

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 $(v_s + v_D)$

$$f \propto v_s$$

[$d = \text{Proportional to}$].

$$f' \propto (v_s + v_D)$$

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 ~~waves~~ undulations lying within 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

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

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

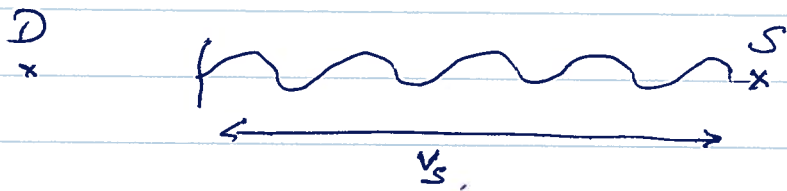
S at $t=0$

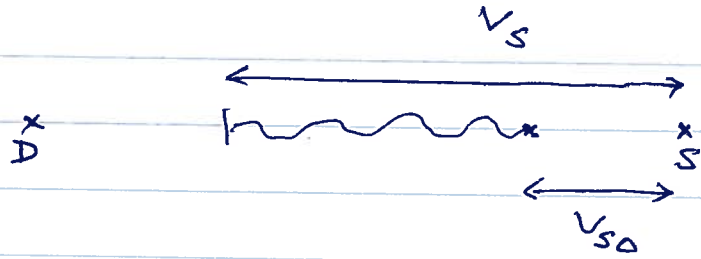
reaches v_s away

in 1 sec. All the waves fit within v_s . Hence wavelength

$$\lambda \propto v_s$$

If source moves toward D by amount v_{s0} in one second





The wave is now "squeezed" into the distance $(v_s - v_{s0})$

so

$$\lambda' \propto (v_s - v_{s0})$$

Hence

$$\frac{\lambda'}{\lambda} = \frac{v_s - v_{s0}}{v_s}$$

But

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

so perceived freq.

$$\frac{f'}{f} = \frac{\lambda}{\lambda'} = \frac{1}{1 - \frac{v_{s0}}{v_s}} \quad \text{Toward.}$$

If source moves away from D wave gets stretched to occupy $(v_s + v_{s0})$

$$\frac{\lambda'}{\lambda} = \frac{v_s + v_{s0}}{v_s}$$

$$\frac{f'}{f} = \frac{1}{1 + \frac{v_{s0}}{v_s}} \quad \text{Away}$$

To summarize, if S moves perceived frequency is given by

$$\frac{f'}{f} = \frac{1}{1 \pm \frac{v_{s0}}{v_s}} \quad \begin{array}{l} + \text{ Away} \\ - \text{ Toward} \end{array}$$