<u>SOUND-DOPPLER EFFECT</u>

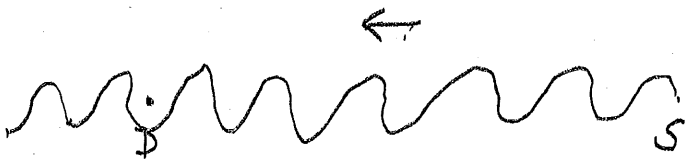
<u>Definition:</u> If either the detector (D) or the source (S) of a wave moves along the line joining them, the perceived frequency is not equal to the emitted frequency.

Consider: D and S and sound waves in air

Source and Detector both at rest

S emits wave of frequency f

D perceives wave of frequency f



That is, f undulations pass by D every second and wave goes past D by the amount $V_s = \sqrt{\frac{\gamma P_0}{\rho_0}}$ every second.

<u>Case I : D Moves Toward</u>

D Moves <u>toward</u> S at V_D m/sec.

Now D will pick up f' undulations per second which lie in the distance $(V_S + V_D)$

$$f \quad \alpha \quad V_S$$

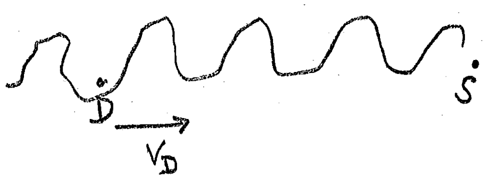
$$f' \quad \alpha \quad (V_S + V_D)$$

[α = proportional to]

So

$$\frac{f'}{f} = \frac{V_S + V_D}{V_S}$$

Toward



<u>Case II: D Moves Away</u>

If D moves <u>away</u> from S by V_D meters/sec all the undulations lying within V_D are no longer counted by it. Hence

$$\frac{f'}{f} = \frac{V_S - V_D}{V_S}$$

Away

So difference between perceived frequency f' and emitted frequency f is essentially a matter of "counting" number of "waves" passing by D every second.

To summarize, when D moves

$$\frac{f'}{f} = \left(1 \pm \frac{V_D}{V_S}\right) \qquad \begin{array}{ll} + & \textit{Toward} \\ - & \textit{Away} \end{array}$$

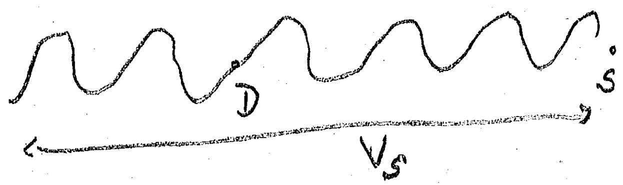
Case III: S-Moves

Note: Speed of wave is controlled by air, if air is stationary speed is

$$V_S = \sqrt{\frac{\gamma P_0}{\rho_0}}$$

even if source moves.

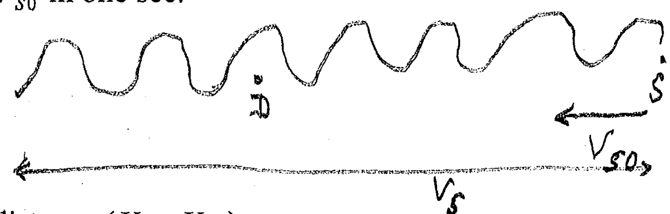
S-Stationary:



Wave leaving S at t = 0 reaches V_S away in 1 sec. All the waves fit within V_S. Hence wavelength

$$\lambda \quad \alpha \quad V_S$$

If source moves toward D by amount V_{S0} in one sec.



The wave is now "squeezed" into the distance ($V_S - V_{S0}$)
So'

$$\lambda' \quad \alpha \quad (V_S - V_{S0})$$

Hence

$$\frac{\lambda'}{\lambda} = \frac{V_S - V_{S0}}{V_S}$$

But

$$\lambda' f' = \lambda f = V_S$$

So perceived frequency

$$\frac{f'}{f} = \frac{\lambda}{\lambda'} = \frac{1}{1 - \frac{V_{S_0}}{V_S}} \qquad \text{Toward}$$

If source moves away from D wave gets stretched to occupy $(V_S + V_{S_0})$

$$\frac{\lambda'}{\lambda} = \frac{V_S + V_{S0}}{V_S}$$

$$\frac{f'}{f} = \frac{1}{1 + \frac{V_{S0}}{V_S}} \qquad \text{Away}$$

To summarize, if S moves, perceived frequency is given by

$$\frac{f'}{f} = \frac{1}{1 \pm \frac{V_{S_0}}{V_S}} \qquad \begin{array}{ll} - & \textit{Toward} \\ + & \textit{Away} \end{array}$$