SOUND - DOPPLER EFFECT

DEFINITION: If either the detector (D) or the source (S) of a wave moves, 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 freq. f.

D perceives wave of freq. 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.

D moves

toward S at V_D m/sec.

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

$$f \propto V_S.$$

[$\propto$ = Proportional to].

$$f' \propto (V_S + V_D)$$

so $$\frac{f'}{f} = \frac{V_S + V_D}{V_S}. \quad \text{Toward}$$

If D moves Away from S by V_D meters/sec all the undulations lying with in V_D are no longer counted by it. Hence

$$\frac{f'}{f} = \frac{V_S - V_D}{V_S} \quad \text{Away}$$

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

$$\frac{f'}{f} = \left(1 \pm \frac{v_D}{v_S}\right) \qquad \begin{array}{l} + \text{ Toward} \\ - \text{ away} \end{array}$$

S-MOVES

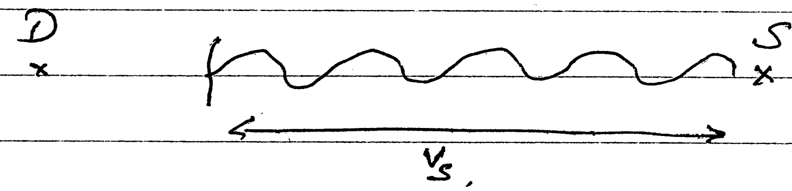
Note: speed of wave is controlled by air, if air is stationary speed is

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

even if source moves.

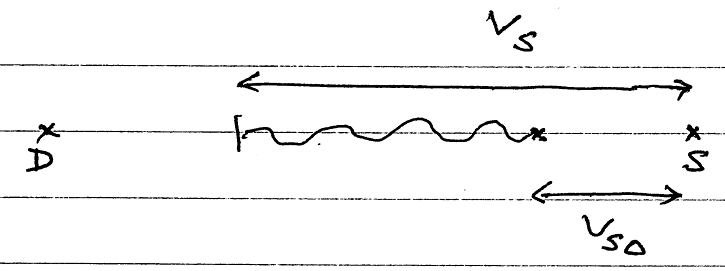
S- Stationary:

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



$$\lambda \propto v_S.$$

If source moves toward D by amount v_{SO} in one second



The wave is now "squeezed" into the distance $(V_S - V_{SD})$
so

$$\lambda' \propto (V_S - V_{SD}).$$

Hence $$\frac{\lambda'}{\lambda} = \frac{V_S - V_{SD}}{V_S}.$$

But

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

so perceived freq.

$$\frac{f'}{f} = \frac{\lambda}{\lambda'} = \frac{1}{1 - \frac{V_{SD}}{V_S}} \quad \text{Toward.}$$

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

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

$$\frac{f'}{f} = \frac{1}{1 + \frac{V_{SD}}{V_S}} \quad \text{Away}$$

To summarize, if S moves perceived frequency is given by

$$\frac{f'}{f} = \frac{1}{1 \pm \frac{V_{SD}}{V_S}} \quad \begin{matrix} + \text{ Away} \\ - \text{ Toward} \end{matrix}$$