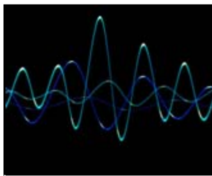


Unit 4: Oscillatory Motion and Mechanical Waves

4.7 The Doppler Effect

https://www.youtube.com/watch?v=Y5KaeCZ_AaY

Recall that **frequency** is defined as the number of waves passing a point in one second.

So a higher frequency means more waves per second and a lower frequency means fewer waves per second.

Christian Doppler described this effect in 1824.

He realized that when a sound source was moving towards the observer, the waves would be (squashed together", increasing their perceived frequency.

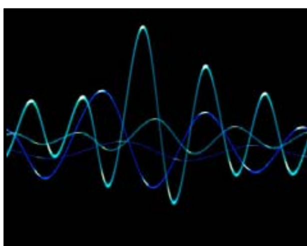
A similar effect will take place when the source moves away; the waves are move "spaced out", causing a lower perceived frequency.

Christian Doppler
(1803-1853)

Random Scientist Facts

Doppler was a man of small stature and was very weak. So much so that he required sick leave after finding teaching a very strenuous job. It also contributed, in part, to him becoming a scientist. His fathers work, stonemasonry, was far to physical for this little man.

http://galileoandeinstein.physics.virginia.edu/more_stuff/flashlets/doppler.htm



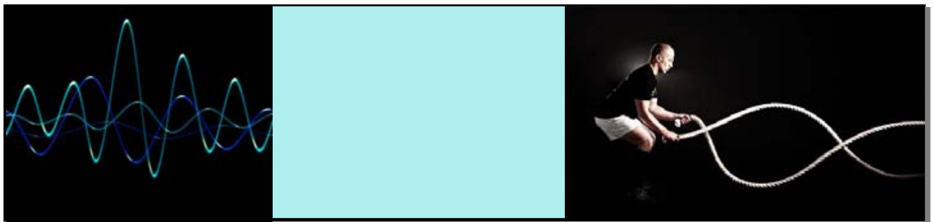
The Doppler Effect Mathematically:

$$f_d = f_s\left(\frac{v_w}{v_w \pm v_s}\right)$$

Where:

- f_d = perceived freq. (Hz)
- v_w = speed of sound in air
- v_s = speed of source
- f_s = freq. of source (Hz)

Note: when the source moves towards the observer use subtraction, when the source moves away from the observer use addition.



Ex.) A police car has a horn with frequency 220 Hz. If the speed of sound is 340 m/s, and the car is moving at 120 km/h, determine the perceived frequency of the horn:

↑ 33.$\bar{3}$ m/s

a) When the car is moving towards you.

b) When the car is moving away from you.

a) $f_d = f_s\left[\frac{V}{V \pm V_s}\right]$

$= 220\left[\frac{340}{(340-33.3)}\right]$

$= \boxed{244\ \text{Hz}}$

b) $f = 220\left[\frac{340}{340+33.3}\right]$

$= \boxed{200\ \text{Hz}}$

Pg. 437 # 18) How fast is a sound source moving toward you if you hear the frequency to be 580 Hz when the true frequency is 540 Hz? The speed of sound in air is 350 m/s. Express your answer in km/h.

$f = f_s\left[\frac{V}{V \pm V_s}\right]$

$\frac{580}{540} = \frac{540\left[\frac{350}{350 - V_s}\right]}{540}$

$1.074... = \frac{350}{350 - V_s}$

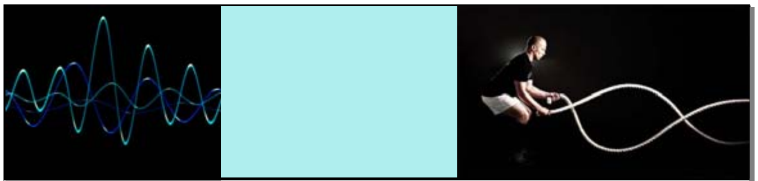
$350 - V_s = \frac{350}{1.074...}$

$350 - V_s = 325.86...$
$-350 \qquad\qquad -350$

$V_s = 24.137...\ \text{m/s}$

↑ ×3.6

$\boxed{V_s = 86.9\ \text{km/h}}$



Pg. 437 # 21) If the speed of sound in air is 350 m/s, how fast must a sound source move towards you if the frequency that you hear is twice the true frequency of the sound? What frequency would you hear if the sound source had been moving away from you?

Towards

$f = f_s \left[\frac{v}{v \pm v_s}\right]$

$2 = 1 \left[\frac{350}{350 - v_s}\right]$

$2 = \frac{350}{350 - v_s}$

$350 - v_s = \frac{350}{2}$

$350 - v_s = 175$

$-350 \qquad -350$

$-v_s = -175$

$v_s = 175\ \text{m/s}$

$v_s = 630\ \text{km/h}$

Away

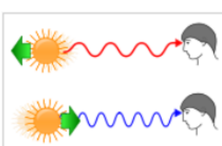
$f = f_s \left[\frac{350}{350 + 175}\right]$

$f = \frac{2}{3} f_s$

You would hear two thirds of the true frequency of the source.

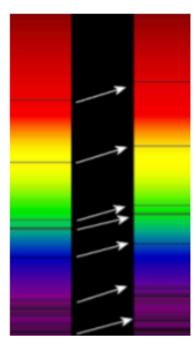
Although Doppler originally intended his equation to be used for sound waves, it applies to other waves, like light waves, as well.

When dealing with light we typically change from frequencies to wavelengths.

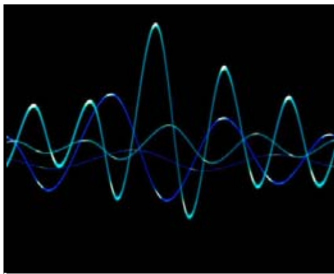


Red shift occurs when the source of light is moving away from the observer.

Blue shift occurs when the source is moving towards the observer.



Astronomers have shown that light from distant stars is red shifted. This has lead to the conclusion that the universe is expanding or moving away from some central point.



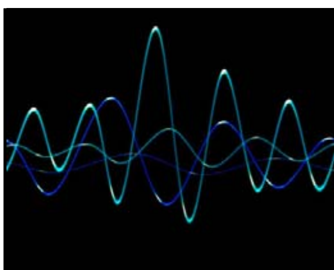

The Sound Barrier

As the speed of sound in air at a particular temperature is fixed, it is possible to exceed this speed.

Objects like a whip, jet plane, or wet dish towel can move faster than the speed of sound, breaking the sound barrier.

If the $v > v_s$, an observer in front of the source will hear a higher frequency than the source is actually producing.

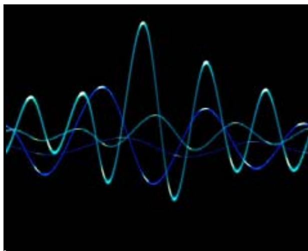
As the speed increases, this frequency also increases.




If the $v = v_s$, a build-up of wave fronts occurs. These waves form an area of high pressure which is difficult to overcome (the barrier).

Mach 1

The increase in pressure can cause a cloud to form at the barrier and is perceived not as a frequency but as a loud "thump" as it hits the observer.



If the $v_s > v$, a sonic boom occurs. The observer will not experience the sound until after the source has passed.

Supersonic

Questions: Finish Unit Assignment.