about  $\frac{1}{10}$  the wavelength the mesh is not a barrier. A metal mesh or sheet enclosure is called a Faraday cage (see: [http://en.wikipedia.org/wiki/Faraday\\_cage](http://en.wikipedia.org/wiki/Faraday_cage) or <http://www.faradaycage.org/>).

Radio carries information by modulating the radio wave – changing it in a way that will reproduce the information at the receiver.

### Extensions

1. How could you prevent signals reaching your mobile phone?
2. A Wi-Fi transmitter in a home computer network usually transmits beyond the boundary of the house. How could you block the transmission in one direction?

### Curriculum Links

#### SOCIAL SCIENCES

- Understand how people make decisions about access to and use of resources.

In this activity you have experimented with a range of different materials such as paper, aluminium foil, glass, wood and brick. Research where each of these materials comes from, how they are made, and what are the potential environmental impacts and considerations. Rank these materials from highest to lowest impact on the environment. Justify your answers.

#### TECHNOLOGY

- Understand how society and environments impact on and are influenced by technology in historical and contemporary contexts and that technological knowledge is validated by successful function.

"On Christmas Eve 1906, Reginald Fessenden used an Alexanderson alternator and rotary spark-gap transmitter to make the first radio audio broadcast, from Brant Rock, Massachusetts. Ships at sea heard a broadcast that included Fessenden playing O Holy Night on the violin and reading a passage from the Bible." — Wikipedia

The discovery of the ability to transmit radio waves has certainly had a huge impact on society. Think of three different ways that radio broadcasts have benefitted society, and provided the ability to do things that couldn't be done before. Create an A3 poster to display your findings.

#### MATHS

- Evaluate the effectiveness of different displays in representing the findings of a statistical investigation or probability activity undertaken by others.

Consider the results you generated from your analysis of different materials, and the impact they have on the transmission of radio waves. What are some different ways that you could present these results? Which way do you think best demonstrates the results? Explain your answer.

## Messages In Light We Cannot See

We probably use radio waves every day, watching television, listening to the radio, texting or talking on a mobile, using a laptop computer on a wi-fi network, using a GPS (which receives radio signals from satellites), and so on.

This activity investigates the transmission of radio waves through various materials.

While we could use the signal strength indication on a mobile phone to see how much radio signal is being received through a material, a better option would be to use a small broadcast radio receiver.

You will be provided with a selection of materials: paper (white, black), card, aluminium foil, metal mesh (e.g. aluminium insect mesh for a door or window). In addition you could test glass and other building materials such as wood, concrete and brick.

1. Are radio waves present throughout your classroom? Explain how you would test this.

What does this indicate about the properties of building materials to transmit radio waves?

2. Suggest why a broadcast radio receiver would be the best choice for testing whether materials transmit radio waves? (Note: 'transmit' means to allow the radio waves to pass through – transparent to radio in other words.)

3. Tune your radio to a clearly received AM or FM station. Leave the FM aerial down, as it is difficult to wrap the radio in a material to be tested if the aerial is poking up. Do not use an earphone to listen to it, as the earphone cord can act as an aerial and lead the radio waves through the test material covering the radio.

Wrap the radio in a test material. No gaps must be present otherwise the radio waves would leak in through the gaps. If the radio can still be heard then the material is allowing the radio waves to pass through it.

Record your results in table form:

Test Material	Result

4. If you have found a material that reduces the sound level or stops the radio completely, what does this indicate about the material?

5. Wrap the radio again in one of the materials that affected the radio volume and then undo it slightly to make a small opening so the radio waves could leak in. Did this affect the sound level? What does it indicate about requirements for making a radio-proof container?

6. Tune the radio to an FM station and lift the FM aerial. Now wrap the radio again in a radio-opaque material but leave the aerial sticking out.

7. The metal gauze is mostly holes, yet probably prevented the radio waves from reaching the receiver. It too must be wrapped carefully around the radio to prevent radio waves leaking in through gaps larger than the holes in the gauze. If you have the materials, compare the properties of a metal mesh with a fibreglass mesh. From this and results from testing all your materials, are metals generally opaque to radio waves? Support your yes/no answer with evidence from your testing of materials.

8. **Homework:** Look at the door of a microwave oven, which uses waves close to radio waves to heat food. These waves can penetrate glass or plastic containers to heat food. What does the door window have inside to stop the microwaves from cooking our eyes when we look into it when food is being heated?

## More Properties Of Light

### Rationale

The previous activities have investigated some of the properties of visible light, infrared and radio waves. For 'invisible light' the focus has been mostly on which materials transmit or absorb infrared and radio radiation. However, all waves behave similarly, whether electromagnetic (a medium is not required for transmission) or physical waves (which require a medium for propagation, e.g. sound, earthquake waves). This activity focuses on the properties of reflection, and perhaps also including scattering, as transmission and absorption were largely the focus of the previous two activities.

Large light telescopes use mirrors to collect and focus light, and some radio telescopes consist of large dish reflectors to collect and focus radio signals. The signals from stars are so faint that any factor likely to adversely affect the signal must be reduced. Light telescopes are usually located high on mountains to reduce atmospheric effects, including scattering.

### Equipment

LED or other torches and/or a table lamp, an infrared remote and the device it controls, a small broadcast radio receiver with a metal can large enough to hold it or sufficient aluminium foil or metal mesh to cover it.

This activity suits an 'activity station' approach, where groups move from one activity to the next.

### Outcomes

At the end of this activity students should have an understanding of the role diffuse reflection of electromagnetic radiation plays in everyday life.

### Background information

Reflection usually refers to mirror-like (specular) reflection where the light is bent in one direction at a surface at the same angle as it met the surface. The surface appears shiny and we see an image of the light source. This distinguishes it from diffuse or random reflection, where light is reflected at random angles. We see the form of most objects by the diffuse reflection of light from them. The characteristics of reflected light are retained (e.g. colours are not reflected differently), although intensity is affected by the reflecting surface.

Scattering is a more complex phenomenon. It is similar to diffuse reflection in that light is bent randomly, but is bent by particles or other irregularities in the medium, and the bending depends on the light wavelength and the size of particles.

The most common example of scattering is the blue of the sky. It is caused by blue light being bent in all directions by air molecules more than other colours (Rayleigh scattering). Light directly from the sun is white, but when looking in any other direction the scattered blue light reaches our eyes.

The use of the infrared remote shows how infrared behaves similarly to visible light in that it reflects off a wide range of materials as visible light does. Radio waves are less affected by diffuse reflection.

### Extensions

**Photography:** Many of your students are likely to have digital cameras. Ask them to take a photo of a friend in sunlight with the light coming from one side. Then repeat the photo, but this time have them stand next to a white wall on their shaded side so light is reflected into the shaded part of the subject. Alternatively hold a piece of white paper to reflect light into the shaded area. Note that the white wall or white paper would reflect diffuse light, producing a much better result than using a shiny reflector. Ask them to present both photos and discuss the use of diffuse reflection to provide more detail in the shaded part of the subject.

### Curriculum Links

#### SOCIAL SCIENCES

- Understand how people make decisions about access to and use of resources.

Brainstorm as many products as you can that use light to transmit messages, such as radios, microwaves, TV's, remote control units etc. Select five products and research what the environmental impacts are when these products are thrown away. How much can be recycled? What happens to the rest? What are the potential hazards associated with their disposal, and how can these hazards be managed?

#### TECHNOLOGY

- Understand how society and environments impact on and are influenced by technology in historical and contemporary contexts and that technological knowledge is validated by successful function.

In most homes today, we still keep candles in case there is a power cut. Apart from candles and electricity, however, there are other technologies that have been developed over the centuries to produce light. Research other forms of creating light. Select one, and create an A3 poster showing how this technology was developed, how it was used, and what its particular strengths and weaknesses were.

#### MATHS

- Use a co-ordinate system or the language of direction and distance to specify locations and describe paths.

There are many devices that use forms of remote control, such as TV remotes, auto garage door openers, keyless vehicle entry, remote controlled cars etc. Select a range of options that you can experiment with to determine the maximum distance each remote works at. Create a number line with each unit measuring one metre, and graph your results. Then compare the results. Find the device that has the maximum working distance and express the distance the other remotes achieve as a percentage of that maximum working distance (to two decimal places).

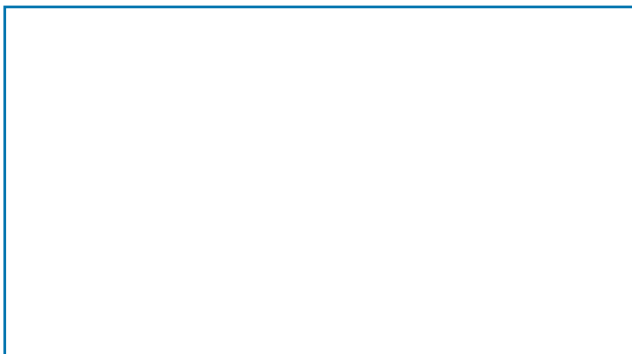
## More Properties Of Light

This activity investigates some more properties of visible light, infrared and radio waves. In previous activities you investigated the materials that would transmit or block infrared and radio.

Another property of these forms of radiation is that they can be reflected. Reflection can be mirror-like, which produces an image, and the reflecting object looks shiny in visible light. Diffuse reflection is more common. Diffuse reflection is where an object reflects light randomly in all directions. Look around you. Anything you are seeing that is not shiny is seen because the light is reflecting off them in all directions. We will investigate whether infrared and radio also show similar behaviour.

- 1. Visible light:** Place an object in a dark place and shine a torch or table lamp directly on it. Now light it indirectly by instead shining the light onto a piece of white paper or card so the object is lit by diffuse light off the card. Replace the card with aluminium foil and repeat. Describe the difference in appearance of the object in each type of lighting.

Imagine you were designing lighting for a living room, where you wanted soft light that also showed details. Would you plan direct lighting or instead use diffuse lighting? Explain.

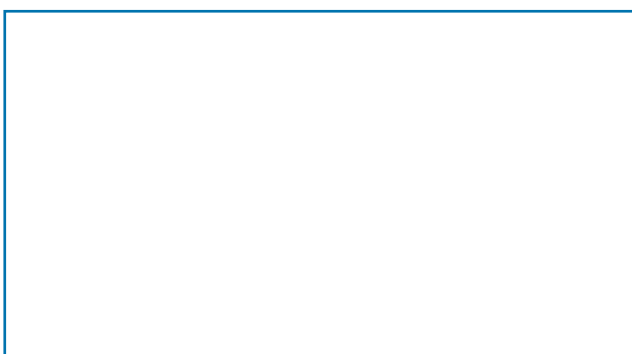


- 2. Infrared:** First, aim the remote control directly at its device to be sure it is working.

**Next:**

- a) aim the remote at the wall behind you;
- b) to one side;
- c) at a piece of paper held at various angles to the remote and the device.

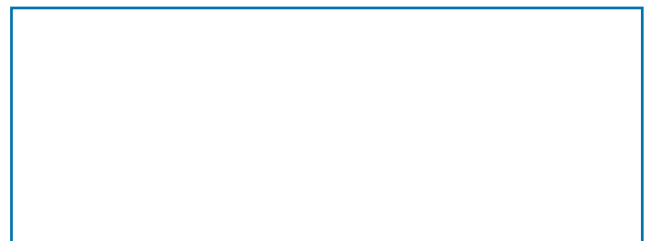
**Hint:** try it with a torch and a mirror and piece of paper to see where the light shines.



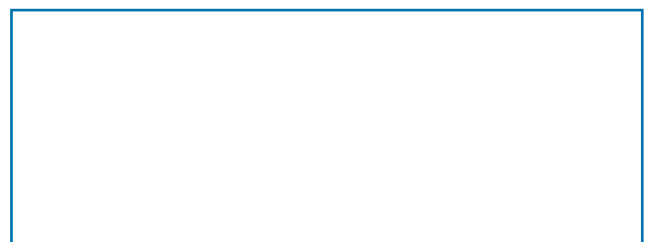
- 3. Radio waves:** Tune the small broadcast radio receiver to an AM station. Turn down the volume until you can just hear it. You may find it is directional, in that it is louder in one direction than another.

Either place it in the metal can provided, or make a cup-shaped container from foil or metal mesh large enough to hold the radio. You may need to hold it part-way in the can, as fully inside may block all reception.

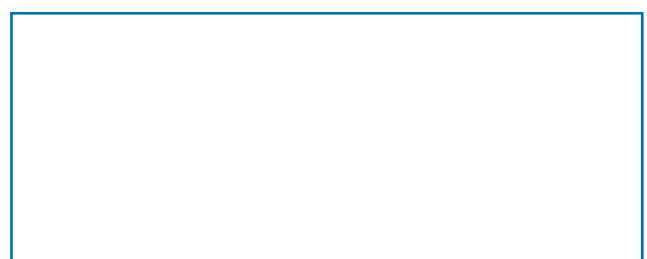
Turn the radio and its container to find the directions where it is heard and where the signal disappears. Make a diagram to show the shape and direction of radio reception.



Are there two directions where it is loudest (best reception) and where it is quiet or quietest (no or little reception)?



Where the radio is loudest is the direction of the radio station's transmitter. What would you need to do to confirm which direction you would take to find the transmitter? Hint: you need to move where directions of best reception would converge.



## How Signals Can Be Swamped

### Rationale

Electromagnetic radiation from stars is very faint. If we find a dark place we can see many stars with the naked eye, but not if we are standing near or under a street light. The light from the street light swamps the light from stars. If the air is dusty or humid, the scattering of light from the street lamp by dust or water particles will completely hide the stars.

Similarly with radio telescopes. Mobile phones communicate in frequencies close to those utilised by some radio telescopes. As signals from stars are so faint nearby and much stronger sources of radio waves can completely hide (or swamp) the faint signal from stars.

Telescopes are located in areas as free from interference as possible: on mountain tops away from light from cities and towns, or in deserts far away from mobile phone cell towers and electricity generation and distribution.

### Equipment

An infrared-controlled toy, such as a helicopter or car for indoor use.

Be sure it is infrared-controlled and not radio-controlled. An infrared transmitter for a toy usually has a red plastic dome or button on its top; a radio transmitter usually has a metal whip aerial.

### Outcomes

At the end of this activity students should have an awareness of how a fainter signal can be hidden or overwhelmed by a much stronger similar signal.

### Background information

Interference is a major problem with any transmitter–receiver combination. Radio frequencies are strictly controlled to reduce interference, and electric and electronic devices are required to meet stringent radiation emission standards. Radio waves are produced by oscillating electrons, so most electrical and electronic devices are capable of producing radio waves. To prevent the propagation of radio waves, cabinets and cables usually have metal or metal mesh enclosing the parts likely to produce radio waves.

If the source of interference is very strong it will completely overwhelm or swamp the signal. One good way of demonstrating this is to use an infrared controlled toy. Although the infrared controller and receiver use a specific infrared frequency and specific pulses to transmit the commands, and should ignore a constant source of infrared, exposure to direct sunlight will swamp the receiver. Sunlight is a very intense source of infrared and the receiver of a toy cannot ‘find’ the controller signal amongst the intense infrared ‘noise’. It is as though someone 10 m away tried to whisper a message to you while in a large crowd cheering a goal by their team!

This is a short activity, more of a demonstration. It is however important. It could be carried out as a project at home, providing everyone has access to the appropriate gear. It is not a good idea to

take a mains-powered stereo to TV outside to see if its remote will work in direct sunlight!

### Extensions

Before taking the toy outside on a cloudy day, make a prediction about what could be expected based on the experiences of cloudy days in general.

Cloud reduces the heating available. Slightly over half the heating is from infrared, the remainder is from the absorption of visible light and a small amount from ultraviolet light. Although a cloudy day has less light, it is still quite bright, so it would be reasonable to assume that much of the reduction in heating is from the infrared being blocked by cloud.

### Curriculum Links

#### SOCIAL SCIENCES

- Understand how people remember and record the past in different ways.

The development of new technologies has had a huge impact on how people remember and record the past in different ways. How are new technologies linked to “messages in light” changing the ways we can remember and record events? Think of some examples of how these technologies might be used in the future to record events.

#### TECHNOLOGY

- Understand that technological systems are represented by symbolic language tools and understand the role played by the “black box” in technological systems.

A remote-controlled TV involves the use of two separate “black box” technologies that combine to achieve a single outcome – a moving picture on a screen for you to watch! Explain what black box technologies are. In the context of a remote-controlled TV, explain how these technologies can be both helpful and unhelpful.

#### MATHS

- Conduct investigations using the statistical enquiry cycle: identifying patterns and trends in context, within and between data sets

In this activity, you have conducted three experiments in different conditions – inside, outside on a sunny day, outside on a cloudy day. You have generated three sets of data. Work out the best way to present your findings, so that you can identify patterns and trends in context, within and between your sets of data.

## How Signals Can Be Swamped

Sometimes we want to receive a faint signal from a distant source. One problem can be trying to find the signal amongst other stronger signals from a nearby source. For example, if you want to look at stars you need to find a very dark place, as otherwise any other light hides the starlight.

If you try listening to a distant shortwave radio station at night you will often hear noises from signals from other sources. This is a simple demonstration to show the idea of interference. In this example a signal may be overwhelmed by a much larger signal.

1. Use an infrared-controlled toy, such as a helicopter or car. First, use it inside. Why is it necessary to first use it inside (especially if it was designed as to be used inside)?

Now, take it outside in bright sunlight and try to control it.

Describe what happens. Warning! The toy is unlikely to be controlled, so take care.

2. If it was not possible to control the toy and it appeared that the control signal was not having any effect, what evidence could you suggest that the infrared signal was being overwhelmed by the infrared in sunlight?

3. Which was being overwhelmed by the sun: the transmitter or the receiver? Give the reasons for your answer.

4. If possible, wait for a cloudy day at the same time and same place and try it again.

Why repeat it at the same time and place? (Hint: what are the variable factors that need to be taken into account?)

If the toy could now be controlled (or not), what is one reason you could suggest about the effect of the clouds?

Should you have first tested it inside as you did for the first investigation in direct sunlight? Explain?

5. If you want to use it outside, suggest what time of the day would be best, and why.