$$n = \frac{v}{4l'}$$

$$\Rightarrow 200 = \frac{40180}{4l'} = \frac{\cancel{40180}}{\cancel{4} \times \cancel{50}}$$

$$\Rightarrow l' = \frac{\cancel{40180}}{\cancel{4} \times 200}$$

$$l' = \frac{\cancel{40180}}{\cancel{4 \times 200}} \quad \cancel{1004.5} \quad 502.25$$

$$= 50.225 \text{ cm}$$

$$200 = \frac{v_0}{4l_0} = \frac{v_\theta}{4l_\theta}$$

$$\Rightarrow \frac{v_0}{v_\theta} = \frac{l_0}{l_\theta}$$

But $$\frac{v_0}{v_\theta} = \sqrt{\frac{T_0}{T_\theta}} = \sqrt{\frac{0+273}{30+273}} = \sqrt{\frac{273}{303}}$$

$$= \sqrt{\frac{91}{101}}$$

$$\Rightarrow \sqrt{\frac{91}{101}} = \frac{50}{l_\theta}$$

Squaring both the sides, we get

$$\frac{91}{101} = \frac{50 \times 50}{l_\theta^2}$$

$$\Rightarrow l_\theta = \sqrt{\frac{2500 \times 101}{91}} \text{ cm} = 52.67 \text{ cm}$$

8.

$n_1 - n_2 = 6$

A has $l_1 = 15$ c.m

B has $l_2 = 30.5$ cm.

According to Question

$n_1 - n_2 = 6$

$$\frac{V}{4l_1} - \frac{V}{2l_2} = 6$$

$$\Rightarrow \frac{V}{4\times 15} - \frac{V}{2\times 30.5} = 6$$

$$\Rightarrow \frac{V}{60} - \frac{V}{61} = 6$$

$$\Rightarrow \frac{71 V - 60V}{60 \times 61} = 6$$

$$\Rightarrow \frac{11 V}{60 \times 71} = 6$$

$$\Rightarrow 6 V = \frac{6 \times 60 \times 71}{11}$$

$$= \cancel{2323.63}\ 2323.63$$

$$n_1 = \frac{V}{4l_1} = \frac{\cancel{2323.63}}{4\times 15}$$

$$n_2 = \frac{V}{4l_2} =$$

Q.

$$\Rightarrow \frac{V}{4\times 15} - \frac{V}{2\times 30.5} = 6$$

$$\Rightarrow \frac{V}{60} - \frac{V}{61} = 6$$

$$\Rightarrow \frac{61V - 60V}{60\times 61} = 6$$

$$\Rightarrow V = 6\times 60\times 61 = 21960$$

$$n_1 = \frac{V}{4l_1} = \frac{21960}{4\times 15} = 366 \text{ hz}$$

$$n_2 = \frac{V}{2l_2} = \frac{21960}{2\times 30.5} = \frac{21960}{61} = 360 \text{ hz}$$

Q. $n_1 = 156$ at $15^\circ C$

$n_2 = 160$ at ?

$\cancel{V = n\lambda}$ at $0^\circ C$ velocity of sound $= 332$ m/sec

$\cancel{\Rightarrow V =}$ in $1^\circ C$ velocity increase $= .6$

in $15^\circ C$ " " $= .6\times 15$

$= 9$ m

velocity $15^\circ = 332 + 9 = 341$ m/sec

For the open organ pipe

$$n_1 = \frac{V_1}{2l}$$

$$n_2 = \frac{V_2}{2l}$$

$$\Rightarrow \frac{n_1}{n_2} = \frac{V_1}{V_2}$$

$$\Rightarrow \frac{156}{160} = \frac{V_1}{V_2}$$

$$\Rightarrow \frac{39}{40} = \frac{V_1}{V_2}$$

We know $\frac{V_1}{V_2} = \sqrt{\frac{T_1}{T_2}}$

$$\Rightarrow \frac{V_1^2}{V_2^2} = \frac{T_1}{T_2} = \frac{15+273}{T_2} = \frac{288}{T_2}$$

$$\Rightarrow .950625 = \frac{288}{T_2}$$

$$\Rightarrow T_2 = \frac{288}{.950625} = 302.958\ K$$

$$T_2 = 302.958 - 273 = 29.95^\circ C$$

(c).

~~First overtone - second overtone =~~

$\cancel{5V}$

Second overtone of close end - First overtone = 100

$$\Rightarrow \frac{5V}{4l} - \frac{V}{l} = 100$$

$$\Rightarrow \frac{5v - 4V}{4l} = 100$$

$\Rightarrow v = 4l \times 100$

$\Rightarrow \cancel{4v = 4l \times 100 = 400l}$

$\Rightarrow l = \frac{v}{400}$

Fundamental frequency $= \frac{v}{2l}$

$= \frac{v}{2 \times \frac{v}{400}}$

$= \frac{\cancel{v} \times 400}{2\cancel{v}}$

$= 200$ hz

11. $n = 256$ $\qquad 0.6r = ?$

$l_1 = 31$ c.m $\qquad v = ?$

$l_2 = 97$ c.m

we know that $l_1 + 0.6r = \frac{\lambda}{4}$ — (i)

$l_2 + 0.6r = \frac{3\lambda}{4}$ — (ii)

$\cancel{\Rightarrow 31 + 0.6r = \frac{\lambda}{4}}$

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

$\Rightarrow 97 - 31 = \frac{\lambda}{2}$

$\Rightarrow 66 = \frac{\lambda}{2}$

$\Rightarrow \lambda = 2 \times 66 = 132$ c.m

Putting this value in eqn (i), we get

$0.6r = \frac{\lambda}{4} - l_1$

$= \frac{132}{4} - 31$

$= 33 - 31$

$= 2$ cm

Velocity of sound $V = n\lambda$

$= 256 \times 2 \times 132$

$= 33792$ cm/sec

$= 337.92$ m/sec

Ram anuman

Problems on Simple Pendulum

Page 214 , 17, 18, 19, 21

17 $l = 98.45$

$T = 1.990$ sec.

we know $T = 2\pi\sqrt{\frac{l}{g}}$

$\Rightarrow 1.99 = 2 \times 3.14 \sqrt{\frac{98.45}{g}}$

$\Rightarrow 1.99 \times 1.99 = \frac{4 \times 3.14 \times 3.14 \times 98.45}{g}$

$\Rightarrow g = \frac{4 \times 3.14 \times 3.14 \times 98.45}{1.99 \times 1.99}$

$= 980.45\ c.m/sec^2$

18. $l = 1.00m$

$T = 2\pi\sqrt{\frac{l}{g}}$

$= 2 \times 3.14 \times \sqrt{\frac{1}{9.8}}$

$= 2 \times 3.14 \times .3194$

$= 2.006$ sec.

19. $T = 2.00$ sec, $l =$; $T = ?$, $(l-2)$ inch

2inch = .16 feet

$T_1 = 2\pi\sqrt{\frac{l}{g}}$; $T_2 = 2\pi\sqrt{\frac{l-2}{g}}$

we know $T^2 = \frac{4\pi^2 l}{g}$

$\Rightarrow l = \frac{T^2 g}{4\pi^2}$

$= \frac{4 \times 32}{4 \times (3.14)^2}$

$= 3.245$ feet

$T_1 - T_2 = 2\pi\sqrt{\frac{l}{g}} - 2\pi\sqrt{\frac{l-2}{g}}$

$= \frac{2\pi}{\sqrt{g}}(\sqrt{l} - \sqrt{l - 0.16})$

$= \frac{2 \times 3.14}{\sqrt{32}}(\sqrt{3.245} - \sqrt{3.245 - .16})$

$= 1.11015(1.8013 - 1.7564)$

$= 1.11015 \times .0449 = 0.0498$

$\simeq .05$ sec

21. $l = 100\ c.m$, $\cancel{T = 2s}$,

Again after 9 page

In 8.38 min it makes 250 complete vibration.

In (8.38×60) sec it makes 250 "

In 1 sec " " $= \frac{250}{8.38 \times 60}$

$= .4972$ vibration

This day 9

$\therefore f = .4972$

$$T = \frac{1}{f} = \frac{1}{.49972} = 2.01126$$

$$g = \frac{4\pi^2 l}{T^2} = \frac{4 \times 3.14 \times 3.14 \times 100}{2.01126 \times 2.01126} = 974.30$$

We know $T = 2\pi\sqrt{\frac{l}{g}}$

$$\Rightarrow T^2 = \frac{4\pi^2 l}{g}$$

$$\Rightarrow l = \frac{T^2 \times g}{4\pi^2}$$

$$= \frac{(2.01126)^2 \times 974.30}{4 \times 3.14 \times 3.14}$$

$$=$$

---

377 page

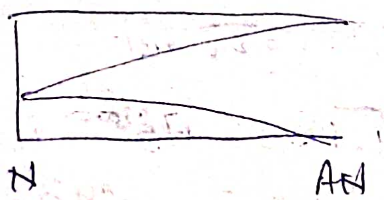
15, 16

or $\cancel{d}n = \frac{V}{4l} = \frac{332\cancel{00}}{4l}$

$\Rightarrow 16 = \frac{332\cancel{00}}{4l}$

$\Rightarrow \cancel{4}l = \frac{332\cancel{00}}{64} = 5.\cancel{1878}$ meter

15.



$\frac{33200}{4 \times l} = 16$

$\Rightarrow 16 l = 332$

We know in fundamental closed end pipe

~~$D = P$~~

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

$f = 16hz$, $V = n\lambda$

$$\Rightarrow 332 = 16.\lambda$$

$$\Rightarrow \lambda = \frac{332}{16} = 20.75 \text{ meter}$$

$$l = \frac{\lambda}{4} = \frac{20.75}{4} = 5.1875 \text{ meter}$$

$= \cancel{0.6875 \text{ meter}}$

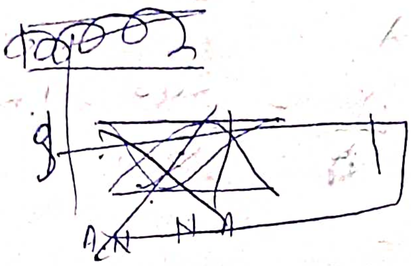
$= \cancel{68.75 \text{ cm}}$

16.

~~n = 340 hz~~ $n = 340\ hz$

$v = 340\ m/sec.$

$n = ?$



when hole is opened from 8.33cm

from closed end

Case -1

$n = 340\ hz$

$v = n\lambda$

$\Rightarrow 340 = 340\lambda$

$\Rightarrow \lambda = 1$ meter $= 100$ c.m.

$$l = \frac{\lambda}{4} = \frac{100}{4} = 25\ cm.$$

Second Case length of the tube

$$= 25.00 - 8.33 = 16.67\ c.m$$

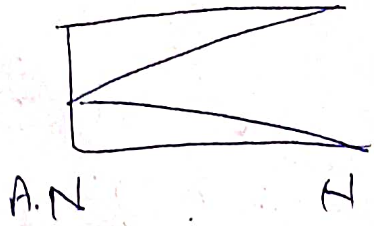
$$l = 16.67 = \frac{\lambda}{4} \Rightarrow \lambda = 66.68$$

$v = 340$

$v = n\lambda$

$$\Rightarrow n = \frac{v}{\lambda} = \frac{340\ m \times 100}{66.68}$$

~~Ayer 76~~



$n = 340$ hz

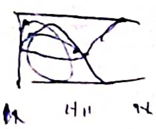
$V = 340$ m/sec.

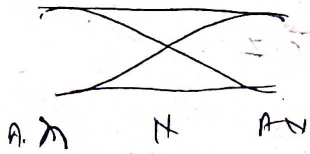
$$V = n\lambda$$

$$\Rightarrow \lambda = \frac{V}{n} = \frac{340}{340} = 1\,m = 100\,cm.$$

$$l = \frac{\lambda}{4} = \frac{100}{4} = 25\,cm.$$

When a hole is opened then it is open end pipe and there is fundamental frequency





$$l = \frac{\lambda}{2}.$$

$$\Rightarrow \lambda = 2l = 2 \times 25 = 50\,cm$$

$$V = n\lambda$$

$$\Rightarrow n = \frac{V}{\lambda} = \frac{\cancel{340}^{6.8} \times 100}{\cancel{50}} = 680 \text{ persec.}$$

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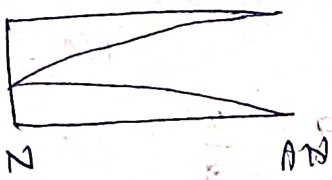
6.



The shortest length $= \frac{\lambda}{4}$

So Here fundamental frequency would be created

$n = 420$ hz

$V = \cancel{3}\ 1100$ ft/sec.

$V = n\lambda$

$\Rightarrow \lambda = \frac{V}{n} = \frac{1100}{420} = 2.619$

$l = \frac{\lambda}{4} \Rightarrow l = \frac{2.619}{4} = .6547$

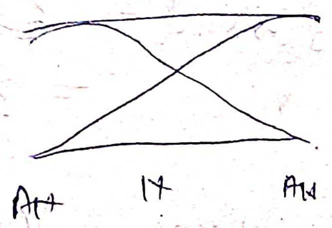
$= .655$ ft.

(b) The next shortest length

would be $\frac{3\lambda}{4} = 3 \times \frac{\lambda}{4} = 3 \times .655$

$= 1.965$ ft

9.



$v = 340$ m/sec

$= 34000$ cm/sec

$n = 420$ hz

Shortest length in open end pipe

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

$n = 420$ hz, $\lambda = \frac{V}{n} = \frac{34000}{420} = 8.953$ c.m

Shortes length

$\frac{\lambda}{2} = \frac{8.953}{2} = 4.47065$ c.m.

(b) next shortest length $= \lambda = 8.953$ c.m.

10. $n = 256$ hz, $V = 340$ m/sec

$V = n\lambda \Rightarrow \lambda = \frac{V}{n} = \frac{340}{256} = 1.32$

Shortest length

for closed end $= \frac{\lambda}{4} = \frac{1.32}{4} = .3305$ m

and open end $= \frac{\lambda}{2} = \frac{1.32}{2} = .66$ m

22. The sound velocity of air at $0°C = 332$ m/sec

-: at the water $= 332$ m/s

In $1°C$ rise of temp velocity sound

increases $= 0.6$ m.

$10°C = .6 \times 10 = 6$ m

In air velocity of sound $= 6m + 332$

$= 338$ m/sec

In air sound takes time $= \frac{\text{Distance}}{\text{velocity}} = \frac{1000m}{338}$

$= 2.958$

In water sound takes time $= \frac{1000}{\cancel{332}1450} = \cancel{3.012}\ 0.689$

-) Data from 20.12 question.

In air ~~water~~ signal reaches later

by $= \cancel{(3.012 - 2.958)}\ 0.689$ = ——— sec

$= (2.958 - .689 = 2.269$ sec

$= 2.27$ sec

21. $n = 800Hz$

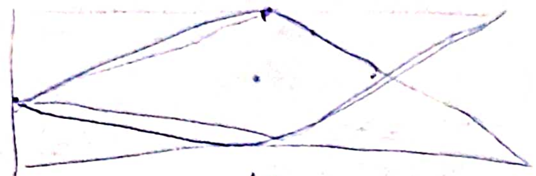
Resonance is observed when distance

from the open end of the tube to

the water are 9.75 cm, 31.25 cm, ~~52.75~~

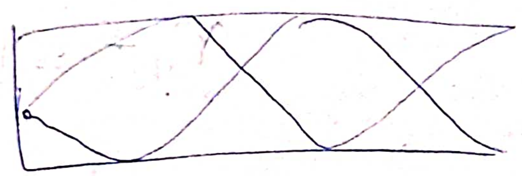
52.75 cm

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



N AN N AN

$l_2 = \frac{3\lambda}{4}$



N . AN . N . AN . N . AN

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

$\therefore$

$$9.75 + 0.6r = \frac{\lambda}{4} \quad \text{——— (i)}$$

$$31.25 + 0.6r = \frac{3\lambda}{4} \quad \text{——— (ii)}$$

$$52.75 + 0.6r = \frac{5\lambda}{4} \quad \text{——— (iii)}$$

Subtracting eqn (i) from eqn (ii), we get

$$31.25 + \cancel{0.6r} = \frac{3\lambda}{4}$$

$$9.75 + \cancel{0.6r} = \frac{\lambda}{4}$$

$$(-) \quad (-) \quad (-)$$

$$21.50 = \frac{\lambda}{2}$$

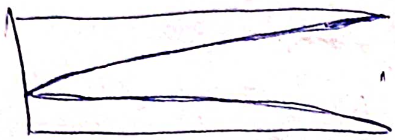
$$\Rightarrow \lambda = 43.00 \text{ cm.}$$

We know

$$v = n\lambda$$

$$\Rightarrow v = 800 \times 43 = 34400 \text{ cm/sec}$$
$$= 344 \text{ m/sec.}$$

23.



N A·N

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

$$n_1 = 160 \text{ Hz.}$$

$$V = n\lambda$$

$$\Rightarrow 1100 = 160 \times \lambda$$

$$\Rightarrow \lambda = \frac{1100}{160} = 6.875 \text{ feet}$$

$$l = \frac{\lambda}{4} = \frac{6.875}{4} = 1.71875 \text{ feet}$$

frequency of first overtone

$$= 3n_1$$
$$= 3 \times 160$$
$$= 480 \text{ Hz.}$$

24. Closed at one end.

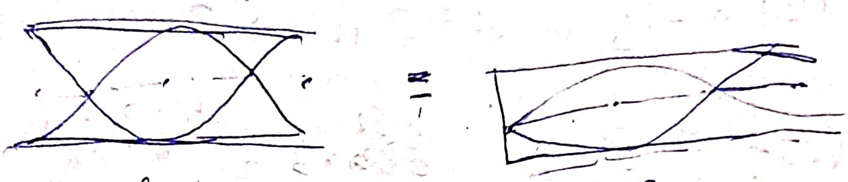
$$l = 8 \text{ in}, \quad l = \frac{\lambda}{4} \Rightarrow \lambda = 4l = 4 \times 8$$
$$= 32 \text{ in}$$
$$= 2.66 \text{ feet}$$

$V = n\lambda$

$\Rightarrow 1100 = n \cdot (2.66)$

$\Rightarrow n = \frac{1100}{2.66} = 412.5\ Hz$

25.



$l = \lambda$ $\qquad$ $l = \frac{3\lambda}{4}$

frequency
First overtone of an open organ pipe

= First over tone of a closed end pipe.

Length of it 3.6 meter in length.

For first overtone of closed end pipe

$l = \frac{3\lambda}{4}$ $\Rightarrow 3.6 = \frac{3\lambda}{4}$

$\Rightarrow \lambda = \frac{4 \times \cancel{3.6}^{1.2}}{\cancel{3}} = 4.8\ m$

this also correct

~~of first overtone $\lambda = 4.8\ m$~~

$V = n\lambda \Rightarrow n_1 = \frac{V}{\lambda} = \frac{332}{4.8} = 69.16$

But frequency of first overtone of

Closed end pipe $\frac{V}{l} = 69.16$

$\Rightarrow l = \frac{V}{69.16} = 4.8$ meter

27. $n = 36{,}000$

$2t = 0.6s$

$\Rightarrow t = 3 sec$

Including

$V = n\lambda$

$\Rightarrow 1100 = 36000 \cdot \lambda$

(b) $\Rightarrow \lambda = \frac{1100}{36{,}000} = .03055$ feet.

(a) Depth $= S = vt = 1100 \times 3 = 3300$ feet.

OR

(a) In water $S = vt = \cancel{332}\ 1450 \times 3 = 4350$ meter

(b) $\lambda = \frac{v}{n} = \frac{1450}{36{,}000} = 0.40277$

(c) In air: frequency $= 36{,}000$ per sec because frequency remains unchanged

(d) wave length $\lambda = \frac{v}{n} = \frac{332}{36{,}000} = .00922$ c.m

29. First Tuning fork has frequency $= 300$ Hz

Second " " " " $= 305$ Hz,

Number of beats $= 305 - 300 = 5$ Hz

30. $V = 345$ m/sec.

This is a closed end pipe.

$l + 0.6r = \frac{\lambda}{4}$

$\Rightarrow 10 + 0.6r = \frac{\lambda}{4}$ —— (i) and another eqn is

$$26 + 0.6r = \frac{3\lambda}{4} \quad \text{—— (ii)}$$

Subtracting eqn (i) from eqn (ii), we get

$$16 = \frac{\lambda}{2}$$

$$\Rightarrow \lambda = 32 \text{ cm},$$

$$V = n\lambda$$

$$\Rightarrow n = \frac{V}{\lambda} = \frac{345 \times 100}{32} = 1078.125.$$

OR Direct formula

$$V = 2n(l_2 - l_1)$$

$$\Rightarrow n = \frac{V}{2(l_2 - l_1)} = \frac{345}{2(26-10)} = \frac{345 \times 100}{16} \text{ meter}$$

$$= 1078.125.$$

21. $l = 100$ cm, 250 Complete rotation (8.35×60) sec

1 " " $= \frac{8.35 \times 60}{250}$ sec.

$$\therefore T = \frac{8.38 \times 60}{250}$$

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$\Rightarrow T^2 = \frac{4\pi^2 l}{g}$$

$$\Rightarrow g = \frac{4\pi^2 l}{T^2}$$

$$= \frac{4\pi^2 \times 100}{T^2}$$

$$= \frac{400\pi^2}{T^2}$$

$$= \frac{400\pi^2}{\frac{(8.38 \times 60)^2}{(250)^2}}$$

$$= \frac{400\pi^2 \times (250)^2}{(8.38 \times 60)^2}$$

We know $= l' = \frac{T^2 g}{4\pi^2}$

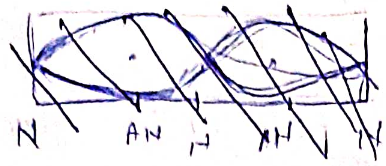
for seconds pendulum

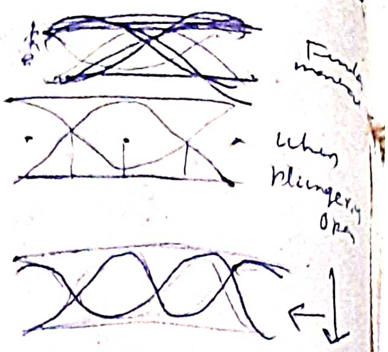
$$= \cancel{\frac{T^2 \times 400\pi^2 / T^2}{4\pi^2}}$$

$$= \frac{\cancel{4} \times 400\cancel{\pi^2} \times (250)^2}{\cancel{4\pi^2} \times (8.38 \times 60)^2}$$

$$= 98.8893 \text{ cm}.$$

32. When plunger is closed then in between two closed ends two nodes will be created.

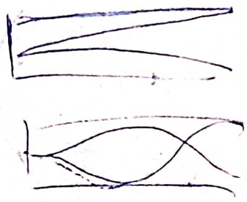




or

$l = 4 \times \frac{\lambda}{4} = \lambda$

when plunger is closed



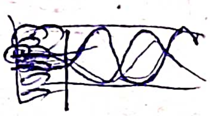
And given that $l = 11\,cm$

$\therefore \lambda = 11\,cm$.

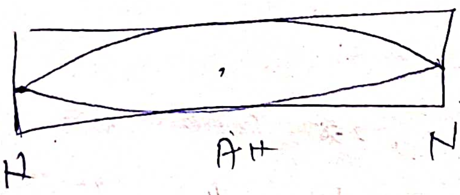
$v = 333\,m/sec$.

$v = n\lambda$

$\Rightarrow n = \frac{v}{\lambda} = \frac{333 \times 100}{11}$



A. When plunger is closed then in



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

$l = 11\,cm$

$\Rightarrow \lambda = 22\,cm$

$v = 333\,m/sec$

$v = n\lambda$

$n = \frac{v}{\lambda} = \frac{333 \times 100}{22} = 1513\,Hz$

Doppler ebbect

The (not actual) apparent change in frequency due to relative motion between the source of sound and the observer is known as Doppler ebbect.

Illustration

It is a common experience for an observer standing on a ~~ral~~ railway platform or level crossing to note that the frequency of an approaching train is higher than the normal frequency. If the train moves away from the observer the frequency appears to decrease.

If the source of sound be stationary and the observer moves towards it then the frequency appears to increase. When he moves away from the stationary source, the frequency appears to decrease.

When both the source and the observer mure relative to one another, then also there is change of frequency. Due to velocity of the wind, there is also further change in frequency.

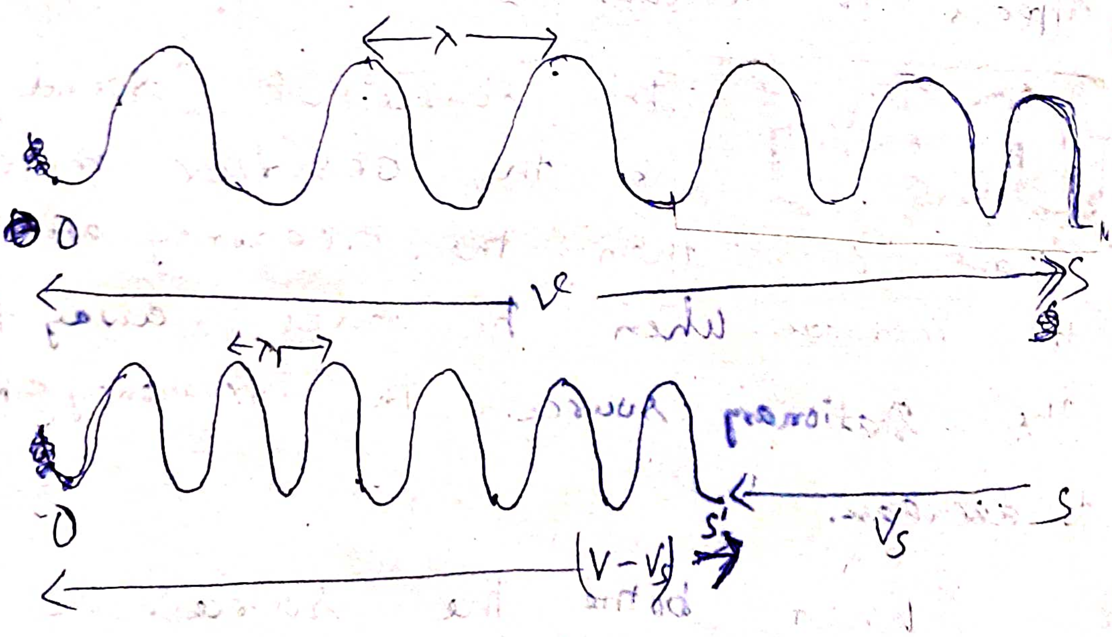
Expression for the apparent frequency

Case-1 Source in motion, Observer at rest

If the source and the Observer are both at rest, all the waves emitted by the source during one second will occupy a distance v units. Hence, normal wavelength is given by $\lambda = \frac{v}{n}$. where

n = actual frequency of the horn attach to the source.

(a) Source moving towards the stationary observer



If the source of sound will move towards the stationary observer with a speed V_s units, then all the n waves emitted by the source will occupy a distance $(V - V_s)$

as shown in the diagram. Then, wave length decreases to λ_1.

$$\therefore \lambda_1 = \frac{V - V_s}{n}$$ ~~but~~

~~by~~ but $V = n_1 \lambda_1$

$$\Rightarrow n_1 = \frac{V}{\lambda_1} = \frac{V}{\frac{V-V_s}{n}}$$

$$= \frac{V.n}{V-V_s}$$

$$\Rightarrow \boxed{n_1 = n \cdot \left(\frac{V}{V-V_s}\right)} \quad \text{——— (i)}$$

Obviously $n_1 > n$.

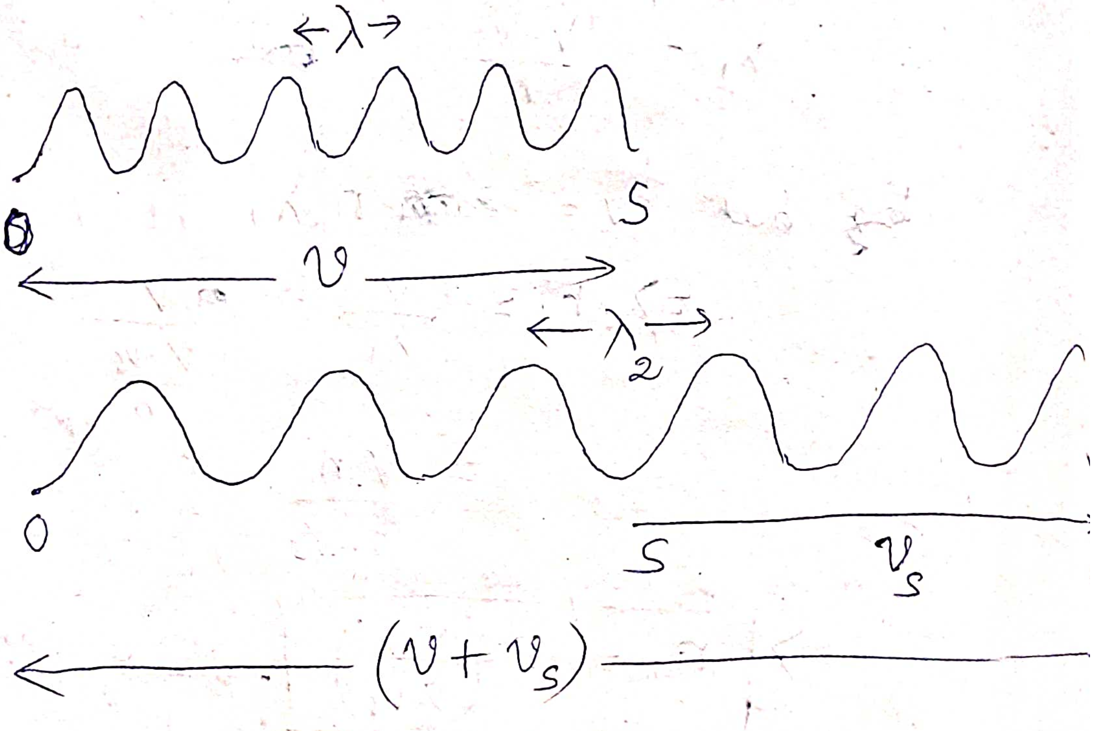
i.e frequency of the sound ~~of~~ an of an approaching train or car appears to be higher than the actual frequency.

(b) Source moving away from the stationary observer

If the source is moving away with a speed V_s units, and observer is at rest, then all the n waves emitted by the source during one second will occupy distance $(V+V_s)$ units. Hence, ~~___~~ wavelength increases given by $\lambda = \frac{V+V_s}{n}$

where n = actual frequency of the

horn attach to the source



$$\lambda_2 = \frac{v + v_s}{n}$$

but $v = n_2 \lambda_2$

$$\Rightarrow n_2 = \frac{v}{\lambda_2} = \frac{v}{\frac{v+v_s}{n}} = \frac{vn}{v+v_s}$$

$$\Rightarrow \boxed{n_2 = n\left(\frac{v}{v+v_s}\right)} \text{ —— (ii)}$$

Obviously $n_2 < n$

i.e frequency of the sound of moving away train or car appears to be lower than actual frequency.

Case - II
Source is Stationary and observer in motion

(a) Observer is moving towards the stationary source. In this case, there is no change in the wavelength of the waves emitted by the stationary source. But, the observer receives some more number of waves due to his motion towards the source of sound.

If the speed of the observer be V_0, then he will receive $\frac{V_0}{\lambda}$ number of extra waves per seconds.

$$\therefore n_3 = n + \frac{V_0}{\lambda}$$

$$= n + \frac{V_0}{\frac{V}{n}}$$

$$= n + \frac{nV_0}{V}$$

$$= n\left(1 + \frac{V_0}{V}\right)$$

$$= n\left(\frac{V + V_0}{V}\right)$$

$$\boxed{n_3 = n \cdot \left(\frac{V + V_0}{V}\right)} \quad \text{(iv)}$$

Obviously $n_3 > n$ i.e frequency

appears to increase when the observer moves towards a stationary source of sound.

(b) <u>Observer is moving away from the stationary source</u>

Observer is moving away from the stationary wave. gn this Case, there is no change in the wave length of the waves emitted by the stationary source. But, the observer Looses some waves due to his motion. away from the source of sound

If the speed of the observer be V_0, then he will Looses ~~receive~~ $\frac{V_0}{\lambda}$ number of waves per sec.

$$n_u = n - \frac{V_0}{\lambda}$$

$$= n - \frac{V_0}{\frac{V}{n}}$$

$$= n - \frac{n V_0}{V}$$

$$= n\left(1 - \frac{V_0}{V}\right)$$

$$= n\left(\frac{V - V_0}{V}\right)$$

$$\boxed{n_4 = n\left(\frac{V - V_0}{V}\right)} \quad \text{———— (iv)}$$

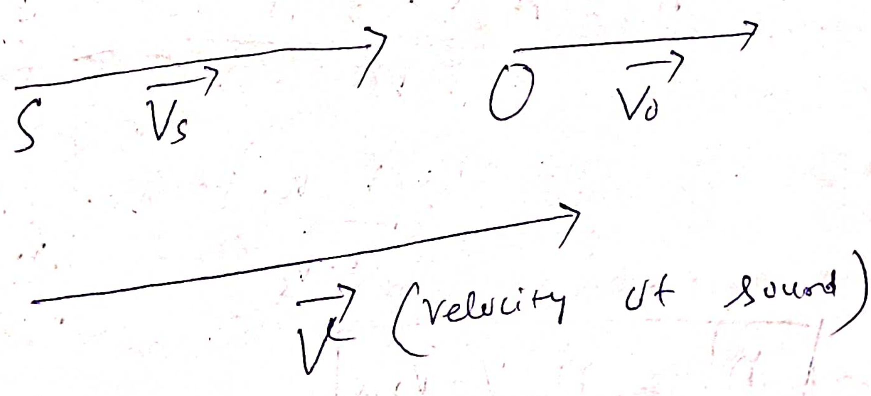
Obviously $n_4 < n$ i.e. frequency appears to decrease when observer moves away from stationary source of sound.

Case - III

Source and observer both are in ~~the~~ motion

(a) Source is moving behind the observer in motion.

In this case, $\vec{V_s}$ ~~vector~~ and $\vec{V_0}$ are having the same direction as ~~as~~ that of $\vec{V}$ (velocity of sound)



Lets first of all imagine the observer to be at rest and the source is moving towards it with a speed V_s then, the frequency will change to n_1 given by eq^n (ii)

$$n_1 = n \cdot \frac{V}{V - V_s} \qquad \text{———— (a)}$$

Now the source can be imagined to be stationary emitting sound of frequency n_1 and ~~how~~ the observer is moving away from it with a speed V_o

From eqn (iv) the net changed frequency is given by

$$n' = n_1 \cdot \frac{V - V_o}{V} \qquad \text{———— (b)}$$

using eqn (a) in eqn (b)

$$n' = n \cdot \frac{\cancel{V}}{V - V_s} \cdot \frac{V - V_o}{\cancel{V}}$$

$$= n \left(\frac{V - V_o}{V - V_s} \right)$$

Remember velocity of sound always from source towards observer

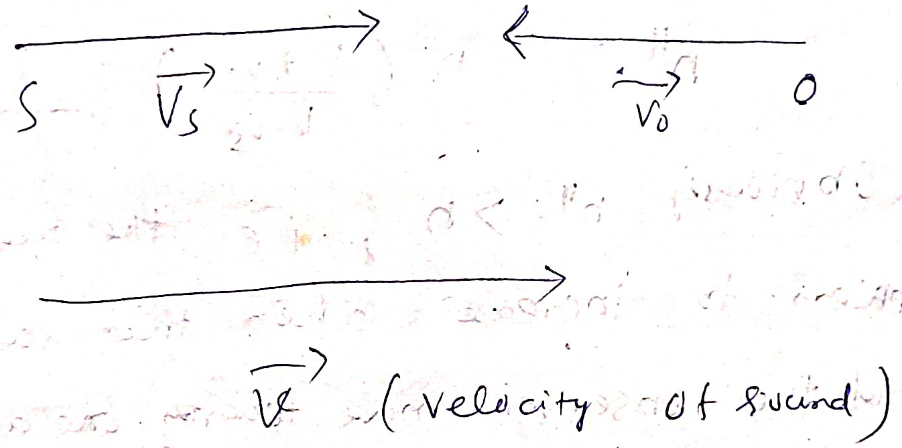
Imp $$\boxed{n' = n \left(\frac{V - V_o}{V - V_s} \right)} \qquad \text{———— (5)}$$

(b) The source and the observer are moving towards one another

~~Source is ho~~ In this case, $\vec{V_s}$ and $\vec{V_o}$ are having opposite direction. ~~as that of~~ $\vec{V}$

(velocity of sound) is same direction of $\vec{V_s}$.

Let's first of all imagine the observer to be at rest and the source is moving towards it with a speed V_s then, the frequency will change to n'',



given by eqn, $n_1 = n \cdot \frac{V}{V - V_s}$ — (a)

~~Now source is imagained to be emitting sound ~~breathing~~ towards to the observer ~~and~~ and observer moving with velocity V_s towards the source with velocity V_0~~

Now source can be imagined to be stationary emitting sound of frequency n_1 and the observer is moving towards it with a speed V_0. From eqn (iii) the

Net change of frequency is given by

$$n'' = n_1 \left(\frac{V + V_0}{V} \right) \text{ —— (b)}$$

using eqn (a) eqn (b) ⇒, we get

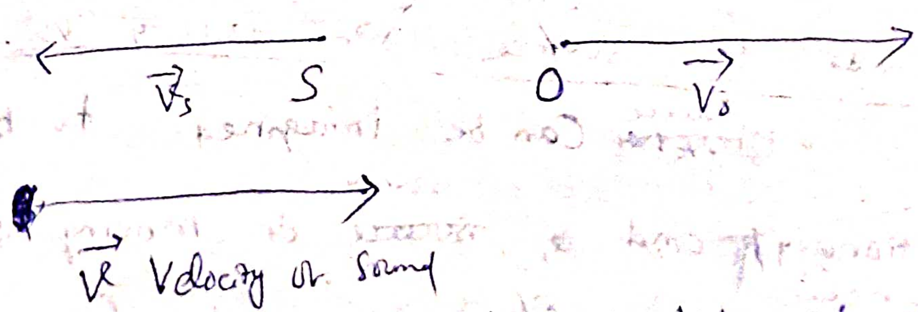
$$n'' = \frac{n V}{V - V_s} \left(\frac{V + V_0}{V} \right)$$

$$n'' = n \left(\frac{V + V_0}{V - V_s} \right) \text{ —— (6)}$$

Obviously $n'' > n$, i.e. the frequency appears to increase when the source and the observer move towards one another.

(c) Source and observer moving away from one another

In this case $\vec{V_s}$ and $\vec{V_0}$ are having opposite direction, velocity of sound is same direction of $\vec{V_s}$



Lets first imagine observer to be at rest and source is moving away with a speed V_s, then frequency will be changed to n_2 given by the eqⁿ (ii)

$$n_2 = n \cdot \frac{V}{V+V_s} \quad \text{——— (a)}$$

Now the source can be imagined to be stationary emitting sound of frequency n_2 and the observer moving away from it with a speed V_0. From eqⁿ (iv) the net changed frequency is given by

$$n''' = n_2 \left(\frac{V-V_0}{V}\right) \quad \text{——— (b)}$$

using eqⁿ (a) in eqⁿ (b), we get

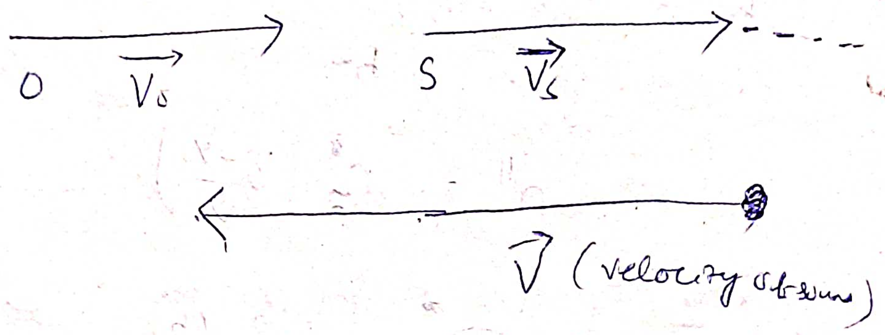
$$n''' = n \cdot \frac{\cancel{V}}{V+V_s} \left(\frac{V-V_0}{\cancel{V}}\right)$$

$$= n \left(\frac{V-V_0}{V+V_s}\right) \quad \text{——— (7)}$$

Obviously $n''' < n$, i.e. frequency appears to decrease when source and observer move away from one another

(d) Souṛce and Observer moving along same direction with ~~source~~ source of sound moving in front of the observer

In this case $\vec{S}$ (Source) and $\vec{O}$ (observer) are moving with same direction as that of $\vec{v}$ (velocity of sound)



Lets first imagine observer to be rest and the source moving away with a ~~velocity~~ speed $\vec{V_s}$, then frequency will change to n_2 given by eq^n

$$n_2 = n \cdot \frac{v}{v+v_s} \quad \text{——— (a)}$$

Now source can be imagined to be stationary emitting sound of frequency n_2 and observer is moving towards to it with a velocity V_o

From eq^n (iii), the net changed frequency is given by

$$n'''' = n_2 \left(\frac{V+V_o}{V} \right) \quad \text{———} (b)$$

using eq^n (a) in eq^n (b), we get

$$n'''' = n \frac{\cancel{V}}{V+V_s} \times \frac{(V+V_o)}{\cancel{V}}$$

$$n'''' = n \left(\frac{V+V_o}{V+V_s} \right) \quad \text{———} (8)$$

Case-4 : Medium in motion along with source and observer

Suppose wind is blowing in the same direction as that of the sound then, the effective velocity of sound will become $V+w$, so that eq (5) gets changed to

$$n'_1 = n \left(\frac{V+w-V_o}{V+w-V_s} \right) \quad \text{—} (9)$$

If wind blows in the direction opposite that of the sound, then the effective velocity becomes $V-w$ and eq^n (5) becomes

$$n'_2 = n \left(\frac{V-w-V_o}{V-w-V_s} \right) \quad \text{—} (10)$$

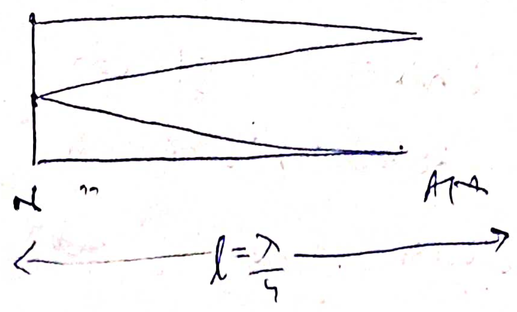
If $V_o = V_s$ as in the case of a passenger in train, then

$$n_1' = n = n_2'$$

i.e Doppler effect will not be observed.

Doubt Clear Problems

377 range
16 प्रश्न

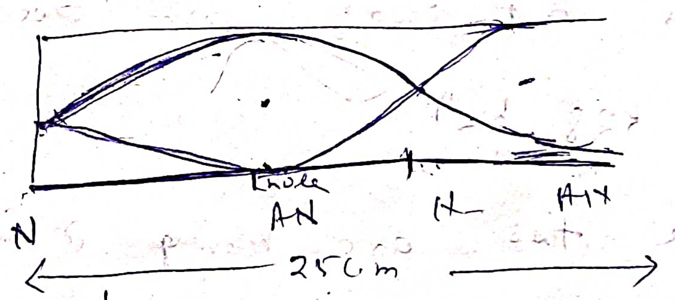


$v = 340m/sec, \quad n = 340hz$

$$\lambda = \frac{v}{n} = \frac{340}{340} = 1m = 100cm.$$

$$l = \frac{\lambda}{4} = \frac{100}{4} = 25cm.$$

When a hole is opened 8.33 cm from close end then there must be antinode so figure will be



$$8.33 = 8\frac{1}{3} = \frac{25}{3}$$

$$l = \frac{3\lambda}{4} \Rightarrow \lambda = \frac{4l}{3} = \frac{4\times 25}{3} = \frac{100}{3}$$

$$v = n'\lambda'$$

$$\Rightarrow 34000 = n' \times \frac{100}{3}$$

$$\Rightarrow n' = \frac{340\cancel{00}\times 3}{\cancel{100}} = 1020 \text{ per second.}$$

Problem

Q. The whistle of an engine moving at 30 mile/hour is heard by a motorist driving at 15 mile/hour He estimates the pitch to be 500. what must be the actual frequency of the whistle when

(a) The two are moving in opposite directions but approaching each other.

Ans:- (473 hz)

(b) The two are moving in opposite directions but away from one another.

(Ans : 528 hz)

(c) The two are moving in the same directions, motorist being behind the engine

(Ans : 509 hz)

(d) The two are moving in the same direction, motorist being ahead of the engine.

(Ans : 491 hz)

velocity of sound - 1200 ft/sec

15 mile/hour → 22 ft/sec

Doppler effect in light

It is commonly believed that stars are stationary. But, evidence shows that stars are also in motion. When the light emitted by the stars are analysed by grating spectrometer it is found that the wavelength of ~~stem~~ some of the lines are higher than the corresponding lines found on the earth. For some stars, the wavelengths are less than the corresponding lines found on the earth. This fact can be explained with the help of Doppler effect. But we have to assume that stars are in motion

Case - 1

Star moving towards the earth

Suppose the wavelength of the light emitted by the star is λ when it is at rest. The frequency of light be ν

$$\therefore \quad c = \nu \lambda$$

where c = velocity of light in vacuum.

$= 3 \times 10^8$ meter / sec.

These ν waves will occupy a distance C units in 1 sec.

If the star will move towards the earth with a speed V_s, these ν waves will occupy a distance $C - V_s$.

Then wave length of the light waves will decrease to λ_1 given by

$$\lambda_1 = \frac{\text{Distance}}{\text{Number}}$$

$$= \frac{C - V_s}{\nu}$$

$$= \frac{C - V_s}{\frac{C}{\lambda}}$$

$$= \lambda \left(\frac{C - V_s}{C} \right)$$

$$= \lambda \left(1 - \frac{V_s}{C} \right)$$

$$= \lambda - \frac{\lambda V_s}{C}$$

$$\Rightarrow \boxed{\Delta\lambda = \lambda - \lambda_1 = \frac{V_s \cdot \lambda}{C}}$$

Since the wave length has decreased we can say that there is a <u>blue shift</u>

Case - II

Star moving away from Earth

Suppose the wavelength of the light emitted by the star ~~is~~ is λ when it is at rest. The frequency of light by ν

$$\therefore \quad c = \nu\lambda$$

where c = velocity of light in vacuum.
$= 3 \times 10^8$ meter/sec.

These ν waves will occupy a distance c units in 1 sec.

If the star will move ~~toward~~ away the earth with a speed V_s, these ν waves will occupy a distance $c + V_s$.

Then the wavelength of the light waves will increase to λ_2 given by

$$\lambda_2 = \frac{\text{Distance}}{\text{Number}}$$

$$= \frac{c + V_s}{\nu}$$

$$= \frac{c + V_s}{\frac{c}{\lambda}}$$

$$= \lambda\left(\frac{c + V_s}{c}\right)$$

$$= \lambda\left(1 + \frac{V_s}{c}\right)$$

$$\lambda_2 = \lambda + \lambda \frac{V_s}{c}$$

$$\Rightarrow \boxed{\Delta\lambda = \lambda_2 - \lambda = \frac{V_s \lambda}{c}}$$

Since wavelength has increased we can say that there is ~~Red shift~~.

Problem

A spectrum line of wavelength 4000 A° in the spectrum of light from a star is found to be displaced from the normal position towards red end of the spectrum by an amount 10^{-8} cm, what velocity of the star in the line of sight would account for this?

(Ans ÷ 75 Km/sec, moving away from the earth)

Ans

For red shift we know that

$$\Delta\lambda = \frac{V_s \cdot \lambda}{c}$$

$$\Rightarrow 10^{-8}\,\text{cm} = \frac{V_s \cdot 4000 \times 10^{-8}\,\text{cm}}{3\times10^{8}\,\text{m/sec}}$$

$$\Rightarrow V_s = \frac{10^{-8} \times 3 \times 10^{8}}{4000 \times 10^{-8}} = \frac{3}{4} \times \frac{10^{8}}{10^{3}}\ 10^{5}$$

$$= .75 \times 10^{5}\ \text{meter/sec}$$

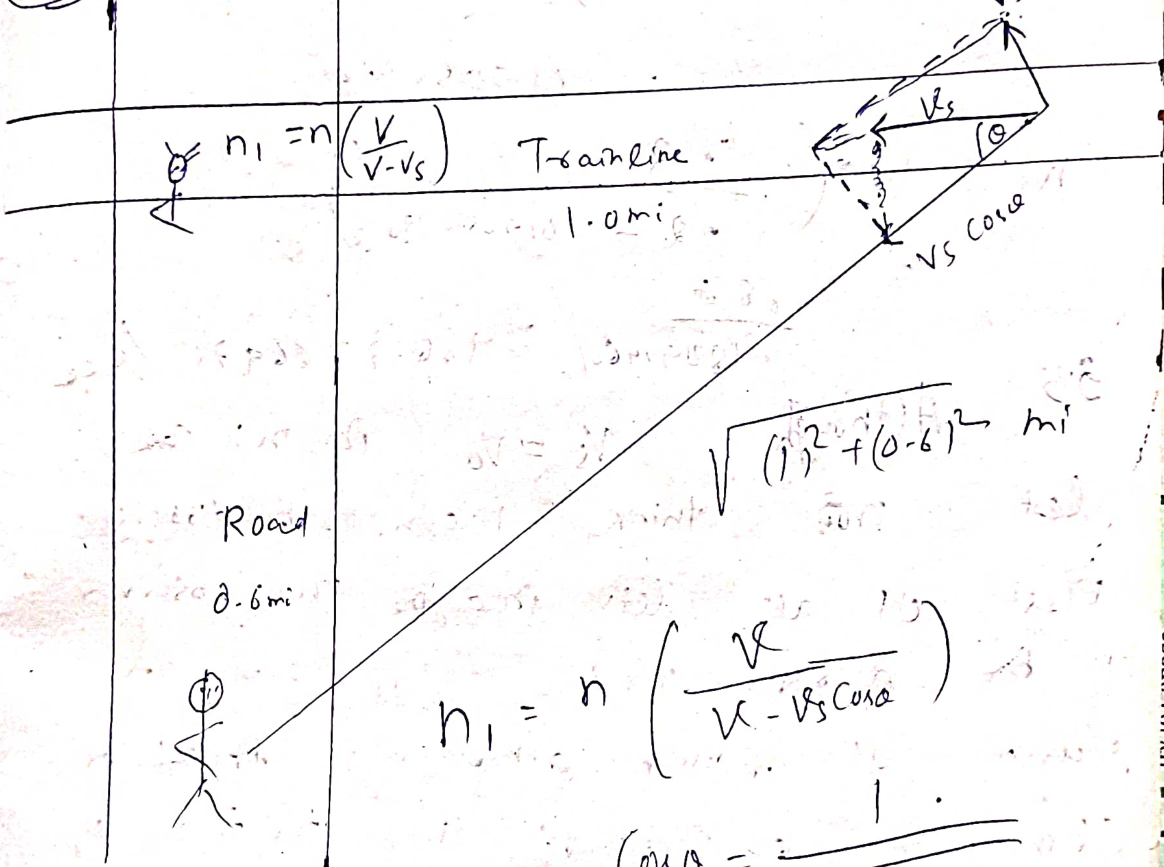
$$= \cancel{75 \times \overset{10^2}{\cancel{100}}\ Km/sec}$$

$$= 75 \times 10^3 \text{ meters/sec}$$

$$= 75 \text{ Km/sec}, m$$

Since spectrum line is displaced to red end, wave length has increased; so the star moved away from the earth.

33.



$$n_1 = n\left(\frac{V}{V - V_s\cos\theta}\right)$$

$$\cos\theta = \frac{1}{\sqrt{1.36}}$$

$$V_s = 80 \text{ mile/hour}$$

$$= \frac{8\cancel{0} \text{ mile}}{360\cancel{0}} = \frac{1}{45} \text{ mile/sec}$$

$\cancel{V = 1 \text{ mile}}$ $V = 0.2 \text{ mi/sec}$

$$n_1 = n\left(\frac{V}{V - V_s}\right) = 440\left(\frac{0.2}{0.2 - \frac{1}{45}}\right)$$

$$= 440\left(\frac{0.2 \times 45}{9-1}\right) = 55 \times \frac{9}{\cancel{05}} = 495 \text{ Hz}$$

(b) Case $= \frac{1}{\sqrt{1.36}} = \frac{1}{1.166190319} = .857492925$ ~~.8955602~~

.857492925 ~~.8955606~~

V_s Case $= \frac{1}{45} \times$

$= .019055398$

$$n_1 = 440\left(\frac{.2}{.2 - .019055398}\right)$$

$$= \frac{88}{.180944601} = 486.3366975 \text{ /sec}$$

35. Although $V_s = V_0$ in this case, let now think them to be different. First of all lets imagine the observer to be at rest on the cliff and the source of sound approaching ~~speed the~~ cliff with a speed V_s then the frequency will change to,

$$n_1 = n\left(\frac{V}{V - V_s}\right)$$

Now, the source of sound can be imagined to be on the cliff, emitting a sound of frequency n_1 which is approached by the observer with a speed V_0 then eqn (3) can be used to give $n' = n_1\left(\frac{V + V_0}{V}\right)$.

$$n' = n \cdot \frac{V}{V - V_s}\left(\frac{V + V_0}{V}\right)$$

$$= \frac{n(V + V_0)}{(V - V_s)}$$

Here $n = 440\,Hz$

$n' = 495\,hz$

$V_0 = V_s$

$$\cancel{495}^{\cancel{99}\,9} = \cancel{440}^{\cancel{88}\,8} \frac{(V + V_s)}{(V - V_s)}$$

$$9V - 9V_s = 8V + 8V_s$$

$$\Rightarrow V = 17 V_s$$

$$\Rightarrow V_s = \frac{V}{17}$$

If $v = 340$ m/sec, then

$$V_s = \frac{340}{17} = 20 \text{ m/sec.}$$

Problem

—— o ——

1. A person is standing at a level crossing observes that the frequency of an approaching train change in the ratio 6 : 5 when the train just passes him. Calculate the speed of the train.

Velocity of sound – 1100 ft/sec (Ans –

Hints : $\frac{n_1}{n_2} = \frac{6}{5}$

Ans :

$$\frac{n_1}{n_2} = \frac{6}{5}$$

$$\Rightarrow \frac{n \frac{V}{V-V_s}}{n \frac{V}{V+V_s}} = \frac{6}{5}$$

$$\Rightarrow \frac{\cancel{nV}}{V-V_s} \times \frac{V+V_s}{\cancel{nV}} = \frac{6}{5}$$

$$\Rightarrow \frac{1100+V_s}{1100-V_s} = \frac{6}{5}$$

$$\Rightarrow 5500 + 5V_s = 6600 - 6V_s$$

$$\Rightarrow 11V_s = 1100.$$

$$\Rightarrow V_s = \frac{1100}{11} = 100 \text{ ft/sec.}$$

2. What will be the speed of the car if a police ~~man~~ man detects a drop of 15%. in the pitch of its horn as it crosses him. Ans : 26.9 m/sec.

$V = 332$ m/sec.

Hints : $\frac{n_1}{n_2} = \frac{100}{85} \Rightarrow \frac{n\left(\frac{V}{V-V_s}\right)}{n\left(\frac{V}{V+V_s}\right)} = \frac{100}{85}$

$$\cancel{\frac{n_1}{n_2}} = \cancel{\frac{20}{17}}$$

$$\Rightarrow \frac{V+V_S}{V-V_S} = \frac{20}{17}$$

$$\Rightarrow \frac{332+V_S}{332-V_S} = \frac{20}{17}$$

$$\Rightarrow 5644 + 17V_S = 6640 - 20V_S$$

$$\Rightarrow 37V_S = \begin{array}{r} 6640 \\ -5644 \\ \hline 996 \end{array} = 996$$

$$\Rightarrow V_S = \frac{996}{37} = 26.9 \ m/sec$$

3. Calculate the speed of a tram when its frequency appears to be
(a) doubled of the actual frequency
(b) reduced to half of the original frequency? $\left(V_S = \frac{V}{2},\ V_S = V\right)$

Ans:
When tram approaches the observer at rest the frequency increases

$$\therefore n_1 = 2n$$

$$\Rightarrow \text{but } n_1 = \frac{nV}{V-V_S} = 2n$$

$$\frac{V}{V-V_s} = 2$$

$$\Rightarrow V = 2V - 2V_s$$

$$\Rightarrow V = 2V_s$$

$$\Rightarrow V_s = \frac{V}{2}$$

(b) when train move away the the Observer the frequency decrease.

$$n_1 = \frac{1}{2} n_0$$

$$\Rightarrow \frac{\cancel{n}V}{V+V_s} = \frac{\cancel{n}}{2}$$

$$\Rightarrow V+V_s = 2V$$

$$\Rightarrow \cancel{V_s =}$$

$$\Rightarrow V_s = V$$

4. An Observer at on a railway platform Observed a train passing through a station at a speed b. Show that the frequency of the whistle changes by $\frac{2nVb}{V^2-b^2}$

Ans: Change in frequency $= \Delta n$

$$= n_1 - n_2$$

$$\Delta n = \frac{nv}{V \mp b} - \frac{nv}{V+b}$$

$$= \cancel{nv\left(\frac{1}{1}\right)}$$

$$= nv\left(\frac{1}{V-b} - \frac{1}{V+b}\right)$$

$$= nv\left(\frac{\cancel{V}+b-\cancel{V}+b}{V^2-b^2}\right)$$

$$= \frac{2nvb}{V^2-b^2}$$

∴ Change in frequency $\frac{2nvb}{V^2-b^2}$

5. Two aeroplanes pass each other in opposite directions and one of them is blowing a whistle of frequency 540 Hz. Calculate the of frequency heard in the frequency of the note other aeroplane

(a) before } they have passing each other
(b) After }

velocity of either of the aeroplane is 540 Km/hour and velocity of sound = 350 m/sec

Ans: 1350 Hz; 216 Hz.

$540\ \text{km/hour} = \frac{540\times1000}{3600} = \frac{600}{4} = 150\ \text{m/sec}$

$$n' = n\left(\frac{V+V_0}{V-V_s}\right)$$

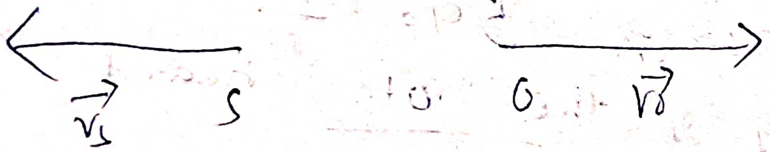
$$= 540\left(\frac{350+150}{350-150}\right)$$

$$= \cancel{540}\left(\cancel{\frac{482}{482}}\right)$$

$$= \overset{270}{\cancel{540}} \times \frac{\cancel{500}}{\cancel{200}}$$

$$= 1350\ \text{sec}^{-1}$$

(ii)



$$n'' = n\left(\frac{V-V_0}{V+V_s}\right)$$

$$= 540\left(\frac{350-150}{350+150}\right)$$

$$= \overset{108}{\cancel{540}} \times \frac{200}{\cancel{500}}$$

$$= 216\ \text{sec}^{-1}$$

6. V_s = 30 mile/hour = 44 feet/sec

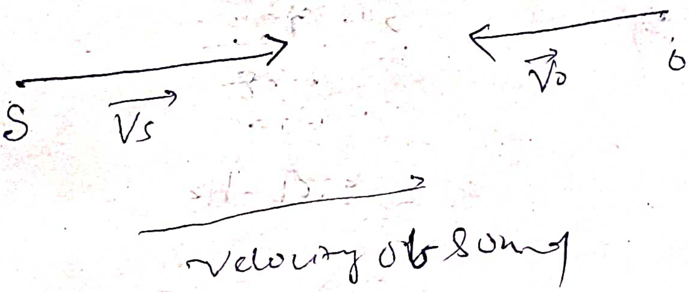
V_o = 15 mile/hour = 22 feet/sec.

$$\left(\because \quad 15 \frac{mile}{hour} = 22 \frac{feet}{sec} \qquad 30 \frac{mile}{hour} = 44 \text{ feet/sec} \right)$$

~~When~~ The motorist estimate the pitch to be 500 Hz ∴

It must be the apparent frequency n' (Say).

(a)



$$n' = n \left(\frac{V + V_o}{V - V_s} \right)$$

$$500 = n \left(\frac{1200 + 22}{1200 - 44} \right)$$

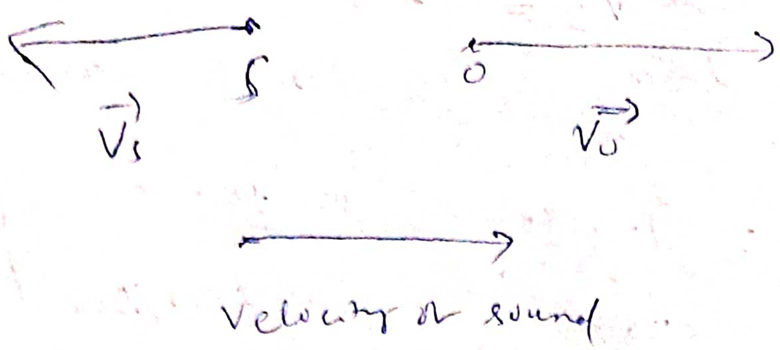
$$= n \left(\frac{\cancel{1222}}{\cancel{1156}} \right) \frac{611}{578}$$

$$\Rightarrow n = \frac{500 \times 578}{611}$$

$$= 472.99$$

$$= 473 \text{ Hz}$$

(b)



$$n' = n\left(\frac{V - V_0}{V + V_s}\right)$$

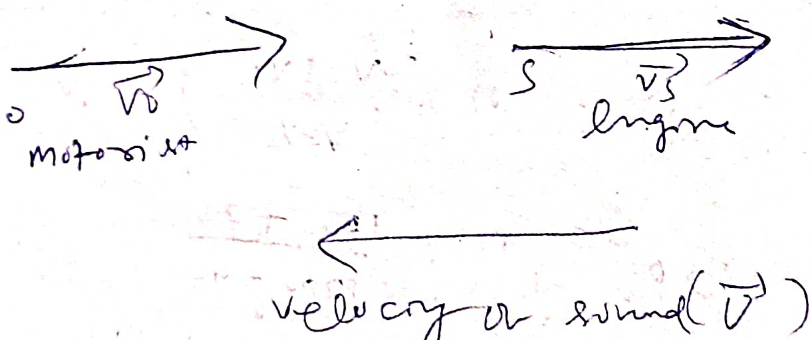
$$\Rightarrow 500 = n\left(\frac{1200 - 22}{1200 + 44}\right)$$

$$= n\left(\frac{1178}{1244}\right)$$

$$\Rightarrow n = \frac{500 \times \cancel{1244}^{622}}{\cancel{1178}_{589}}$$

$$= 528.01 \text{ Hz}$$

(c)



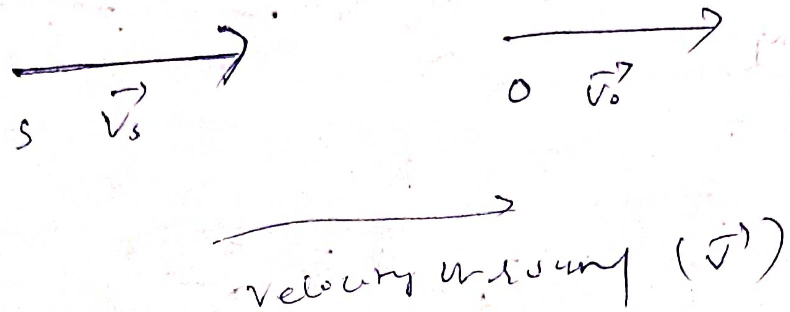
$$n' = n\left(\frac{V + V_0}{V + V_s}\right)$$

$$\Rightarrow n = \frac{n'(V + V_s)}{V + V_0} = \frac{500(1200 + 44)}{(1200 + 22)}$$

$$= \frac{500 \times \cancel{1244}^{622}}{\cancel{1222}_{611}}$$

$= 509.0016\ hz$

(d)



$$n' = n\left(\frac{V - V_o}{V \mp V_s}\right)$$

$$n = \frac{n'(V - V_s)}{V - V_o}$$

$$= \frac{500\,(1200 - 44)}{(1200 - 22)}$$

$$= \frac{500 \times \cancel{1156}\ 578}{\cancel{1178}\ 589}$$

$$= 490.66\ hz$$

— o —

7.02.2K1

Transverse Vibration of a Stretched String

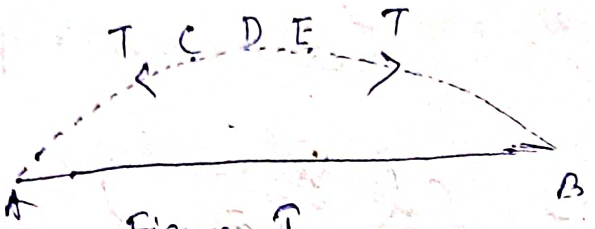


Figure-I

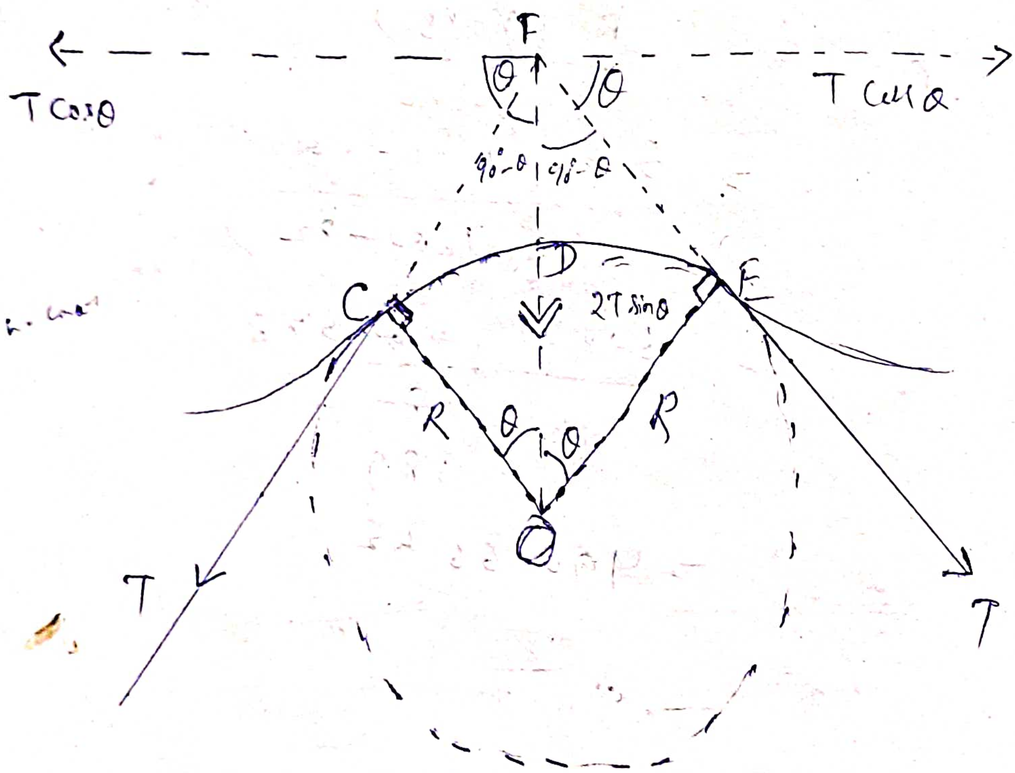


Fig-(2) Enlarged view of fig (i)

AB represents a streched string which is disturbed in a transverse direction by means of a force. After the disturbance the wire vibrates for sometime about the mean position of rest.

This is shown by the dotted curve of fig(i). CDE is a small portion of the disturbed position of the string. Tensions acts at C and E towards A and B respectively. So that the wire can be brought back to its original position.

In fig(ii), the enlarged view of the portion CDE of fig(i) has been shown. Resolving the two tensions into two rectangular components, we see that the $T\cos\theta$ components cancel each other and there is only $2T\sin\theta$ acting towards the center O. This provides the centripetal force $\frac{Mv^2}{R}$ for the string CDE.

$$\therefore \frac{mv^2}{R} = 2T\sin\theta \quad \text{———— (i)}$$

where m = mass of the string CDE
= Length of the string CDE × mass per unit length of the string. (μ)

$$2\theta \text{ in radian} = \frac{\text{Arc length CDE}}{\text{radius (R)}}$$

$\Rightarrow$ Arc length CDE = $2\theta \cdot R$

Since CDE is a small length Considered the angle 2θ is also small.
Hence $\sin\theta \simeq \theta$ approximation can be used.

∴ Eqn (i) becomes

$$\frac{2\cancel{R}\theta \cdot \mu \cdot v^2}{\cancel{R}} = \cancel{2}T\cancel{\theta}$$

where μ = mass per unit length

$$\Rightarrow v^2 = \frac{T}{\mu}$$

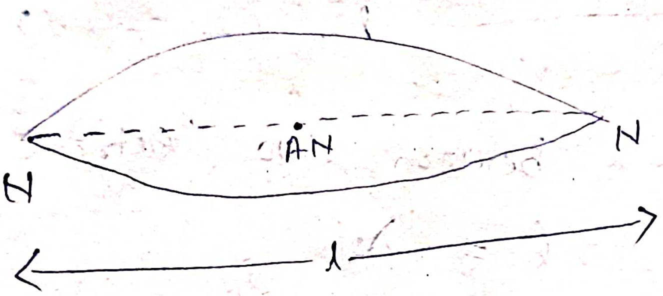
$$\Rightarrow \boxed{v = \sqrt{\frac{T}{\mu}}} \quad \text{—(ii)}$$

Eqn (ii) gives the expression for the velocity of the transverse waves created inside the wire due to transverse vibration of the string

Modes of vibration

Due to transverse vibration of the string, transverse waves are generated inside the string which move towards the fixed end points A and B and get reflected. As a result a stationary wave is formed in the string with two nodes at A and B. With this restriction the string can vibrate in various ways.

(i) <u>Fundamental</u>



Distance between two consecutive nodes

$$= \frac{\lambda_1}{2} = l$$

$$\Rightarrow \lambda = 2l$$

But $V = n_1 \lambda_1$

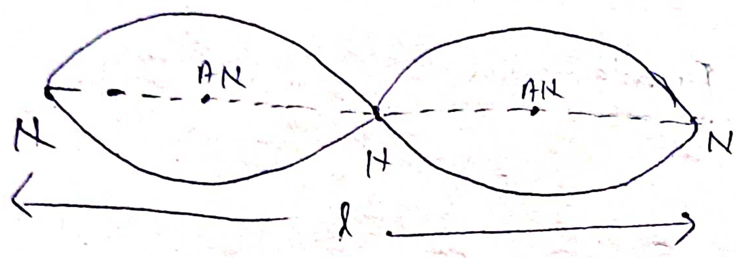
$$\Rightarrow n_1 = \frac{V}{\lambda_1} = \frac{V}{2l}$$

This is called <u>fundamental frequency</u>.

$$\boxed{n_1 = \frac{1}{2l}\sqrt{\frac{T}{\mu}}}$$

(2.) 1st overtone

In addition two nodes at the two ends, there is one node at the mid point.



Distance between two extreme nodes

$$= l = \lambda_2$$

But $v = n_2 \lambda_2$

$$\Rightarrow n_2 = \frac{v}{\lambda_2} = \frac{v}{l} = 2 \cdot \frac{v}{2l}$$

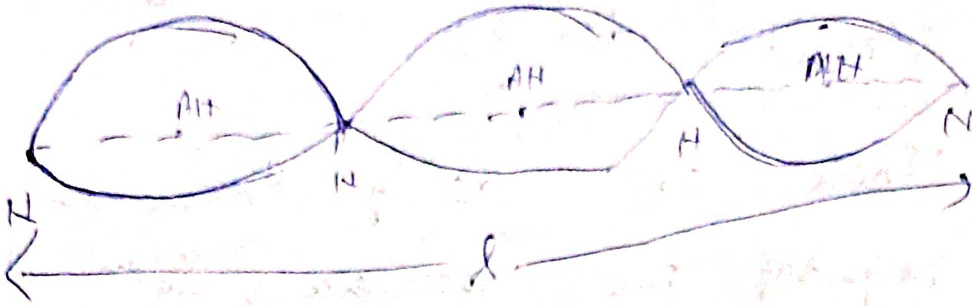
Thus, frequency of the first overtone is double of fundamental frequency.

Hence This is called 2nd harmonic.

$$\therefore n_2 = \frac{1}{l} \sqrt{\frac{T}{M}}$$

(3). 2nd overtone

In addition two nodes at the two ends, there are two nodes at the middle region of the wire as shown in the figure



Distance between two extreme nodes

$$= l = \frac{3\lambda_3}{2}$$

$$\Rightarrow \lambda_3 = \frac{2l}{3}$$

But $v = n_3 \lambda_3$

$$\Rightarrow n_3 = \frac{v}{\lambda_3} = \frac{v}{\frac{2l}{3}} = 3 \cdot \frac{v}{2l}$$

Thus the frequency of 2nd overtone is 3 times of fundamental frequency.

Hence this is called 3rd harmonic.

$$\therefore n_3 = \frac{3}{2l} \sqrt{\frac{T}{\mu}}$$

Proceeding like this one can show that frequency is emitted by a streched string due to transverse vibration are in the

ratio 1 : 2 : 3 : 4 : 5 - - - - - - -

i.e both even and odd harmonics are present

Imp

Laws Of transverse vibration Of a Stretched String

There are mainly three laws regarding the transverse vibration of a stretched string.

(1) Law of length.

The frequencies emitted by stretched string due to transverse vibration are inversely proportional to the length of the string when tension and mass per unit length of the string are kept constants.

$$\therefore n \propto \frac{1}{l}$$, when T and M are kept constants.

(2) Law Of tension

The frequencies emitted by stretched string due to transverse vibration are directly proportional to the square root of the tension in the string when length of the string and mass per unit length of the string are kept constants.

$\therefore n \propto \sqrt{T}$, when l and M are Kept constants.

(3) Law of mass per unit length

The frequency emitted by stretched string due to transverse vibration are inversely proportional to the square root of mass per unit length when length of the string and tension in the string are kept constants.

$$\therefore n \propto \frac{1}{\sqrt{M}}, \text{ when } T \text{ and } l \text{ are kept constants.}$$

The two more laws follow from the third law like

(a) law of diameter ($n \propto \frac{1}{d}$)

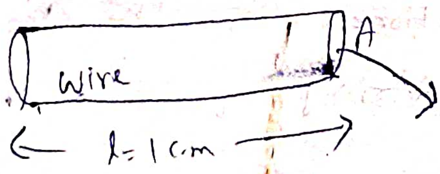
(b) law of density ($n \propto \frac{1}{\sqrt{\rho}}$)

Derivation of law of diameter and density

Lets consider 1 cm length of the wire.

Its volume $= \frac{\pi d^2}{4} \cdot 1$ cm^3

where d = diameter of the wire



$= \pi r^2 = \frac{\pi d^2}{4}$

If f be the density of the material of the wire, then

Mass of the string = volume × density

$$= \frac{\pi d^2}{4} \times f$$

$$= \mu \quad (\text{by defn})$$

All the frequencies emitted by the stretched string can be written as

$$n = \frac{p}{2l}\sqrt{\frac{T}{\mu}} \quad (\text{where } p = 1, 2, 3, 4 \ldots)$$

$$= \frac{p}{2l}\sqrt{\frac{T}{\frac{\pi d^2}{4} \cdot f}}$$

$$= \frac{p}{ld}\sqrt{\frac{T}{\pi f}}$$

Thus $n \propto \frac{1}{d}$ when l, T, f are kept constants.

$n \propto \frac{1}{\sqrt{f}}$ when l, T, d are kept constants.

Defn

Law of diameter

The frequencies emitted by stretched string due to transverse vibration are inversely proportional to the diameter of the ~~wire~~ string when length of the string, tension in the string, and density are kept constants.

$n \propto \frac{1}{d}$ when l, T, f are kept constants.

Law of density :-

The frequencies emitted by stretched string due to transverse vibration are inversely proportional to the square of density, when length of string, tension in the string and diameter of the string are kept constants.

$n \propto \frac{1}{\sqrt{\rho}}$, when l, T, d are kept constants.

—o—

Problems

1. A string vibrates 100 times / sec. Its length is doubled and its tension is altered until it makes 150 vibration / sec. What is the relation of the new tension to the original

(Ans: $T_2 : T_1 = 9 : 1$)

2. When the wire of the sonometer is 73 cm long, it is in tune with a tuning fork. On shortening wire by 5 mm, it makes 3 beats

per sec with the fork. What is the frequency of the fork?

(Ans: 435 Hz)

Hints: $n = \frac{1}{2\times 73}\sqrt{\frac{T}{m}}$

$n+3 = \frac{1}{2\times 72.5}\sqrt{\frac{T}{m}}$

(3) A stretched wire under tension of 1 kg weight ~~is~~ is in unison with fork of frequency 320/sec. What alternation in tension would make the wire vibrate in unison with fork of frequency 256?

(Ans: $\frac{9}{25}$ kg weight)

Hints:

$320 = \frac{1}{2l}\sqrt{\frac{1\times 9.8}{M}}$

$256 = \frac{1}{2l}\sqrt{\frac{x\times 9.8}{M}}$

4. On increasing the stretching weight of a given string by 2.5 kg, the frequency is altered in the ratio of 2 : 3. Find the

original stretching weight.

Ans: (2 kg)

5/ 2 steel wires have length in the ratio 1:2, tensions in the ratio 1:4 and diameters in a ratio 1:3. Compare the frequencies emitted by the wires.

(Ans - 3 : 1)

—o—

5: We know that

$$n = \frac{P}{ld}\sqrt{\frac{T}{\pi \rho}}$$

For the first wire

$$n_1 = \frac{P_1}{l_1 d_1}\sqrt{\frac{T_1}{\pi \rho_1}}$$

$$n_2 = \frac{P_2}{l_2 d_2}\sqrt{\frac{T_2}{\pi \rho_2}}$$

Lets take $P_1 = P_2$, $\rho_1 = \rho_2$

Dividing eqn (i), by (ii), we get

$$\frac{n_1}{n_2} = \frac{l_2 d_2}{l_1 d_1} \cdot \sqrt{\frac{T_1}{T_2} \cdot \frac{\rho_2}{\rho_1}}$$

$$\Rightarrow \frac{n_1}{n_2} = \frac{2\cancel{l_1} \cdot 3\cancel{d_1}}{\cancel{l_1} \cdot \cancel{d_1}} \sqrt{\frac{\cancel{T_1}}{4\cancel{T_1}} \cdot 1}$$

$\frac{n_1}{n_2} = \cancel{2}.6 \times \frac{1}{2} = 3:1$

9.

we know $n = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$

let $n_1 = \frac{1}{2l_1}\sqrt{\frac{T_1}{\mu}}$

$n_2 = \frac{1}{2l_2}\sqrt{\frac{T_2}{\mu}}$

$\frac{n_1}{n_2} = \frac{1}{\cancel{2}l_1} \times \frac{\sqrt{T_1}}{\cancel{\sqrt{\mu}}} \times \frac{\cancel{2}l_2}{1} \times \frac{\cancel{\sqrt{\mu}}}{\sqrt{T_2}}$

$= \frac{\cancel{l_2}}{\cancel{l_1}}\sqrt{\frac{T_1}{T_2}}$

$\Rightarrow 2:3 = \cancel{\emptyset}\sqrt{\frac{m.\cancel{g}}{(m+2.5)\cancel{g}}}$

$\Rightarrow \frac{\cancel{2}\,4}{9} = \frac{m}{m+2.5}$

$\Rightarrow 4m + 10 = 9m$

$\Rightarrow \cancel{5}m = 10$

$\Rightarrow m = \frac{10}{5} = 2\,Kg$

3. ~~T = 1 Kg~~

Let

1. $n_1 = 100$ /sec

original Tension $= T_1$, Length $= l_1$

$n_2 = 150$ /sec

New tension $= T_2$, length $= 2l_1$

Relat

$$n_1 = \frac{1}{2l_1}\sqrt{\frac{T_1}{\mu_1}}$$

$$n_2 = \frac{1}{2l_2}\sqrt{\frac{T_2}{\mu_2}}$$

Same string so $\mu_1 = \mu_2$

$$\frac{n_1}{n_2} = \frac{1}{\cancel{2l_1}} \times \frac{\sqrt{T_1}}{\cancel{\sqrt{\mu_1}}} \times \frac{\cancel{\sqrt{\mu_2}} \times \cancel{2l_2}}{\sqrt{T_2}}$$

$$\Rightarrow \frac{100}{150} = \frac{\sqrt{T_1}\ 2\cancel{l_1}}{\cancel{l_1} \times \sqrt{T_2}}$$

$$\Rightarrow \frac{\sqrt{T_1}}{\sqrt{T_2}} = \frac{100\ 50}{150} \times \frac{1}{2} = \frac{50}{150} = \frac{1}{3}$$

$$\Rightarrow \frac{T_1}{T_2} = 1:9$$

(Ans)

$$\Rightarrow \frac{T_2}{T_1} = 9:1$$

2. $l_1 = 73\text{ cm} = 730\text{ mm}$

$l_2 = 730 - 5 = 725\text{ mm}$

$n_2 - n_1 = 3$

$\Rightarrow \frac{1}{2l_2}\sqrt{\frac{T}{\mu}} - \frac{1}{2l_1}\sqrt{\frac{T}{\mu}} = 3$

$\Rightarrow \frac{1}{2\times 725}\sqrt{\frac{T}{\mu}} - \frac{1}{2\times 730}\sqrt{\frac{T}{\mu}} = 3$ (Tension and μ are constant)

$\Rightarrow \sqrt{\frac{T}{\mu}}\left(\frac{1}{1450} - \frac{1}{1460}\right) = 3$

$\Rightarrow \sqrt{\frac{T}{\mu}}\left(\frac{\cancel{10}\,1}{\cancel{1460\times1450}\;1450\times146}\right) = 3$

$\Rightarrow \sqrt{\frac{T}{\mu}} = 3\times1450\times146$

$\Rightarrow \cancel{\frac{T}{\mu}} =$

frequency of the fork

$= n_1 = \frac{1}{2l_1}\times\sqrt{\frac{T}{\mu}}$

$= \frac{1}{\cancel{2\times730}}\times 3\times\cancel{1450}\times\cancel{146}$

$= 435\text{ Hz}$

2. $T_1 = 1$ Kg weight

$n_1 = 320$

$n_2 = 256$/sec.

$$n_1 = \frac{1}{2l}\sqrt{\frac{T}{\mu}}, \quad n_2 = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$$

$$\Rightarrow 320 = \frac{1}{2l}\sqrt{\frac{1\times 9.8}{\mu}}, \quad \Rightarrow 256 = \frac{1}{2l}\sqrt{\frac{x\times 9.8}{\mu}}$$

$$\frac{n_1}{n_2} = \frac{\cancel{320}}{\cancel{256}} = \sqrt{\frac{9.8}{x\times 9.8}}$$

$$\Rightarrow \frac{5}{4} = \sqrt{\frac{9.8}{x\times 9.8}}$$

$$\Rightarrow \frac{25}{16} = \frac{9.8}{x\times 9.8}$$

$$\Rightarrow x = \frac{16\times \cancel{9.8}}{25\times \cancel{9.8}}$$

~~Beats and Sonometer Resonance~~

~~Ans~~ Alternation in tension

$$= 1-\frac{16}{25} = \frac{9}{25} \text{ Kg weight}$$

After all Numerical

Problems

1. If the earth were a homogeneous sphere and a straight hole were bored in it through its center, show that if a body were ~~touched~~ dropped into the hole, it ~~will~~ would execute S.H.M. Find its time period.

($T = 2\pi\sqrt{\frac{R}{g}}$)

2. 3 strings x, y and z are of equal length. These are stretched on the sonometer with tensions 27 kg, 12 kg and 12 kg respectively. If the wires have masses of 18 kg, 8 kg and 2 kg respectively, then find the ratio of the frequencies of the sound produced.

(Ans: 1:1:2)

3. The following eq^n represents a stationary wave in a medium

$$y = 5\cos\frac{2\pi x}{12}\cdot\sin 60\pi t$$

where x and y are in meter and t in sec. Find

(a) Amplitude

(b) velocity of two component waves.

(c) Distance between node and the nearest antinode.

(Ans : 2.5 m, 360 m/sec, 3m)

4) Two tuning forks A and B produce 4 beats/sec. Tuning fork A is in resonance with 30 cm of a stretched wire on a sonometer and another fork B is in unison with 25 cm of the same wire under the same tension. Find the frequency of the forks A and B.

(Ans : 20 hz, 24 hz)

5) Two tuning forks A and B are sounded together to produce 2 beats per sec. Frequency of B is 256 Hz. When fork A is loaded, the beat changes to 3 per sec. Find the frequency of the fork A.

(Ans : 254 Hz)

6. In Q.5 if fork B is loaded and the new beat is 3 per sec, what is the frequency of fork A. (Ans: 258 Hz)

7. In Q.5, if fork A is filed and the new beat is 3 per sec, what is the frequency of the fork A. (Ans: 258 Hz)

8. In Q.5, if fork B is filed and the new beat is 3 per sec, what is the frequency of the fork A. (Ans: 254 Hz).

9. An engine is approaching a tunnel surmounted by a cliff and emits a short whistle when $\frac{1}{2}$ a mile away. The echo reaches the engine after 4.5 sec. Calculate the speed of the engine. (Assume that the velocity of sound 1100 ft/sec)

~~(Ans:~~

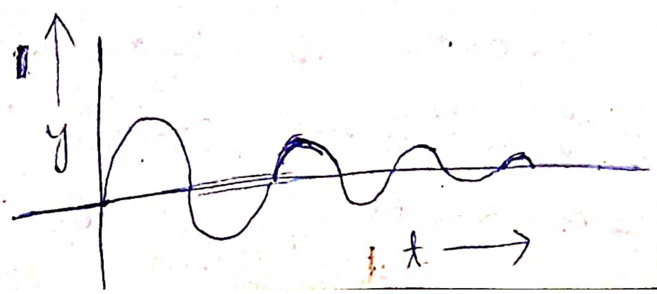
(Ans: 50 mile/hour)

10. A man standing between two parallel cliffs fires a gun. He hears the first echo after 2 secs and the next after 5 secs. What is the position between the cliffs and when will he hear the third echo, 4th eco, 5th eco ------) (Ans: He divides the distance the cliffs in the ratio 2:5, 7 sec, 9 sec, 12 sec, 14 sec, 16 sec --)

(Given: v = 1120 ft/sec)

Qualitative idea about a forced and damped Vibration

Suppose air is absent, then a simple pendulum will oscillate with same amplitude with the passage of time. If air will be present, then the amplitude gradually decreases with time and ultimately becomes zero. This type of vibration is called damped harmonic motion.



This ~~~~ happens due to the resistance of the medium. ~~~~

To overcome damping a period force has to be applied on the vibrating body. Initially the body may be vibrating with same frequency different from the frequency of the forced vibration. ~~~~ Ultimately the body vibrates with a frequency of the external force. This type of motion is called forced harmonic motion.

Beats

When two sounding bodies having frequencies nearly equal to one another be vibrated at one place, then in addition to the orginal frequencies, a frequency equal to the difference of two frequencies is also heard ~~sound~~ which we call as beat frequency.

Example: Policeman's whistle

It consists of two open tubes of slightly different lengths put side by side. As a result two frequencies are emitted which are slightly different

from one another. For example, if the two tubes emit sound of frequency 250 Hz and 276 Hz, then number of beats produced per second = 276 Hz − 250 Hz
= 26 Hz.

This can be heard upto a great distance.

Theory of Beats

Let the frequencies of two sounding bodies be n_1 and n_2 Hz. The displacement of a particle of the medium due to the waves starting from the two sounding bodies are given by

$$y_1 = A_1 \sin \omega_1 t = A_1 \sin 2\pi n_1 t \quad \text{---(i)}$$

$$y_2 = A_2 \sin \omega_2 t = A_2 \sin 2\pi n_2 t \quad \text{---(ii)}$$

From the ~~prin~~ principle of superposition, the resultant displacement of a particle is given by

$$y = y_1 + y_2 = A_1 \sin 2\pi n_1 t + A_2 \sin 2\pi n_2 t \quad \text{---(iii)}$$

Let $n_1 > n_2$, so that $n_1 - n_2 = n$ = frequency difference.

Introducing 'n' in place of n_1 by the substitution $n_1 = n_2 + n$ in eqn (3), we get

$$y = A_1 \sin 2\pi (n_2 + n) t + A_2 \sin 2\pi n_2 t$$

$$y = A_1 \sin 2\pi n_2 t \cdot \cos 2\pi n t + A_1 \cos 2\pi n_2 t \cdot \sin 2\pi n t + A_2 \sin 2\pi n_2 t$$

$$y = \sin 2\pi n_2 t \left(A_1 \cos 2\pi n t + A_2 \right) + \cos 2\pi n_2 t \left(A_1 \sin 2\pi n t \right) \quad \text{—— (4)}$$

By substituting $A \cos\alpha = A_1 \cos 2\pi n t + A_2$ —— (5)

And $A \sin\alpha = A_1 \sin 2\pi n t$ —— (6)

in eqn (4), we get

$$y = \sin 2\pi n_2 t \, A \cos\alpha + \cos 2\pi n_2 t \, A \sin\alpha$$

$$= A \left[\sin 2\pi n_2 t \cdot \cos\alpha + \cos 2\pi n_2 t \cdot \sin\alpha \right]$$

$$= A \left[\sin (2\pi n_2 t + \alpha) \right] \quad \text{—— (7)}$$

where A is effective amplitude of the resultant displacement given by

~~$A^2 = A^2 \cos^2\alpha + A$~~

$$A^2 = (A \cos\alpha)^2 + (A \sin\alpha)^2$$

$$= (A_1 \cos 2\pi n t + A_2)^2 + (A_1 \sin 2\pi n t)^2$$

$$= A_1^2 \cos^2 2\pi n t + A_2^2 + 2 A_1 . A_2 \cos 2\pi n t + A_1^2 \sin^2 2\pi n t$$

$$\therefore A^2 = A_1^2 + A_2^2 + 2 A_1 . A_2 \cos 2\pi n t \quad \text{—— (8)}$$

$$\tan\alpha = \frac{A \sin\alpha}{A \cos\alpha} = \frac{A_1 \sin 2\pi n t}{A_1 \cos 2\pi n t + A_2}$$

$$\therefore \alpha = \tan^{-1}\left(\frac{A_1 \sin 2\pi n t}{A_1 \cos 2\pi n t + A_2}\right) \quad \text{---(9)}$$

Comparing eqn (2) and (7) we see that the amplitudes are different and the resultant wave has a phase change by 'α'.

Intensity of sound is directly proportional to the square of amplitude. Thus maximum intense sound will be heard when A^2 = maximum.

~~For~~ From eqn (8), it is clearly seen that A^2 will be max^m only when

$\cos 2\pi n t$ = maximum $= 1$

$\therefore \cos 2\pi n t = \cos 2K\pi$ where $K = 0, 1, 2$ ---------

$\therefore n t = K$

or $t = \frac{K}{n} = 0, \frac{1}{n}, \frac{2}{n}, \frac{3}{n}$, --------- etc

$\therefore \Delta t$ = Time interval between two max^m sounds $= \frac{1}{n}$

$\therefore$ Number of maximum sounds heard per second $= \frac{1}{\Delta t} = \frac{1}{\left(\frac{1}{n}\right)} = n = n_1 - n_2$ = Difference of two frequencies.

Minimum sound will be produced when

A^2 is min^m.

~~Fom~~ From eq^n (8), we see that this is possible when $\cos 2\pi nt = -1$

$= \cos(2K+1)\pi$, where $K = 0, 1, 2, 3 \cdots$

$\therefore \quad 2\pi nt = (2K+1)\pi$

$\Rightarrow t = \frac{2K+1}{2n} = \frac{1}{2n}$ for $K=0$

$= \frac{3}{2n}$ for $K=1$

$= \frac{5}{2n}$ for $K=2$

$\vdots$

Δt = Time interval between two min^m sound

$= \frac{3}{2n} - \frac{1}{2n} = \frac{2}{2n} = \frac{1}{n}$

$\therefore$ Number of beats per second

= Number of min^m sounds produced per second.

$= \frac{1}{\left(\frac{1}{n}\right)} = n = n_1 - n_2$ = Difference of the individual frequencies.

Determination of unknown ~~frequency~~ frequency by method of beats

Method-1 -: By loading with little wax

For this purpose, a tuning fork of unknown frequency is to be chosen and number of beats found out. After loading with little wax, again number of beats determined. This helps in knowing the actual frequency of the second fork before loading.

Example:

Two tuning forks ~~produce~~ produce 4 beats/sec when sounded together. The frequency of one is 200 and the other is loaded with little wax, the beats stop. Find the frequency of the second fork.

(Ans : 204 Hz)

Ans:

Since number of beats/sec = Difference of two frequencies, frequency of the 2nd fork may be $200-4 = 196$ Hz or

$200+4 = 204$ Hz.

If the second fork be loaded with a little wax, then number of vibration ~~was 197~~ decreases. If the original frequency was 196 Hz, then may decrease to 190 Hz. So that number of beats per seconds will be

$$200 - 190 = 10 \text{ Hz}$$

This contradicts the question.

If the original frequency of the 2nd fork would be 204 Hz, then due to loading it is probable to have the frequency reduced to 200 Hz. Then number of beats will be zero.

~~There~~ Therefore, the original frequency of the second tuning fork = 204 Hz.

<u>Method-2. By filing a little</u>

Here also, another tuning fork of unknown frequency is necessary. Due to filing, frequency will increase (Because mass has decreased). This helps in ~~[illegible]~~ knowing the actual frequency of the second fork before filing.

Example :

Two tuning forks A and B, the frequency of B being 512, are sounded together and it is found that 5 beats are heard per second. A is filed and it is found that the beats occure at shorter intervals. Find the frequency of A. (Ans: 517 Hz)

Ans: Since the number of beats/sec = Frequency difference, the frequency A may 507 or 517 Hz.

If the original frequency of A be 507 Hz, then by filing its frequency will increase to 510 Hz (say). Number of beats made with the tuning fork

$B = 512 - 510 = 2$ Hz.

$\therefore \Delta t =$ Time interval between two consecutive maximum sounds

$= \frac{1}{2} = 0.5$ sec.

Previously it was $\frac{1}{5} = 0.2$ sec.

Thus, the time interval between two beats has increases after filing. This does not satisfy the question. Hence the original frequency of A cannot be 507 Hz.

If the original frequency of A be 517 Hz, then by filing it will increase to 520 Hz (say) so that number of beats made with B

$$= 520\ Hz - 512 = 8\ Hz$$

$\therefore \Delta t = \frac{1}{8} = 0.125$ sec. Previously it was

$\frac{1}{5} = 0.2$ sec.

Thus Δt decrease after filing. This satisfy the question.

$\therefore$ frequency of A = 517 Hz before filing.

Energy transferred by a progressive wave

When a wave moves through a medium, the particles of the medium get disturbed from their original positions. After the waves passes away they continue to vibrate simple harmonically with the same period and amplitude about their mean position of rest.

If the mass of the particle be m, then its total energy (potential and kinetic)

$$= \frac{1}{2} K A^2 = \frac{1}{2} m \omega^2 A^2 = \frac{1}{2} m (2\pi n)^2 A^2$$

$$= 2\pi^2 m n^2 A^2$$

If 1 c.c of the medium like air be considered, then total energy present in it

= Sum of the total energy all the particles present in 1 c.c

$$= 2\pi^2 (m_1 + m_2 + \cdots m_3)^2 n^2 A^2$$

My hints,

$$= 2\pi^2 \rho n^2 A^2$$

$\left(\because \rho = \frac{M}{V} \right)$

$\left(\rho = \frac{M}{1 cc} \right)$

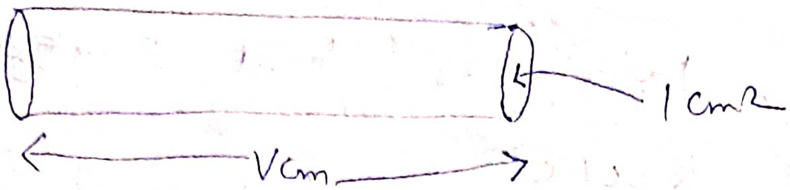
$\left(\Rightarrow M = \rho \right)$

ρ = density of air.

If the velocity of propagation of the wave be 'v' cm/sec, then the wave must be disturbing all the particles present in the length v cm.

Let us imagine a cylinder of length v c.m. and area a cross section 1 cm².

Then volume of the cylinder = v c.c



∴ Total energy present in this cylinder $= 2\pi^2 \rho n^2 A^2 v$. This is called intensity of the wave (I)

$$\boxed{I = 2\pi^2 \rho n A^2 v}$$

Definition of intensity :-

Intensity is defined as the energy transferred by a progressive wave per sec per unit area to the particles of the medium through which it propagates.

$$\therefore I \propto A^2$$

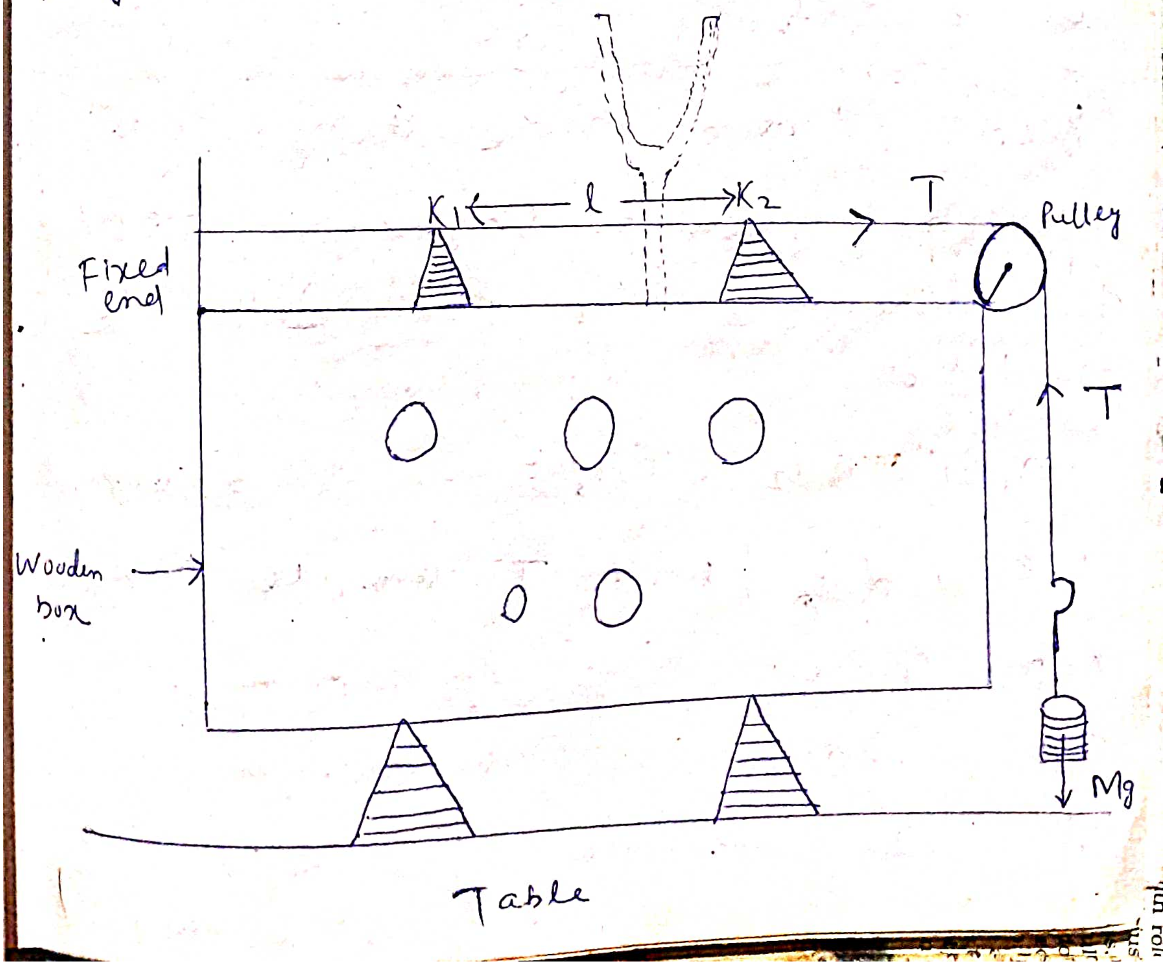
or Intensity is directly proportional to the square of the amplitude.

Sonometer :-

This is an apparatus by which the laws of transverse vibration of the stretched string can be verified. Unknown frequencies of a tuning fork can be determined.

Description

It consists of a hollow rectangular box having several holes in it. A long wire is kept stretched on its surface with one end fixed at one edge and other end passes over a pulley kept at the opposite end of the box. The free end of the string is connected to a hook into which different masses can be hung so that the tension can be verified. Two knife edges K_1 and K_2 are used to vary the length of the string undergoing vibration.



A tuning fork is struck with a rubber pad and kept in a vertical position in between the two knife edges without touching the string. By trial and error method, the distance between the knife edges is changed till resonance is produced when the frequency of the tuning fork will be equal to the fundamental frequency of the string of length 'l' between the knife edges.

Verification of the law of length and determination of the unknown frequency of a tuning fork

Keeping tension in the string fixed, different vibrating lengths are obtained for different tuning forks. It will be found that

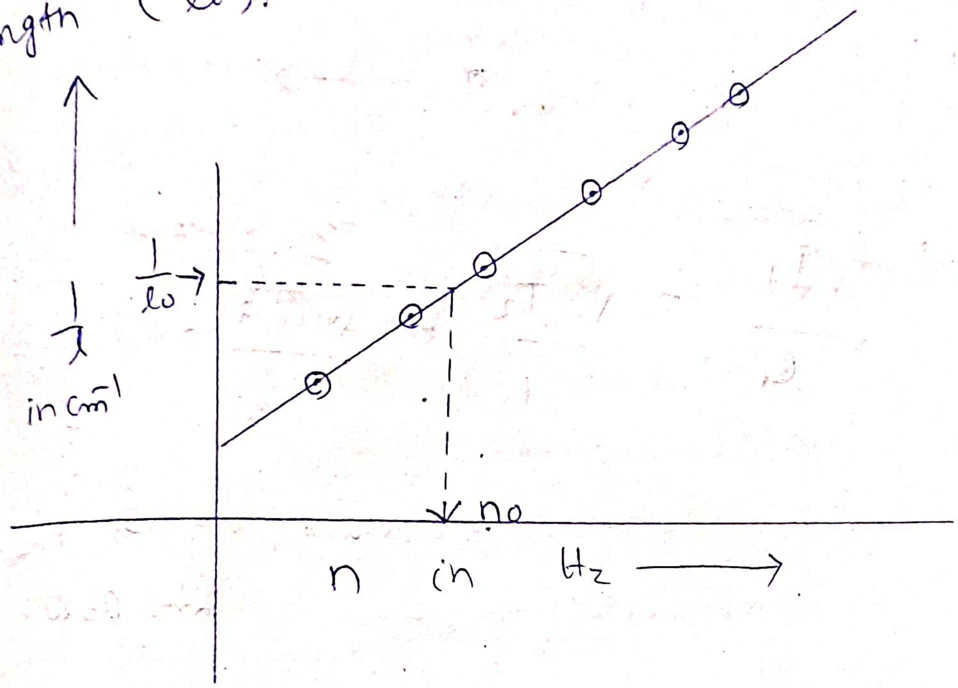
$$n_1 l_1 = n_2 l_2 = n_3 l_3 = \text{--------} = \text{Constant.}$$

i.e $n \propto \frac{1}{l}$, when T and μ are kept constant

This verifies the 1st law.

A graph can be plotted with n along x-axis and $\frac{1}{l}$ along ~~the~~ the

Y-axis which comes out to be a straight line. unknown frequency (n_0) can be obtained from this graph by finding its resonating length (l_0).



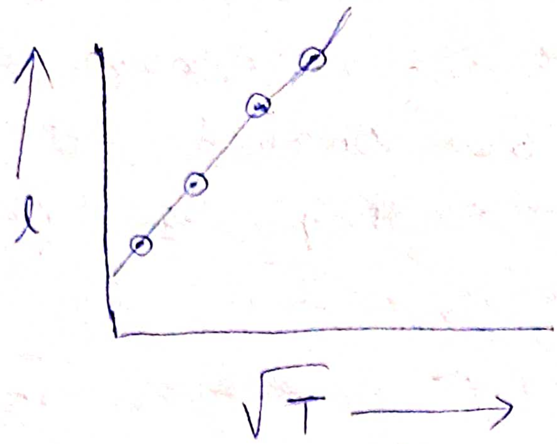
Experimental verification of the law of tension

This law can not be verified directly because all possible frequencies are not available and all possible tensions are not possible. Hence one tuning fork is taken and for different tensions, different resonating lengths are obtained.

$$n = \frac{1}{2l}\sqrt{\frac{T}{\mu}} \quad \text{gives}$$

$$\frac{\sqrt{T}}{l} = \text{constant}, \text{ with } T = Mg, M = \text{Mass}$$

hanging from the hook (along with the mass of the hook)



$$\therefore \frac{\sqrt{T_1}}{l_1} = \frac{\sqrt{T_2}}{l_2} = \frac{\sqrt{T_3}}{l_3} = \text{------}$$

= constant, verifies the 2nd law.

Resonance :-

Every natural body has a frequency characteristic of its own. If such a body ~~can~~ be made to vibrate by means of some external force having almost the same frequency as that of the body, then resonance is said to take place and the body vibrates with max^m amplitude.

Ex-1

Soldiers marching on a bridge are advised to break steps to avoid resonance between their marching frequency and natural frequency of vibration of the bridge.

Ex-2 :-

In the resonance column experiment to determine the velocity of sound, frequency of the air column is made equal with the frequency of the tuning fork. By this, amplitude of vibration becomes max^m and intensity of sound also becomes max^m.

Ex-3

In radio circuits the frequency of L.C.R circuits is made equal to the frequency of the particular radio station so as to select that particular sound.

Characteristics of musical sound :-

Sound may be divided into two classes.

1. Musical sound.
2. Noise.

A musical sound is a continuous pleasing sound produced by regular and periodic vibration.

Examples : Sounds produced by a tuning fork, a violin, a piano etc

Noise is a general term including all sounds other than the musical sounds. It is discordant and unpleasant to the ear.

It is difficult to draw a clear line of demarcation between a musical sound and noise as it depends on the listner.

Musical sounds differ from one another in the following three particulars.

1. Intensity or loudness.
2. Pitch
3. Quality or Timbre

1. Intensity

It is the energy contained in unit volume of the medium through which sound waves pass.

Or It can be measured by the energy passing per unit area per sec with the area kept normal to the direction of propagation

(a) Intensity is directly proportional to the square of the amplitude.

$$I \propto A^2$$

(b) The intensity of sound is directly proportional to the density of the medium in which the sound is produced.

~~Eho~~ That is why sound is more intense in CO_2 than in air.

(c) The intensity of sound depends upon the size of the vibrating body.

If the size be larger, then a larger volume of the medium is put into vibration and a greater amount of energy will pass per unit area. Hence the sound heard will be louder.

(d) The intensity of sound is increased by the presence of ~~boto~~ resonant bodies.

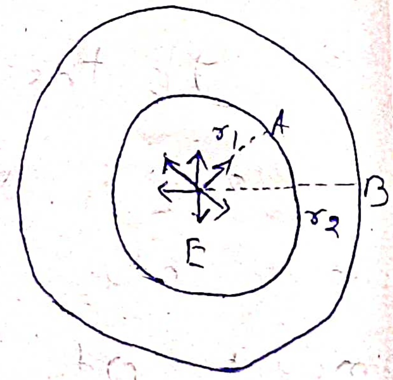
The sound of a tuning fork or a vibrating string in air is much intensified when placed on a sounding box which undergoes forced vibration.

(e) The intensity of sound is inversely proportional to the square of the distance of the listener or a observer from the source.

(Inverse square Law)

Suppose it is required to compare the intensities of the sounds at two points A and B distant r_1 and r_2 from a source of sound from which the total sound energy emanating per second uniformly in all directions is E decibel.

If two concentric spheres be drawn with the source of sound as the centre with radii r_1 and r_2 respectively, then the amount of energy flowing per second per unit area of $A = I_A = \frac{E}{4\pi r_1^2}$



Similarly, the intensity at B

$$= I_B = \frac{E}{4\pi r_2^2}$$

$$\therefore \frac{I_A}{I_B} = \frac{r_2^2}{r_1^2}$$

i.e. $I_A \propto \frac{1}{r_1^2}$

and $I_B \propto \frac{1}{r_2^2}$ (Proved)

2. Pitch :-

The pitch of a note is that physical cause which enables us to distinguish a shrill (sharp) sound from a dull (flat or grave) sound of the same intensity sounded on the same musical instrument. It depends on the frequency of vibration of the emitted sound. The higher the frequency, the more shrill is the sound and we say that the sound rises in pitch. As pitch ~~say that~~ is directly proportional to the frequency, it is customary to express the pitch as a note by its frequency.

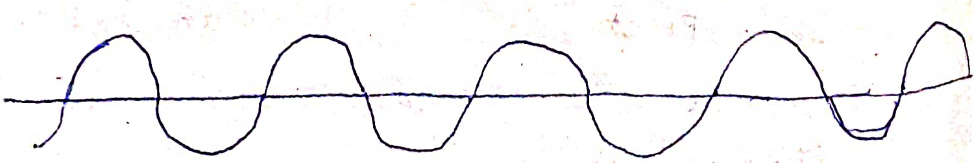
The pitch is a fundamental property as a musical sound and a noise has no definite pitch.

3// Quality or Timbre –:

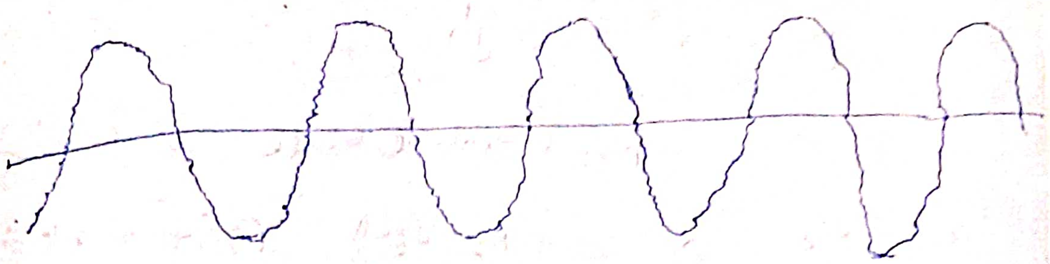
It is characteristics of musical note which enables us to distinguish a note sounded an one musical instrument from a note of the same pitch and loudness sounded an another instrument.

A musical note Consists of a mixture as several simple tones as these the one having the lowest frequency is called fundamental which is relatively most intense. Its frequency ~~as~~ determines the pitch of the note. ~~The quality of as~~ ~~one instrument~~ ~~determines the pitch as the note~~. The quality of one instrument differs from others due to the ~~other~~ ~~instrument~~ difference of the number of other tones or overtunes, their order of succession and their relative intensities.

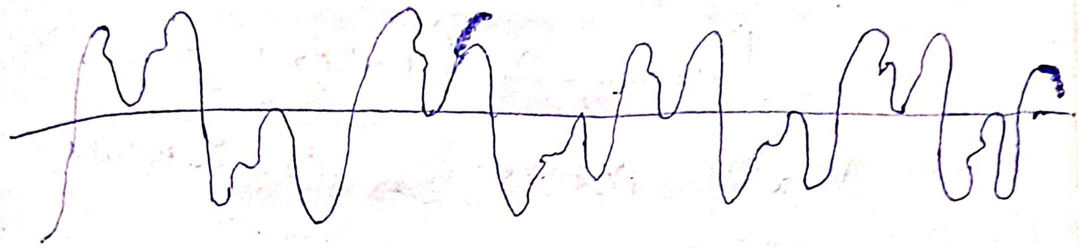
Helmholtz found experimentally that the waves forms differ due to the quality as shown in the ~~gate~~ diagram.



tuning fork.



Violin



Clarinet

Interference in sound

when two systems of waves travel through the same medium simultaneously, the actual disturbance at any point of the medium at any instant is the resultant of the disturbances produced by the component waves separately. i.e principle of superposition is applicable.

If the crests of the two waves arrive simultaneously at the same point i.e if they are initially in the same phase then they will combine to produce a larger crest. Similarly, superposition

Of two ~~thos~~ troughs will produce a greater trough.

The net amplitude will be $A_1 + A_2$ or $-(A_1 + A_2)$. But intensity is directly proportional to the square of the amplitude.

$$I_{max} \propto (A_1 + A_2)^2$$

i.e Max^m intensity is possible

If the crests of one wave will fall on the trough of the other then the resultant amplitude becomes $A_1 - A_2$ and intensity is proportional to $(A_1 - A_2)^2$.

If $A_1 = A_2$, then intensity of sound will be zero and perfect silence will be produced.

The Conditions for interference of two sounds waves are

(i) The component waves must have the same frequency and amplitude. This is achieved by deriving the two waves from the same source. (coherent condition)

(ii) The displacements caused by them

must be in the same line.

(iii) the type of the two waves should be preferably similar.

Experimental demonstration of acoustical interference :-

Quincke made an experimental device to show interference of sound waves. Two separate sources can not produce interference. Hence his apparatus consists of a mouth piece A connected to the two limbs B and C which combine again at E where the ear is placed.

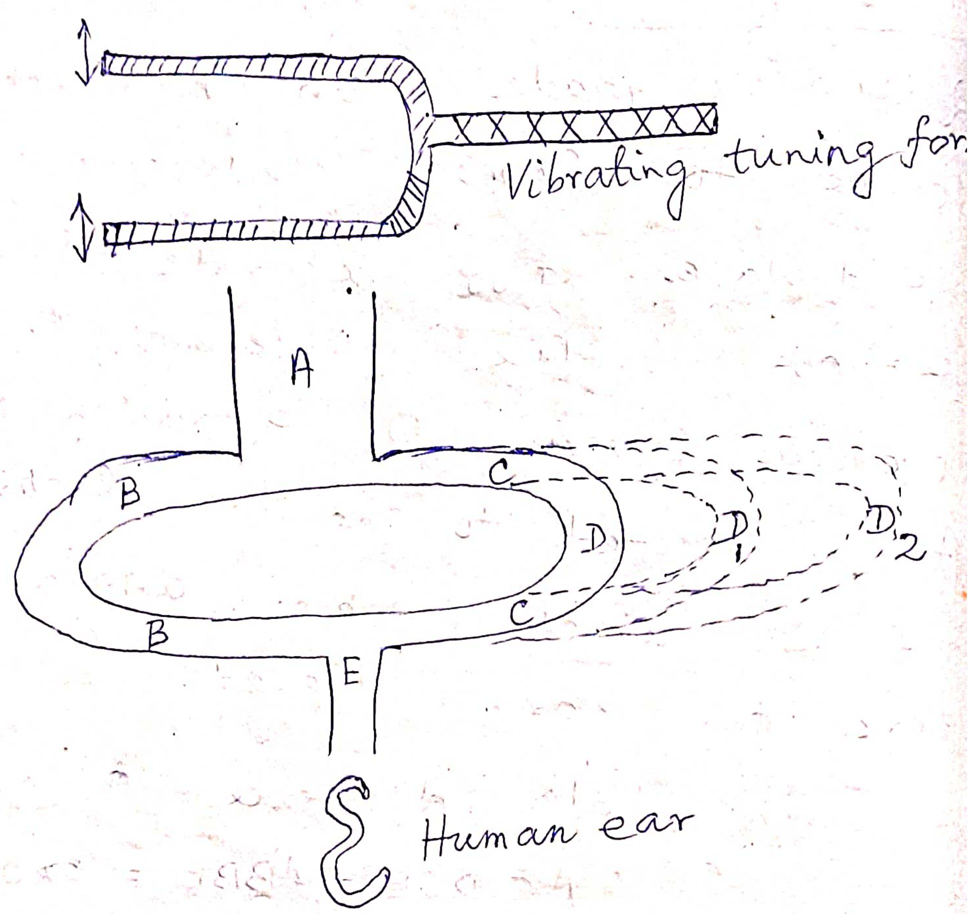
The path difference

$$ACDCE - ABBE = 0 \cdot \frac{\lambda}{2} = 0$$

should be an even multiple of $\frac{\lambda}{2}$ for the occurance of max^m sound. A vibrating tuning fork acts like a source. By shifting the sliding tube 'D' into a position 'D_1', consecutive interference is found to be possible because $ACD_1CE - ABBE =$ even multiple of λ_2

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

Similarly for the position D_2, Interference is again possible provided $ACD_2CE - ABBE =$ Even multiple of $\lambda_2 = 4 \cdot \frac{\lambda}{2}$



Comparision between progressive and stationary waves is given below

Progressive waves	Stationary waves
(a) These are produced by the periodic vibrations of the particles of the medium.	(a) These are formed due to superposition of two sets of identical progressive waves moving in opposite direction.
(b) The waves travel	(b) The waves only

Onward with a definite velocity.

(c) The particles of the medium vibrate one after another as the waves travel through it.

(d) Each particle of the medium executes identical periodic motion about its mean position of rest

(e) During a complete vibration the particles never pass through their mean positions of rest simultaneously.

(f) At any instant of time the phases of the particles along the direction of propagation differ continually.

expand or shrink but do not travel in either direction with time.

(c) As the waves do not travel through the medium the vibration characteristics of each particle is fixed and does not pass on to the adjacent particle.

(d) All the particles of the medium except those at the nodes execute periodic motions with varying amplitudes but equal periods. The amplitude is maximum at antinodes and zero at nodes.

(e) Twice in each complete vibration all the particles reach their positions of rest simultaneously.

(f) Between two adjacent nodes all the particles are in phase. They are in opposite phase with the particles in between the next pair of nodes.

(g) Similar changes of pressure and density take place at any point of the medium as a complete wave passes through it. After each period the pressure and density regain their original values.

(h) Energy is transferred from one point of the medium to another due to passage of such a waves.

(g) During each period max^m change of pressure and density takes place at nodes, where as min^m change take place at antinodes.

(h) There is no transfer of energy through the medium inside which stationary waves are formed.

Problems

(1) The lengths of a sonometer wire between two fixed points is 110 Cm. where should the two bridges (K_1 and K_2) be placed so as to divide the wire into 3 segments whose fundamental frequencies are in the ratio 1 : ~~3~~ 2 : 3 ?

(Ans: 20 Cm, and 50 Cm from one end)

(2) Calculate the ratio of to displacement to amplitude when

Kinetic energy of a body is thrice its potential energy.

(Ans ÷ 1 : 2)

(3). The max^m acc^n of a particle vibrating in S.H.M is ~~(a)~~ 'a' and a max^m velocity is 'b'. Calculate the amplitude and period of ~~a~~ oscillations.

(Ans ÷ $\frac{b^2}{a}$, $\frac{2\pi b}{a}$)

(4). At what temperature in Kelvin, the speed of sound in hydrogen will be the same as in oxygen at 47° C. ?

(Ans 20 K)

(5) Two identical guitar strings are tuned to the same frequency of 300 cycle/sec. If the tension of one of the strings is increased by 2%, How many beats per sec will be heard when the two strings are sounded together?

(Ans ÷ 3)

~~Problems~~ ~~of 21. 02~~ 2K

1. ~~(6)~~ An open pipe has a fundamental frequency of 500 Hz in air. The first harmonic of this pipe is in unison with the first harmonic of a closed pipe containing CO_2. Find the length of the pipes if the velocity of sound in air and CO_2 are respectively 300 meter/sec and 264 m/sec.

(Ans : 30 cm for open pipe
13.2 cm for closed pipe)

(7) A source of sound produces waves of $\lambda = 40$ cm in air. If the source moves towards east with speed $\frac{1}{4}$ of the speed of sound, calculate the values of λ of the waves observed, in the same and opposite direction.

(Ans : 50 cm, 30 cm)

8. The spectral line $\lambda = 5000\,A^0$ in the light coming from a distant stars is observed to be 5200 A^0. Find the velocity with which the star is moving away from the earth.

(Ans: 1.2×10^7 m/sec)

9. Two wires of the same material and diameter having lengths 100 cm and 80 cm respectively emit the same fundamental tone. If the tension of the longer wire is 25 Kg weight, find the tension of the other.

(Ans: 16 Kg weight)

10. Two open end pipes when sounded togher produce 57 beats in three secs at 16°c. If the temp is raised to 57°c, find the beat frequency?

(Ans:- 19 beats/sec

21.07.2K11 Problem. Sol^{n}s to the problems

1. From the application of Newtons law of gravitation the value of gravity at a depth 'h' from the surface of the earth is known ~~Know~~ to be

$$g'' = g\left(1-\frac{h}{R}\right)$$
$$= g\left(\frac{R-h}{R}\right)$$
$$= \frac{gx}{R}$$

where $x = R-h$ = Distance of the point from the centre of the earth.

Considering a particle of mass m at that point, we see that it is attracted towards the centre of earth with the accln.

$$a = g'' = \frac{gx}{R} = \omega^2 x$$

$$\Rightarrow \omega^2 = \frac{g}{R}$$

$$\Rightarrow \omega = \sqrt{\frac{g}{R}} = \frac{2\pi}{T}$$

$$\Rightarrow T = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{\frac{g}{R}}} = 2\pi\sqrt{\frac{R}{g}}.$$

Since the accn is proportional to the displacement so the body will execute S.H.M and time period is $2\pi\sqrt{\frac{R}{g}}$ (Proved)

(Ans)

2, 3 Strings x, y, z

x	y	z
length = l	l	l
$T_1 = 27kg$	$T_2 = 12kg$	$T_3 = 12kg$
$m_1 = 18kg$	$m_2 = 8kg$	$m_3 = 2kg$
$n_1 = \frac{1}{2l}\sqrt{\frac{T_1}{m_1}}$	$n_2 = \frac{1}{2l}\sqrt{\frac{T_2}{m_2}}$	$n_3 = \frac{1}{2l}\sqrt{\frac{T_3}{m_3}}$

$$n_1 : n_2 : n_3 = \sqrt{\frac{T_1}{\frac{m_1}{l}}} : \sqrt{\frac{T_2}{\frac{m_2}{l}}} : \sqrt{\frac{T_3}{\frac{m_3}{l}}}$$

$$= \sqrt{\frac{27l}{m_1}} : \sqrt{\frac{12l}{m_2}} : \sqrt{\frac{12l}{m_3}}$$

(Ans)

$$= \sqrt{\frac{27}{m_1}} : \sqrt{\frac{12}{m_2}} : \sqrt{\frac{12}{m_3}}$$

$$= \sqrt{\frac{27}{18}} : \sqrt{\frac{12}{8}} : \sqrt{\frac{12}{2}}$$

$$= \frac{3\sqrt{3}}{3\sqrt{2}} : \frac{2\sqrt{3}}{2\sqrt{2}} : \frac{2\sqrt{3}}{2\sqrt{2}}$$

$$= \frac{\sqrt{3}}{\sqrt{2}} : \frac{\sqrt{3}}{\sqrt{2}} : 2 \cdot \frac{\sqrt{3}}{2}$$

$$= 1 : 1 : 2 \quad \text{(Ans)}$$

3. General eqn of stationary wave is

$$y = 2A \cancel{\sin \frac{2\pi}{\lambda} x \cdot \cos \frac{2\pi}{\lambda} vt}$$

$$= 2A \cos \frac{2\pi}{\lambda} x \sin \frac{2\pi}{\lambda} vt$$

The given eqn is

$$y = 5 \cos \frac{2\pi}{12} x \cdot \sin 60\pi t$$

$$= \cancel{5 \sin 60\pi t \cdot \cos \frac{2\pi}{12} x}$$

Here $2A = 5 \Rightarrow A = 2.5$ meter

$$\frac{\cancel{2\pi}}{\lambda} x = \overset{30}{\cancel{60}}\cancel{\pi} t$$

$$\Rightarrow x = 30\lambda t \quad \text{——— (i)}$$

$$\frac{vt}{\lambda} = \frac{x}{12}$$

$$\Rightarrow x = \frac{12 vt}{\lambda} \quad \text{——— (ii)}$$

Equating $30\lambda \cancel{t} = \frac{12 v \cancel{t}}{\lambda}$

$$\Rightarrow 30\lambda^2 = 12 v$$

$$\Rightarrow 30 \cdot \left(\frac{v^2}{n^2}\right) = 12 \cancel{v}$$

$$\Rightarrow \frac{v}{n^2} = \frac{12}{30} = \frac{2}{5}$$

Q4. Let the the frequency of A = n_1

" " B = n_2

Given that $n_2 - n_1 = 4$ beats/sec.

$l_1 = 30$ cm , $l_2 = 25$ cm.

$$n_1 = \frac{1}{2l_1}\sqrt{\frac{T}{\mu}}$$

$$n_2 = \frac{1}{2l_2}\sqrt{\frac{T}{\mu}}$$

$$\cancel{n_2 - n_1 = \sqrt{\frac{T}{\mu}}\left(\sqrt{\frac{1}{2l_2}} - \sqrt{\frac{1}{2l_1}}\right)}$$

$$n_2 - n_1 = \sqrt{\frac{T}{\mu}}\left(\frac{1}{2l_2} - \frac{1}{2l_1}\right)$$

$$4 = \sqrt{\frac{T}{\mu}}\left(\frac{1}{50} - \frac{1}{60}\right) = \sqrt{\frac{T}{\mu}}\left(\frac{10}{3000}\right).$$

$$\Rightarrow \sqrt{\frac{T}{\mu}} = 4 \times 300 = 1200$$

frequency of $A = \frac{1}{2l_1}\sqrt{\frac{T}{\mu}}$

$= \frac{1}{\cancel{2\times30}}\sqrt{\cancel{\times12\ldots}}\ 20$

$= 20$ hz.

Frequency of $B = \frac{1}{2l_2}\sqrt{\frac{T}{\mu}}$

$= \frac{1}{\cancel{2\times25}} \cancel{\times 12\ldots}\ 24$

$= 24$ hz.

5. Since number of beats / sec = Difference ~~...~~ of two frequencies, frequency of ~~...~~ A may be

$256-2 = 254$ or $256+2 = 258$

If the A ~~...~~ be loaded with little wax, then number of vibration decreases. If frequency of A was 258 hz then it may decrease to 257 hz.

So number of beats will be $257-256 = 1$ beat / sec.

which contradicts the question.

If the ~~...~~ frequency of A be 254 hz, then due to loading

of wax it is probable to have frequency reduce to 253 hz.
So number of beats will be 3.
So the frequency of A is ~~253~~ 254 hz.

~~6. If A has frequency = 256 hz.~~
~~Since number of beats/sec = ~~frequency~~ difference ~~beats~~ of frequency, frequency of B maybe 256+2 = 258 or 256 − 2 = 254 hz.~~

~~If the~~

6. Since number of beats/sec of two frequencies, = Difference of frequency. of A maybe 254 hz or 258 hz.
B has frequency = 256 hz.
It ~~beat~~ is loaded with wax. So ~~So~~
~~Of~~ its frequency decreases. ~~So~~
~~its frequency may 254 hz it~~
~~will may reduce~~ to 255 hz.
or may decrease
If A has frequency 254 hz
then number of beats will be 1
which contradicts the question

If A has frequency 258 hz
then number of beats will be
258 - 255 = 3 beats/sec
So it satisfy the ~~B~~ question
So frequency A must be 258 hz

7 Since number of beats
= Frequency difference
B has frequency = 256 hz.
A ~~has~~ may have frequency may be 254 hz or 258 hz
But A is filed. So its frequency has increased. If A has frequency 254 hz it ~~must~~ may increase to 255 hz.
So number beats will be = 256 - 255 = 1 hz.
which contradicts the question.
If A has frequency 258 hz.
It may increase to 259 hz.
So number of beats will be = 259 - 256 = 3 beats/sec
which satisfy the question.
So frequency of A must have
frequency 258 hz.

8. A ~~[illegible]~~ may have frequency 254 hz

or ~~[illegible]~~ 258 hz.

when B is filed its frequency

must have increased. ($\because$ 257 hz).

If A has frequency 258 hz

then number of beats will be 1 ~~[illegible]~~ beat/sec

which contradicts the question

If A has frequency 254 hz

then number of beats will be 3 beat/sec

which satisfy the question

$\therefore$ A has frequency 254 hz.

9. The engine when emits whistle

it must reaches the tunnel and

reflected to the engine.

the sound has covered distance

$= 2 \times \frac{1}{2} = 1$ mile.

which takes 4.5 sec.

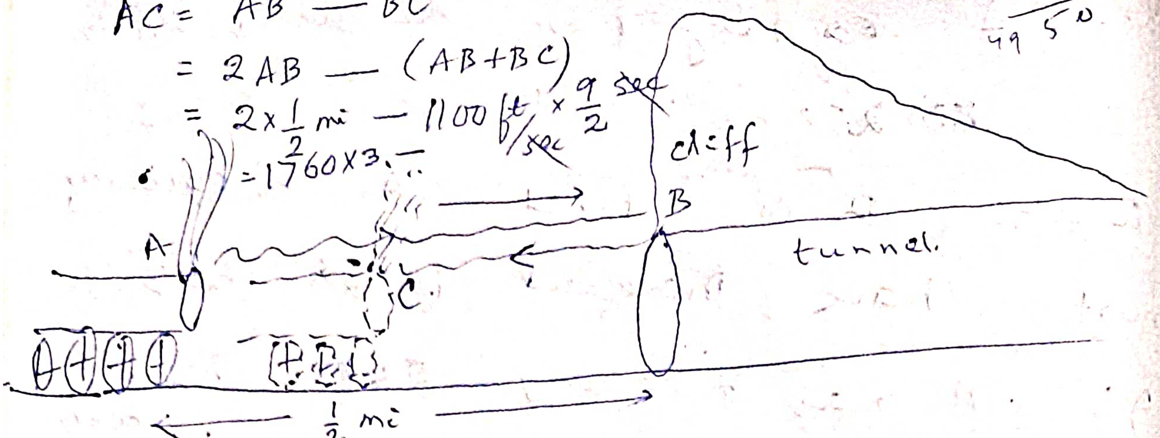
$t = 4.5$ sec, $S = 1$ mile

$$v = \frac{S}{t}$$

Ac $= 5280 - 4950 = 330$ ft/sec

$$AC = AB - BC$$
$$= 2AB - (AB+BC)$$
$$= 2 \times \frac{1}{2} mi - 1100\ ft/sec \times \frac{9}{2} sec$$
$$= 1760 \times 3 -$$

$$\begin{array}{r} 550 \\ 9 \\ \hline 4950 \end{array}$$



$$v = \frac{AC}{4.5} = \frac{330}{4.5} = \frac{3300}{45}$$ ~~73.33 ft/sec~~

45) 3300 (73.33
315
150
135
150

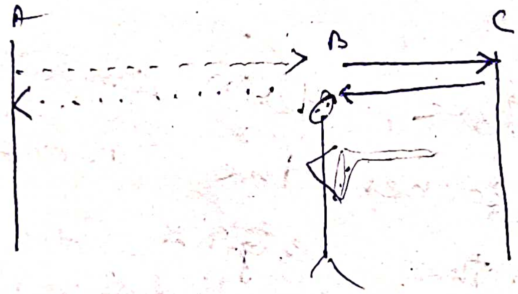
$22\ ft/sec = 15\ mile/hour.$

$1\ ft/sec = \frac{15}{22}$

$\frac{3300}{45}\ ft/sec = \frac{15}{22} \times \frac{3300}{45}$

$\simeq 50\ mile/hr$

10.



A man is standing on two parallel cliffs.

He hears the echo after 2 secs.

2 sec = Time taken to go to one side of the cliff and come back to the man.

Time taken to go to one side of the wall = 1 sec

velocity of sound in 1sec = 1120 ft/sec.

In figure

∴ BC = 1120 ft.

He hears the second echo after 5 sec.

~~oooo~~ To reach AB he takes time = 2.5 sec

AB = $1120 \times 2.5 = 2800$

$\frac{BC}{AB} = \frac{1120}{2800} = \frac{1}{2.5} = \frac{2}{5}$

∴ The man ~~dives~~ devides the distance between the cliff in the ratio 2:5

He will listen the sound waves that moves towards ~~the~~ ~~the~~ ~~sound~~ right after 2 sec then 7 sec, 9 sec, 14 sec, 16 sec, 21 sec.

He listens the sound waves which moves towards left after 5 sec then 7 sec, 12 sec, 14 sec, 19 secs, 21 sec.

Brain will analyse them they would

be listen the true man after

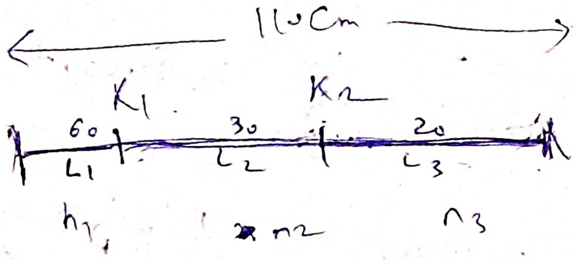
~~ooff~~ · 7 sec, 9 sec, 12, ~~13~~ sec, 14 sec.

16 sec, 19 sec, 21 sec, 23 sec

Problems.

A.

1. $l = 110\,cm$



. Fundamental frequency $n = \frac{V}{4l}$

$l_1 + l_2 + L_3 = 110\,c.m$,

$n_1 = \frac{1}{2l_1}\sqrt{\frac{T}{\mu}}$, $n_2 = \frac{1}{2l_2}\sqrt{\frac{T}{\mu}}$, $n_3 = \frac{1}{2l_3}\sqrt{\frac{T}{\mu}}$

Given that, $n_1 : n_2 : n_3 = 1 : 2 : 3$.

$\frac{n_1}{n_2} = \frac{1}{2} \Rightarrow \frac{\frac{1}{2l_1}}{\frac{1}{2l_2}} = \frac{1}{2} \Rightarrow \frac{1}{2l_1} \times \frac{2l_2}{1} = \frac{1}{2}$

$\Rightarrow \frac{l_2}{l_1} = \frac{1}{2}$

$\Rightarrow l_1 = 2l_2$.

$\frac{n_2}{n_3} = \frac{2}{3} \Rightarrow \frac{\frac{1}{2l_2}}{\frac{1}{2l_3}} = \frac{2}{3} \Rightarrow \frac{l_3}{l_2} = \frac{2}{3}$

$\Rightarrow l_2 = \frac{3l_3}{2}$.

$\frac{n_1}{n_3} = \frac{1}{3} \Rightarrow \frac{l_3}{l_1} = \frac{1}{3}$ $\Rightarrow l_1 = 3l_3$.

$l_1 + \frac{l_1}{2} + \frac{l_1}{3} = 110$

$\Rightarrow \frac{6l_1 + 3l_1 + 2l_1}{6} = 110$

$\Rightarrow 11l_1 = 660$

$\Rightarrow l_1 = \frac{660}{11} = 60$

$60 + 30 + l_3 = 110$

$\Rightarrow l_3 = 20$

$60 + l_2 + \frac{2l_2}{3} = 110$

$\Rightarrow \frac{180 + 3l_2 + 2l_2}{3} = 110$

$\Rightarrow 180 + 5l_2 = 330$

$\Rightarrow 5l_2 = \frac{330 - 180}{150}$

$\Rightarrow l_2 = \frac{150}{5} = 30$

2.

We know that

displacement $y = A \sin\omega t$

$\Rightarrow \frac{y}{A} = \sin\omega t$

Potential energy $= \frac{1}{2} K A^2 \sin^2\omega t$

Kinetic energy $= \frac{1}{2} K A^2 \cos^2\omega t$

$\frac{y}{A} = \sin\omega t$

$= \frac{\frac{1}{2} K A^2 \sin^2\omega t}{\frac{1}{2} K A^2 \cos^2\omega t} \times \frac{\cos^2\omega t}{\sin\omega t}$

$= \frac{P.E}{KE} \times \frac{1 - \sin^2\omega t}{\sin\omega t}$

$= \frac{P.E}{3 P.E} \times \frac{1 - \frac{y^2}{A^2}}{\frac{y}{A}}$

$\frac{y}{\cancel{A}} = \frac{1}{3} \left(\frac{A^2 - y^2}{\cancel{A}^2} \times \frac{\cancel{A}}{y} \right)$

~~$\Rightarrow 3y^2 = A^2 - 3y^2$~~

~~$\Rightarrow 4y^2$~~

$\Rightarrow 3y^2 = A^2 - y^2$

$\Rightarrow 4y^2 = A^2$

$\Rightarrow \frac{y^2}{A^2} = \frac{1}{4} = 1 : 2$ (Ans)

3\. 3.

$$\text{Max}^m \ \text{accl}^n = a_{max} = a = \omega^2 A$$

$$\text{max}^m \ \text{velocity} = V_{max} = b = A\omega$$

$$A = ?, \quad T = ?$$

$$\because b = A\omega \Rightarrow \omega = \frac{b}{A}$$

$$a_{max} = a = \omega^2 A$$

$$\Rightarrow A = \frac{a}{\omega^2} = \frac{a}{\frac{b^2}{A^2}} = \frac{aA^2}{b^2}$$

$$\Rightarrow \cancel{A} = \frac{a \cdot A^{\cancel{2}}}{b^2}$$

$$\Rightarrow a \cdot A = b^2$$

$$\Rightarrow A = \frac{b^2}{a} \quad \text{(Ans)}$$

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{\frac{b}{A}} = \frac{2\pi A}{b} = \frac{2\pi b^2}{ab} = \frac{2\pi b}{a} \quad \text{(Ans)}$$

4\.

Velocity of sound in oxygen at $(47°c)$ or $(320K)$ is $V_1 = \sqrt{\frac{\gamma R(320)}{M}}$

Velocity of sound in hydrogen $V_2 = \sqrt{\frac{\gamma \cdot RT}{M}}$

But $V_1 = V_2$

$$\Rightarrow \cancel{\sqrt{\gamma}} \cdot \cancel{\sqrt{R}} \cdot \sqrt{\frac{320}{32}} = \cancel{\sqrt{\gamma}}\cancel{\sqrt{R}}\sqrt{\frac{T}{2}}$$

$$\Rightarrow \sqrt{10} \times \sqrt{2} = \sqrt{T}$$

$\Rightarrow T = 20\,K$

Sr

Gitar (1st | Gitar (2nd)

Length = l | Length = l

$n_1 = 300$ | $n_2 = 300$

Tension = T | Tension = T

When tension increase by 2%, then $T_1 = T + \frac{T}{50}$

$= \frac{51T}{50}$

$n_1' - n_2 = ?$

$$n_2 = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$$

$$\Rightarrow 300 \times 2l = \sqrt{\frac{T}{\mu}}$$

$$\Rightarrow 600\,l = \sqrt{\frac{T}{\mu}}$$

$$n_1' = \frac{1}{2l}\sqrt{\frac{\frac{51T}{50}}{\mu}} = \frac{1}{2l}\sqrt{\frac{51T}{50\mu}}$$

$$= \frac{1}{\cancel{2l}} \times \sqrt{\frac{51}{50}} \times \cancel{600}^{300}\,\cancel{l}$$

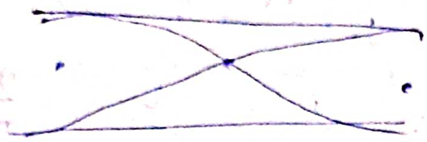
Number of beats = $n_1' - n_2$

$= \quad - 300$

$= 302.98 - 300$

$= 2.98$

6.



$l = \cancel{\frac{22}{7}} = \frac{\lambda}{2}$

$l = \frac{\lambda}{2} \Rightarrow \lambda = 2l$

$n = \frac{V}{\lambda} = \frac{V}{2l} = 500\ Hz$

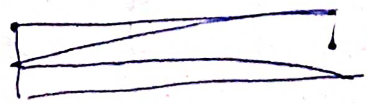
$\Rightarrow \frac{\cancel{300}/150}{2l} = 500$

$\Rightarrow l = \frac{\cancel{150}^{3}}{\cancel{500}_{10}}$ meter

$= \left(\frac{3}{10} \times 100\right) Cm$

$= 30\ Cm$. (Ans)

for open pipe



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

$\Rightarrow \lambda = 4l$

$n = \frac{V}{\lambda} = \frac{V}{4l}$

given that $n = n_1$

$\Rightarrow 500 = \frac{v}{4l_1}$

$\Rightarrow 2000 l_1 = v$

$\Rightarrow l_1 = \frac{v}{2000} = \frac{26400}{2000}$

$= 13.2$ cm

for closed pipe

7. $\lambda = 40$ cm

when observer is at rest and source is moving towards it

$$n' = n\left(\frac{v}{v - v_s}\right)$$

$$\Rightarrow \frac{\cancel{v}}{\lambda'} = \frac{\cancel{v}}{\lambda}\left(\frac{v}{v - \frac{v}{4}}\right)$$

$$\Rightarrow \frac{1}{\lambda_1} = \frac{1}{\cancel{40}_{10}}\left(\frac{\cancel{V}\times 4}{3\cancel{V}}\right)$$

$$= \frac{1}{30}$$

$$\Rightarrow \lambda_1 = 30 \text{ cm.}$$

when Observer is at rest and source is moving away from it, then

$$n' = n\left(\frac{V}{V+V_s}\right)$$

$$\Rightarrow \frac{\cancel{V_s}}{\lambda_1} = \frac{\cancel{V_s}}{\lambda}\left(\frac{V}{V+\frac{V}{4}}\right)$$

$$\Rightarrow \frac{1}{\lambda_1} = \frac{1}{\cancel{40}_{10}}\left(\frac{\cancel{V}\times 4}{5\cancel{V}}\right)$$

$$\Rightarrow \frac{1}{\lambda_1} = \frac{1}{50}$$

$$\Rightarrow \lambda_1 = 50 \text{ cm}$$

The value of λ when same direction is 50 cm then when opposite direction 30 cm.

8. Star is moving away from the earth.

$$\cancel{n' = n\left(\frac{V}{V+V_s}\right)}$$

$\therefore \lambda_1 = \lambda + \frac{V_s \cdot \lambda}{C}$

$\Rightarrow \frac{V_s}{n_1} = \frac{V_s}{n} + \frac{V_s \cdot \frac{V_s}{n}}{V}$

$\Rightarrow \frac{V_s}{5200} = V_s \left(\frac{1}{5000} + \frac{V_s}{5000 \times 3 \times 10^8} \right)$

$\Rightarrow \frac{1}{5200} = \left(\frac{3 \times 10^8 + V_s}{15 \times 10^8} \right)$

$\Rightarrow 52 \times 10^{10} + 5200 V_s = 15 \times 10^8$

$\Rightarrow 5200 \cdot V_s =$

$\lambda = 5000 A^\circ = 5000 \times 10^{-8}$ cm

$= 5000 \times 10^{-10}$ meter

$\lambda 1 = 5200 A^\circ = 5200 \times 10^{-10}$ meter

We know that

$\lambda_1 = \lambda + \frac{V_s \cdot \lambda}{C}$

$\Rightarrow 5200 \times 10^{-10} = 5000 \times 10^{-10} + \frac{V_s \cdot (5000 \times 10^{-10})}{3 \times 10^8}$

$\Rightarrow 52 \times 10^{-8} = \frac{150 + V_s \cdot 50 \times 10^{-7}}{3 \times 10^8}$

$\Rightarrow 156 = 150 + V_s \cdot 5 \times 10^{-7}$

$\Rightarrow V_s = \frac{6}{5 \times 10^{-7}} = 1.2 \times 10^7$ m/sec

9. 1st Metali wire

μ

$l = 100$ cm

$T_1 = 25$ Kg weight

d

2nd metali wire

4μ

$l = 80$ cm

$T_2 = ?$

d

$\cancel{n_1 = \frac{1}{2l}\sqrt{\frac{T}{\mu}} = \frac{1}{200}\sqrt{\frac{25}{\mu}}}$

$n_2 = \cancel{\frac{1}{2l}\sqrt{\frac{T}{\mu}}} = \frac{1}{160}\sqrt{\frac{T}{\mu}}$

$n_1 = \frac{P}{ld}\sqrt{\frac{T}{\pi \rho}}$

$n_2 = \frac{P}{l_1 d}\sqrt{\frac{T_1}{\pi \rho}}$

$n_1 = n_2 \Rightarrow \frac{\cancel{P}}{l\cancel{d}}\sqrt{\frac{T}{\cancel{\pi\rho}}} = \frac{\cancel{P}}{l_1\cancel{d}}\sqrt{\frac{T_1}{\cancel{\pi\rho}}}$

$\Rightarrow \frac{\sqrt{T}}{l} = \frac{\sqrt{T_1}}{l_1}$

$\Rightarrow \frac{\sqrt{25}}{100} = \frac{\sqrt{T_1}}{80}$

$\Rightarrow \frac{5}{\cancel{100}_{20}} = \frac{\sqrt{T_1}}{80}$

$\Rightarrow \sqrt{T_1} = \frac{80}{20} = 4$

$\therefore T_1 = 16$ Kg weight

$\therefore$ Tension in the other string is

16 Kg weight.

10. The velocity of sound at

0°C 330 m/sec.

~~[illegible]~~ ~~[illegible]~~

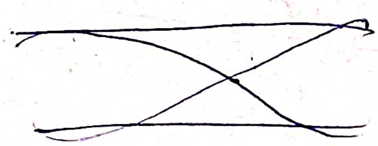
In 1° rise of temp velocity sound

increase by .6 m.

In 16° C $.6 \times 16 = 9.6$ meter

at 16° velocity of sound $= 339.6$ m/sec

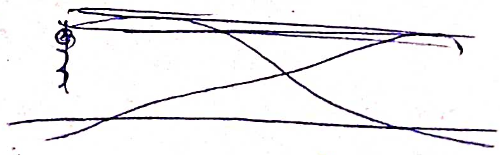
$\cancel{n_1 = \frac{1}{2l_1}\sqrt{\frac{T}{m}}}$



$V = n\lambda$

$l_1 = \frac{\lambda_1}{2}$

$\therefore n_1 = \frac{V}{\lambda_1} = \frac{V}{2l_1}$



$n_2 = \frac{V}{2l_2}$

$l_2 = \frac{\lambda_2}{2}$

$n_1 - n_2 = \frac{339.6}{2l_1} - \frac{339.6}{2l_2}$

$\Rightarrow \cancel{[illegible]} = \frac{339.6}{2}\left(\frac{1}{l_1} - \frac{1}{l_2}\right)$

$\Rightarrow \frac{1}{l_1} - \frac{1}{l_2} = \frac{17 \times 2}{339.6}$

At $51^\circ C$ velocity sound

$= 330 + (.6 \times 51)$

$= 330 + (30.6)$

$= 360.6$ m/sec.

$$n_1 - n_2 = \frac{v}{2l_1} - \frac{v}{2l_2}$$

$$= \frac{360.6}{2}\left(\frac{1}{l_1} - \frac{1}{l_2}\right)$$

$$= \frac{360.6}{\cancel{2}}\left(\frac{17 \times \cancel{2}}{339.6}\right)$$

$= 18.05$

$$17 = \frac{v_{16}}{2l_1} - \frac{v_{16}}{2l_2} = \frac{v_{16}}{2}\left(\frac{1}{l_1} - \frac{1}{l_2}\right) \quad \text{——— (1)}$$

$$\Delta n = \frac{v_{51}}{2}\left(\frac{1}{l_1} - \frac{1}{l_2}\right) \quad \text{——— (2)}$$

Dividing eq^n (2) by eq^n (1), we get,

$$\frac{\Delta n}{17} = \frac{v_{51}}{v_{16}} = \sqrt{\frac{51+273}{16+273}}$$

$$\Rightarrow \Delta n = 17 \times \sqrt{\frac{324}{289}} = \cancel{17} \times \frac{18}{\cancel{17}} = 18 \text{ Hz.}$$