ASTROPHYSICS

3-1 The Doppler Effect

1. As the star moves away from Earth, the wavelength of the light it emits is longer than that for the star being stationary because in each time interval Δt the star travels a distance vΔt, where v is the star's speed. The peaks already emitted travel a distance cΔt in the opposite direction. An observer on Earth thus sees the peaks as being more widely spaced. The change in the wavelength being $\frac{v\lambda}{c}$ (compared to the star being stationary).

2. laboratory λ = 656 nm (= 6.56×10^{-7} m)

Shift in λ = -0.035 nm (= -3.5×10^{-11} m)

As the figures are used in a ratio, conversion is not in fact necessary.

Since the shift is negative, the star is moving towards the Earth.

$\Delta\lambda = -\frac{v\lambda}{c}$ therefore $v = -\frac{\Delta\lambda\ c}{\lambda}$

$$= -\frac{-0.035 \times 3.0 \times 10^{8}}{656}$$

$$= 1.6 \times 10^{4}\ ms^{-1}$$

3. (a) (i) The variation is periodic because the two stars move such that they move alternately towards and away from the Earth as they rotate (about their common centre of rotation) at a fixed frequency of rotation.

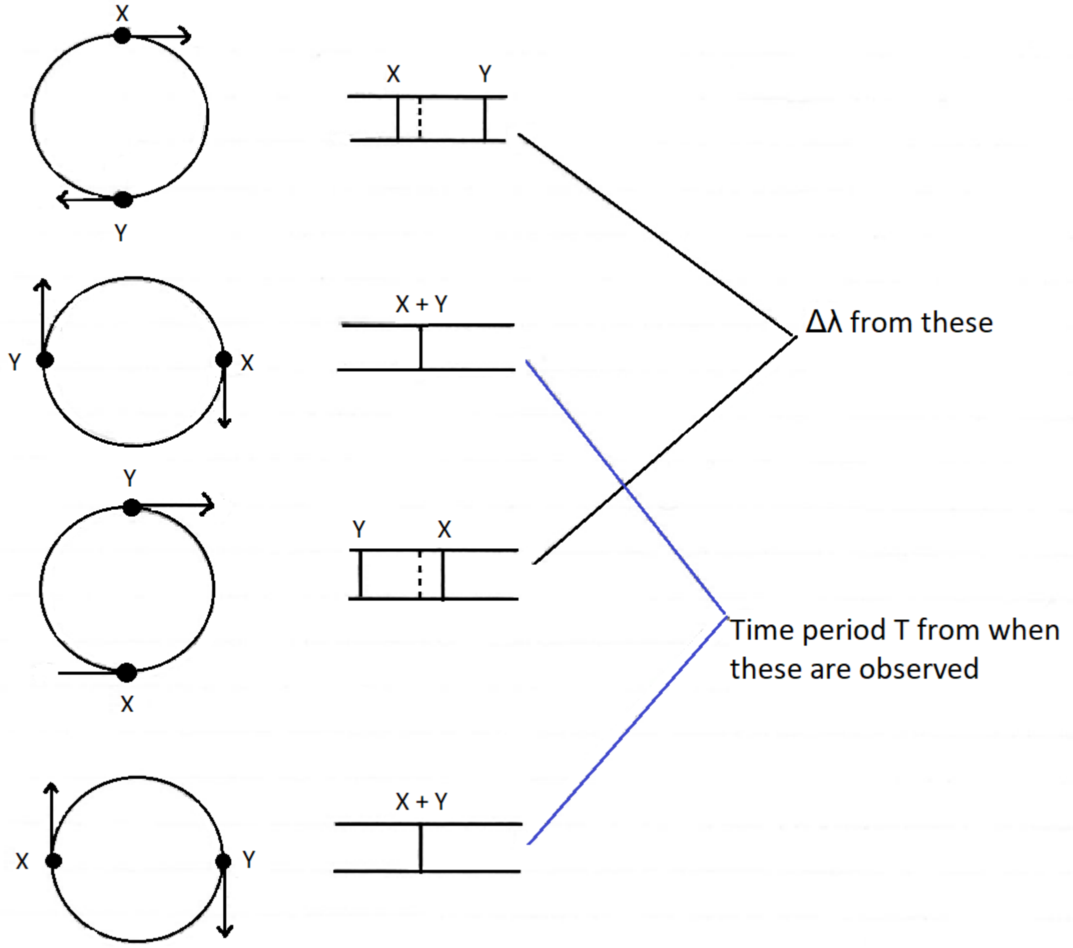
(ii) The variation is over the narrow range of wavelengths defined by the Doppler shift of the line as the star moves away (λ + Δλ) and the Doppler shift as the stars move towards the Earth (λ - Δλ).

(b) (i) Observations from such a system give two values for the displacement of the line from the laboratory wavelength. The time interval between the stars crossing the line of sight can also be determined by observing when the lines merge.

(ii) The orbital speed of each star can be found from the two values for the displacement of the line from the laboratory wavelength using $\Delta\lambda = \frac{v\lambda}{c}$.

Once the orbital speed is known then by assuming the orbit to be circular, the orbital radius can be calculated using

$v = \frac{2\pi r}{T}$ where T is the time period



4. laboratory $\lambda = 618 \text{ nm} = 618 \times 10^{-9} \text{ m}$

Shift in $\lambda = -0.082 \text{ nm} = -0.082 \times 10^{-9} \text{ m}$

$T = 2.5 \text{ years} = 2.5 \times 365 \times 24 \times 60 \times 60 \text{ s}$