

**State Examination Commission – Physics Higher Level, 2007**

**Question 7**

What is the Doppler effect?

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

The emission line spectrum of a star was analysed using the Doppler effect.

Describe how an emission line spectrum is produced. (12)

The red line emitted by a hydrogen discharge tube in the laboratory has a wavelength of 656 nm. The same red line in the hydrogen spectrum of a moving star has a wavelength of 720 nm.

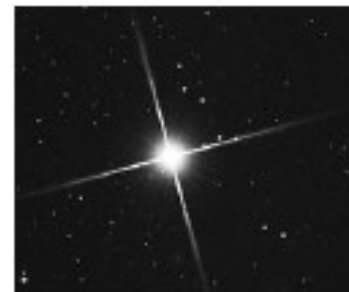
Is the star approaching the earth? Justify your answer. (8)

Calculate:

(i) the frequency of the red line in the star's spectrum

(ii) the speed of the moving star. (18)

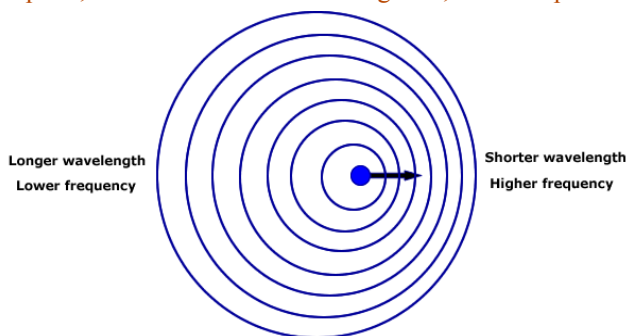
(speed of light =  $3.00 \times 10^8 \text{ m s}^{-1}$ )



What is the Doppler effect?

The Doppler effect is the change in frequency and wavelength of a wave for an observer moving relative to the source of the waves.

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



When the source of the waves is moving towards the observer (on the right in diagram), the waves appear to be of greater frequency and shorter wavelength.

When the source of the waves is moving away from the observer (on the left in diagram), the waves appear to be of lower frequency and longer wavelength.

The emission line spectrum of a star was analysed using the Doppler effect.

Describe how an emission line spectrum is produced. (12)

When the electrons in a monatomic gas are excited, they jump to higher energy levels. As the electrons fall back down, and leave the excited state, energy is re-emitted in the form of em radiation, the wavelength of which refers to the discrete lines of the emission spectrum. Each element has its own characteristic signature line spectrum.

The red line emitted by a hydrogen discharge tube in the laboratory has a wavelength of 656 nm. The same red line in the hydrogen spectrum of a moving star has a wavelength of 720 nm.

Is the star approaching the earth? Justify your answer. (8)

It is receding from the earth because the wavelength is shifted towards the red end of the visible spectrum where the wavelength is longer. This red shift is known as “Doppler red shift”, as it is explained by the Doppler effect.

Calculate:

(i) the frequency of the red line in the star's spectrum. (This is the apparent frequency of the red light, the real frequency of the red light from the star is the frequency of the red light from the discharge tube in the lab)

$$f' = v/\lambda' = 3.00 \times 10^8 / 720 \times 10^{-9} = 4.17 \times 10^{14} \text{ Hz}$$

(ii) the speed of the moving star.

(18)

The real frequency of the red light from the star is

$$f = v/\lambda = 3.00 \times 10^8 / 656 \times 10^{-9} = 4.57 \times 10^{14} \text{ Hz}$$

Now when a source of waves is receding from the observer of those waves, the relationship between the apparent frequency and the real frequency is given by

$$\begin{aligned} f' &= [c/(c + u)]f \\ 4.17 \times 10^{14} &= [3.00 \times 10^8 / (3.00 \times 10^8 + u)] 4.57 \times 10^{14} \\ u &= 2.92 \times 10^7 \text{ ms}^{-1} \end{aligned}$$

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