Introduction to Physical Science

Doppler Effect

Presented by Robert Wagner

The Doppler Effect

- A change in frequency because of the motion of the source or observer
  - Moving closer => Shift to higher frequencies
  - Moving away => Shift to lower frequencies
- Motion causes the wavefronts to be compressed in the direction of motion and expanded opposite to the direction of motion
- Will also occur when the observer is moving and the source stationary

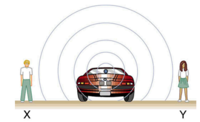

Figure 17.13 Sounds emitted by a source spread out in spherical waves. Because the source, observers, and air are stationary, the wavelength and frequency are the same in all directions and to all observers.

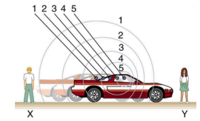

Image Credit: OpenStax College Physics - Figure 17.13 & 17.14 CC BY 4.0

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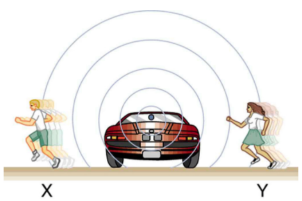


Image Credit: OpenStax College Physics - Figure 17.15 CC BY 4.0

The Doppler Effect (2)

- The observed frequency is given by:
  -
  - For a stationary observer and a moving source
  - Here, approach is indicated by the - sign and recession by the + sign
- Or, by
  -
  - For a moving observer and a stationary source
  - Here, approach is indicated by the + sign and recession by the - sign

Example

- Suppose a train that has a 150. Hz horn is moving at 35.0 m/s in still air on a day when the speed of sound is 340. m/s. What frequencies are observed by a stationary person at the side of the tracks as the train approached and recedes?
  - Draw a sketch (if applicable)
  - Identify known values
  - Identify equation
  - Enter values in the equation and solve

$v_w = 340. m/s\ ;\ f_s = 150.\ Hz\ ;\ v_s = 35.0\ m/s$

$$f_{obs} = f_s\left(\frac{v_w}{v_w - v_s}\right)$$

$$f_{obs} = (150.\ Hz)\left(\frac{340.\ m/s}{340.\ m/s - 35.0\ m/s}\right) = 167\ Hz$$

$$f_{obs} = f_s\left(\frac{v_w}{v_w + v_s}\right)$$

$$f_{obs} = (150.\ Hz)\left(\frac{340.\ m/s}{340.\ m/s + 35.0\ m/s}\right) = 136\ Hz$$

Example

- Suppose a train that has a 150. Hz horn is moving at 35.0 m/s in still air on a day when the speed of sound is 340. m/s. What frequency is heard by the train's engineer traveling on the train?
  - Draw a sketch (if applicable)
  - Identify known values
  - Identify equation
  - Enter values in the equation and solve

$v_w = 340. m/s\ ;\ f_s = 150.\ Hz\ ;\ v_s = 35.0\ m/s$

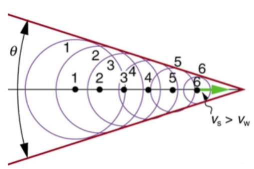
Relative velocity between them is 0 m/s!

With no velocity difference, there will be no Doppler shift!

The source and observer are not moving relative to one another.

Sonic Boom

- What would happen if the moving source approaches or exceeds the speed of sound?
- Constructive interference will occur along the red lines in the image
- Two sonic booms are created - one from the nose of the plane and the other from the tail
- For lower altitudes, the boom can break windows!



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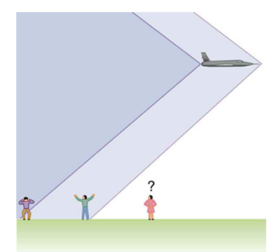

Summary

- The Doppler effect is a change in frequency due to the motion of the source or observer
- Approaching motion results in higher frequency while receding motion results in a lower frequency
- A sonic boom can occur when an aircraft exceeds the speed of sound