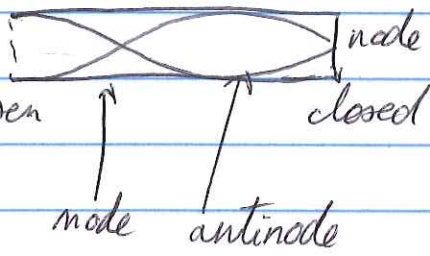
* Organ pipes



2nd order, 1st overtone

open/closed

$L = n\frac{\lambda}{4}$

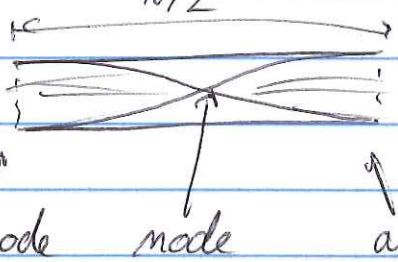
$n = 1, 3, 5, \ldots$ odd

$\longrightarrow f = \frac{nv}{4L}$ for $n = 1, 3, 5, 7, \ldots$ odd

~~closed~~

~~open~~

open/open



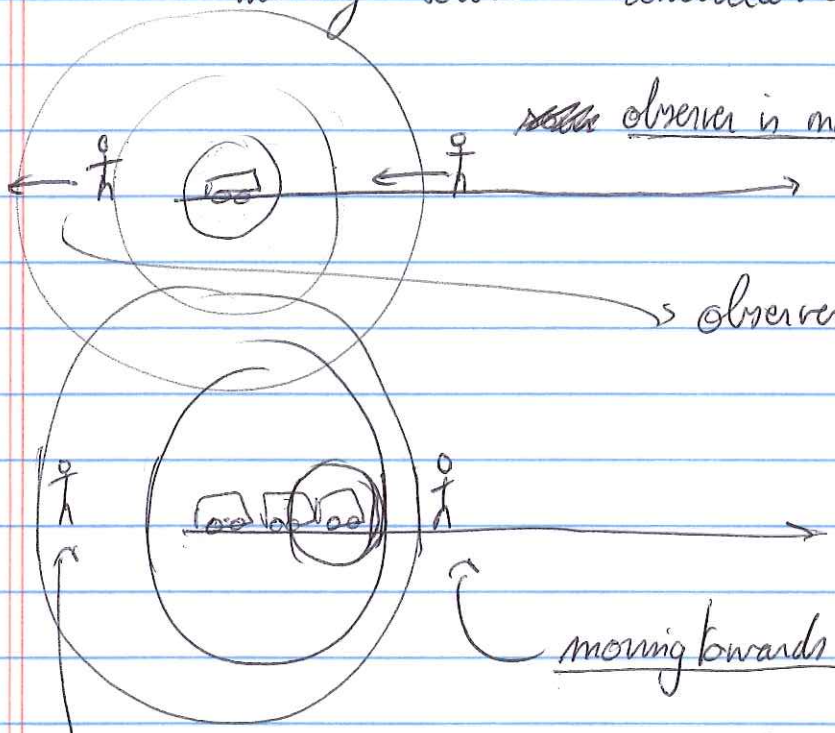
$L = n\frac{\lambda}{2}$

$n = 1, 2, 3, \ldots$

$\longrightarrow f = \frac{nv}{2L}$ for $n = 1, 2, 3, 4, \ldots$

* Doppler effect : effect of velocity of source or observer on the frequency

- moving source : ambulance



observer is moving towards source → higher frequency → +

observer moving away from source → lower frequency → −

moving towards observer : higher frequency → (−)

moving away from observer → lower frequency → +

$$f_{obs} = f_s \frac{v}{v \pm v_s}$$

v_s : speed of source

$$f_{obs} = f_s \frac{v \pm v_{obs}}{v}$$

Train is entering station, whistles at 1000Hz = f_s
Observer hears a frequency f_{obs} = 1122 Hz, at 0°C

source is moving towards the observer

$$f_{obs} = f_s \frac{v}{v \mp v_s}$$

$$1122\ Hz = 1000\ Hz \cdot \frac{331\ m/s}{331\ m/s - v_s}$$

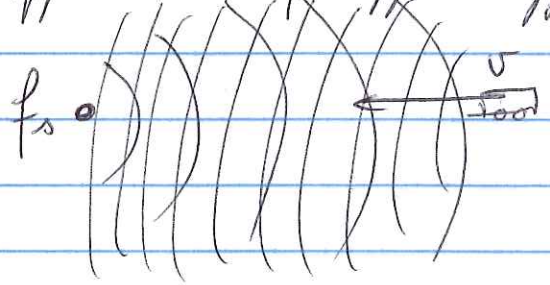
$$\hookrightarrow v_s = 36\ m/s$$

If this train leaves the station, what will be f_{obs}?

$$f_{obs} = f_s \frac{v}{v + v_s} = 1000\ Hz \frac{331\ m/s}{331\ m/s + 36\ m/s}$$

$$= \underline{902\ Hz}$$

Applications of Doppler effect



- radar guns
- echolocation in bats
  ↳ speed, direction
- blood vessel ultrasound
  ~~echo~~ Doppler ~~echocardiogra~~ echocardiography
- Doppler weather radar
- Astronomy

$f_{obs} = f_s \left(\frac{v}{v - v_s} \right)$, when moving towards observer

$v_s = v$ = speed of sound → Mach 1

Mach # = $\frac{v_s}{v}$