Physics 5B: Sound Waves III Dopler

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I. Interference

- Assume λ is same for both A and B

  if $|d_{\mathrm{AX}} - d_{\mathrm{BX}}| = n\lambda$, constructive interference

  if $|d_{\mathrm{AX}} - d_{\mathrm{BX}}| = \left(n + \frac{1}{2}\right)\lambda$ destrcutive interference

  and evertying in between

- Example:

  Loud speakers are 3m apart. Microphone is 3.2m away from the center of the loud speakers distance.

  $d_{\mathrm{AX}} = \sqrt{(3.2)^2 + (1.5)^2}$ $\qquad d_{\mathrm{AX}'} = \sqrt{(3.2)^2 + d^2}$

  $d_{\mathrm{BX}} = \sqrt{(3.2)^2 + (1.5)^2}$ $\qquad d_{\mathrm{BX}'} = \sqrt{(3.2)^2 + (3.0 - d)^2}$

  $d'_{\mathrm{AX}} - d_{\mathrm{BX}'} = \frac{1}{2}\lambda$

- If λ are not the same for A and B

  Effet is constructive interference at regular frequency, less than indivual frequencies.

  Beat frequency is $|f_1 - f_2|$ independent of microphones position.

- $D_1 = \mathrm{A}\sin(w_1 t) = \mathrm{A}\sin(2\pi f_1 t)$

  $D = D_1 + D_2$

  $= \mathrm{A}\sin(2\pi f_1 t) + \mathrm{A}\sin(2\pi f_2 t)$

  $= A\left[2\sin\frac{1}{2}(2\pi f_1 t + 2\pi f_2 t)\cos\frac{1}{2}(2\pi f_1 t - 2\pi f_2 t)\right]$

  $= 2\mathrm{A}\cos\left[2\pi\left(\frac{f_1 - f_2}{2}\right)t\right]\sin\left[2\pi\left(\frac{f_1 + f_2}{2}\right)t\right]$

  Varying amplitude $\qquad$ Average freq.

- $I \sim A^2$, so max intensity occurs twice per cycle when (when $\cos[....] \pm 1$

  Beats have

II. Doppler Effect

- The Frequency of sound waves at a source is not always the same as the frequency measured by observer.

  Distance between crests is λ and $f = \frac{v}{\lambda}$

  Start with moving source with v_{source}

  At t= T, crest must of moved a distance of $v_{\mathrm{source}} T$

$$\lambda' = v_{\text{sound}}T - v_{\text{source}}T = \frac{v_{\text{sound}}}{f} - v_{\text{source}}\frac{1}{f} = \lambda$$

$$= \lambda - v_{\text{source}}\frac{\lambda}{v_{\text{sound}}} = \lambda\left(1 - \frac{v_{\text{source}}}{v_{\text{sound}}}\right)$$

Since $f = \frac{v}{\lambda} \Rightarrow \lambda = \frac{v}{f}$ then, $\frac{v}{f'} = \frac{v}{f}\left(1 - \frac{v_{\text{source}}}{v_{\text{sound}}}\right)$

$f' = \dfrac{f}{\left(1 - \frac{v_{\text{source}}}{v_{\text{sound}}}\right)}$ Moving source, and stational observer

- If the observer moves instead,

  Wavelenths is constant, but the frequency changes and also velocity changes

  $$v' = v_{\text{sound}} + v_{\text{observer}}$$

  $$f' = \frac{v'}{\lambda} = \frac{v_{\text{sound}} + v_{\text{obserber}}}{\lambda} = \frac{v_{\text{sound}}}{\lambda} + \frac{v_{\text{observer}}}{\lambda}$$

  $$= f + \frac{v_{\text{observer}}}{\frac{v_{\text{sound}}}{f}} = f + f\left(\frac{v_{\text{observer}}}{v_{\text{sound}}}\right) = f\left(1 + \frac{v_{\text{observer}}}{v_{\text{sound}}}\right)$$

  $$= f\left(\frac{v_{\text{sound}} + v_{\text{observer}}}{v_{\text{sound}}}\right)$$

- If both source and observer move,

  $f' = f\left(\frac{v_{\text{sound}}}{v_{\text{sound}} + v_{\text{source}}}\right)$ From moving source

  observer hears: $f'' = f'\left(\frac{v_{\text{sound}} + v_{\text{observer}}}{v_{\text{sound}}}\right)$

  $$= f\left(\frac{v_{\text{sound}}}{v_{\text{sound}} v_{\text{source}}}\right)\left(\frac{v_{\text{sound}} + v_{\text{observer}}}{v_{\text{sound}}}\right)$$