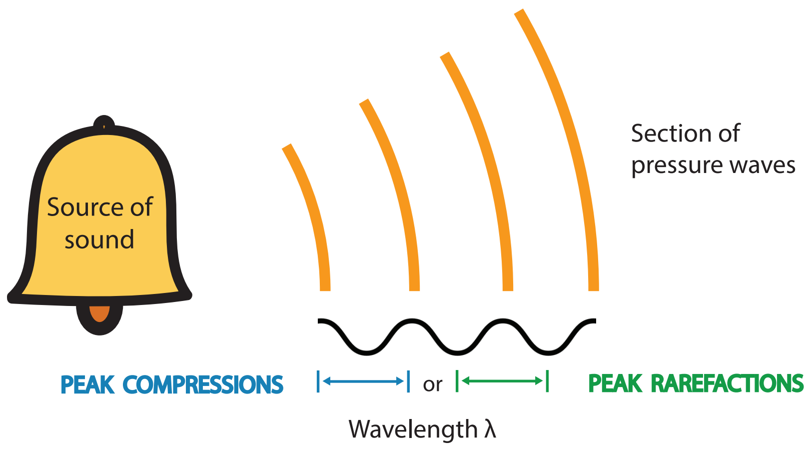
Discover

Doppler Effect

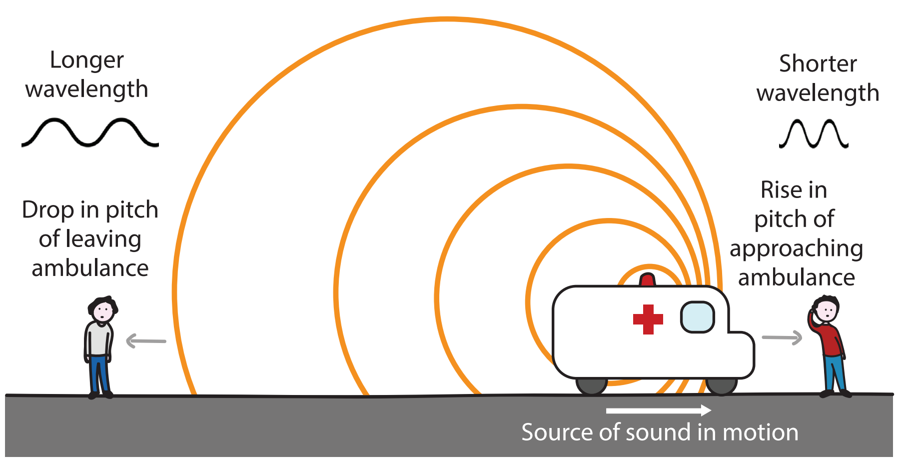
Ramgopal (RamG) Vallath

Can there be anything common between the change in pitch of the sound of a motorbike as it zips past us and the light emitted by distant stars as they move away from us? Yes! They are both subjected to the Doppler effect.

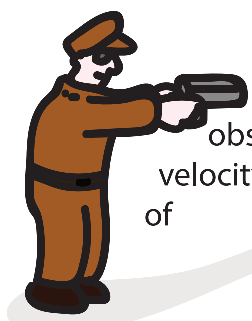
Sound travels when its source generates pressure waves in the medium surrounding it. These waves move outwards from the source in alternating patterns of varying high and low pressure referred to as **compressions** and **rarefactions**. The distance between two successive peak compressions or rarefactions is called the **wavelength** of the wave. The number of compression or rarefaction peaks passing any point in a second is called its **frequency**.



As the source of sound (~ the ambulance) moves towards an observer, each successive compression or rarefaction peak is emitted a bit closer to the observer. In effect, the wave gets compressed, causing its frequency to increase and its wavelength to reduce. This effect is also seen when the observer moves towards the source, with each successive peak hitting his eardrums sooner. Conversely, when the source moves away from the observer, or the observer moves away from the source, the wave gets elongated and its frequency is reduced.

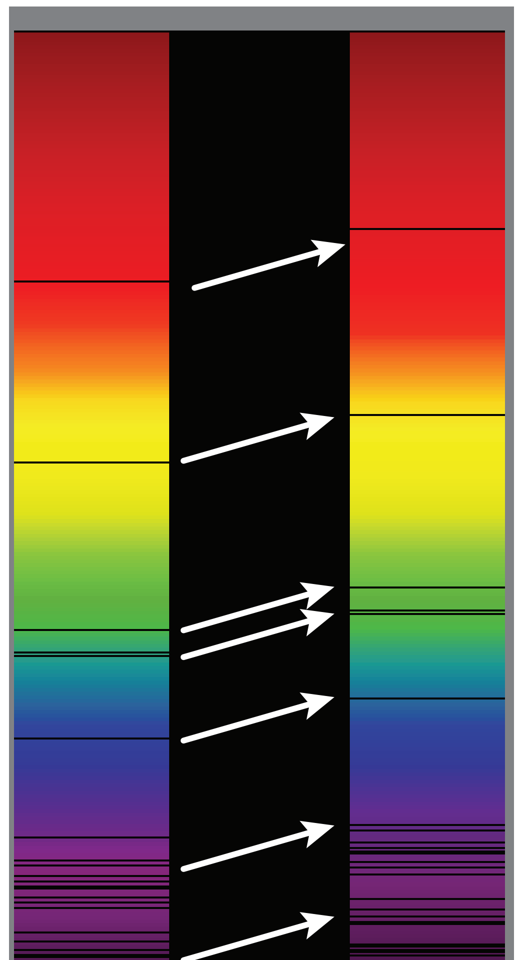


This can be observed in the sudden drop in the pitch of the sound of a vehicle as it races towards us, passes us, and races away. This phenomenon is called Doppler effect after the physicist Christian Doppler who first proposed it in 1842.



We can use this effect to calculate the speed at which the source is approaching or receding from the observer if we know the velocity of sound (a constant 343 m/s in air), the frequency at which it is emitted, and its observed frequency. In fact, this is how police speed guns help determine if a vehicle is speeding. Conversely, we can calculate the observed frequency of sound if we know the velocities of the wave, the source of sound and the observer.

This is also true for all electromagnetic radiations such as visible light, x-rays, gamma rays, infrared rays, ultraviolet rays and radio waves. We know the typical frequencies of radiations emitted by stars. We also know that some of these frequencies are absorbed by chemical elements in the outer layers of the stars. These absorbed frequencies appear as gaps (called **absorption lines**) in the radiation pattern (called **spectrum**) of the star.



Absorption lines in the optical spectrum of a supercluster of distant galaxies (BAS11) (right), as compared to those in the optical spectrum of the Sun (left). Arrows indicating Redshift.

If we observe a shift in the absorption lines of a star's spectrum to higher frequencies, called **blueshift**, it indicates that a star is moving towards us. Conversely, a shift to lower frequencies, called **redshift**, indicates that the star is moving away from us. The amount of shift helps us calculate the speed at which this movement occurs.

Ramgopal (RamG) Vallath is a motivational speaker. He is also the bestselling author of the children's science fiction, 'Oops the Mighty Gurgle'. He delivers motivational talks and science workshops in schools. He can be contacted at ramgopal.vallath@gmail.com

i wonder... Rediscovering school science
Azim Premji University