Problem of the week

The Doppler effect (SL&HL)

(a) Using wavefront diagrams, outline the Doppler effect for sound with reference to wavelength and frequency observed for the case of
   (i) a source approaching a stationary observer,
   (ii) an observer moving away from a stationary source.

(b) A galaxy emits light of wavelength 656 nm. The light when observed on earth is measured to have a wavelength of 647 nm.

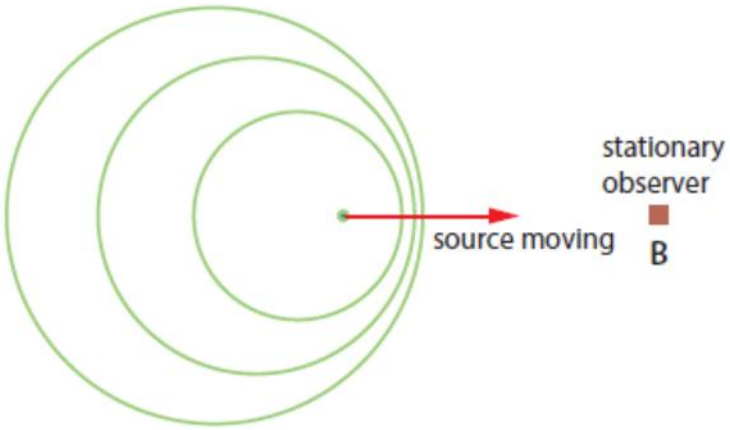
   Estimate the velocity of the galaxy.

(c) Suggest whether the estimate in (b) gives an overestimate or an underestimate of the speed of the galaxy.

Answers

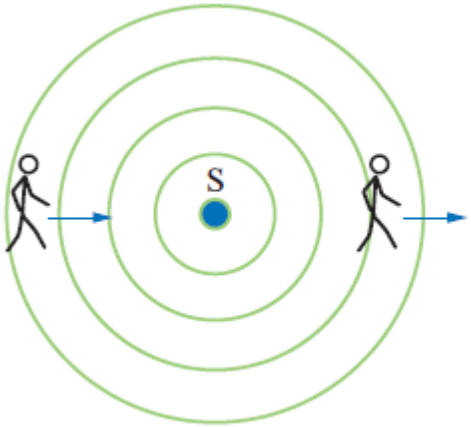
(a)

(i)



The stationary observer at B says that the wavefronts are closer together, so she measures a smaller wavelength than that emitted. The wavefronts arrive at the observer more frequently than they are emitted so she measures a higher frequency than that emitted.

(ii)



The observer moving away measures the same wavelength as that at the source but crosses wavefronts less frequently so he measures a lower frequency.

(b) From $\frac{\Delta\lambda}{\lambda}=\frac{v}{c}$ we get $\frac{9}{656}=\frac{v}{c}\Rightarrow v=4.1\times10^{6}\ \text{m s}^{-1}$. The wavelength received is shorter than that emitted so the galaxy is approaching earth.

(c) The measured velocity in (b) is the component of velocity along the line of sight. The galaxy most likely has a component of velocity at right angles to the line of sight and so the speed is greater than the value in (b).