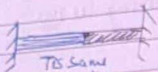
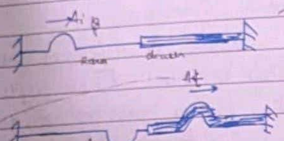
The Medium in which speed of wave is less is denser medium in comparision to the medium in which wave speed is more

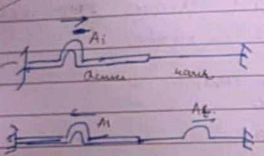


$V = \sqrt{\frac{T}{\mu}}$

$\mu \uparrow \; V \downarrow$ - Denser

$\rightarrow y = A_i \sin(\omega t - kx)$





Eq^n $y = A_r \sin(\omega t + \underbrace{kx}_{-\text{ve direction}} + \underbrace{\pi}_{\text{phase diff. after reflection}})$

Eq^n $y = A_t \sin(\omega t - \underbrace{k_1 x}_{})$ ← v is changed hence k is changed.

~~After~~ Before reflection $y = A_i \sin(\omega t - kx)$

$\cancel{y = A_r \sin(\omega t + kx)}$

After reflection $y_r = A_r \sin(\omega t + kx)$

$y_t = A_t \sin(\omega t - k_1 x)$

$$\boxed{A_r = \left(\frac{v_2 - v_1}{v_2 + v_1}\right) A_i \qquad A_t = \frac{2v_2}{v_2 + v_1} A_i}$$

Standing wave

$y_1 = A \sin(\omega t - kx)$

$y_2 = A \sin(\omega t + kx)$

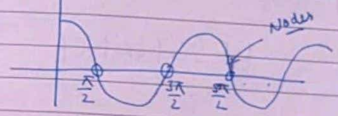
$y = y_1 + y_2 = 2A \sin\omega t \cos kx.$

$= \underbrace{(2A \cos kx)}_{}(\sin\omega t)$

$y = A_0 \underbrace{\sin\omega t}_{SHM}$

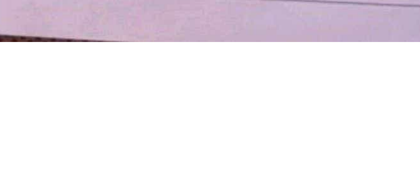
$A_0 = 2A \cos kx.$

Particles will be at extreme position at same time and also at mean position at same time



$kx = \frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2} \ldots$

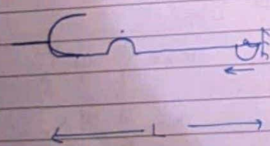
$x = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4} \ldots$



Date ___/___/___

- When standing waves are produced on a string then some points of the string always remains at rest. these points are known as nodes.
- The minm seperation b/w 2 nodes is $\frac{\lambda}{2}$
- Other the nodes all the points of string perform SHM with diff. Amplitudes. The particles position of of particles having Maxm amplitude is known as Antinode.
- Minm seperation b/w 2 ~~anti~~ antinodes is $\frac{\lambda}{2}$
- Minm seperation b/w Node & an antinode is $\frac{\lambda}{4}$.
- All the particle in given loop are in phase.
- The particles of ~~adjecnt~~ adjecent loops are out of phase.
- Energy of a given loop remains const.

RESONANCE



- Standing waves are produced in a string when it is resonance with tunning ~~form~~ fork
- The frequency at which resonance is achieved are known as resonant or natural frequency

Read out p.g. → 312 - 317 sec. 15.10

Date ___/___/___

- Standing waves produced on a string fixed at both the ends

$y_1 = A\sin(\omega t - kx)$

$y_2 = A\sin(\omega t + kx + \phi)$

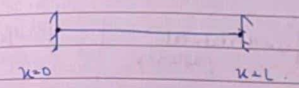
$y = y_1 + y_2 = 2A\sin\left(kx + \frac{\phi}{2}\right)\cos\left(\omega t + \frac{\phi}{2}\right)$

4 possiblities.

Sin(   ) sin(   )

Cos(   ) Sin(   )

Cos(   ) Cos(   )



Boundary Condition

i) At

$x = 0$ = Node

$\Rightarrow y = 0$

$0 = 2A\sin\frac{\phi}{2}\cdot\cos\left(\omega t + \frac{\phi}{2}\right)$

$\sin\frac{\phi}{2} = 0$

$\phi = 0$

$y = 2A\sin kx\cdot\cos\omega t$.

ii) At $x = L$ = Node ⇒ $y = 0$

$0 = 2A\sin(kL)\cos\omega t$

$kL = n\pi$ ($n = 1, 2, 3 \ldots$)

$n \neq 0$ because we have taken this condition)

$\frac{2\pi}{\lambda}L = n\pi \Rightarrow L = \frac{n\lambda}{2}$ $\left(L = \frac{\lambda}{2}, \lambda, \frac{3\lambda}{2}, \ldots\right)$

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

$\frac{2L}{n} = \lambda$ → At this λ resonance will occur.

$f = \frac{v}{\lambda}$

$$\boxed{f = \frac{nv}{2L}}$$

$n=1$; $f_1 = \frac{v}{2L} = f_0$ → first frequency at which resonance will occur.

$n=1$; $f_1 = \frac{v}{2L} = f_0$	fundamental frequency.	1st Harmonic
$n=2$, $f_2 = \frac{v}{L} = 2f_0$	1st overtune → 1st frequency after fundamental where we will get resonance	2nd Harmonic
$n=3$, $f_3 = \frac{3v}{2L} = 3f_0$	2nd overtune	3rd Harmonic
$n=4$, $f_4 = \frac{2v}{L} = 4f_0$	3rd overtune	4th Harmonic

$$\boxed{\begin{aligned} L &= \frac{n\lambda}{2} \\ L &= \frac{\lambda}{2},\ n=1 \\ L &= \lambda,\ n=2 \\ L &= \frac{3\lambda}{2},\ n=3 \\ L &= 2\lambda,\ n=4 \end{aligned}}$$

Date __/__/__

* Standing wave on a string fixed at one end

$y = 2A\sin\left(kx + \frac{\phi}{2}\right)\cos\left(\omega t + \frac{\phi}{2}\right)$

At $x=0$ Node.

$\Rightarrow y=0 \Rightarrow \phi = 0$

$y = 2A\sin kx \cos\omega t$

At $x = L$;

Antinode ($\because$ end is not fixed)

$\sin kx = \pm 1$

$kL = \underbrace{(2n-1)}_{\text{to start from 1}}\frac{\pi}{2}$

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

$\frac{2\pi}{\lambda} \cdot L = (2n-1)\frac{\pi}{2}$

$L = (2n-1)\frac{\lambda}{4}$

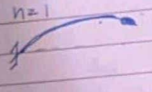
$L = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}, \ldots$

$f = \frac{v}{\lambda} \Rightarrow f = \frac{(2n-1)v}{4L}$

$n=1;\ f_1 = \frac{v}{4L} = f_0$	fundamental frequency	1^{st} overtone
$n=2;\ f_2 = \frac{3v}{4L} = 3f_0$	1^{st} ~~harmonic~~ overtone	3^{rd} overtone
$n=3;\ f_3 = \frac{5v}{4L} = 5f_0$	2^{nd} ~~Harmonic~~ O.T	5^{th} overtone
$n=4;\ f_4 = \frac{7v}{4L} = 7f_0$	3^{rd} ~~Harmonic~~ O.T	7^{th} overtone

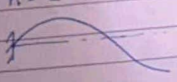
overtone mean n times fundamental frequency

n=1



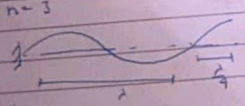
$L = \frac{\lambda}{4}$

n=2



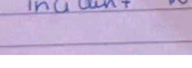
$L = \frac{3\lambda}{4}$

n=3



$L = \frac{5\lambda}{4}$

n=4



$= L = \frac{7\lambda}{4}$

Reflection of sound wave.

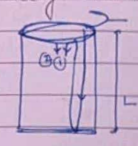
Whenever there is a discontinuity in a med. sound wave is reflected. When a sound wave is reflected at closed end then incident wave and reflected wave are in same phase. * When a sound wave is reflected from an open end then an incident wave reflected wave are out of phase.

* A closed end is displacement node & pressure antinode (∵ phase diff. b/w displacement & pressure is $\frac{\pi}{2}$.)

* An open end is a pressure node & displacement antinode.

Standing waves.

Closed Organ pipe



$$\text{phase diff} = \underbrace{K(2L)}_{\text{path diff}} + \underbrace{\pi}_{\text{due to reflection at open end}}$$

$$2n\pi = \frac{2\pi}{\lambda}(2L) + \pi$$

$$\frac{2\pi}{\lambda}(2L) = (2n-1)\pi$$

$$\boxed{L = (2n-1)\frac{\lambda}{4}}$$

$$L = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4} \ldots$$

$$f = \frac{v}{\lambda}$$

$$f = \frac{(2n-1)v}{4L}$$

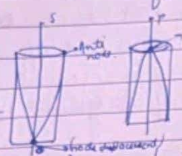
Date __/__/__

$n=1$; $f_1 = \frac{V}{4L} = f_0$ fundament freq. / 1^{st} H.

$n=1$

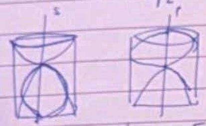
$L = \frac{\lambda}{4}$

$f_1 = \frac{V}{4L}$



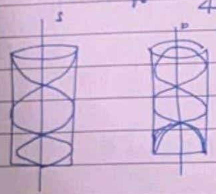
→ node (pressure)
- phase difference b/w displacement & Pressure is $\pi/2$ (Q).
where there is displacement node there will be pressure antinode.

$n = 2$; $f_2 = \frac{3V}{4L} = 3f_0$ 1^{st} O.T / 3^{rd} H



→ $L = \frac{3\lambda}{4}$, $f = \frac{3V}{4L}$

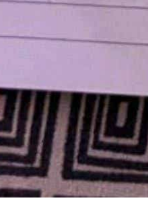
$n = 3$, $f_3 = \frac{5V}{4L} = 5f_0$ 2^{nd} O.T / 5^{th} H



$L = \frac{5\lambda}{4}$

$f = \frac{5V}{4L}$

Open organ pipe.



$\Delta\phi = \cancel{\theta}\ K(2L) + \pi + \pi$
reflection at open end.

$\Delta\phi = 2\pi + K(2L) = K(2L)$

$2\pi + \theta = \theta$

Date __/__/__

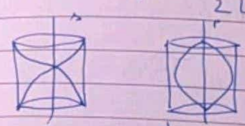
$2n\pi = K2L$

$\frac{n\pi}{K}$ $2L$

$\boxed{\frac{\lambda\, \cancel{\theta}\, \pi}{2\pi} \quad 2L}$

$\boxed{f = \frac{nV}{2L}}$

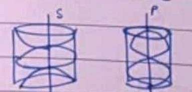
$n = 1$; $f_1 = \frac{V}{2L} = f_0$ - fundamental / 1^{st} H



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

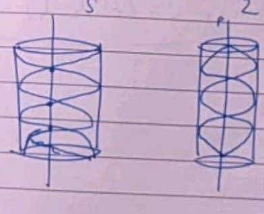
$f_1 = \frac{V}{2L}$. $n = 2$; $f_2 = \frac{V}{L} = 2f_0$ 1^{st} OT / 2^{nd} H.

$n = 2$



$L = \lambda$; $f = \frac{V}{L}$

$n = 3$, $f_3 = \frac{3V}{2L} = 3f_0$ 2^{nd} OT / 3^{rd} H.



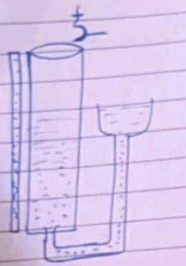
* End Correction (d)

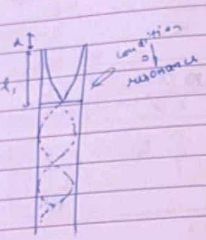
→ Antinodes or nodes are not at surface of tube. practically hence they are at a distance 'd' from surface

$\boxed{d = 0.6\, r}$

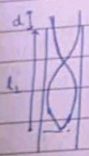
Date __/__/__

Resonance Column tube





$l_1 + d = \frac{\lambda}{4}$ — (1)



$l_2 + d = \frac{3\lambda}{4}$ — (2)

$l_2 - l_1 = \frac{\lambda}{2}$

$\lambda = 2(l_2 - l_1)$

$V = f\lambda \Rightarrow \boxed{V = 2f(l_2 - l_1)}$ Imp.

Beats:-

$p_1 = p_0 \sin\omega_1 \left(t - \frac{x}{v}\right)$

$p_2 = p_0 \sin\omega_2 \left(t - \frac{x}{v}\right)$

$p = p_1 + p_2$

Date __/__/__ After solving

$p = 2p_0 \cos\frac{\omega_1 - \omega_2}{2}\left(t - \frac{x}{v}\right) \cdot \sin\frac{\omega_1 + \omega_2}{2}\left(t - \frac{x}{v}\right)$

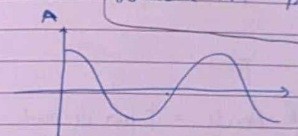
$|\omega_1 - \omega_2| = \Delta\omega$

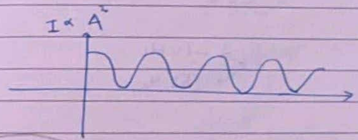
$\frac{\omega_1 + \omega_2}{2} = \omega$

$\boxed{p = 2p_0 \cos\frac{\Delta\omega}{2}\left(t - \frac{x}{v}\right) \sin\omega\left(t - \frac{x}{v}\right)}$

$\boxed{p = A \sin\omega\left(t - \frac{x}{v}\right)}$

$\boxed{\text{where } A = 2p_0 \cos\frac{\Delta\omega}{2}\left(t - \frac{x}{v}\right)}$





No. of beats heard per second is known as beat frequency.

$T_A = \frac{2\pi \cdot 2}{\Delta\omega}$ $\left[\because A = 2p_0 \cos\frac{\Delta\omega}{2}\left(t - \frac{x}{v}\right)\right]$

$T = \frac{2\pi}{\omega}$ where $\omega = \frac{\Delta\omega}{2}$

$T_I = \frac{2\pi}{\Delta\omega}$ $\left[\because T_I = \frac{T_A}{2}\right]$

Beat frequency

$$= \frac{\Delta \omega}{2\pi}$$

$$= \frac{|\omega_1 - \omega_2|}{2\pi}$$

$$= \boxed{|f_1 - f_2|}$$

eg →

$f_1 = 512 Hz$

$f_2 = ?$

No. of beats = 4 per second.

$f = ?$

$f \to 260 Hz$, $252 Hz$

* If some wax is applied on prong of a tunning fork then its frequency decreases
* If prong of a tunning fork is rubbed then its frequency increases.

Q. A tunning fork of unknown frequency produces 6 beats per second with another tunning fork of frequency 512Hz. If some wax is applied on prong of the unknown tunning fork the beat frequency decreases to of 4 beats per second find frequency of unknown tunning fork.

Ans →

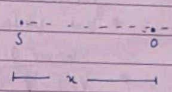
$$|f_1 - f_2| = 6$$

$$|f_1 - 512| = 6$$

$$f_1 \to 506 Hz, \; 518 Hz$$

When wax is applied frequency decrease when f is 506 then after applying wax ~~frequency~~ no. of beats will increase. hence unknown frequency is 518Hz.

DOPPLER EFFECT



speed of sound = v

first pulse produced $t = 0$

$t = T_0$

$$t_1 = \frac{x}{v}$$

$$t_2 = T_0 + \frac{x}{v}$$

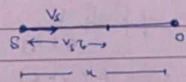
$$T = t_1 - t_2 = T_0$$

$$f_0 = \frac{1}{T_0}$$

$$f = \frac{1}{T} = \frac{1}{T_0} = f_0$$

*

$t = 0$



$$t_1 = \frac{x}{v}$$

$$t_2 = T_0 + \frac{x - V_s T_0}{v}$$

distance moved by source in T_0 time

Date ___/___/___

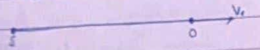
Saathi

$$T = t_2 - t_1$$
$$= T_0 - \frac{V_S T_0}{V}$$
$$T = T_0\left(1 - \frac{V_S}{V}\right)$$

$$f = \frac{1}{T} = f = f_0\left(\frac{V}{V - V_S}\right)$$

frequency detected by Observer — frequency of source

* When observer moves.



* $$\boxed{f = f_0\left(\frac{V \pm V_0}{V \pm V_S}\right)}$$

* f_0 is frequency produced by the source.
* f is frequency of sound detected by the observer.
* $V \rightarrow$ ~~velocity~~ Speed of sound w.r.t given medium.
* $V_0 \rightarrow$ Component of velocity of Observer along the ~~joining~~ joining line of observer & Source.
* $V_S \rightarrow$ component of velocity of source along the joining line of observer & source.

$$f = f_0\left(\frac{V \pm V_0}{V \pm V_S}\right)$$

* S → - - - O $\quad f = f_0 \frac{V}{(V - V_S)}$

when source comes towards the observer it increases the frequency

← S - - - O $\quad f = f_0 \frac{V}{(V + V_S)}$

S - - - O → $\quad f = f_0\left(\frac{V - V_0}{V}\right)$

Date ___/___/___

Saathi

* S ← O $\quad f = f_0 \frac{V + V_0}{V}$

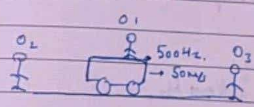
* S → O → $$f = f_0\left(\frac{V - V_0}{V - V_S}\right)$$

* S → ← O $$f = f_0\left(\frac{V + V_0}{V - V_S}\right) \qquad \boxed{f = f_0\left(\frac{V \pm V_0}{V \pm V_S}\right)}$$

* ← S O → $$f = f_0\left(\frac{V - V_0}{V + V_S}\right)$$

* ← S ← O $\quad f = f_0\left(\frac{V + V_0}{V + V_S}\right)$

Eg



$V_{Sound} = 300\ m/s$

$V_S = 50\ m/s$

$O_1 \rightarrow \quad f = f_0 \frac{V + V_0}{V + V_S}$

$O_1 \rightarrow 50\ m/s \qquad S \rightarrow 50\ m/s$

$$f = f_0 \frac{300 + 50}{300 + 50}$$

$$f = f_0 = 500\ Hz$$

$O_2 \quad f = f_0 \frac{V}{V + 50} = f = f_0 \frac{300}{350}$

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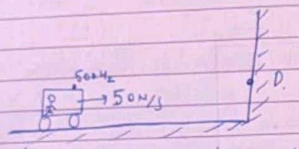
$f = \frac{\overset{500}{\cancel{300}} \times 6}{7}$

$O_3 \quad f = f_0 \frac{V}{V - V_s}$

$= f_0 \frac{300}{250}$

$f = 600\,Hz$

Eg



i) find frequency of sound detected by the detector.

ii) find frequency of sound reflected by the wall.

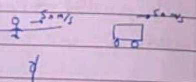
iii) find ~~frequency~~ diff. b/w the frequency observed by the observer.

sol^n → i) → $f = f_0 \frac{V}{V - 50}$

$f = \frac{500 \times 300}{250} = 600\,Hz$

ii) $600\,Hz$

iii) $f = f_0 \left(\frac{V + V_0}{V + V_s}\right)$



$f = f_0 = 500\,Hz$

diff b/w frequency heard by observer.

Observer will hear 2 frequency one reflected & other on vehical

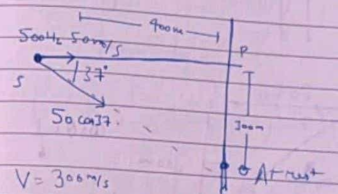
$f_2 = 600 \left(\frac{300 + 50}{300}\right)$

$= \frac{600 \times 350}{300} = 700\,Hz$

$f_1 = 500\,Hz$

$f_2 - f_1 = 200\,Hz$

Eg.



$V = 300\,m/s$

find frequency of the sound detected by the observer which was produced by the source at a distance of 400m from point P.

$f = f_0 \frac{V \cancel{+ 50\cos 37}}{V - 50\cos 37}$

$f = 500 \left(\frac{300 \cancel{+ 50 \times \frac{4}{5}}}{300}\right)$

$f = 500 \left(\frac{300}{300 - 40}\right)$

$f = 500 \left(\frac{300}{260}\right)$

$f = \frac{500 \times 30}{26}\,Hz$

Q. In previous situation if the source is continously emitting the sound then find

i) frequency of the sound detected by the observer which was produced when the source was at point P.

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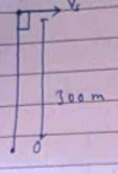
b) frequency of the sound detected by the observer at the instant when source is at point P

sol^n a) ~~at~~



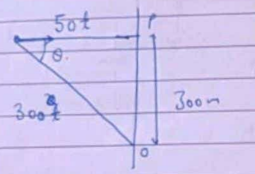
in ~~this~~ sound is ~~produced when source is at point~~

$$f_1 = 500\left(\frac{\cancel{v}}{\cancel{v}}\right)$$

$$f_1 = 500\ Hz \quad (V_s \cos 90^\circ = 0)$$

b)

in ~~this sound~~ ~~with reach point P~~



$$\cos\theta = \frac{1}{6}$$

$$\cos\theta = \frac{1}{6}$$

$$f = f_0 \frac{v}{v - v_s\cos\theta} = 500 \times \frac{300}{300 - 50\times\frac{1}{6}}$$

$$= \frac{3600}{7}\ Hz$$

Q. A small source of sound oscillate in SHM with amplitude of 17 cm. A detector is placed along the line of motion of the source. The source emit a sound of frequency 800 Hz which travels at a speed of 340 m/s. If the width of the frequency band detected by the detector is 8 Hz then time period of the source.

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$\frac{V}{V \pm V_s} \rightarrow$ max at mean position moving towards

sol^n → frequency will be max^m when source is at positive extreme.

$$f_{max} = f_0\left(\frac{v}{v - v_s}\right)$$

when it is moving towards −ve extreme.

$$f_{min} = f_0\left(\frac{v}{v + v_s}\right)$$

$$f_{max} - f_{min} = 8$$

$$f_0 v\left(\frac{1}{v - v_s} - \frac{1}{v + v_s}\right) = 8$$

$$f_0 v\left(\frac{\cancel{v} + v_s - \cancel{v} + v_s}{(v - v_s)(v + v_s)}\right) = 8$$

$$800 \times 340\ \frac{(2V_s)}{(800)^2 - (V_s)^2} = 8$$

$$340 \times 100 \times 2V_s = 640000 - V_s^2$$

$$V_s^2 + 2V_s\ 68000 - 640000 = 0$$

$$\boxed{V_s = A\omega}$$

$$A^2\omega^2 + A\omega 6800 - 64000 = 0$$

Q. A train running at 108 Km/hr towards east whistles at a dominate frequency 500 Hz. Speed of sound in air is 340 m/s. A wind is blowing towards east at a speed of 36 Km/hr. Calculate the frequency heard by the passenger sitting in the train and by the passenger standing near the track when train just passed

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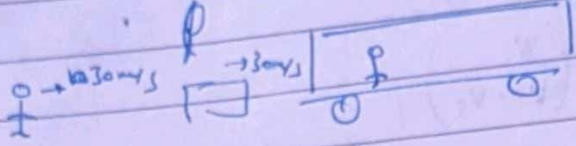
20 m/s

$V_{train/G} = 30 - \underset{\text{speed of wind}}{10} = 20$

Ans→ V_{sound} in medium $= 340\ m/s - 36\ km/hr \times \frac{5}{18}$

$= 330\ m/s.$



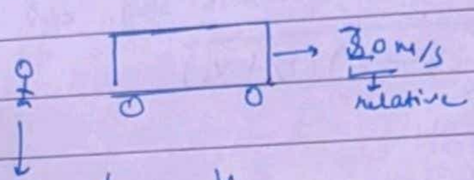
$\rightarrow 108 \times \frac{5}{18} = 30\ m/s$

frequency heard by passenger.

$$f = f_0\left(\frac{V + V_0}{V + V_s}\right)$$

$$f = f_0 = 500\ Hz.$$

passenger near track.



$$f = f_0 \frac{V}{V + 20}$$

$$= 500 \times \frac{330}{360}\ Hz =$$