The Doppler Effect

Doppler Effect: The change in frequency of a wave detected by an observer because the wave source and the observer have different velocities with respect to the medium of the wave propagation.

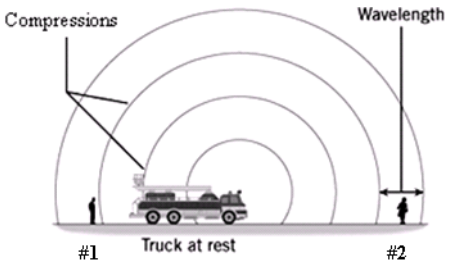
Sound –

Light –

Note: In general, the velocities of the source and/or detector are specified with respect to the medium of propagation. However, light is unique in that there is no medium of propagation so it is the relative velocity of the source and detector that is relevant.

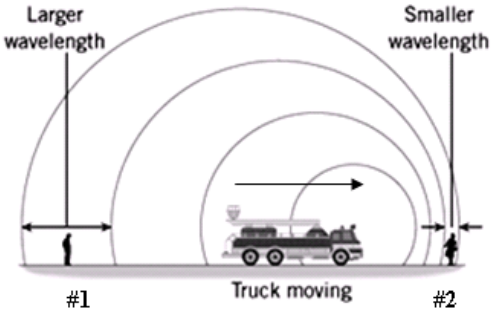
Stationary source and stationary observers

The number of compressions reaching each observer's ear per second is the same so each hears a sound of the same frequency. This frequency is identical to the frequency of the source so there is no Doppler shift.



Moving source and stationary observers

Source moving away from observer #1:



Source moving toward observer #2:

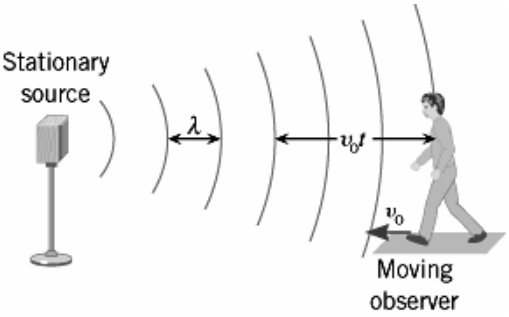
For truck moving at constant velocity:

For truck speeding up:

Doppler Formula (moving source)

EXAMPLE - A high-speed train is traveling at a speed of 44.7 m/s (100 mi/h) when the engineer sounds the 415-Hz warning horn. The speed of sound in air is 343 m/s. What are the frequency and wavelength of the sound, as perceived by a person standing at a crossing, when the train is approaching?

Doppler shift for moving observer and stationary source



Observer moving toward source:

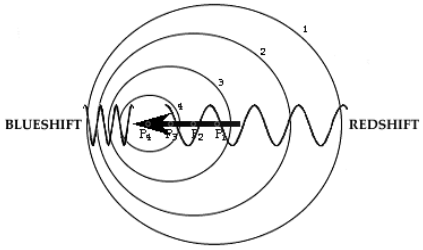
Observer moving away from source:

Is a moving observer equivalent to a moving source?

Doppler Formula (moving observer)

EXAMPLE - The security alarm on a parked car goes off and produces a frequency of 960 Hz. The speed of sound in air is 343 m/s. What is the frequency you perceive as you drive toward this parked car at 20. m/s?

Doppler Shift for EM radiation



Blue shift:

Red shift:

Doppler Formula (EM radiation)

EXAMPLE – A star is moving away from Earth at a speed of 3.0×10^5 m/s. One of the elements in the star emits light with a frequency of 6.0×10^{14} Hz. By how much is the frequency shifted when it is received by a telescope on Earth?