Name: ______________________

Class: ______________________

Due Date: ______________________

C.5 Doppler Effect

Understandings

- The nature of the Doppler effect for sound waves and electromagnetic waves.
- The representation of the Doppler effect in terms of wavefront diagrams when either the source or the observer is moving.
- The relative change in frequency or wavelength observed for a light wave due to the Doppler effect where the speed of light is much larger than the relative speed between the source and the observer as given by $\frac{\Delta f}{f} = \frac{\Delta \lambda}{\lambda} \approx \frac{v}{c}$.
- Shifts in spectral lines provide information about the motion of bodies like stars and galaxies in space.

Equations

$$\frac{\Delta f}{f} = \frac{\Delta \lambda}{\lambda} \approx \frac{v}{c}$$

Additional HL Understandings

- The observed frequency for sound waves and mechanical waves due to the Doppler effect as given by:
  moving source $f' = f\left(\frac{v}{v \pm u_s}\right)$ where u_s is the velocity of the source
  moving observer $f' = f\left(\frac{v \pm u_o}{v}\right)$ where u_o is the velocity of the observer.

Additional HL Equations

Moving source: $f' = f\left(\frac{v}{v \pm u_s}\right)$

Moving observer: $f' = f\left(\frac{v \pm u_o}{v}\right)$

The solutions can be found on the YouTube channel Go Physics Go:

https://www.youtube.com/@gophysicsgo/playlists

1. C: Define the *Doppler effect*.

2. C: **Use a pencil!** Draw a wavefront diagram for a moving source and stationary observer in front of the source and behind the source.

3. C: **Use a pencil!** Draw a wavefront diagram for a stationary source and moving observer in front of the source and behind the source.

4. C: Describe the equation $\frac{\Delta f}{f} = \frac{\Delta \lambda}{\lambda} \approx \frac{v}{c}$ and define each variable.

5. C: Describe the term *red shift*.

6. C: Describe the term *blue shift*.

7. C: Describe the term *expanding universe*.

8. C: A train approaches and then passes a train station with a constant speed. During the whole time the train is emitting a sound. Draw a *frequency vs. time* graph of the observed frequency measured by the people at the train station.

9. C: An accelerating train approaches and then passes a train station. During the whole time the train is emitting a sound. Draw a *frequency vs. time* graph of the observed frequency measured by an observer at the train station.

10. E: An element on Earth has one emission wavelength of 8.67×10^{-7} m. This same element, when detected from a moving distant galaxy, has the same emission wavelength of 3.09×10^{-7} m.

    a. Is this galaxy moving towards or away from Earth?

    b. What is the speed of this moving galaxy?

11.E: This is the classic "the emitter becomes the detector" problem! A stationary police car emits a microwave with a frequency of 3.00×10^{10} Hz to an approaching car. The microwave is reflected off the moving car and is received by the stationary police car. The police car detects that the frequency is altered by 6.00×10^{3} Hz.

a. What is the wavelength of the microwave being emitted by the police car?

b. What is the speed of the approaching car?

c. How much has the wavelength altered?

Additional HL Content

12.C: Describe the equations for the Doppler effect given in the IB physics data booklet.

13.E: Late to class! Usain Bolt runs towards his physics class with a constant speed of 10.44 m/s while blasting music from his boom box which emits a frequency of 440. Hz. What is the observed frequency and wavelength detected by the students in his physics classroom? The speed of sound in air at sea level is approximately 340.29 m/s.

14.E: Class ends! Usain Bolt runs away from his physics class towards the cafeteria with a constant speed of 10.44 m/s while blasting music from his boom box which emits a frequency of 440. Hz. What is the observed frequency and wavelength detected by the students in his physics classroom? The speed of sound in air at sea level is approximately 340.29 m/s.

15.E: Late to class! Usain Bolt runs towards his physics class with a constant speed of 10.44 m/s. He can hear his physics teacher lecturing with frequency of 440. Hz. What is the observed frequency and wavelength detected by Usain Bolt as he is running towards his physics class? The speed of sound in air at sea level is approximately 340.29 m/s.

16. E: Class ends! Usain Bolt runs away from his physics class to the cafeteria with a constant speed of 10.44 m/s. He can hear his teacher continue to lecture with frequency of 440. Hz. What is the observed frequency and wavelength detected by Usain Bolt as he is running towards the cafeteria? The speed of sound in air at sea level is approximately 340.29 m/s.

17. E: This is the classic "the emitter becomes the detector" problem! An emitter at rest emits a sound wave of frequency 3.00×10^4 Hz towards a car. The wave is reflected back to the emitter. The emitter now becomes the receiver. The receiver receives the sound wave with a frequency of 2.90×10^4 Hz. The speed of sound is $3.30 \times 10^2\ \frac{\text{m}}{\text{s}}$. Determine the speed of the car.

18.E: This is another classic "the emitter becomes the detector" problem! An emitter at rest emits a sound wave of frequency 3.00×10^4 Hz towards a car. The wave is reflected back to the emitter. The emitter now becomes the receiver. The receiver receives the sound wave with a frequency of 3.10×10^4 Hz. The speed of sound is $3.30 \times 10^2 \ \frac{\text{m}}{\text{s}}$. Determine the speed of the car.