PhysicsTutor

Doppler effect

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Problem:

- A bat uses a 60 kHz ultrasound wave to track an insect initially 30 cm away, then moving to be 40 cm away.
- Find the difference in echo times.
- If the insect moved the 10 cm directly away in a time of 0.50 sec, what is the magnitude of the frequency shift of the reflected wave picked up by the bat?

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- For observers moving away from a stationary source there is a frequency decrease.
- The reflected waves (of decreased frequency) are perceived by the bat as coming from a receding source.

Equations associated with ideas:

1) $t_1 = \frac{2x_1}{v_s}$; $t_2 = \frac{2x_s}{v_s}$; $\Delta t = t_2 - t_1$

2) Doppler - moving observer stationary source $f_{obs} = f_{src}\left(1 - \frac{v_{obs}}{v_s}\right)$

↑ obs. moves away

3) Doppler - moving source stationary observer $f_{obs} = \frac{f_{src}}{1 + \frac{v_{src}}{v_s}}$

To lowest order in $\frac{v_{src}}{v_s}$ or $\frac{v_{obs}}{v_s}$ it doesn't matter whether one distinguishes between cases (2), (3). There is an $\mathcal{O}\left(\left(\frac{v}{v_s}\right)^2\right)$ difference which for $v \ll v_s$ is negligible.

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- The insect is treated as a moving observer, then it gives off the reflected waves at the shifted frequency.
- The bat observes the reflected waves from a moving source.
- The Doppler effect kicks in twice.

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- reflected waves produced with $f_{obs} = 59.965\ kHz = f_R$
- bat : $f_{obs} = \frac{f_R}{1 + v_{src}/v_s}$; $v_{src} = 0.2\ \frac{m}{s}$; $f^{echo} = 59.930\ kHz$

Frequency shift $\Delta f = f^{emitted} - f^{echo} = 70\ Hz$