THE DOPPLER EFFECT 9 APRIL 2013

Lesson Description

In this lesson we:

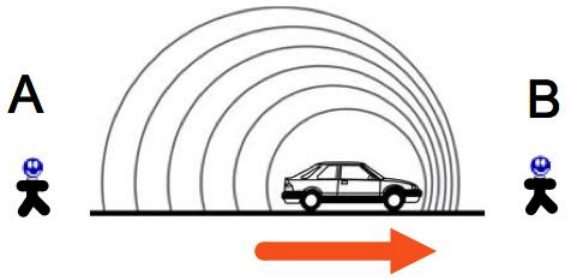
- Learn that objects that move relative to one another causes a change in the observed frequency of a wave.
- Apply the Doppler equation to solve examination style questions related to the Doppler Effect.
- Answer past exam questions which use the Doppler Effect.

Key Concepts

- Waves are emitted from a source to a listener. When the source is moving, the distance between waves (the wavelength) is changed. Because the wavelength changes, the frequency that is heard will change.
- The Doppler Effect is the change in observed frequency as a result in a difference of velocities between source and listener.
- The Doppler equation can be used to calculate the new frequency as a result of the movement.

Wavelength and Frequency

When a source of waves, like a car, moves, it changes the spaces between the waves. The waves in front of the car become closer and the waves behind are spaced out.



The listener at point A will hear waves that are more spread out.

Listener B will received waves which are more tightly packed.

How does this affect the pitch (frequency) of the sound?

$$v = f\lambda$$

Rearranging the formula we get:

$$f = \frac{v}{\lambda}$$

So, when the wavelength decreases, the frequency will increase. So that means when objects are moving closer to one another, the frequency increases.

When objects are getting further apart, the wavelength is increased and the frequency is decreased.

The Doppler Equation

The Doppler equation uses a fraction made of the velocities of the waves, the source and the listener to change the source frequency.

The fraction is:

$$\left(\frac{v \pm v_L}{v \pm v_S}\right)$$

Where "v" is the velocity of the waves, "v_L" is the velocity of the listener and "v_S" is the velocity of the source.

I choose "+" or "-" so that the fraction becomes bigger (for objects getting closer) or smaller (for objects moving away from one another).

Combining it into one equation:

$$\therefore f_L = \left(\frac{v \pm v_L}{v \pm v_S}\right) f_S$$

Terminology

Sound wave: a wave of pressure moving through air at roughly 340 $m.s^{-1}$.

Doppler Effect: The change in observed frequency as a result of a difference in velocity between the source of the wave and the listener.

Source: The object making the wave.

Listener: The receiver of the waves.

Demonstration

Go outside and listen to cars going by. Stand next to a road where cars are moving fast.

Listen to the pitch, or note of the cars coming towards you. When the cars go past, you'll notice that the frequency (pitch) changes to a lower one.

This is very apparent when you listen to a police car or siren making the noise.

You can even use this change in frequency to calculate how fast the cars were travelling!

Questions

Question 1

(Adapted from Mar 2011, DOE, Question 6, Paper 1)

The whistle of a train emits sound waves of frequency 2 000 Hz. A stationary listener measures the frequency of these emitted sound waves as 2 080 Hz. The speed of sound in air is 340 $m \cdot s^{-1}$.

a.) Name the phenomenon responsible for the observed change in frequency. (1)
b.) Is the train moving AWAY FROM or TOWARDS the stationary listener? (1)
c.) Calculate the speed of the train. (4)
d.) Will the frequency observed by a passenger, sitting in the train, be GREATER THAN, EQUAL TO or SMALLER THAN 2 000 Hz? Explain the answer. (2)
[8]

Question 2

(Adapted from Feb/Mar 2012, DOE, Question 6, Paper 1)

An ambulance approaches an accident scene at constant velocity. The siren of the ambulance emits sound waves at a frequency of 980 Hz. A detector at the scene measures the frequency of the emitted sound waves as 1 050 Hz.

a.) Calculate the speed at which the ambulance approaches the accident scene. Use the speed of sound in air as 340 $m \cdot s^{-1}$. (4)
b.) Explain why the measured frequency is higher than the frequency of the source. (2)
c.) The principle of the Doppler Effect is applied in the Doppler flow meter. State ONE positive impact of the use of the Doppler flow meter on humans. (2)
[8]

Links

- http://www.mindset.co.za/learn/xtra
- http://www.education.gov.za/Examinations/PastExamPapers/tabid/351/Default.aspx
- http://en.wikipedia.org/wiki/Doppler_effect
- http://www.webmd.com/a-to-z-guides/doppler-ultrasound