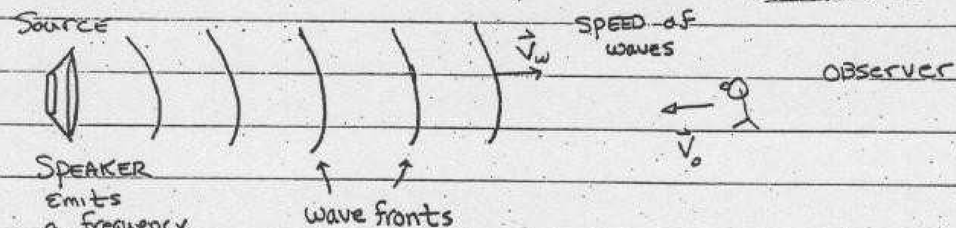
THE DOPPLER EFFECT:

the apparent shift in frequency (or "pitch") due to the relative motion between source & observer.

CASE ① STATIONARY Source; OBserver Moving toward Source



SPEAKER emits a frequency f_s, wavelength λ

OBserver Measures the speed of the wavefronts passing by to be V_ω';

$$V_\omega' = V_\omega + V_o$$

OBserver Measures the frequency f' to be:

(λ, the distance between peaks is unchanged)

$$f' = \frac{V_\omega'}{\lambda} = \frac{V_\omega + V_o}{\lambda}$$

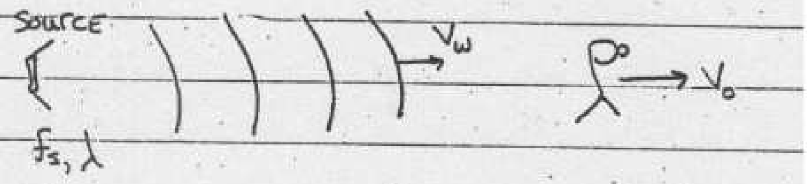
but $V_\omega = \lambda f_s$, so $\lambda = \frac{V_\omega}{f_s}$

$$f' = \frac{V_\omega + V_o}{\left(\frac{V_\omega}{f_s}\right)} \Rightarrow \boxed{f' = f_s\left(\frac{V_\omega + V_o}{V_\omega}\right)}$$

OBserver Moving toward STATIONAR[Y] Source.

Freq "heard" by observer.

CASE ② STATIONARY Source; OBSERVER Moving AWAY From Source



The speed of the wave fronts V_ω' as measured by the OBSERVER is

$$V_\omega' = V_\omega - V_o$$

Obs. now measures a frequency f'; $\left[\lambda = \frac{V_\omega}{f_s}\right]$

$$f' = \frac{V_\omega'}{\lambda} = \frac{V_\omega - V_o}{\lambda} = \frac{V_\omega - V_o}{\left(\frac{V_\omega}{f_s}\right)}$$

$$f' = f_s\left(\frac{V_\omega - V_o}{V_\omega}\right)$$

heard by OBS

OBS. Moving AWAY From STATIONary Source

Doppler EFFect For STATIONARY Source:

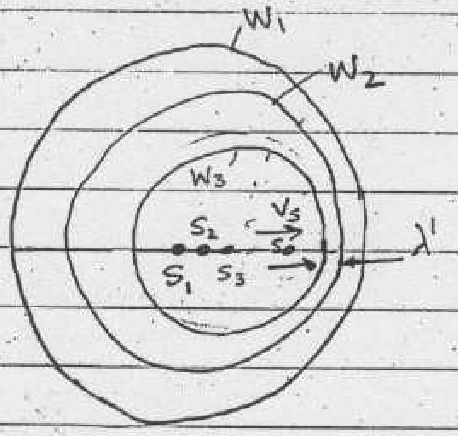
$$f' = f_s\left(\frac{V_\omega \pm V_o}{V_\omega}\right)$$

toward "+"

away "−"

CASE ③ Source Moving toward Stationary Observer

Source S emits a wave at equal time intervals. $V_S \equiv$ speed of source, wave has f_s, λ.



W_1 emitted when source was at S_1
W_2 " " " " S_2
W_3 " " " " S_3

Observer at Rest

The source is at point S_0 about to emit another wavefront.

The observer perceives a shorter wavelength λ', & thus a higher frequency.

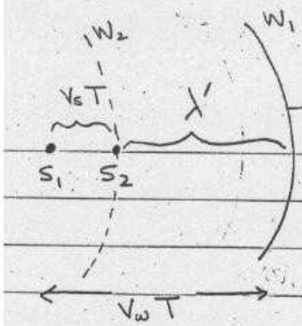
Frequency f' as measured by observer is: $f' = \frac{V_\omega}{\lambda'}$

$V_\omega \equiv$ speed of the sound wave in the air ($V_\omega = 343$ m/s)

$\lambda \equiv$ wavelength as meas by source

We need to find λ'; the shortened wavelength measured by the observer.

$\Longrightarrow$



Distance W_1 has moved in one period T. W_2 is about to be emitted

Source has moved a distance $V_s T$.

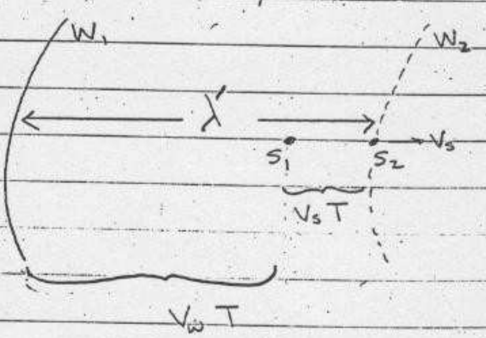
$$\lambda' = V_\omega T - V_s T$$

$$\lambda' = \frac{V_\omega}{f_s} - \frac{V_s}{f_s} = \frac{1}{f_s}(V_\omega - V_s)$$

so
$$f' = \frac{V_\omega}{\lambda'} = \frac{V_\omega}{\frac{1}{f_s}(V_\omega - V_s)} = f_s\left(\frac{V_\omega}{V_\omega - V_s}\right)$$

$$f' = f_s\left(\frac{V_\omega}{V_\omega - V_s}\right)$$ Source Moving toward stationary observed.

Case (4) Source Moving Away From Stationary Observer



$$\lambda' = V_\omega T + V_s T$$

$$\therefore\ f' = f_s\left(\frac{V_\omega}{V_\omega + V_s}\right)$$

Source Moving Away From stationary observer

W_1 has moved this Distance in a time T

4.

We can write case 3 & 4 as

$$\boxed{f' = f_s \left(\frac{V_\omega}{V_\omega \mp V_s} \right)}$$ Moving Source. STATIONARY OBSV

upper sign = toward ⇒ increase in f $\left(\frac{1}{\text{small } \#} \right)$

Lower sign = away ⇒ decrease in f $\left(\frac{1}{\text{Big } \#} \right)$.

CASE 5 Both Source & OBSERVER ARE Moving

Recall case 1 & 2 $f' = f_s \left(\frac{V_\omega \pm V_o}{V_\omega} \right)$ Moving OBSV, Source stationary

If now the source also moves, we replace f_s with f' for a moving source.

$$f' = \left[f_s \left(\frac{\cancel{V_\omega}}{V_\omega \mp V_s} \right) \right] \left(\frac{V_\omega \pm V_o}{\cancel{V_\omega}} \right)$$

V_s ≡ speed of source

V_o ≡ speed of observer

V_ω ≡ speed of sound.

$$\boxed{f' = f_s \left(\frac{V_\omega \pm V_o}{V_\omega \mp V_s} \right)}$$ General Doppler Effect EQ

Works for all cases: 1 → 5.

* upper sign ≡ towards ⇒ $\frac{\text{Big } \#}{\text{small } \#}$ → High f

* Lower sign ≡ away ⇒ $\frac{\text{small } \#}{\text{Big } \#}$ → Low f

5 End