A Guide to the Doppler Effect

Teaching Approach

The Doppler Effect refers to the observed change in the pitch of sound as the source moves. To help learners understand the Doppler Effect we use the illustration of a water wave to explain the Doppler Effect. This is done for both a moving source towards and away from a stationary listener. The change in the pitch of the sound is highlighted in lessons 1. In Doppler Effect we observe the change in pitch as the source moves away from a stationary listener or as the source moves towards a stationary listener. The change in pitch can be explained by looking at the frequency of the sound wave. When the frequency in which the listener hears the sound is high then the pitch will be high, this means that the source of sound moves towards the listener. We use the equation of Doppler Effect to calculate the actual frequency of the source.

In lesson 2 the original equation of the Doppler Effect is shown as \[ f_L = \left(\frac{v + v_s}{v - v_L}\right) f_s \] and its use is explained. We then show how to work step by step with the Doppler Effect equation to solve problems. The concept of away and towards, and the use of positive and negative for the speed of the source or the speed of the listener in the equation could confuse the learners. The best way to indicate them is that when the source moves towards the listener the frequency heard by the listener will be greater than the frequency of the source. This means that the fraction which is multiplied by the frequency of the source must be greater than one. In this case the speed of the source is negative and the speed of the listener must be positive.

If the source moves away, the fraction must be less than one, which means the speed of the source will be positive and the speed of the listener negative.

In lesson 3 and 4 we expose learners to the application of Doppler Effect in real life, in areas such as medicine, sports and astronomy. In medicine we focus on ultrasound and in astronomy, on motion of the stars and the universe. This give learners the opportunity to use the Doppler Effect equation and principle to explain how things work in reality i.e. how a radar gun is used to measure the speed of tennis ball or vehicle on the road.

The use of animation and videos to show the application of Doppler Effect in everyday life and how to solve problems with the Doppler Effect equation is useful for learners. It enables them to understand the concept of increase in pitch when the source moves towards the listener and the decrease in pitch as the source moves away from the listener. When the source move towards the listener, there is an increase in the frequency of the listener and that the speed of the source will be negative.

Finally, the videos can either be used independently for the learners to revise with after the content at school, or as part of the lessons. The use of multimedia to explain and reinforce concepts helps the learners understand and grasp new concepts better.
The task video has been prepared in such a way as it could be used as either an exercise or as a way for the students to test their knowledge independently.

**Video Summaries**

Some videos have a ‘PAUSE’ moment, at which point the teacher or learner can choose to pause the video and try to answer the question posed or calculate the answer to the problem under discussion. Once the video starts again, the answer to the question or the right answer to the calculation is given.

Mindset suggests a number of ways to use the video lessons. These include:

- Watch or show a lesson as an introduction to a lesson
- Watch or show a lesson after a lesson, as a summary or as a way of adding in some interesting real-life applications or practical aspects
- Design a worksheet or set of questions about one video lesson. Then ask learners to watch a video related to the lesson and to complete the worksheet or questions, either in groups or individually
- Worksheets and questions based on video lessons can be used as short assessments or exercises
- Ask learners to watch a particular video lesson for homework (in the school library or on the website, depending on how the material is available) as preparation for the next day’s lesson; if desired, learners can be given specific questions to answer in preparation for the next day’s lesson

1. **Doppler Effect in Everyday Life**
   In this lesson the focus is on the basic concept of Doppler Effect. This lesson shows that when the source moves away from the listener, the pitch of the sound decreases, and when it moves towards the listener, the pitch of the sound increases.

2. **Calculations on the Doppler Effect**
   In this lesson the Doppler Effect equation is used. There is a use of animation to illustrate and explain each part of the equation. The equation is used to calculate the frequency heard by the listener when the source is moving.

3. **Applications of the Doppler Effect**
   There is an investigation on how an ultrasound and radar gun operates. These instruments are used to measure the movement of an object, and thus determine its speed using the Doppler Effect equation.

4. **Expanding universe**
   This lesson focuses on light waves. It looks at how the Doppler Effect is used to explain the movement of stars in the galaxy, and the expansion of the Universe.
## Resource Material

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<table>
<thead>
<tr>
<th></th>
<th></th>
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<tbody>
<tr>
<td>1. Doppler Effect in Everyday Life</td>
<td><a href="http://hyperphysics.phy-astr.gsu.edu/hbase/sound/dopp.html">http://hyperphysics.phy-astr.gsu.edu/hbase/sound/dopp.html</a></td>
<td>Explanation of basic concepts relating to sound.</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.astro.ucla.edu/~wright/doppler.htm">http://www.astro.ucla.edu/~wright/doppler.htm</a></td>
<td>Doppler Shift. Red and blue shifts. Light from moving objects will appear to have different wavelengths depending on the relative motion of the stars.</td>
</tr>
</tbody>
</table>
Task

Question 1
A man stands alongside the road while a fire engine approaches him at 130 km·h⁻¹. The fire engine siren emits a sound with frequency of 750 Hz.

1.1 What is the Doppler Effect?
1.2 Explain why the man will hear the pitch of the sound higher as the fire engine approaches him.
1.3 Calculate the frequency in which the man will hear the sound.

Question 2
Consider this diagram

![Diagram of a train]

2.1 What does the diagram imply about the motion of the train?
   a) The train is stationary.
   b) The train moves towards Bibo.
   c) The train moves towards Bonita.
   d) The train is moving away from Bibo.

2.2 The frequency and pitch of the sound heard by Bonita compared to that heard by Bibo is
   a) Smaller sound frequency and lower pitch.
   b) Smaller sound frequency and higher pitch.
   c) Greater sound frequency and higher pitch.
   d) Greater sound frequency and lower pitch

2.3 Describe the pattern on the diagram below in terms of the frequency and wavelength of the waves

![Diagram of wave pattern]

2.4 What does it mean when the wavelength of a wave decreases due to the movement of a source?
2.5 A train is driving along the tracks with a velocity of $20 \text{ m}\cdot\text{s}^{-1}$. The train is blowing its whistle, which has a frequency of 1000 Hz. A car is parked along a road that is next to the railway track. The speed of sound waves in air is $340 \text{ m}\cdot\text{s}^{-1}$

Calculate the frequency of the note that the driver of the car would hear before the train passes her and then after it has passed her.

**Question 3**
A traffic officer sets up a stationary radar device so that the speed the vehicle moves with can be determined. The radar emits waves with a speed of $3 \times 10^8 \text{ m}\cdot\text{s}^{-1}$ and a frequency of 3.3 GHz towards the vehicle.

3.1 Calculate the speed of the vehicle in $\text{m}\cdot\text{s}^{-1}$ if the radar device receives a signal with a frequency of 3.30000003 GHz

3.2 If the speed limit for this section of road is $120 \text{ km}\cdot\text{h}^{-1}$ determine if the vehicle exceeded the speed limit or not.

**Question 4**
4.1 What is a red shift?
4.2 How can the Doppler Effect be used to measure the relative motion of stars and Earth?
4.3 The space telescope detected a star. The light from the star shows the biggest red shift ever measured. What does the measurement of its red shift tell the scientist about this star?
Task Answers

Question 1
1.1 Doppler Effect is the observed change in the pitch of sound as the source moves
1.2 The sound waves that are formed have higher frequency and shorter wavelength. Thus a higher
pitch sound is heard than is made by the fire engine
1.3

\[ f_L = \left( \frac{v \pm v_s}{v \pm v_L} \right) f_s \]

\[ f_L = \left( \frac{340 + 0}{340 - 36.11} \right) 750 \]

\[ f_L = 839.12 \text{ Hz} \]

Question 2
2.1 B
2.2 A
2.3 The frequencies and the wavelength have changed from the front and behind the source. In front
the wavelength is decreased then the frequency is increased. Behind the source the wavelength
has increased and the frequency has decreased
2.4 If the source moves away from you, the waves are “stretched out” and a sound with a lower
frequency will be noticed.
2.5 Towards (as it approach the car) away (as it passes)

\[ f_L = \left( \frac{v \pm v_L}{v \pm v_s} \right) f_s \]

\[ f_L = \left( \frac{340 + 0}{340 - 20} \right) 1000 \]

\[ f_L = 1062.50 \text{ Hz} \]

\[ f_L = \left( \frac{v \pm v_L}{v \pm v_s} \right) f_s \]

\[ f_L = \left( \frac{340 + 0}{340 + 20} \right) 1000 \]

\[ f_L = 944.44 \text{ Hz} \]

Question 3
1.1

\[ 3.3000003 \times 10^9 = \left( \frac{3 \times 10^8 + 0}{3 \times 10^8 - v_s} \right) 3.3 \times 10^9 \]

1.2 27.27 x 3.6 = 98.17 km·h⁻¹ does not exceed the speed limit.

\[ v_s = 27.27 \text{ m·s}^{-1} \]

Question 4
4.1 Light moves to red end of the spectrum or wavelength increases
4.2 The lines in the spectrum of a luminous body such as a star are similarly shifted towards the
violet if the distance between the star and the Earth is decreasing and towards the red if the
distance is increasing. By measuring this shift, the relative motion of the Earth and the star can be calculated.

4.3 It is the star detected furthest from the earth or it is moving away fastest.
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