12-2 Doppler Effect

Vocabulary

Doppler Effect: A change in the apparent frequency of sound due to the motion of the source of the receiver.

You probably associate the Doppler effect with the change in pitch (frequency) of a loud car or siren just as it passes you. The pitch suddenly drops just as the object moves by. Light can also be Doppler shifted but the Doppler shift of light will not be discussed in this chapter.

The equation that describes this effect can be used whether the source is approaching or receding from the observer. It also works if either the source or observer is at rest, or if there is a chase situation in which both are moving in the same direction.

$$\textbf{perceived frequency} = \textbf{actual frequency}\,\frac{(\textbf{speed of sound} + \textbf{speed of observer})}{(\textbf{speed of sound} - \textbf{speed of source})}$$

or $$f = f_o \frac{(v + v_o)}{(v - v_s)}$$

Here, f_o refers to the actual frequency being emitted by an object, while f is the frequency heard by the observer as the source approaches or recedes. If a source approaches, the perceived frequency will be higher than the actual frequency. If a source recedes, the perceived frequency is lower than the actual frequency.

In order for this equation to work properly, there is a standard convention to which you must adhere whenever solving Doppler exercises.

v_o is (+) if the observer moves toward the source.
v_o is (−) if the observer moves away from the source.
v_s is (+) if the source moves toward the observer.
v_s is (−) if the source moves away from the observer.

Remember, it is not necessary to always have both the observer and the source in motion. Often one will be moving and the other will be at rest.

Solved Examples

Example 3: Sitting on the beach at Coney Island one afternoon, Sunny finds herself beneath the flight path of the airplanes leaving Kennedy Airport. What frequency will Sunny hear as a jet, whose engines emit sound at a frequency of 1000. Hz, flies toward her at a speed of 100.0 m/s?

Solution: First draw a diagram of the situation. Notice in the calculation below that Sunny is sitting at rest and the plane is approaching. Therefore, the source is moving toward the observer. The observer remains stationary.

Given: $f_o = 1000.$ Hz
$v_o = 0$ m/s
$v = 340.\ 0$ m/s
$v_s = 100.0$ m/s

Unknown: $f = ?$
Original equation: $f = f_o \frac{(v + v_o)}{(v - v_s)}$

Solve: $f = f_o \frac{(v + v_o)}{(v - v_s)} = 1000.\text{ Hz}\,\frac{(340.0\text{ m/s} + 0\text{ m/s})}{(340.0\text{ m/s} - 100.0\text{ m/s})} = \textbf{1417 Hz}$

Example 4: In the previous example, what frequency will Sunny observe as the jet travels away from her at the same speed?

Solution: Again, draw a diagram of the situation. This time, the source is moving away from the observer, so the value for v_s must be negative.

Given: $f_o = 1000.\ \text{Hz}$
$v_o = 0\ \text{m/s}$
$v = 340.0\ \text{m/s}$
$v_s = -100.0\ \text{m/s}$

Unknown: $f = ?$
Original equation: $f = f_o \dfrac{v + v_o}{v - v_s}$

Solve: $f = f_o \dfrac{(v + v_o)}{(v - v_s)} = 1000.\ \text{Hz} \dfrac{(340.0\ \text{m/s} + 0\ \text{m/s})}{(340.0\ \text{m/s} - [-100.0\ \text{m/s}])} = \mathbf{772.7\ Hz}$

Example 5: A sparrow chases a crow with a speed of 4.0 m/s, while chirping at a frequency of 850.0 Hz. What frequency of sound does the crow hear as he flies away from the sparrow with a speed of 3.0 m/s?

Given: $f_o = 850.0\ \text{Hz}$
$v_o = -3.0\ \text{m/s}$
$v = 340.0\ \text{m/s}$
$v_s = 4.0\ \text{m/s}$

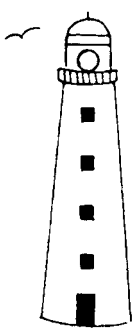
Unknown: $f = ?$
Original equation: $f = f_o \dfrac{(v + v_o)}{(v - v_s)}$

Solve: $f = f_o \dfrac{(v + v_o)}{(v - v_s)} = 850.0\ \text{Hz} \dfrac{(340.0\ \text{m/s} + [-3.0\ \text{m/s}])}{(340.0\ \text{m/s} - 4.0\ \text{m/s})} = \mathbf{852.5\ Hz}$

Therefore, since the sparrow is approaching the crow, the crow hears a frequency that is higher than the original.

Practice Exercises

Example 5: One foggy morning, Kenny is driving his speed boat toward the Brant Point lighthouse at a speed of 15.0 m/s as the fog horn blows with a frequency of 180.0 Hz. What frequency does Kenny hear as he moves?



Answer: _____

Example 6: Dad is driving the family station wagon to Grandma's house when he gets tired and pulls over in a roadside rest stop to take a nap. Junior, who is sitting in the back seat, watches the trucks go by on the highway and notices that they make a different sound when they are coming toward him than they do when they are moving away. a) If a truck with a frequency of 85.0 Hz is traveling toward Junior with a speed of 27.0 m/s, what frequency does Junior hear as the truck approaches? b) After the truck passes, what frequency does Junior hear as the truck moves away?

Answer: **a.** _____

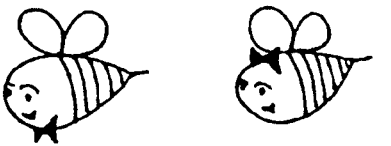
Answer: **b.** _____

Exercise 7: One way to tell if a mosquito is about to sting is to listen for the Doppler shift as the mosquito is flying. The buzzing sound of a mosquito's wings is emitted at a frequency of 1050 Hz. a) If you hear a frequency of 1034 Hz, does this mean that the mosquito is coming in for a landing or that it has just bitten you and is flying away? b) At what velocity is the mosquito flying?

Answer: **a.** _____

Answer: **b.** _____

Exercise 8: Barney, a bumblebee flying at 6.00 m/s, is being chased by Betsy, a bumblebee who is flying at 4.00 m/s. Barney's wings beat with a frequency of 90.0 Hz. What frequency does Betsy hear as she flies after Barney?



Answer: _____

Exercise 9: Mrs. Gonzalez is about to give birth and Mr. Gonzalez is rushing her to the hospital at a speed of 30.0 m/s. Witnessing the speeding car, Officer O'Malley jumps in his police car and turns on the siren, whose frequency is 800. Hz. If the officer chases after the Gonzalez' car with a speed of 35.0 m/s, what frequency do the Gonzalezes hear as the officer approaches?

Answer: _____

5. 188 Hz
7. b) -5.26 m/s
9. 813 Hz