

DOPPLER EFFECT LESSON PLAN

Description

Through experiments students will see and hear the Doppler effect, and apply their new knowledge to the hydrogen emission spectrum.

Curriculum Fit

Grade 9, Unit E: Space Exploration

Specific Learner Expectations

1. Describe and apply techniques for determining the position and motion of objects in space, including:
describing in general terms how parallax and the Doppler effect are used to estimate distances of objects in space and to determine their motion

Key Terms

- *Doppler effect*: an increase (or decrease) in the frequency of sound, light, or other waves as the source and observer move toward (or away from) each other. The effect causes the sudden change in pitch noticeable in a passing siren, as well as the redshift seen by astronomers
- *Redshift*: When light or any waves on the electromagnetic spectrum are lengthened as the source of those waves moves away from us. It is called a 'redshift' in the light as the wavelength shifts toward the red side (longer wavelengths) of the electromagnetic spectrum
- *Blueshift*: When light or any waves on the electromagnetic spectrum are shortened (compressed) as the source of these waves moves toward us. It is called a 'blueshift' in the light as the wavelength shifts toward the blue side (shorter wavelengths) of the electromagnetic spectrum
- *Exoplanet*: A planet outside of our solar system
- *Emission Spectrum*: A spectrum of the electromagnetic radiation emitted by a source

Introduction

Watch the “**Doppler Effect**” video as an introduction to this lesson.

Have you heard the wail of an emergency vehicle’s siren as the vehicle races toward you, and then experienced the sudden drop in pitch as it passes you? This change can be explained by the Doppler effect. The Doppler effect is the stretching or compression of sound or light waves as the source moves either towards or away from you. In this lesson you will be able to see and hear evidence of the Doppler effect, and then apply your knowledge of the Doppler effect to the emission spectrum of hydrogen!

Activity One: Visual Representation of the Doppler Effect

Goal: Understand how the Doppler effect happens using a visual example .

Materials:

- 1 piece of construction paper
- Toy car or any similar-sized object
- Tape
- Scissors

Instructions:

1. Cut one piece of construction paper the long way into inch-wide strips. You will need 5 of these strips and they will all be 11” long. Leave the first strip that length; cut an inch off of the second strip so that it’s 10” long; cut two inches off of the second strip so that it’s 9” long; and so on so that each strip of paper is an inch shorter than the last one.
2. Tape the ends of the five strips of construction paper together so they form loops. Put the loops inside of each other (largest outside to smallest inside). Place the car in the middle of the loops. The loops are your sound waves; they show how the sound of the car’s engine travels outward when the car is standing still.
3. Draw a picture or take a photo of the car and the loops the way they look now.
4. Now gently roll the car forward until it pushes all the loops in front of it together so that they all touch. This shows what happens to the sound waves when the car is moving: the ones at the front get squished together, or compressed, so that they sound higher-pitched, while the sound waves at the back get spread out or stretched so that the sound they make is lower-pitched. That’s the Doppler effect!
5. Draw a picture or take a photo of the car and the loops in this position.
6. Now look at your two models, of the car standing still and the car in motion. You can see how the sound waves are affected by the movement of the car.

TIP: This is what you should see in Step 3.



Activity Two: Doppler Effect in a Sock

Goal: Create the Doppler effect in your own home.

Materials:

- 1 long sock (18 inches would be ideal)
- Smart phone
- Free tone generator app

Instructions:

1. Download a free tone generator app onto the smartphone. The Tone generator app by Micheal Heinz is an app used in Telus World of Science programs.
2. Select a frequency on the app, and turn it on
3. Slide the phone, with the tone generator on, into the bottom of the sock
4. Ensure that you are in a clear open space in the house, with no one close to you
5. Hold on tightly to the end of the sock with the opening and swing it around above your head. You should be able to hear the Doppler effect in the noise echoing off the walls.

TIP: 1. Ask a family member to swing the sock while you listen so that you can more easily hear the Doppler effect.

2. Try out different tones on the generator app to hear the Doppler effect in different frequencies!

Activity Three: Shifting the Emission Spectrum of Hydrogen

Goal: Understand how a redshift or blueshift will change the observed emission spectrum of a star.

Materials:

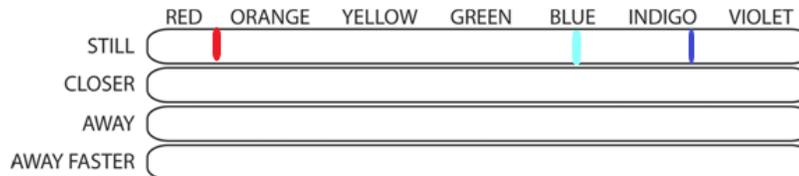
- Coloured pencils or markers. If possible, find the following colours for the markers or coloured pencils: light red, dark red, orange, green, light blue, dark blue, purple.
- Paper

Instructions:

1. If possible, print out this activity. If you cannot print it out you can copy it onto the piece of white paper.
2. Stars are composed of mostly hydrogen and helium gases. The image below has the normal emission spectrum of hydrogen which represents what we might see using spectroscopy to study a star. They are the 3 coloured lines.



3. When you draw in the new emission spectrum, (on the worksheet given below) you will shift those 3 lines either to the right or left. If you shift the lines to the left, the red line will become darker and the blue lines will become lighter or even green. If you shift to the right, the red line will become more orange, and the blue lines will become darker.
4. If a star was moving toward you (a blueshift), what would the new emission spectrum look like? Draw in the new emission spectrum in the 'CLOSER' row.
5. If the star was moving away from you (a redshift) what would the new emission spectrum look like? Draw in the new emission spectrum in the 'AWAY' row.
6. If the star was moving away from you (a redshift) even faster than in the previous question, what would the new emission spectrum look like? Draw in the new emission spectrum in the 'AWAY FASTER' row.



("Still" in the above worksheet means the star is not moving)

Discussion Questions

1. Edwin Hubble observed galaxies and noticed the light coming from them was redshifted. Why did he then propose that the universe was expanding?
2. When a speeding car passes a speed camera, and is moving away from the camera, laser light from the camera hits the car, and the laser waves return to the camera at a changed frequency. Will the returned laser waves be compressed or lengthened when they arrive back at the speed camera? What would happen if the speeding car was coming toward the radar?
3. Looking at the sound wave model for the car created in Activity 1, draw the sound waves you would expect for a supersonic airplane that is traveling faster than the speed of sound and breaks the sound barrier.

Assessment

1. What is the Doppler effect?
2. What is a redshift?
3. What is a blueshift?
4. How does the Doppler effect help us discover exoplanets?

Background Information

Who was Doppler?

The Doppler effect is named after an Austrian physicist, Christian Doppler. Doppler first described how the observed frequency of light and sound waves is affected by the relative motion of the source and the detector in 1842.

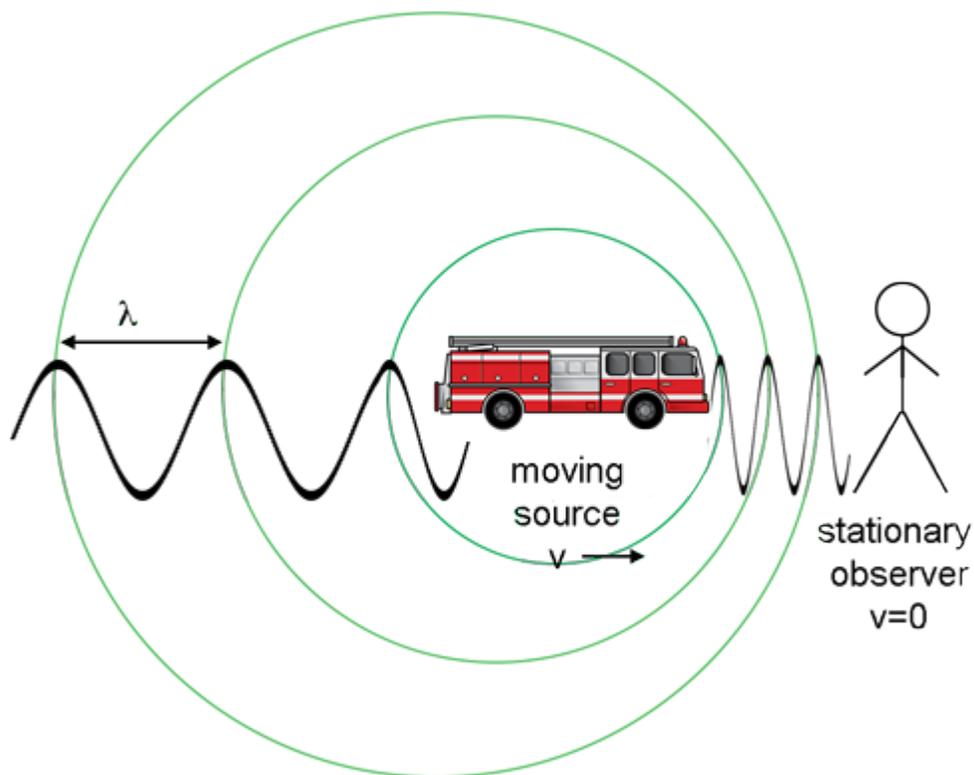
What is the Doppler effect?

The Doppler effect is a change in the wavelength of a wave due to a change in distance between the wave source and the observer. This effect can be observed with both sound and light waves!

Sound waves:

For sound waves, the pitch of the sound changes due to the Doppler effect

- The observer will hear a higher pitched sound when the sound source is approaching (compressed sound waves)
- The observer will hear a lower pitched sound when the sound source is moving away (stretched sound waves)
 - Ex. the siren of an emergency vehicle

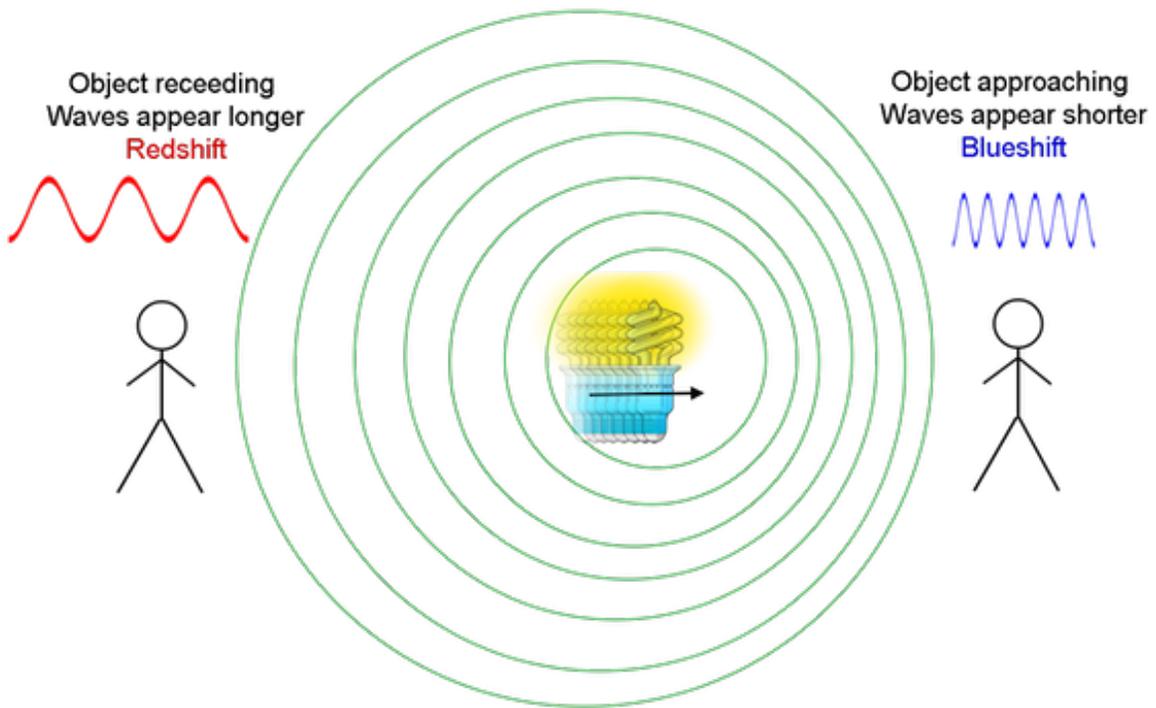


Credit: NASA's Imagine the Universe

Light Waves:

How does the Doppler effect result in redshift/blueshift?

When the source of light waves is travelling towards us, the waves get squished together resulting in a shorter wavelength. The shorter wavelengths mean they are shifted towards blue in the visible spectrum. But when the source of light waves is travelling away from us, the waves get stretched which results in longer wavelengths or a shift towards the colour red.



Credit: NASA's Imagine the Universe

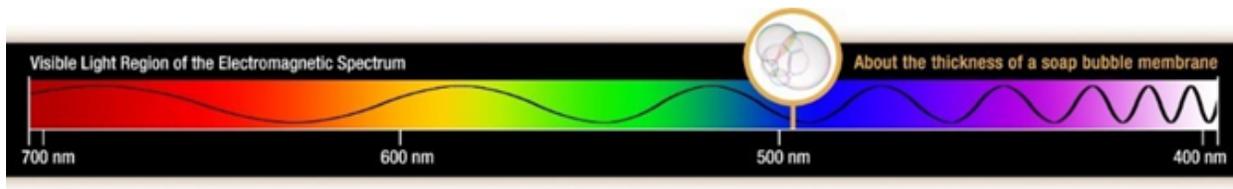
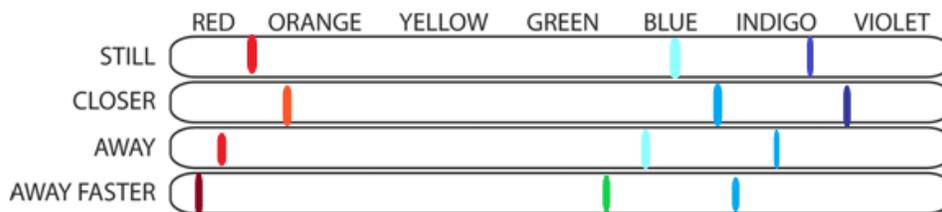


Image of the electromagnetic spectrum, from NASA

Answer key for activity 3:



References

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- <https://www.abc.net.au/science/articles/2013/04/10/3730713.htm>
- https://imagine.gsfc.nasa.gov/features/yba/M31_velocity/spectrum/doppler_more.html
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