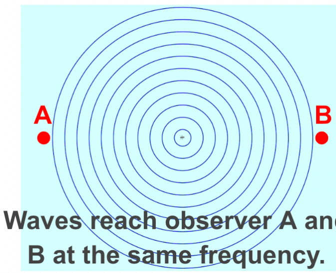
The Doppler Effect
Lesson Notes

Learning Outcomes
- What is the Doppler effect?
- Why does the Doppler effect occur?
- What are the mathematics of the Doppler effect?

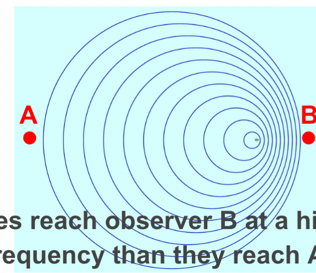
Disturbing Bugs
The Doppler effect is observed when a wave source is moving with respect to an observer. The observed effect depends on whether the wave source is moving towards or away from the observer.

Stationary Bug



Waves reach observer A and B at the same frequency.

Moving Bug

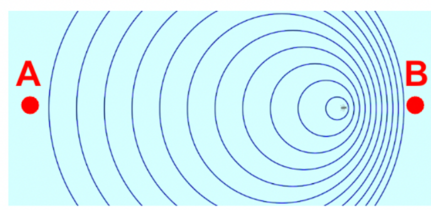


Waves reach observer B at a higher frequency than they reach A.

The Doppler Effect
The **Doppler Effect** is the effect produced when *a source of waves is moving with respect to an observer*, causing …
- an apparent upward shift in frequency for observers towards whom the source is approaching, and
- an apparent downward shift in frequency for observers from whom the source is receding.

Wave Source: moving to right

A observes a low frequency. The source is receding.



B observes a high frequency. The source is approaching.

The Doppler Effect … Explained
- Since the ambulance is moving rightward, each successive wave has its center positioned at a location that is closer to the observer B.
- The distance such waves need to travel to reach observer B is less than the distance to reach observer A.
- With less distance to travel to reach observer B, those waves reach observer B at a higher frequency than they reach observer A

Ambulance Image by Vectorportal.com (CC BY) Person Image from @clipartmax.com

Doppler Equation Moving Source

The observed frequency ($f_{observed}$) can be calculated if the speed of the waves (v_{wave}), the speed of the wave source (v_{source}) and the frequency at which the source generates waves (f_{source}) are known.

$$f_{observed} = \frac{f_{source}}{1 \pm (v_{source} / v_{wave})}$$

In denominator:
Use - if source is approaching observer. Use + if source is receding from observer

Moving Source Example Problem

An ambulance traveling at 28 m/s has a siren that produces a 750 Hz sound wave that travels through air at 340 m/s. Determine the frequency a stationary person observes as it approaches and as it recedes.

Approaching ambulance:

Observes higher freq.

$$f_{observed} = \frac{750 \text{ Hz}}{1 - (28 \text{ m/s} / 340 \text{ m/s})} = \frac{750 \text{ Hz}}{0.917647\ldots} = \mathbf{817\ Hz}\ (\sim 820 \text{ Hz})$$

Receding ambulance:

Observes lower freq.

$$f_{observed} = \frac{750 \text{ Hz}}{1 + (28 \text{ m/s} / 340 \text{ m/s})} = \frac{750 \text{ Hz}}{1.082352\ldots} = \mathbf{693\ Hz}\ (\sim 690 \text{ Hz})$$

Doppler Equation – Moving Observer

The observed frequency ($f_{observed}$) can be calculated if the speed of the waves (v_{wave}), the speed of the observer ($v_{observer}$) and the frequency at which the source generates waves (f_{source}) are known.

$$f_{observed} = f_{source} \cdot \left(1 \pm \frac{v_{observer}}{v_{wave}}\right)$$

Inside parenthesis:
Use + if observer is approaching the source. Use - if observer is receding from source.

Moving Observer Example Problem

A malfunctioning horn on a parked car is emitting sound waves with a frequency of 625 Hz. What frequency would you observe as you approach and recede from the parked car at a speed of 24 m/s? Sound waves travel at 345 m/s.

Observer Approaches Sound Source:

Observes higher freq.

$$f_{observed} = 625 \text{ Hz} \cdot \left(1 + \frac{24 \text{ m/s}}{345 \text{ m/s}}\right) = 625 \text{ Hz} \cdot (1 + 0.06956\ldots) = \mathbf{668\ Hz}\ (\sim 670 \text{ Hz})$$

Observer Recedes from Sound Source:

Observes lower freq.

$$f_{observed} = 625 \text{ Hz} \cdot \left(1 - \frac{24 \text{ m/s}}{345 \text{ m/s}}\right) = 625 \text{ Hz} \cdot (1 - 0.06956\ldots) = \mathbf{582\ Hz}\ (\sim 580 \text{ Hz})$$