STARS RESOURCES

Teacher notes

Make your own spectroscope

ACTIVITY

In this activity students will

- conduct simple qualitative experiments using a variety of light sources.

- explore the limitations of a simple spectroscope

- appreciate the applications of spectroscopy to astronomy

CURRICULUM LINKS

Chemistry Unit 1 (Ver. 8.4)

Flame tests and atomic absorption spectroscopy are analytical techniques that can be used to identify elements; these methods rely on electron transfer between atomic energy levels. (ACSCH019)

Atoms can be modelled as a nucleus surrounded by electrons in distinct energy levels, held together by electrostatic forces of attraction between the nucleus and electrons; atoms can be represented using electron shell diagrams (all electron shells or valence shell only) or electron charge clouds (ACSCH018)

Design investigations, including the procedure/s to be followed, the materials required, and the type and amount of primary and/or secondary data to be collected; conduct risk assessments; and consider research ethics (ACSCH002)

Conduct investigations, including the use of devices to accurately measure temperature change and mass, safely, competently and methodically for the collection of valid and reliable data (ACSCH003)

Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSCH010)

Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSCH011)

CURRICULUM LINKS cont'd

Chemistry Unit 4 (Ver. 8.4)

Data from analytical techniques, including mass spectrometry, x-ray crystallography and infrared spectroscopy, can be used to determine the structure of organic molecules, often using evidence from more than one technique. (ACSCH130)

Physics Unit 4 (Ver. 8.4)

Development of the quantum model (ACSPH123)

Atomic phenomena and the interaction of light with matter indicate that states of matter and energy are quantised into discrete values (ACSPH135)

On the atomic level, electromagnetic radiation is emitted or absorbed in discrete packets called photons; the energy of a photon is proportional to its frequency; and the constant of proportionality, Planck's constant, can be determined experimentally (for example, from the photoelectric effect or the threshold voltage of coloured LEDs) (ACSPH136)

Atoms of an element emit and absorb specific wavelengths of light that are unique to that element; this is the basis of spectral analysis (ACSPH138)

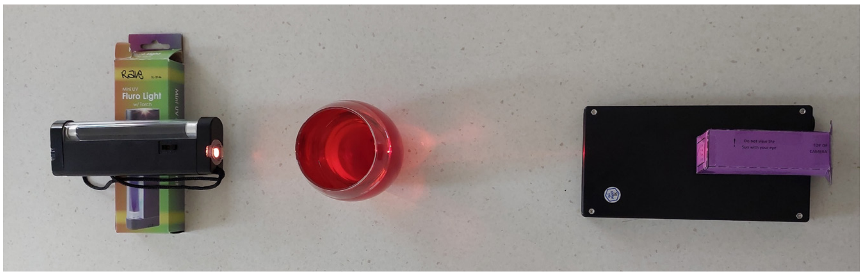
The Bohr model of the hydrogen atom integrates light quanta and atomic energy states to explain the specific wavelengths in the hydrogen spectrum and in the spectra of other simple atoms; the Bohr model enables line spectra to be correlated with atomic energy-level diagrams (ACSPH139)

Conduct investigations, including use of simulations and manipulation of spectral devices, safely, competently and methodically for the collection of valid and reliable data (ACSPH116)

EQUIPMENT

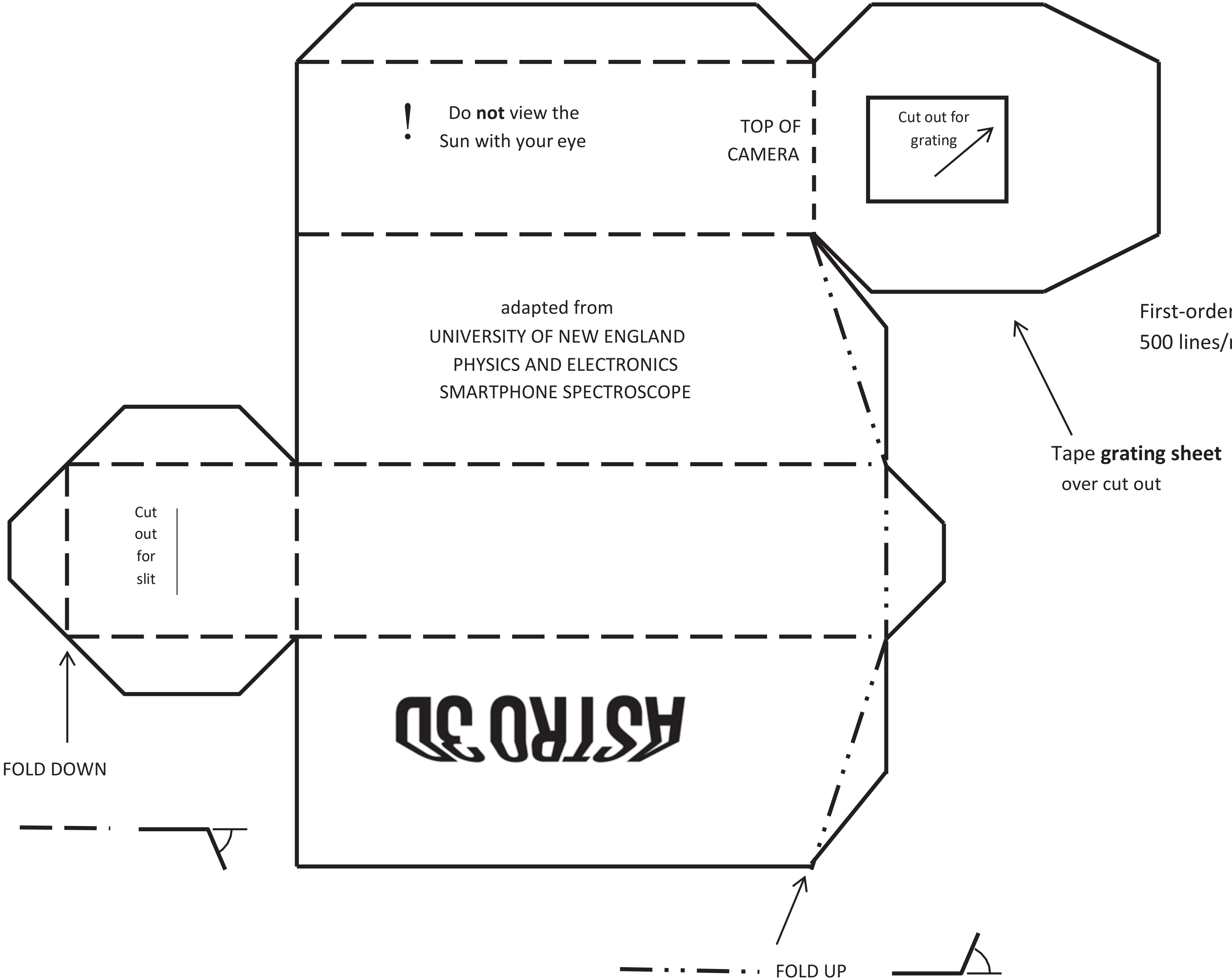
In addition to the equipment list for the students, you will need some light sources. Suggestions include:

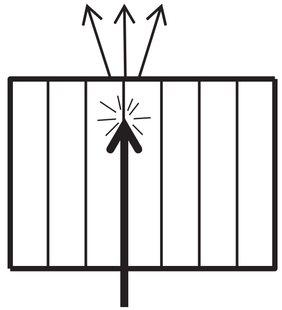
- spectral tubes (e.g. hydrogen, helium, neon, argon) (use in a dark room, or in a booth to reduce stray light, otherwise it's almost impossible to see the thin emission lines from the spectral tubes)
- old-fashioned incandescent lamp
- fluorescent lamps (perhaps in the ceiling)
- LED bulbs (of different colours, if possible)
- white LEDs ('cool' and 'white', if possible)
- a modern computer screen that can have its colour settings changed
- If sunlight enters the room, set up a large piece of white cardboard and have the students look at the Sun's reflected light
- For absorption spectrum, make up solution of food dye (red, blue and green work best) and a dilute solution of cola in water using a drinking glass or unmarked laboratory glass vessel. See the set-up in the photo below.



You may need to cut up the sheets of grating in advance into the right size for the spectrograph (about 3cm x 3cm).

Supervise the students while they assemble their spectroscope, making sure they minimize how much they touch the grating with their fingers.





First-order diffraction 18° at 600 nm
500 lines/mm 25 x 34 mm grating

Smartphone Spectroscope
Ron Bradbury
Physics and Electronics
University of New England
Armidale NSW

Materials:

- This sheet printed on 160gsm dark coloured paper
- Diffraction grating sheet Edmund Optics 54.509, cut long side in nine pieces each 34mm, cut short side in six pieces each 25mm
- Sticky tape

Tools:

- Scissors
- Smartphone or tablet, with built-in camera

Method:

- Cut out spectroscope on solid line
- Cut a 1mm slit (or as small as possible) where indicated.
- Fold up spectroscope such that black surface is inside and fix with tape
- Fix diffraction grating over hole with sticky tape
- Place grating onto smartphone camera lens

Use:

- Point slit toward light source (fluorescent tube etc.)
- Adjust camera zoom
- View spectrum on smartphone

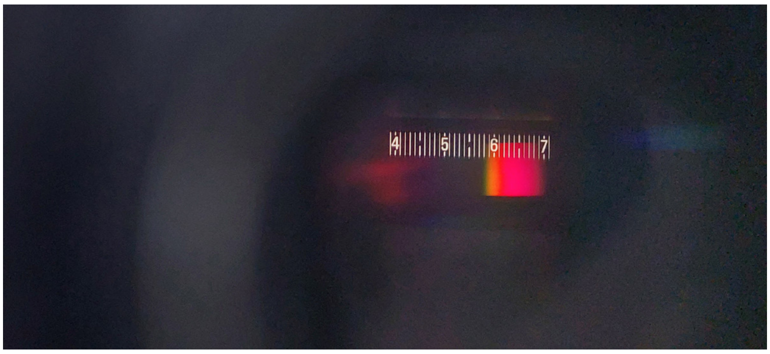
Warning: Do not view the sun with your eye

For further details and an instructional video see: https://astro3d.org.au/education-and-outreach/diy-smartphone-spectroscope/

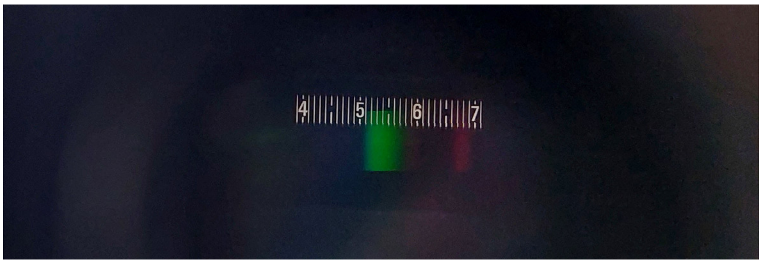
RESULTS

- Students should notice differences in the spectra from their range of light sources.
- The Sun may appear to be a continuum. Some students may see a few darker (absorption) patches which will be the Fraunhofer lines.
- Fluorescent lights should show prominent green and purple lines.
- Warm LED should have strong orange/red and less blue.
- Cool LED should have a little blue and lots of yellow.
- Incandescent lamp will show a continuum from its blackbody filament.

The absorption spectrum from red food dye:



The absorption spectrum from green food dye:



Spectrum from dilute cola contains no blue or purple.

FOLLOW-UP QUESTIONS

1. Define these words:

a) spectrum *(the finite range of wavelengths or frequencies contained within a signal)*

b) spectrograph/spectroscope *(the instrument that splits up the colours and analyses them) (Read more: https://spie.org/publications/fg08_p02_spectrometerspectroscopespectrograph#_=_)*

c) spectrogram *(essentially a graph/plot of wavelength or frequency on the x-axis and intensity on the y-axis)*

2. If you compare the colours you can see through your spectroscope with your eye, to the colours/number of lines you can see in the photograph, are there any differences? Why do you think that might be?

The eye is more sensitive to variations in colour than a digital, commercial-bought CMOS detector found in standard smartphones, tablets and digital cameras. However, students may see a line beyond the visible red, into the infrared. This line(s) may be real. CMOS detectors can sense light into the near infrared region. This can be tested by holding down a button on television remote control and pointing a smartphone camera at the light bulb of the remote control. The light bulb will appear as a bright red dot on your smartphone's screen.

3. If you observed a spectral lamp, or the Christmas lights, do you see unexpected colours of light through your spectroscope? What might be the source of these colours? And what steps might you conduct to exclude that light?

The lamp is not in a room free of stray light or other light sources. A closed black box containing the light source and the spectroscope, plus the observer, would be required.

FOLLOW-UP QUESTIONS

4. How do you think astronomers remove unwanted light?

This is a tricky one as there are no perfect solutions to this problem. One is to make observations in dark places with dark skies. Another is to collect a lot of light with a big telescope and be prepared to throw away a lot of it in order to find the light you want; this can be done using optical elements in highly-engineering spectrophotometers, such as filters and slits. A third is to use fibre optics to target only small patches of the sky. The fourth is to have their telescopes in space, away from bright light sources. Read more about fibre optic techniques here: https://astro3d.org.au/sami-hector-surveys/ and https://astralis.org.au/projects/hector/

5. Before digital sensors like CCDs existed, how do you think astronomers recorded the intensity of light? Read this article to find out more: https://onlinelibrary.wiley.com/doi/full/10.1002/asna.20230066

Making use of the photoelectric effect through devices such as photomultiplier tubes (PMTs) which were used into the 21st century.