5.1 What is light?

Lesson outcomes

At the end of this activity students will be able to:

- describe different models to explain light
- describe different parts of the electromagnetic spectrum.

What ideas might your students already have?

Students should be able to use the wave model to describe the behaviour of light, but will probably not be familiar with the photon model.

Key vocabulary

Electromagnetic, photons, spectrum.

Equipment list:

Each STUDENT will require:

- ***Notebook***
- internet access

Things to consider

You may wish to skip this look at the particle model for light, due to the conceptual conflict associated with the idea of there being two ways of explaining common phenomena. A particular issue is that students at this level are not familiar with experimental observations that require a particle model for explanation, such as the photoelectric effect and electronic orbitals and emission spectra.

An important point for students to understand is that this dual model of light will not make sense in terms of comparing it to any macroscopic phenomenon they are familiar with. It is special to light and particles at the atomic level and smaller. It is essential for understanding a range of phenomena at this level, but cannot be imagined in terms of familiar objects around us.

Teacher content information:

Wave-particle duality is a complex topic, but at this level we are purely identifying that models help our understanding and one model isn't always enough. In this activity, we have limited the exploration to visible light, but of course this duality applies for the whole electromagnetic spectrum and, in reverse, for particles such as electrons. For further background reading on photons see http://www.universetoday.com/74027/what-are-photons/ and a summary of wave-particle duality can be found at http://www.newscientist.com/blogs/nstv/2011/10/one-minute-physics-how-a-particle-can-also-be-a-wave.html Students are guided to watch two videos illustrating the dual nature of light and it would be appropriate for students to watch as a whole class followed by a discussion.

Lesson plan:

Step 1: Introduce this activity by asking students to explain the behaviour of light using the wave model. Direst students to the *Student Guide* and introduce the wave/particle duality model.

Step 2: Invite students to click on the digital link and explore the electromagnetic spectrum and watch the video introducing the electromagnetic spectrum.

Step 3: Direct students to the ***Notebook*** tasks. It would be advisable to watch both videos as a class, pausing at appropriate times to clarify concepts.

Step 4: Conclude with a class discussion on which model best explains light behaviour.

Suggested question/s:

1. Why are there two models for explaining the behaviour of light?
2. Which model is best for explaining the behaviour of light?
3. What is the electromagnetic spectrum?
4. What is a photon?

5.2 UV light?

Lesson outcomes

At the end of this activity students will be able to:

- describe uses of UV radiation
- design and carry out a fair test on the effectiveness of sunscreens.

What ideas might your students already have?

Students may think that sunscreen factor tells them the safe length of sun exposure time directly, and that it is the same for everyone. You may wish to leave this open to discuss at the end of activity, rather than correct them at the start.

Key vocabulary

Energy, fluorescence, nanometre, ultraviolet, wavelength.

Equipment list:

Can ultraviolet radiation be useful?

Each GROUP will require:

- UV lamp
- bottle of tonic water or bitter lemon
- bottle of water
- Australian bank notes
- Ziploc® bag of washing powder.

Each STUDENT will require:

- ***Notebook***
- internet access

UV protection

Each GROUP will require:

- selection of UV beads (refer to *Things to consider*). These beads become brightly coloured when exposed to UV light
- small ziplock bags
- sunscreens with different SPF ratings or other materials to protect from UV.

Things to consider

UV beads are available from *Scientrific: Science Education Resources* (https://www.scientrific.com.au/product.php?p=3769). They come in bags of around 250 beads of mixed colours for around $20. The beads can be used multiple times. The kit also comes with ideas for a range of investigations. There are other varieties available with single colours and scales. Different coloured beads can respond to different wavelengths, which can show up when experimenting with sunscreens.

If the beads are placed inside Ziploc® bags and the sunscreen applied on the outside, this saves cleaning them afterwards and makes them easier to re-use.

Students are asked to carry out an independent investigation of how well sunscreens work, and may require different levels of scaffolding depending on the level of the class. This investigation could be extended to include other materials (rash vests, T-shirts, glass, etc.).

Teacher content information:

Ultraviolet radiation is used for many things, from bees' vision to crime scene investigation (for more facts see https://sites.google.com/site/uvraysallyouneedtoknow/interesting-facts-2).

Lesson plan:

Can ultraviolet radiation be useful?

Step 1: Introduce the activity by asking students to brainstorm what they know about ultraviolet radiation (it is expected that they would be able to recall the slip-slop-slap campaign and the cancer connection; some may mention crime detection due to TV viewing). Encourage them to classify their ideas in terms of properties - useful or dangerous.

Step 2: Demonstrate, or if multiple lamps are available, form groups, and show how some objects fluoresce under UV. The laundry detergent will have small beads, usually blue, that will fluoresce and these are what make whites "brighter".

Digital activities

Step 3: Invite the students to watch the two videos about ultraviolet radiation and complete the ***Notebook*** tasks. Review students' answers to the ***Notebook*** questions. This prepares students for the independent investigation that follows.

UV protection investigation

Step 4: Place a small number of beads in direct sunlight to test how they change when exposed to UV. Make a note of how long it takes for their colour to change. You will need this information when planning your investigation in **Step 5**.

Step 5: Design an experiment to investigate the effectiveness of sunscreens with different SPF ratings in blocking UV radiation.

Step 6: Prepare a short presentation to share your group's results with the rest of the class.

Suggested question/s:

1. Is UV dangerous?
2. What does SF 30+ mean?
3. Can UV radiation be useful?
4. How does the time of day affect the amount of UV that reaches the surface of the Earth?
5. Is autumnal sun more damaging than summer sun?
6. What conclusions could be drawn from your investigation?
7. Were there any problems with your investigation? For example, how well could your results be applied to the application of the sunscreens to human skin under normal conditions?

5.3 Heating up

Lesson outcomes

At the end of this activity students will be able to:

- describe radiation as a method of heat transfer
- design and demonstrate an understanding of a fair test.

What ideas might your students already have?

Students may think black objects stay hotter for longer as they absorb heat. Students may think that remote controls emit red light, no light or work by magic.

Key vocabulary

Heat transfer, infra-red, radiation, temperature.

Equipment list:

Each GROUP will require:

- TV (or similar) remote control
- digital or mobile phone camera
- glass of water
- black garbage bag
- 6 sheets of A4 white paper
- 5 m tape measure
- mirror
- TV.

Each STUDENT will require:

- ***Notebook***
- internet access

Things to consider

You may wish to group the students so that repeat values are obtained through sharing.

You may need to ask students to bring in old remote controls and mobile phones. The digital cameras on mobile phones work well. Some new models have an IR filter on the back camera, but not the front camera. Hence, you will obtain good results using the front camera.

You may wish to set the TV investigation as a homework exercise to enable students to perform this activity, or conduct it as a demonstration.

Teacher content information:

This activity allows students to reflect on their understanding of an everyday object. Infra-red radiation is different to visible light – plastic (even when opaque to visible light) is transparent, paper will scatter the infra-red, but some will still pass through it, water is marginally opaque and glass is opaque (although you may find some that can work through glass jars).

Find out more about remote controls by reading http://electronics.howstuffworks.com/remote-control2.htm. You may wish to show the video http://www.spitzer.caltech.edu/video-audio/145-ask_ir-Infrared-More-Than-Your-Eyes-Can-See as an introduction. You may wish to expand this activity to a range of investigations depending on your resources, see http://www.discoveriescience.com/Exploring_Infrared_Radiation_Using_a_Television_Remote_C.pdf.

Lesson plan:

Step 1: Introduce the activity by asking: 'How does your TV remote work?' Brainstorm ideas. Then pose the question: 'Do you think they would work through the window?' Note down their ideas about this for later.

Step 2: Invite students to read the *Student Guide* and conduct the investigation.

Step 3: Share as a class the conclusions and query whether they conducted a fair test. (E.g. Did they control the distance between remote and camera?)

Step 4: Invite them to design an extension experiment to complement the one they have done.

Step 5: If time and organisation permit, allow the students to conduct the investigation, otherwise invite them to submit their designs to conclude the lesson.

Step 6: Invite students to guess the infra-red images and then find out if they were correct. This could be done as a class discussion with a computer projector.

Suggested question/s:

1. How does your TV remote work?
2. What materials are opaque to IR?
3. What further investigation might you need to do?
4. Why do you get warm in direct sunshine?
5. How does a grill cook food?

5.4 Microwave fun

Lesson outcomes

At the end of this activity students will be able to:

- understand how a microwave oven works
- describe the uses of microwave radiation.

What ideas might your students already have?

Students may be aware that microwaves are used for communication, as well as cooking. They may have some knowledge of the claims around mobile phones damaging your brain.

Key vocabulary

Magnetron, radar, amplitude, communication, energy, frequency, microwave, molecule, rotation, wavelength.

Equipment list:

The CLASS will require:

- microwave popcorn and microwave oven.
- big jam jar with lid
- mobile phone
- aquarium or large bucket of water
- aluminium foil

Each STUDENT will require:

- ***Notebook***
- internet access

Things to consider

You may wish to recap students' understanding of water molecules (refer to **Activities 2.2** and **2.3** of the year 7 *Science by Doing* unit **Enough Water Fit for Drinking**).

Teacher content information:

Microwave ovens operate at a frequency of 2,450 MHz, and the wavelength is about 12 cm. The radiation at such energies is limited to the production of molecular rotation and torsion of water and fat molecules in the food. Any rotational motion results in more collisions and therefore increases the kinetic energy of the molecules. The net result of microwave interaction in microwave ovens is to heat the material in the oven.

Microwaves are of a longer wavelength than visible light. This means that a mesh, such as the screen door of a microwave oven, appears to be solid to the microwave radiation. An equivalent idea would be you trying to use visible light to see atoms. For further background information see http://www.scientificamerican.com/article/how-the-microwave-works/.

Lesson plan

Step 1: Introduce the activity by posing the question: 'What happens when you put popcorn in the microwave?' Collate ideas on the board and invite students to read the instructions in the *Science by Doing Student Guide*.

Step 2: Ask for volunteers to help with the class demonstration.

Step 3: Conduct the mini investigation into microwaving popcorn and have the class brainstorm ideas about what would happen to other objects.

Step 4: Ask students to predict whether a mobile phone will detect a signal if sealed underwater and then demonstrate the transmission through water using two volunteer mobile phone carriers.

Step 5: Invite students to work through the digital component – predicting how various objects will behave in a microwave, followed by a simulation at the molecular level.

Step 6: Conclude the activity with a class discussion – particularly focussing on how the model in the simulation was valid or not

Suggested question/s:

1. What happens when you microwave popcorn?
2. How did the corn change?
3. Do all objects behave this way?
4. Why shouldn't you put metals into a microwave oven?
5. What changes are observed when you put an object in the microwave?
6. What happens at a molecular level when you microwave coffee?
7. What do you notice about the number of cycles taken for the coffee to remain at a high temperature?
8. The simulation shows coffee as water molecules in a cup. Is this valid? Explain your answer.

5.5 Listen to the radio

Lesson outcomes

At the end of this activity students will be able to:

- describe two uses of radio waves
- explain how radio is linked to SETI
- interpret information provided in video and written form.

What ideas might your students already have?

Most students will know that radio waves are used for communication – TV and radio. They may have the misconception that this is a sound wave.

Key vocabulary

Radio, reception, transmission.

Equipment list:

The CLASS will require:

- rulers/tape measures
- assorted shielding materials such as paper, card, metal sheet.

Each GROUP will require:

- portable radio (preferably with visible antenna)
- fresh 1.5V battery
- short length of wire.

Each STUDENT will require:

- ***Notebook***
- internet access.

Things to consider

Safety – students should not maintain a short circuit for more than a few seconds. If the battery begins to feel hot, cease the experiment.

You will probably need to ask students to bring in portable radios or ask colleagues to loan them, depending on the number of groups.

The video clips explain radio telescopes and how the SETI institute uses them. You may wish to review prior learning about the universe before students engage with this section. You may wish to extend this activity to include a research exercise on radio telescopes and their discoveries as part of Science as a Human Endeavour.

You may wish to set up access to a cathode ray oscilloscope or other visual means of measurement, such as a phone app to demonstrate the signal's appearance as well as allow students to qualitatively make measurements.

Teacher content information:

Students should find broad band (static) noise radiated by the plasma (the small sparks) formed between the wire and the battery terminal. Most radios will be more sensitive between the stations, but will also pick up background noise.

For the shielding investigation students might expect an electrical conductor to shield, but the magnetic fields can produce rapidly varying currents in a conductor, and these radiate electromagnetic radiation. Insulators are usually radio transparent, but this can vary depending on additives.

You may wish to expand upon the Titanic link and have students code and uncode Morse messages.

Lesson plan

Step 1: Introduce the activity by asking students about their favourite radio stations and guide the conversation to explore what they know – AM/FM/long waves/digital/analogue.

Step 2: Explain that they will explore how radio transmission is affected and invite students to read the *Science by Doing Student Guide*.

Step 3: Provide time for students to conduct their own investigations.

Step 4: During the activity, ask students questions such as: 'Why did you choose …?' and 'Have you thought about…?'

Step 5: Conclude the classroom activity with a class summary of what affected the radio transmission and the Titanic example. Then invite them to engage with the *Science by Doing Student Digital* resource.

Step 6: Conclude the digital activity with a class discussion on the search for extra-terrestrial life.

Suggested question/s:

1. What is your favourite radio station?
2. What affects how radio waves are transmitted and received?
3. Will radio travel through water?
4. Why did you choose …?
5. Have you thought about …?
6. What is a radio telescope?
7. How do they work?
8. What is SETI?
9. Are we alone in the Universe?

5.6 High energy

Lesson outcomes

At the end of this activity students will be able to:

- discuss the limitations and dangers of high energy radiation
- describe benefits of high energy radiation to society.

What ideas might your students already have?

Most students will have had an x-ray taken, if only at the dentist. Students may have the idea that X-rays and gamma radiation is dangerous, regardless of exposure time.

Key vocabulary

Exposure, gamma, imaging, irradiation, PET scan, radiation, safety, X-ray.

Equipment list:

Each STUDENT will require:

- ***Notebook***
- internet access.

Things to consider

If your school teaches a senior physics course then it may be possible to have the physics teacher demonstrate some radioactive sources using a Geiger counter. Part of this could include a demonstration of the different absorption of different types of high energy radiation by different materials.

Teacher content information:

High energy radiations come from nuclear reactions that usually involve the decay of an unstable nucleus. The high energies involved are in the high velocities, or kinetic energy, of the particles emitted, or in the case of gamma radiation, the extremely high energy of the very short wavelength gamma photons.

Nuclear medicine is a broad field that utilizes nuclear radiations for imaging, diagnosis (through tracers) and treatment of cancer in particular (using gamma radiation).

Lesson plan

Step 1: Students view the videos and answer the ***Notebook*** questions.

Suggested questions

1. Would the world be a better place without high-energy radiation?
2. How does society use high-energy radiation?
3. How does society use x-ray technology?
4. What is gamma radiation useful for?
5. Are irradiated foods safe to eat?

5.7 Concept mapping

Lesson outcomes

At the end of this activity students will be able to:

- demonstrate their understanding of the electromagnetic spectrum and other forms of radiation through a concept map.

Key vocabulary

Concept map.

Equipment list:

Each STUDENT will require:

- ***Notebook*** or butchers' paper
- internet access.

Things to consider

- Guidelines for **Concept Maps** can be found the *Science by Doing* Professional Learning Module **Inquiry-based Teaching**.
- How much experience do your students have at constructing **Concept Maps**?
- What will be the most effective way to give feedback?
- How will you build on these understandings in future lessons?
- See the *Science by Doing* Professional Learning Module **Assessment** for further information on the role of **formative assessment**.

Lesson plan

Step 1: Briefly discuss the electromagnetic spectrum with students. Explain that they will create a **Concept Map** to show what they have learned so far about the electromagnetic spectrum.

Step 2: Allow students time to plan and construct their presentation.

Step 3: Encourage students to add any further terms and linking words to their presentation.

Step 4: Collect and read students' presentations. Provide feedback to students regarding their progress, strengths and weaknesses in their understanding of concepts.

5.8 Sample test

A sample **summative test** and a **marking scheme** have been developed and are available to teachers from *Science by Doing* at sbd@science.org.au. Both are editable versions, so you can adapt them to your students' needs. You may choose to use this in addition to the assessment task outlined in **Activity 5.3**.

Note - *Science by Doing* provides sample assessment items and whilst every effort has been made, the security of these items cannot be guaranteed. *Science by Doing* encourages teachers to modify the items to suit individual teaching programs.

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