Answer on Question #60711, Physics / Atomic and Nuclear Physics

Neutral hydrogen atoms are moving along the axis of a vacuum tube with a speed of 2.0×10^6 ms^{-1}. A spectrometer receives light emitted by these atoms in the direction of their forward motion. If emitted from hydrogen atoms at rest, this light would have a measured wavelength of 486.13 nm. Calculate the expected wavelength for light emitted from the approaching atoms, using the relativistic formula.

Solution:

Relativistic beaming (also known as Doppler beaming, Doppler boosting, or the headlight effect) is the process by which relativistic effects modify the apparent luminosity of emitting matter that is moving at speeds close to the speed of light.

The corresponding wavelengths are related by

$$\frac{\lambda_o}{\lambda_s} = \sqrt{\frac{1+\beta}{1-\beta}}$$

λ_s is the wavelength of the wave the source emitted, λ_s is the observed , $\beta = v/c$ is the velocity of the observer in terms of the speed of light.

In our case,

$$\beta = \frac{v}{c} = \frac{2 \cdot 10^6}{3 \cdot 10^8} = \frac{1}{150}$$

Thus,

$$\lambda_o = 486.13 \cdot 10^{-9} \cdot \sqrt{\frac{1+\frac{1}{150}}{1-\frac{1}{150}}} = 489.38 \cdot 10^{-9}\ \mathrm{m} = 489.38\ \mathrm{nm}$$

Answer: The light is redshifted to 489.38 nm.