Key Concepts

Chapter 9

Doppler effect

Wavelength

Frequency

Takeaways

As the detector approaches the source, the observed frequency will be higher than the emitted frequency, and when the detector moves away from the source, the observed frequency will be smaller than the emitted frequency. The same rule applies to the motion of the source. Therefore, when determining the right form of the Doppler equation, use the sign in the equation that will yield the appropriate observed frequency.

Doppler Effect

Two cars, car A and car B, are moving towards each other at 50 m/s when car B starts to beep its 475 Hz horn. Assuming that the speed of sound is 343 m/s, what is the wavelength of the horn as perceived by the driver of car A?

1) Identify this as a Doppler effect problem and determine the source and detector of the wave.

The source is the object that emits the wave: car B.

The detector or observer is the object that detects the wave: the person in car A.

Whenever you are given two objects with one emitting a wave and are asked to determine a perceived frequency or wavelength, the Doppler effect is involved.

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2) Determine the effect of the velocity of the observer on the perceived frequency.

Every Doppler effect problem can be solved using the Doppler effect equation, which states that

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

where f_o is the frequency observed, f_s is the frequency emitted by the source, v is the speed of the wave, v_o is the speed of the observer, and v_s is the speed of the source.

Remember: *Isolate the Doppler effect into two parts: effect of velocity of source and effect of velocity of detector. When solving for what's asked, disregard the other variable.*

In this problem, the observer is moving toward the source (car A is moving toward car B), and we are not concerned with the motion of the source, car B. Therefore, the observed frequency (f_o) must be greater than the emitted frequency (f_s), and the numerator must be greater than 1, so we must use the positive sign in the numerator of the problem.

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

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3) Determine the effect of the velocity of the source on the perceived frequency.

The source is also moving toward the detector (car B is moving toward car A). This should also make the perceived frequency greater than the emitted frequency. Thus, for f_o to be greater than f_s, the denominator must be smaller than 1. Hence, we must use the negative sign in the denominator.

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

Alternate Method: If you look at the first equation in step 2, you will notice that in the denominator, the order of plus and minus signs is switched from the order in the numerator. This is written this way for a specific reason. When an object moves toward another object, the top sign is used. When an object moves away from an object, the bottom sign is used. In our case, because both the observer and source are moving toward each other, we used the top sign in both the numerator and the denominator.

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4) Plug the values for the emitted frequency and the different velocities into the Doppler effect equation.

$$f_o = 475\left(\frac{50+343}{50-343}\right) = 637\,\text{s}^{-1}$$

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5) Convert frequency to wavelength.

$$v = f\lambda$$

$$\lambda = \frac{v}{f}$$

$$\lambda = \frac{343\,\text{m/s}}{637\,\text{s}^{-1}}$$

$$\lambda = 0.54\,\text{m}$$

Things to Watch Out For

Always separate Doppler questions into two parts, the effect of the source and the effect of the observer. Be careful in problems where the object and the source are moving in the same direction. If the source is ahead of the detector, the source will be moving away from the detector while the detector is moving toward the source, regardless of their speed. If the detector is ahead of the source, the detector will be moving away from the source while the source is moving toward the detector.

Similar Questions

1) Suppose a policeman traveling at 5 m/s is firing his gun at a rate of 20 bullets per minute while chasing a bank robber who is peddling his bicycle at 50 m/s. At what rate do the bullets reach the bank robber (use 500 m/s for the speed of a bullet)?
2) A bungee jumper yells in triumph at 350 Hz as he falls off a bridge toward a river at a rate of 20 m/s. What are the frequencies heard by the observers on the bridge and a boat on the river (the speed of sound is 343 m/s)?