

State Examination Commission – Physics Higher Level, 2010

Question 7

The Doppler effect applies to all types of waves and is named after Christian Johann Doppler, an Austrian scientist who explained this phenomenon in 1842.

What is the Doppler effect?

Explain, with the aid of labelled diagrams, how this phenomenon occurs. (18)

Describe a laboratory experiment to demonstrate the Doppler effect. (9)

In the early part of the twentieth century, Hubble and other astronomers made the first measurements on the spectra from distant stars. They observed that these spectra were shifted and they used the Doppler effect to explain these shifts.

What causes the red shift in the spectrum of a distant star? (6)

The yellow line emitted by a helium discharge tube in the laboratory has a wavelength of 587 nm as shown in the diagram. The same yellow line in the helium spectrum of a star has a measured wavelength of 590 nm.

What can you deduce about the motion of the star?

Calculate the speed of the moving star. (18)

Give another application of the Doppler effect. (5)

(speed of light = $3.00 \times 10^8 \text{ m s}^{-1}$)

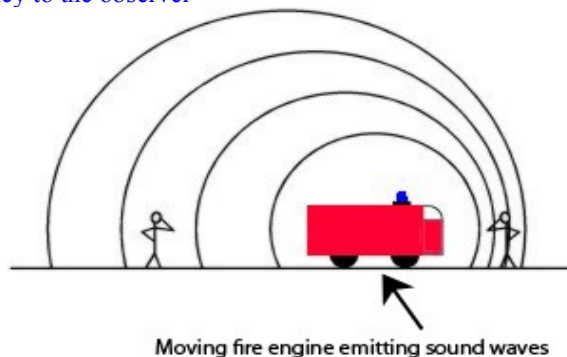
The Doppler effect applies to all types of waves and is named after Christian Johann Doppler, an Austrian scientist who explained this phenomenon in 1842.

What is the Doppler effect?

The apparent change in the frequency of a wave for an observer when there is relative motion between the wave source and the observer.

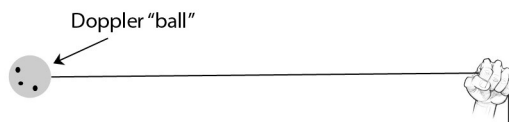
Explain, with the aid of labelled diagrams, how this phenomenon occurs. (18)

When the source is moving towards the observer, the waves “bunch together” making the wavelength shorter and increasing their apparent frequency to the observer



When the source is moving away from the observer, the waves move apart, making the wavelength longer and decreasing their apparent frequency to the observer

Describe a laboratory experiment to demonstrate the Doppler effect. (9)



If a ball, within which a small buzzer has been placed, is swung in a horizontal path above the head, a person standing several metres away will hear a sound of varying frequency. The frequency of the buzzer will appear higher when the ball is approaching the observer, and lower when receding from her.

In the early part of the twentieth century, Hubble and other astronomers made the first measurements on the spectra from distant stars. They observed that these spectra were shifted and they used the Doppler effect to explain these shifts.

What causes the red shift in the spectrum of a distant star? (6)

The distant star is moving away from the earth, so the frequency of its light is apparently lower (wavelength greater)

The yellow line emitted by a helium discharge tube in the laboratory has a wavelength of 587 nm as shown in the diagram. The same yellow line in the helium spectrum of a star has a measured wavelength of 590 nm. What can you deduce about the motion of the star?

The wavelength observed from the star is higher because it is receding from the observer on earth

Calculate the speed of the moving star.

(18)

$$\text{frequency, } f, \text{ of light observed} = 3.00 \times 10^8 / 5.87 \times 10^{-7} = 5.1107325 \times 10^{14} \text{ Hz}$$

$$\text{apparent frequency, } f', \text{ of light observed} = 3.00 \times 10^8 / 5.90 \times 10^{-7} = 5.0847458 \times 10^{14} \text{ Hz}$$

$$f' = \frac{c}{c + u_s} f$$

$$u_s = c \left(\frac{f}{f'} - 1 \right)$$

$$u_s = 3.00 \times 10^8 \left(\frac{5.1107325 \times 10^{14}}{5.0847458 \times 10^{14}} - 1 \right)$$

$$u_s = 1.53 \times 10^6 \text{ ms}^{-1} \quad (3 \text{ significant figures})$$

Give another application of the Doppler effect.

(5)

Used in speed traps