

## SHOW ME THE MATH THE DOPPLER EFFECT

The **Doppler effect** is the effect that shifts the wavelengths of spectral features in objects that are moving toward or away from the observer. This particular section will focus on the analysis of light waves from objects moving toward or away from us, but sometimes it's easiest to understand this effect using sound waves. Think about the sound you hear from a train or an ambulance as it approaches you and then passes by you, and then try to make sense of the picture below.

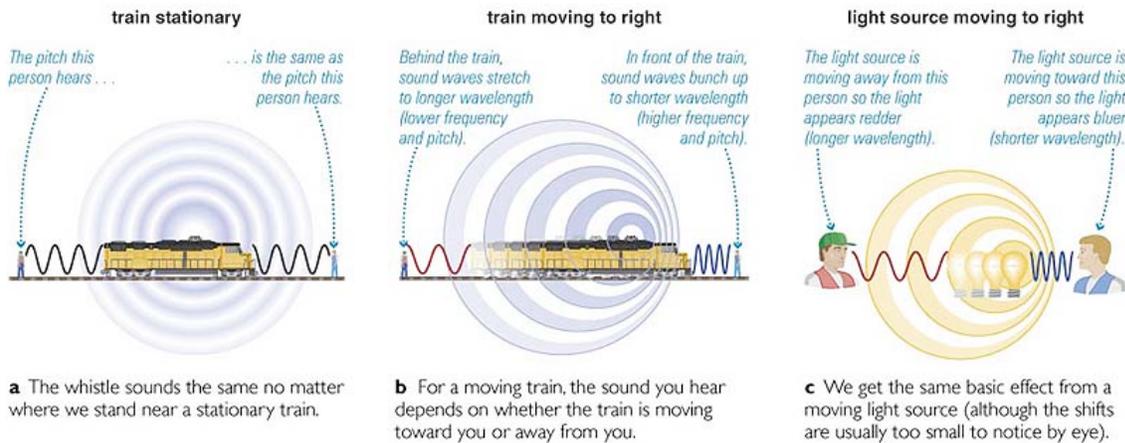


Image credit: Pearson Education

The same is true for light waves. When an object is moving toward you, the light waves reach you faster than if the object was moving away from you. We say that the object's spectrum is blue shifted since the waves are bunched together, and the color blue has the shortest **wavelength** in the visible spectrum. An object's spectrum is said to be red shifted when the object is moving away from us. The light wave stretches out and the wavelengths become longer, and the color red has the longest wavelength in the visible spectrum. [Click here to play with the Doppler shift of an emission-line spectrum.](#)

Let's say you're analyzing the visible spectrum from a star. You recognize the pattern of spectral lines as those for the star Vega, but you see that one of the hydrogen lines appears to have an observed wavelength of 656.255 nanometers (nm). The rest wavelength of this particular hydrogen line is 656.285 nm. Can you calculate the velocity of Vega using this information?

Absolutely! There is an equation that relates the velocity of a star or planet to the spectral shift in wavelength:

$$\frac{v}{c} = \frac{\lambda_{shift} - \lambda_{rest}}{\lambda_{rest}}$$

where  $v$  is the velocity of the star, and  $c$  is the speed of light ( $3.0 * 10^8 \frac{m}{s}$ ). Before we plug in numbers, let's see what we can figure out from the information given.

$$\lambda_{rest} = 656.285nm \quad \lambda_{shift} = 656.255nm \quad c = 3 * 10^8 \frac{m}{s}$$

The observed wavelength is shorter than the rest wavelength. That means that the spectral line has been blue shifted, and the star is moving toward us.

$$v = \frac{\lambda_{shift} - \lambda_{rest}}{\lambda_{rest}} * c$$

$$v = \frac{656.255nm - 656.285nm}{656.285nm} * (3.0 * 10^8 \frac{m}{s})$$

$$v = \frac{-0.03nm}{656.285nm} * (3 * 10^8 \frac{m}{s})$$

$$v = -13714 \frac{m}{s} = -13.7 \frac{km}{s}$$

So, Vega is moving toward us at  $13.7 \frac{km}{s}$ .