Spectroscopy – Lesson Outline

Syllabus References

9.7.3.1 – Spectroscopy is a vital tool for astronomers and provides a wealth of information

Resources

Video: Spectra
http://www.hscphysics.edu.au/resource/Spectra.flv

Pre-video Activities

Pre-video Activity: Spectroscopy Worksheet

Students should fill out worksheets individually. When finished, organise students into groups of three. Provide each group with a blank sheet of A3 paper and markers.

Students write a definition to answer the question: “What is light?” (Encourage diagrams)

Recall (from Preliminary Course work – The World Communicates)
Students list types of electromagnetic waves and order them from shortest to longest wavelengths

Sample response:
gamma rays, x-rays, ultraviolet radiation, visible light, infra red radiation, microwaves, radio waves
Increasing wavelength →

Representatives present the group’s responses to the rest of the class. Encourage class discussion and questioning

View Video

Video: Spectra
http://www.hscphysics.edu.au/resource/Spectra.flv

Stop the video after the explanation and illustration of how a hot and cool star can be represented together on a graph of intensity versus wavelength.

Activities

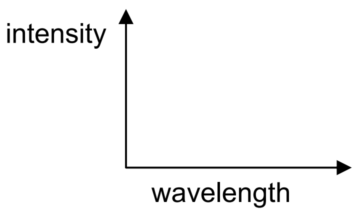
Re-organise students into their groups of three. Provide each group with another blank sheet of A3 paper and markers to record group responses to the following discussion questions

1. The sun is a great source of EM radiation. Where does the sun get its energy from?
(Answer: nuclear fusion – according to Einstein's famous equation $E=mc^2$)

2. Name two ways that white light can be dispersed into its component colours.
(Answer: prism or diffraction grating – teacher can demonstrate this using a simple CD)

3. Sequence the steps used by an astronomer to study the light from a star
(Answer: telescope collects and focuses light ► spectroscope splits light into components ► computer analyses resulting spectra)

4. Plot the light curves (blackbody curves) for a hot blue star and a cool red star on the axes provided



Each group should present their work to the rest of the class. Then replay the section of video to consolidate student understanding and to address any misconceptions

View Video

Video: Spectra
http://www.hscphysics.edu.au/resource/Spectra.flv

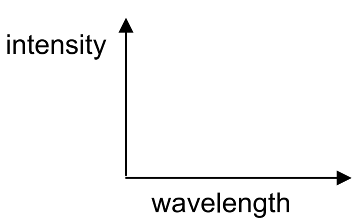
Replay the video from the start to consolidate student understanding and address any misconceptions.

Stop video at completion of explanation about spectral classes

Activities

In the same groups of three, students should discuss and record responses to the following questions on their butcher paper:

1. Explain how absorption spectral lines are produced.
2. Sketch the light curve for a real stellar spectrum on the axes provided



3. Explain how stellar spectral lines are formed. You might like to use diagrams.

Classification of stars - spectral classes
Groups complete the following table using the video stimulus: (some further research may be required)

Sample answers:

Spectral class	colour	Surface temp (◦C)	Distinguishing spectral features
O	Blue	> 20 000	Ionised Helium
B A F	White Yellow	7000 – 20 000	Strong Hydrogen
G	Yellow	5000 - 6000	Ionised Calcium
K M	Red	2 000 - 4500	Neutral metals + molecules

One representative presents the group's interpretations to the rest of the class. Encourage class discussion and questioning. Teacher collates all groups' responses on board or screen. Ensure different group members are presenting findings to class

View Video

Video: Spectra
http://www.hscphysics.edu.au/resource/Spectra.flv

Replay the last section of the video to consolidate student understanding and address any misconceptions.

Activities

Complete the table following the next section of video

Aspects of stellar motion	**Spectral features**	**Explanations**
Translational motion	Doppler shift of spectral lines Red shift – star is moving away relative to observer Blue shift – star is moving towards observer	
Rotational motion	The faster a star rotates the broader are its spectral lines	
Binary stars (ext)	Periodic splitting of spectral lines	

Replay the last section of the video to consolidate student understanding and address any misconceptions.

Post-Video Activities

Post-video Activity: Cloze Passage

Students complete following cloze passage, which represents the script for this video. The missing key words are listed out of order directly following the passage.

Post-video Test: Concepts in Astronomy

Students complete the post test individually to check for conceptual change.

In groups of 3 students use the following key words to produce a concept map in groups.

Light
Dispersion
Spectrum
Absorption
Spectrograph
Doppler shift
Spectral class
EM radiation
Blackbody curve
Red shift
Blue shift
Surface temperature
Spectral features

Spectroscopy – Pre-video Worksheet

Match the words on the left with one of the descriptions on the right. Four of the descriptions are red herrings and shouldn't be used at all!

Neutron Star	Celestial body of irregular shape that orbits stars
	The birthplace of stars
Black Hole	Large but cool star
	Composed mostly of carbon
Nebula	Theoretical object – none of these have been found yet
	Gravity is so strong here that not even light can escape
Red Giant	Extremely dense, spinning object
	Very hot and bright star
Blue Giant	Our Sun is one of these

Are these statements True or False? See what your score out of 10 is!

1. UV radiation is what makes us tan.
2. The sun is a 'main sequence' star.
3. Radio waves travel slower than x-rays.
4. Light from the sun takes six minutes to reach Earth.
5. The sun gets its energy from nuclear fission reactions.
6. Microwaves heat things up by exciting their molecules.
7. A shiny black object would absorb more heat than a dull black object.
8. An object moving away from us would demonstrate red shift.
9. A larger star is always hotter than a smaller star.
10. Planets rotate – stars can rotate as well.

Spectroscopy – Cloze Passage

Astronomy is a fascinating subject for so many people, whether they're chasing eclipses, studying star charts or stargazing at night. What you may not know is that we can gain a lot of information about stars just from studying their light.

What is light? Light is an ______________________________wave, a combination of oscillating electric and magnetic fields that travel through space. Visible light forms only a small part of the electromagnetic spectrum, which is divided into groups by _____________________________.

The shortest wavelengths in the electromagnetic spectrum are _____________________ rays. X-rays come with slightly longer wavelengths, and then ultraviolet waves. The visible light spectrum is next. Just after visible light are the ___________________ waves, and as the wavelengths get longer, we move into the region of microwaves and finally _____________________ waves.

The __________________ is a massive source of electromagnetic waves. It radiates plenty of visible light, as we can see around us during the day. It also emits in other parts of the electromagnetic spectrum – ___________________________ radiation is what makes us tan (or burn), and we get infrared radiation from the sun as well, which is simply ________________.

The sun doesn't emit all these wavelengths equally; in fact, it's useful to plot the __________________________ of electromagnetic radiation versus its wavelength. Then we see that the sun produces light of wavelength 500nm most often, and shorter and longer wavelengths with less intensity.

But where does the Sun get all this electromagnetic energy from? As the laws of physics tell us, you can't get something from nothing. The Sun gets its energy from ______________. Fusion is the process whereby light nuclei combine to form heavier nuclei, releasing _______________________. In the core of the sun, hydrogen is fused into helium yielding enormous amounts of energy.

While the Sun's light may appear to be yellow or white, it is actually made up of all different colours. If we put the Sun's light through a _______________________, we can split it up into its component colours. Long visible wavelengths around 700 nanometres look ______________, while short wavelengths around 400 nanometres look ___________________________.

The Sun is the star we are most familiar with, but we can split light from other stars in a very similar way. The technology that we use to gather information about stars is just like the prism we were using. Things are more complicated for other stars because they are far away – we need a ______________________________ to focus the image first. Then we use a, _______________________________________ which splits up the light by its wavelength so that we can see its different colour components.

When we do this we find that not all stars look like the sun; some have more blue light, some have more red. But when we plot the intensity of the light versus the wavelength, all graphs have a similar ______________________; in fact, everything that is hot emits electromagnetic radiation with this characteristic shape. The _______________________the object is, the more the peak wavelength moves toward the blue area. The _________________ the object the more it moves to the red area. Hotter objects emit greater overall intensity in all parts of the ____________________________.

However these graphs are not exactly what we see from stars. Looking closer, we see some parts of the spectrum appear to be _______________________. The curve is not perfectly smooth like we saw before.

Why are certain wavelengths so low in intensity? Well, just like the earth, stars have atmospheres, of relatively cool ____________. This gas can absorb certain wavelengths of electromagnetic radiation. Different gas atoms absorb light of different wavelengths. So we can say which elements are in the atmosphere of distant stars by seeing what wavelengths are really low – which ones have been ________________________. We call these absorbed wavelengths '______________________________'.

Looking at these graphs, called stellar spectra, astronomers decided to group stars into spectral _________________________ based on similarities among the pictures. There are seven general classifications labelled by the letters O B A F G K M. This might seem a bit tricky to remember but people have come up with a range of mnemonics like Oh Big And Furry Gorilla Kill Me or Oh Boy, Astronomy Final's Gonna Kill Me.

The O class stars are the hottest and the ____________________________. They are known as blue ___________________, and have surface temperatures of 20,000 degrees Celsius or more. We can identify these O-type blue giants because they are the only ones that show absorption by ionised ________________________ and they have strong emission in the blue part of the spectrum. Stars in the B, A and F classes are cooler, and appear ______________ or white. These B, A and F stars show strong absorption of ____________________. Our Sun is a G-type star with a surface temperature of about 6,000 degrees. The K and M stars are the coolest stars in this classification system, with surface temperatures of around 3000 degrees, they appear red.

Looking at the spectra of distant stars, we find that the spectral lines aren't exactly where we expect them to be. For some stars, spectral lines are ___________________ to the red part of the spectrum, while for others, spectral lines are shifted over to the blue part of the spectrum. This is called _____________________ or 'blue shift'. To understand why this happens, think of a car moving towards you honking its horn. As the car gets closer, you hear the horn at a higher ___________________ than if the car were still. But as the car passes you and starts moving away, the pitch of the horn drops, and the tone is _________________ than if the car were still. It is the same with spectral lines. Red shift indicates that the star is moving _________________ from us, while blue shift indicates that the star is moving _________________ us. The __________________ of this shift tells us how fast.

You can also tell how fast a star is rotating by looking at the _______________ of the absorption lines. For stars of a given size, a very fine, sharp absorption line tells us that the star is barely ________________________ - the light from all sides of the star is equally red-shifted. But if the star is rotating quickly, then we see a ___________________ absorption line because one side of the star is moving towards us and the other side of the star is moving away – light from each side is red-shifted by different amounts.

So simply by looking at the light produced by distant stars we can find out a lot about them. All we need is a telescope and a spectrograph. Who knew you could find out so much from a star by just looking at it?

Word list:

red
pitch
gas
shifted
wider
width
helium
brightest
infrared
magnitude
lower
giants
hotter
spectrum
telescope
radio
rotating
prism
classes
absorbed
intensity
fusion
'red-shift'
yellow
shape
ultraviolet
wavelength
cooler
missing
gamma
Sun
energy
spectral lines
towards
blue
spectrograph
electromagnetic
hydrogen
heat
away

Spectroscopy – Concepts

Q1. Which of the following is not electromagnetic radiation?

A. Visible light
B. Microwaves
C. Gamma rays
D. Beta rays
E. X-rays

Q2. Which of these has the longest wavelength?

A. Red
B. Blue
C. Green
D. Yellow
E. Infrared

Q3. A spectrograph performs a similar function to a:

A. Mirror
B. Lens
C. Prism
D. Aperture
E. Shutter

Q4. Which of these stars has the hottest surface?

A. A-type white star
B. G-type yellow star
C. M-type red star
D. K-type red star
E. Not enough information

Q5. What is the typical surface temperature of a blue giant?

A. 7,000-10,000°C
B. 10,000-15,000°C
C. 15,000-20,000°C
D. 20,000°C or more
E. Not enough information

Q6. Which of these answers most accurately describes the surface temperature of the Sun?

A. 600°C
B. 1,000°C
C. 3,000°C
D. 6,000°C
E. 10,000°C

Q7. The sun emits radiation most intensely in which region?

A. Infrared
B. Visible light
C. Ultraviolet
D. Gamma
E. Microwaves

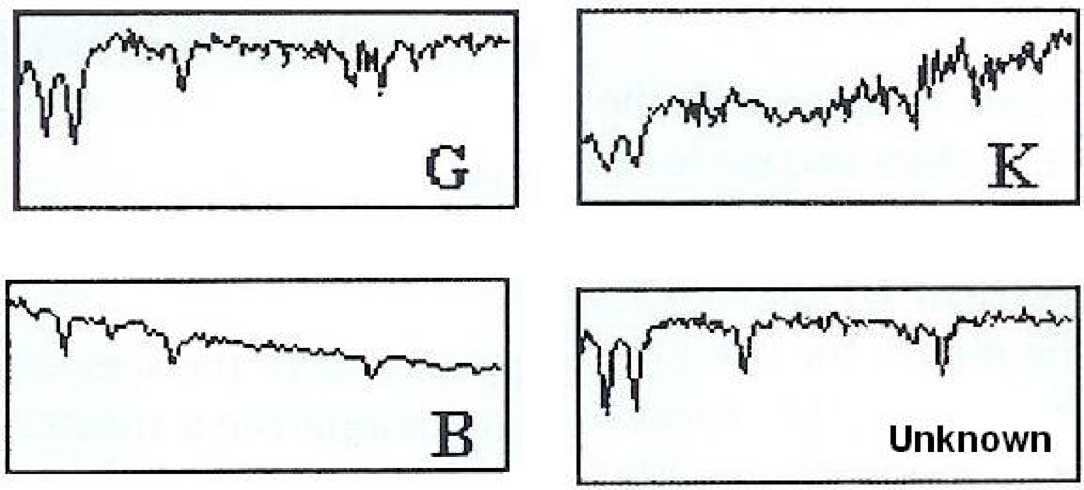
Q8. Given a group of stars of similar size, which temperature star would emit the most UV radiation?

A. 600°C
B. 1,000°C
C. 3,000°C
D. 6,000°C
E. 10,000°C

Q9. Given a group of stars of similar size, which temperature star would emit the most infrared radiation?

A. 600°C
B. 1,000°C
C. 3,000°C
D. 6,000°C
E. 10,000°C

Q10. Given the spectra shown below, what class of star do you think produced the unknown spectrum?



A. R
B. O
C. M
D. F
E. N

Q11. What are spectral lines?

A. Lines that divide the different types of electromagnetic radiation
B. Lines of absorption by the atmosphere of the earth
C. Lines of absorption by the atmosphere of stars
D. Lines in stellar spectra that appear when a star is red-shifted
E. Lines in stellar spectra that appear when a star is blue-shifted

Q12. The sun gets its energy from:

A. The burning of hydrocarbon fuels
B. The combining of light elements into heavier elements
C. The glow from molten rocks
D. Heat left over from the big bang
E. The breaking apart of heavy elements into lighter elements

Q13. Red shift can be described as:

A. Seeing lots of red stars
B. Light shifted to shorter wavelengths when stars are moving away from us
C. Light shifted to shorter wavelengths when stars are moving towards us
D. Light shifted to longer wavelengths when stars are moving away from us
E. Light shifted to longer wavelengths when stars are moving towards us

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Extended Response

Q14. Populations of stars can be distinguished by their chemical composition. Explain how astronomers can determine this information. (3 marks)

Q15. A friend tells you she has discovered a blue giant that is moving away at a speed of 1 milliparsec per year, and it is rotating quickly. How would you verify each of her conclusions? (6 marks)

Q16. A tungsten filament in a light bulb has a temperature of about 3000 degrees Celsius. Evaluate the efficiency of light bulbs as light sources, giving reasons for your answer. (3 marks)