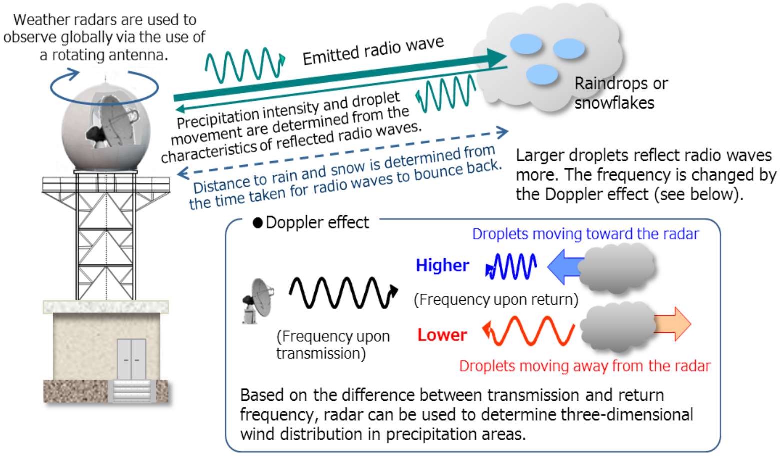
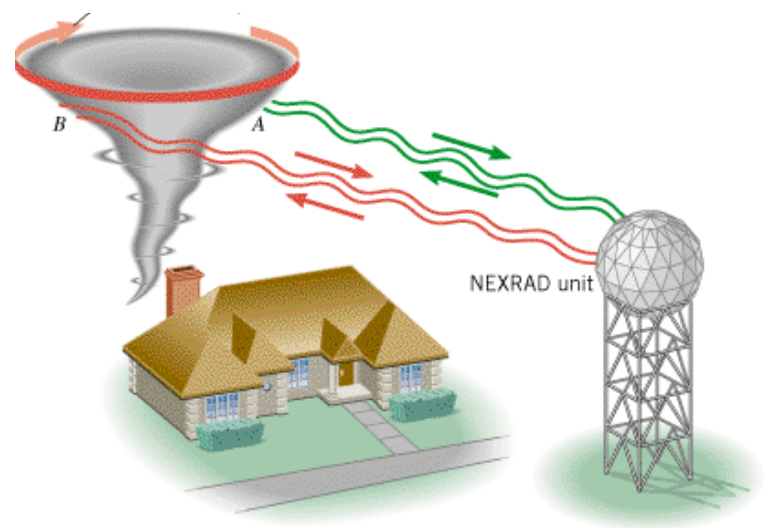
13.4 The Doppler Effect

- Doppler Effect





(b)

Doppler Effect

A change in sound frequency caused by motion of the sound source, motion of the listener, or both.

- As a source of sound approaches, an observer hears a higher frequency
- When the sound source moves away, the observer hears a lower frequency

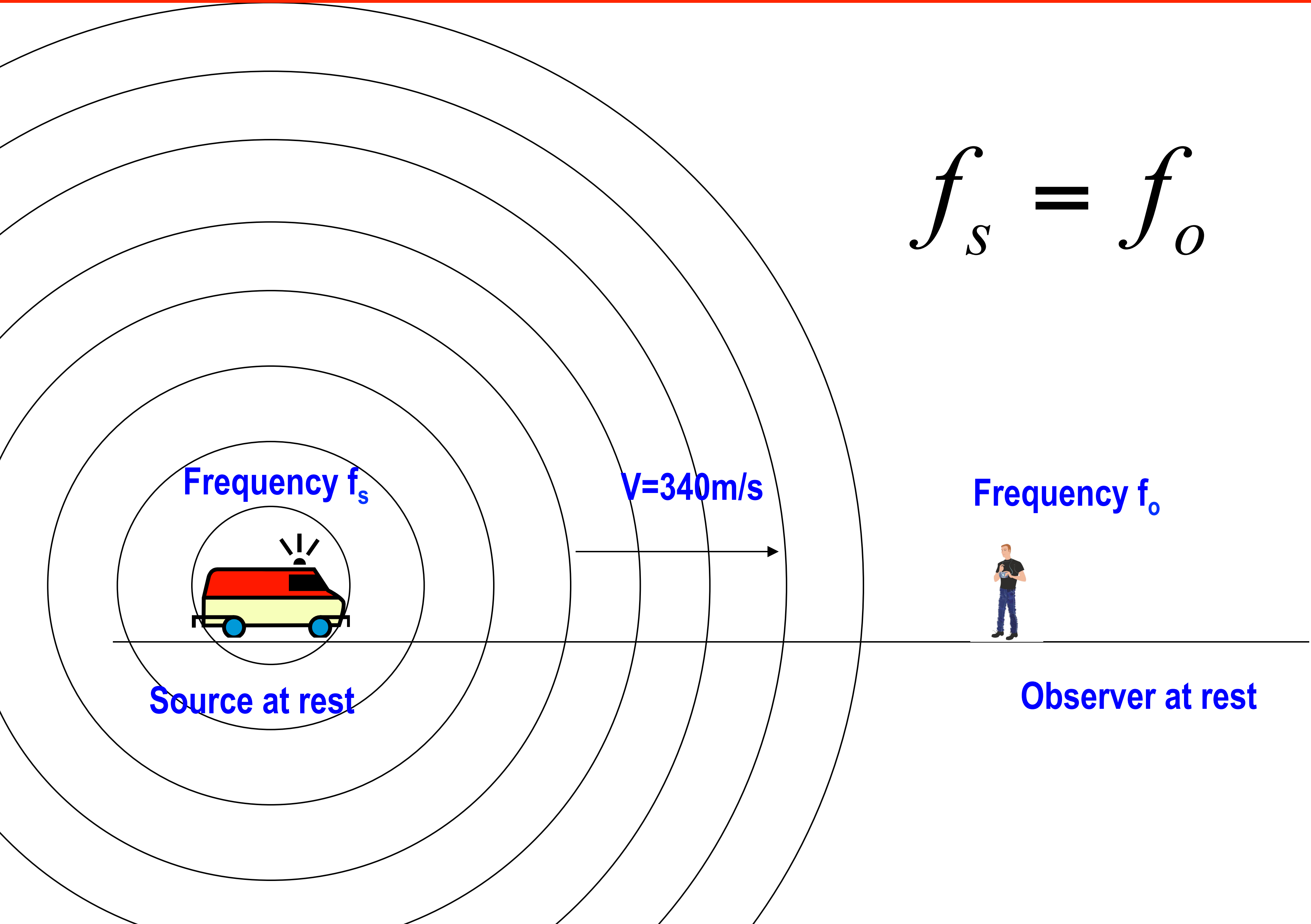
Doppler Effect

	Stationary Observer	Observer moving towards Source	Observer moving away from Source
Stationary Source	$f_o = f_s$	$f_o = f_s\left(\frac{V+Vo}{V}\right)$	$f_o = f_s\left(\frac{V-Vo}{V}\right)$
Source moving towards observer	$f_o = f_s\left(\frac{V}{V-Vs}\right)$	$f_o = f_s\left(\frac{V+Vo}{V-Vs}\right)$	$f_o = f_s\left(\frac{V-Vo}{V-Vs}\right)$
Source moving away from observer	$f_o = f_s\left(\frac{V}{V+Vs}\right)$	$f_o = f_s\left(\frac{V+Vo}{V+Vs}\right)$	$f_o = f_s\left(\frac{V-Vo}{V+Vs}\right)$

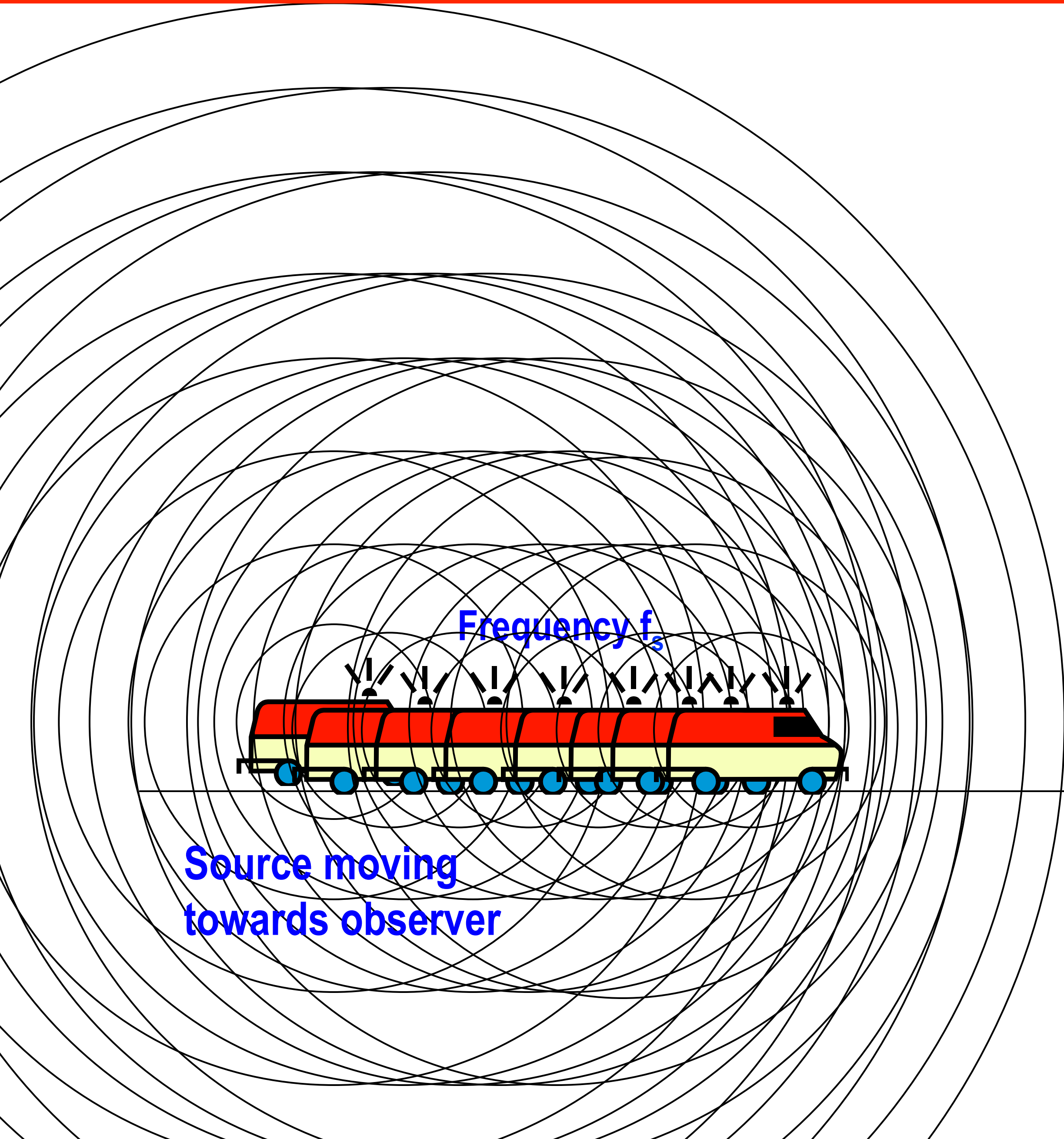
f_O = frequency of the observer
f_S = frequency of the source
V = speed of sound
V_O = speed of observer
V_S = speed of observer

Source and Observer: Stationary

$$f_s = f_o$$



Sound Souce moving towards Stationary Observer

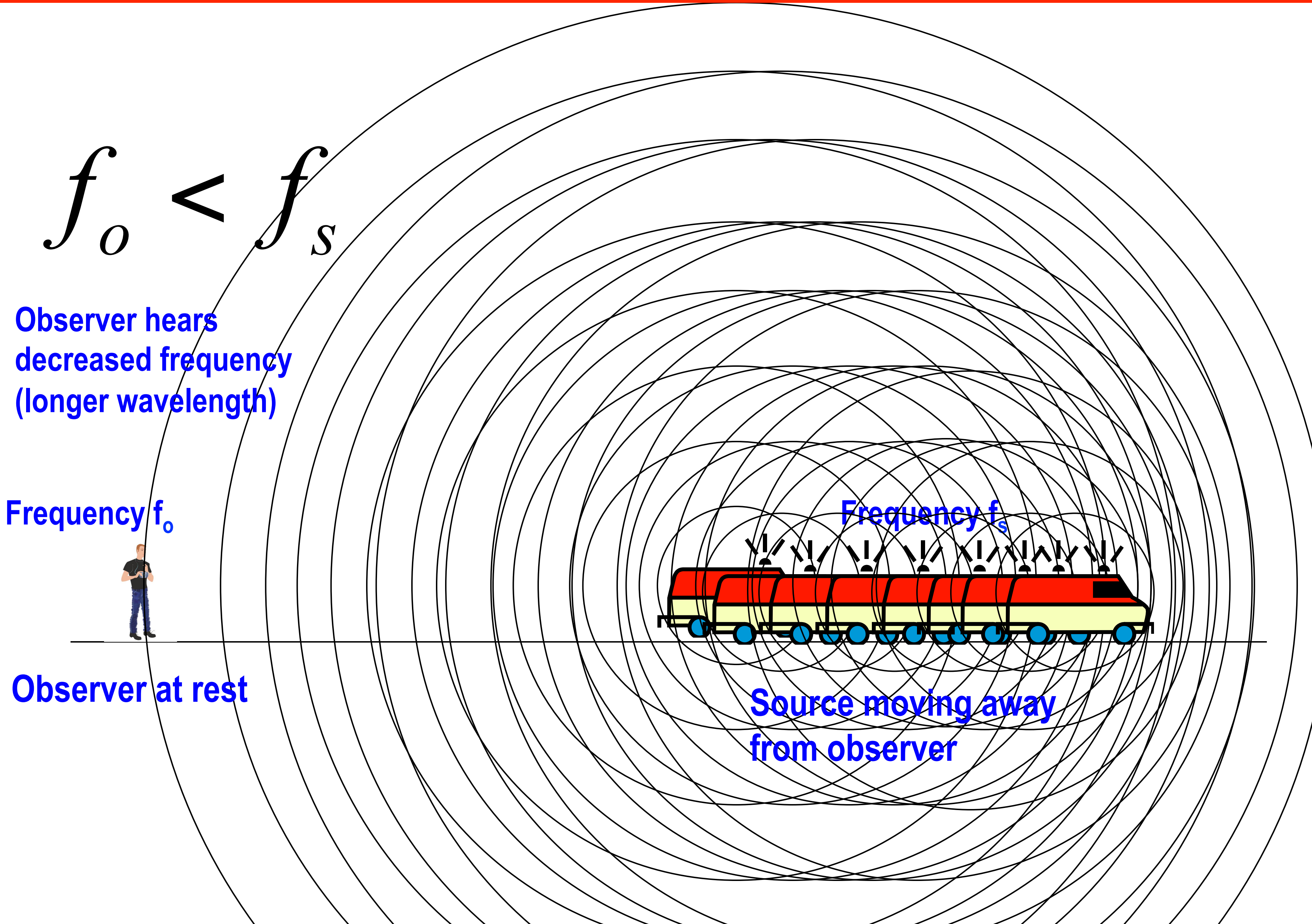


$$f_o > f_s$$

Observer hears increased frequency (shorter wavelength)

Sound Souce moving away Stationary Observer

$$f_o < f_s$$



Doppler Effect

Car Horn:
https://www.youtube.com/watch?v=a3RfULw7aAY

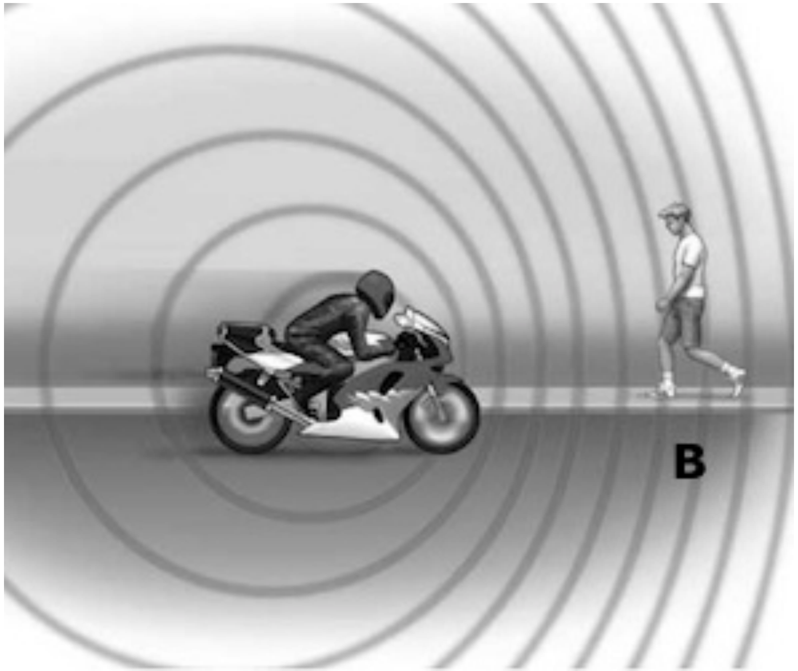
Big Bang Theory
https://www.youtube.com/watch?v=z0EaoilzgGE

Frequency heard by observer
Wave source moving TOWARDS Stationary Observer

Source moving toward observer

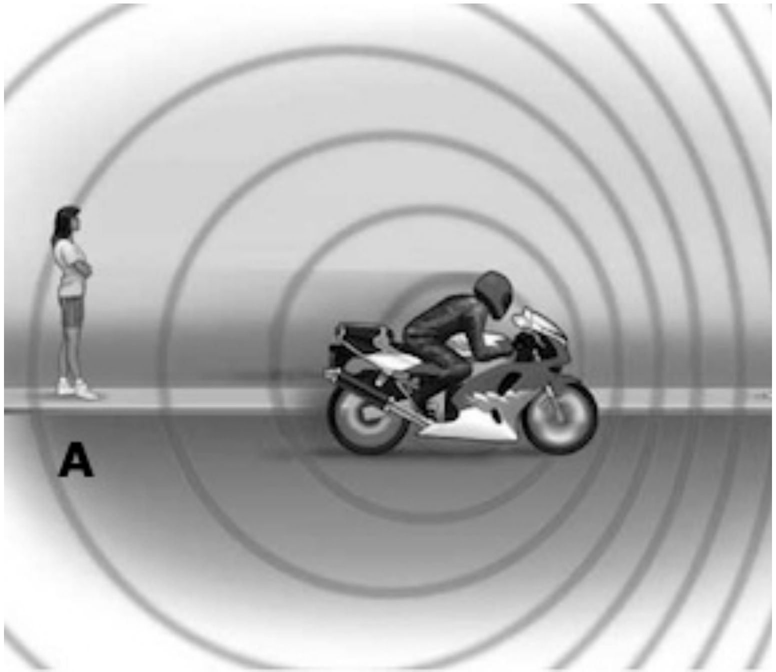
$$f_o = f_s\left(\frac{v}{v - v_s}\right)$$

Increase in Frequency



f_o = frequency heard from the observer
f_s = actual frequency of source in air
v = speed of sound in air (assume 340 m/s, unless otherwise specified)
v_s= velocity of source

Frequency heard by observer
Wave source moving AWAY from Stationary Observer



Source moving away from observer

$$f_o = f_s\left(\frac{v}{v + v_s}\right)$$

Decrease in Frequency

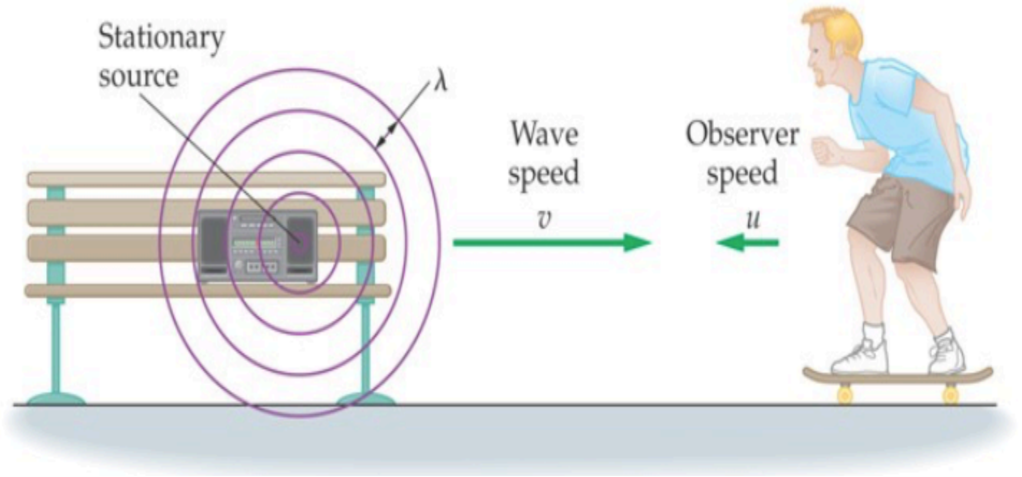
f_o = frequency heard from the observer
f_s = actual frequency of source in air
v = speed of sound in air (assume 340 m/s, unless otherwise specified)
v_s= velocity of source

Frequency heard by observer
Wave Source Stationary / Observer Moving

Observer moving toward source

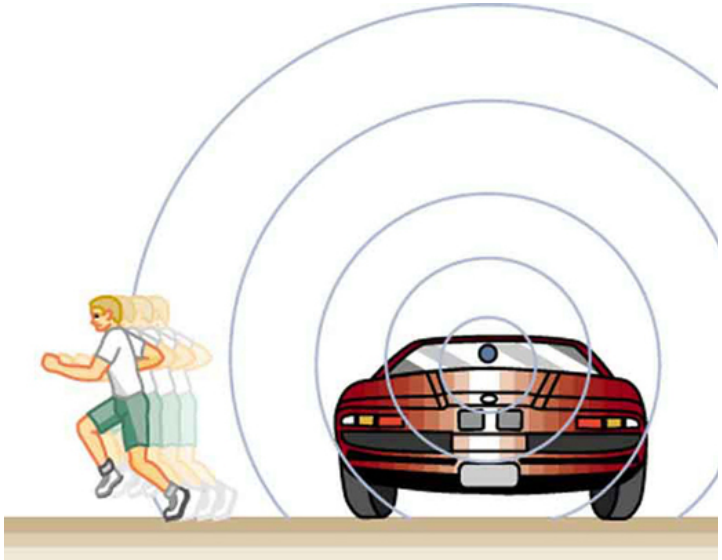
$$f_o = f_s\left(\frac{v+v_o}{v}\right)$$

Increase in Frequency



f_o = frequency heard from the observer
f_s = actual frequency of source in air
v = speed of sound in air (assume 340 m/s, unless otherwise specified)
v_o= velocity of observer

Frequency heard by observer
Wave Source Stationary / Observer Moving



Observer moving
away from Source

$$f_o = f_s\left(\frac{v - v_o}{v}\right)$$

Decrease in Frequency

f_o = frequency heard from the observer
f_s = actual frequency of source in air
v = speed of sound in air (assume 340 m/s, unless otherwise specified)
v_o= velocity of observer

Frequency heard by observer
Wave Source Moving / Observer Moving

Observer moving toward source
Source moving towards observer

$$f_o = f_s\left(\frac{v+v_o}{v-v_s}\right)$$

Observer moving toward source
Source moving away from observer

$$f_o = f_s\left(\frac{v+v_o}{v+v_s}\right)$$

Observer moving away from source
Source moving away from observer

$$f_o = f_s\left(\frac{v-v_o}{v+v_s}\right)$$

Observer moving towards source
Source moving away from observer

$$f_o = f_s\left(\frac{v-v_o}{v-v_s}\right)$$

Doppler Effect

Example #1

A police car, parked by the roadside, sounds its siren which has a frequency of 1,000 Hz.

a. **What frequency do you hear if you are driving directly toward the police car at 33 m/s.**

   1,097.06 Hz

Doppler Effect

Example #1

A police car, parked by the roadside, sounds its siren which has a frequency of 1,000 Hz.

b. **If you are driving away from the police car at this same speed, what frequency will you now hear?**

902.94 Hz

Doppler Effect

Example #1

A police car, parked by the roadside, sounds its siren which has a frequency of 1,000 Hz.

c. **Suppose that you are at rest and the police car is coming toward you at 33 m/s. What frequency do you now hear?**

1,107.49 Hz

Doppler Effect

Example #1

A police car, parked by the roadside, sounds its siren which has a frequency of 1,000 Hz.

d. Suppose that the police is driving away from you at the same speed. What frequency do you hear?

911.53 Hz

Doppler Effect

Example #2

Mary is riding a roller coaster. Mary yells "Hello" at her mother who is standing on the ground in front of her at a frequency of 920 Hz. Mary is moving at 27.4 m/s towards her mom. What frequency does Mary's mom hear?

1,000.64 Hz

Doppler Effect

Example #3

A high speed train is traveling at a speed of 44.7 m/s when the engineer sounds the 415-Hz warning horn. The speed of sound is 340 m/s. What are the frequency and wavelength of the sound, as heard by the person standing at the crossing, when the train is approaching?

f = 477.82 Hz

λ = 0.712 m

Doppler Effect

Example #4

A source moving at 15 m/s and a listener is moving at 20 m/s. If the frequency of sound emitted by the source is 500 Hz, calculate the observed frequency when both source and listener are moving towards each other.

554.69 Hz

Doppler Effect

Assessment #1

The changed pitch of the Doppler Effect is due to changes in

a. **Wave Speed**
b. **Wave Frequency**

Doppler Effect

Assessment #2

When an automobile moves away from the listener, the sound of its horn seems relatively

a. Low pitched
b. High pitched
c. Remain Unchanged

Doppler Effect

Assessment #3

When an automobile moves towards a listener, the sound of its horn seems relatively

a. Low pitched
b. High pitched
c. Remain Unchanged

Doppler Effect

Assessment #4

Circle the letter of each statement about the Doppler Effect that is true.

a. It occurs when a wave source moves towards an observer
b. It occurs when an observer moves towards a wave source
c. It occurs when a wave source moves away from an observer
d. It occurs when an observer moves away from a wave source