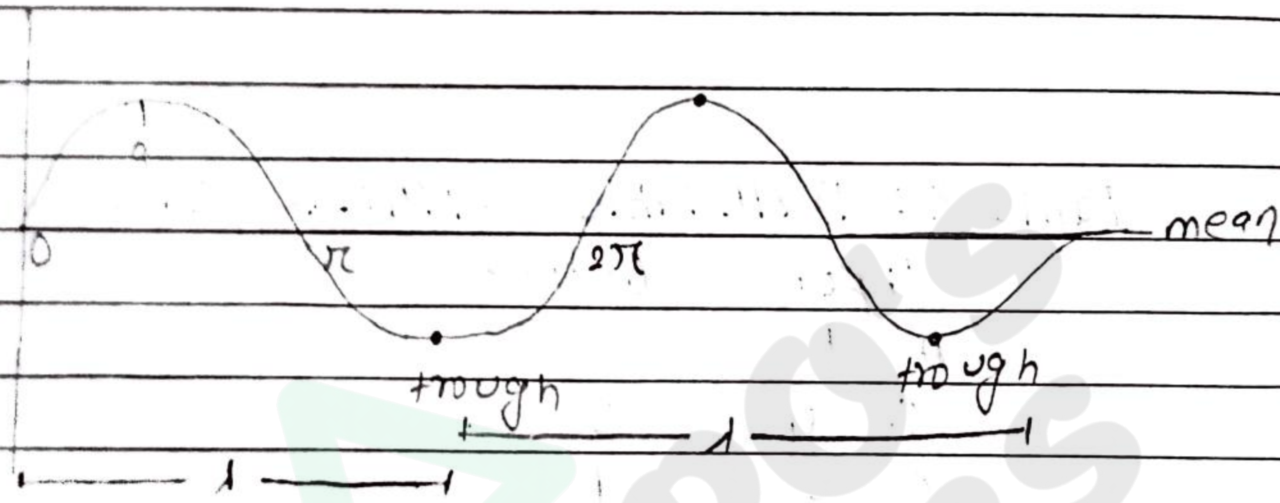
Wave :-



Sound wave:-

The disturbance of the particle of medium is known as the wave.

Amplitude(a):-

The max displacement from mean position is called amplitude(a).

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Crest:-

The highest point corresponding to amplitude is called Crest.

Trough:-

The lowest point corresponding to amplitude is called trough.

Wavelength(λ):-

The distance between two nearest crest or two nearest trough or displacement in one complete cycle in the direction of wave motion is called wavelength (λ).

Time period (T):-

The time taken in one complete cycle is called time period.

Formula:-

$$\text{velocity of wave} = \frac{\text{displacement in one cycle}}{\text{time taken in cycle}} = \frac{\lambda}{T}$$

$$\therefore \boxed{V = f\lambda} \quad \because \frac{1}{T} = \text{frequency } (f)$$

→ for the wave originating at origin 'O' then equation is $\boxed{y = a \sin \omega t}$ where, $\omega = \frac{2\pi}{T} = 2\pi f$ = angular velocity.

→ The phase angle (ϕ) represent the state of the vibrating particle.

→ If the wave originating at distance x from origin then equation wave is

$$\boxed{y = a \sin(\omega t - \phi)} \text{ where } \phi = \frac{2\pi}{\lambda}$$

Types of wave
On the basis of ~~vibrating~~ /vibration of particles
i. Transverse wave: The wave in which the molecules or parti of the medium vibrate in the direction perpendicular to the direction of motion of wave is called transverse waves. . Example:- Radio wave, x-rays, microwave etc.

Longitudinal wave :- The wave in which the particle of medium vibrate parallel to the direction of motion of wave forming compression and rarefaction.

On the basis of velocity and deflection in electric and magnetic force:-
i. Electromagnetic wave:- Electromagnetic waves need no medium for propagation and ~~waves~~ moves with velocity of light in vaccum and is not deflected in electric and magnetic field
Example:- γ-wave, light wave, x-waves, microwave, radio wave etc.
ii. Mechanical wave:- Mechanical wave need medium for propagation and its velocity is less than velocity of light i.e
velocity < velocity of light.

Progressive wave and its equation:-
The wave which moves forward with time is called progressive wave.

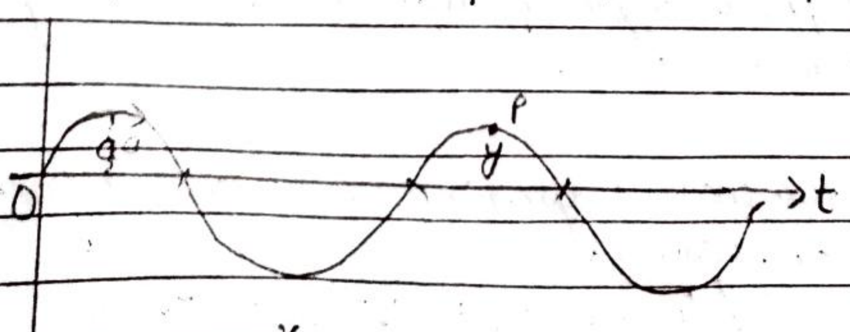

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fig ①

Imp ... progressive and stationary wave with their characters ?

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fig ① show the progressive wave moving in the positive direction of x which frequency 'f' time period 't' and wave velocity 'v'. At point p, the equation of the wave will be $y = a\sin(\omega t - \phi)$ where

$$\phi = \text{Phase angle at } P = \frac{2\pi}{\lambda}\cdot x$$

$$= k\cdot x \text{ where } k = \frac{2\pi}{\lambda} = \text{wave}$$

$$\therefore y = a\sin(\omega t - kx) - i)$$

$$= a\sin\left(\frac{2\pi}{T}\cdot t - \frac{2\pi\cdot x}{\lambda}\right)\left[\because \omega = \frac{2\pi}{T} = 2\pi f\right]$$

$$y = a\sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right) - ii)$$

Eqn (ii) can also be written as.

$$y = a\sin 2\pi\left(f\cdot t \cdot \frac{x}{\lambda}\right)\left[\because \frac{1}{T} = f = \text{frequency}\right]$$

$$= a\sin 2\pi\left(\frac{v}{\lambda}\cdot t \cdot \frac{x}{\lambda}\right) \text{ and } v = f\lambda \quad \therefore f = v/\lambda$$

$$\boxed{y = a\sin\frac{2\pi}{\lambda}(vt - x)}$$

Thus the eqn of progressive wave moving from left to right

$$y = a\sin(\omega t - kx) = a\sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right) = a\sin\frac{2\pi}{\lambda}(vt - x)$$

NOTE:- (Right to left negative -ve)

Further progressive wave moving from right to left (i.e in the negative x direction), the progressive wave equation become

$$y = a\sin(\omega t + kx) = a\sin 2\pi\left(\frac{t}{T} + \frac{x}{\lambda}\right) = a\sin\frac{2\pi}{\lambda}(vt + x)$$

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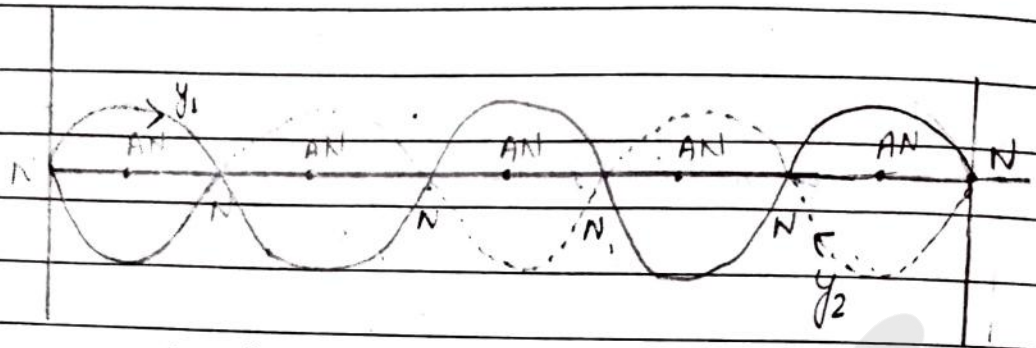
Stationary wave & its equation

When two identical progressive wave moving opposite to each other meet in a medium then the resistant wave is known as Stationary wave.



In fig (i) two plane progressive wave y_1 and y_2 which are other wise identical, moving opposite to each other from stationary wave.

$$y_1 = a\sin(\omega t - kx)$$
$$y_2 = a\sin(\omega t + kx)$$

From the principal of super position the resultant of those waves will be

$$y = y_1 + y_2$$

or, $y = a[\sin(\omega t - kx) + \sin(\omega t + kx)]$

or, $y = a\left\{2\sin\left(\frac{\omega t - \cancel{kx} + \omega t + \cancel{kx}}{2}\right)\cdot\cos\left(\frac{\cancel{\omega t} - kx - \cancel{\omega t} - kx}{2}\right)\right.$

$$\left[\because \sin C + \sin D = 2\sin\left(\frac{C+D}{2}\right)\cdot\cos\left(\frac{C-D}{2}\right)\right]$$

or, $y = 2a\sin\omega t\cdot\cos(-kx)$

or, $y = 2a\sin\omega t\cdot\cos kx \quad [\cos\theta = \cos(-\theta)]$

or, $y = 2a\cos kx\cdot\sin\omega t$

or, $y = A\sin\omega t$ — (i) ~~where $A = 2a\cos kx$ - (ii)~~

Eqn (i) represent stationary wave eqn where,

$$A = 2a\cos kx \text{ — (ii)}$$

From eqn (2)

$A_{max} = 2a$

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and $A_{min} = 0$.

The points at which $A_{max} = 2a$, are called antinodes (A.N) and the points at which $A_{min} = 0$, are called nodes (N) as shown in fig. ①.

* The distance between two consecutive nodes or between two consecutive antinodes is $\lambda/2$

Imp. Difference between progressive and ~~consecutive~~ stationary waves?

S.N	Progressive wave	Stationary waves
①	The amplitude is same at all points of medium	The amplitude are different at different points of medium.
②	The crest or trough or compression and rarefaction move forward and disturbance (or energy) is transferred from particle to particle.	The crest or trough or compression and rarefaction move forward disturbance (or energy) is not transferred from particle to particle. [Not so].
③	No particle is at permanent rest.	The particles at ~~most~~ nodes are at rest.
④	With the advance of wave density & pressure changes.	Density & pressure change or maximum at nodes but no density or pressure changes at AN.
⑤	There exist a regular phase difference between two sucessive points.	All points between two nearest nodes are in same phase.

(6) The value of maximum velocity for all particles of the medium are the same.	The value of maximum velocity for different particles are different and the velocity of particles at the nodes is always (0) zero.

Numericals:- (Progressive)

1Q) The equation of harmonic wave is $y = 4\sin[\pi(2t - 0.01x)]$ where x, y are in cm and t in sec.
find (i) amplitude
(ii) wave length (λ)
(iii) ~~Angular frequency~~ initial phase at origin
iv) Speed.
v) Frequency.

Soln;
the progressive wave eqn is;
$$y = a\sin(\omega t - kx) \quad \text{---(1)}$$ and the given eqn is
$$y = 4\sin[\pi(2t - 0.01x)]$$
$$\text{or, } y = 4\sin(2\pi t - 0.01\pi x) \quad \text{---(2)}$$
Comparing eqn (1) and (2) we get.
(i) Amplitude $(a) = 4\text{ cm} = 0.04$ meter
(ii) Here,
$k = 0.01\pi$
$\frac{2\pi}{\lambda} = 0.01\pi$

$$\lambda = \frac{2}{0.01} = 200\text{ cm}$$
$$= 2\text{ meter}$$

(V) phase angle $(\omega) = 2\pi$

$$2\pi f = 2\pi$$

$$\therefore f = 1 \text{ hertz}.$$

(iii) ~~Phase angle at the origin = 0.01~~

$$\text{phase angle} = \phi = kx$$
$$= 0.01 kx$$

At origin $x = 0$

$\therefore$ phase angle at origin = 0.

(iv) Velocity $(v) = f\lambda$

$$= 1 \times 2$$
$$= 2 ms^{-1}.$$

MCQs [wave motion]

① If $x = a\sin\left(\omega t + \frac{\pi}{6}\right)$ and $x' = a\cos\omega t$, then phase difference between two waves will be

(a) $2\pi/3$ (b) $\pi/6$ (c) $\pi/2$ (d) π

② Phase difference between two sound waves given by $y = a\sin(\omega t - kx)$ and $y' = a\cos(\omega t - kx)$ will be

(a) $\pi/2$ (b) $\pi/4$ (c) π (d) $\frac{3\pi}{4}$

③ Which one is the correct for progressive wave given by $y = 4\sin\left[\pi\left(\frac{t}{5} - \frac{x}{9}\right) + \frac{\pi}{6}\right]$?

(a) $v = 5$ cm (b) $\lambda = 18$ cm (c) $a = 0.04$ cm (d) $f = 50$ Hz.

Answer:-

(1) Hint;

$$x = a\sin[\omega t + \pi/6]$$
$$= a\cos[\pi/2 - (\omega t - \pi/6)]$$
$$= a\cos[\pi/2 + \pi/6 - \omega t]$$
$$= a\cos\left[\cancel{\omega}\frac{4\pi}{6} - \omega t\right]$$

(2) Soln

$$y = a\sin(\omega t - kx)$$
$$= a\cos[\pi/2 - \omega t + kx]$$
$$= a\cos[\omega t - kx - \pi/2]$$
$$\cancel{\therefore \Delta d = \pi/2} = a\cos\left(\omega t - \left(kx + \frac{\pi}{2}\right)\right) \quad \text{--- (1)}$$

$$y^1 = a\cos(\omega t - kx) \quad \text{--- (2)}$$

comparing (1) and (2)

$$\cancel{kx} + \frac{\pi}{2} = \cancel{kx}$$

$$\Rightarrow \boxed{\pi/2}$$

(3) Hint:

$$y = 4\sin\left[\pi\left(\frac{t}{5} - \frac{x}{9}\right) + \frac{\pi}{6}\right]$$
$$= 4\sin\left[2\pi\left(\frac{t}{10} - \frac{x}{18}\right) + \frac{\pi}{6}\right]$$
$$\therefore y = a\sin\left[2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right) + \phi\right].$$

$$\therefore P = \frac{1}{T} = \frac{1}{10} = 0.1, \quad \lambda = 18\text{ cm}.$$

Note: ① Range of audible sound to human being is 20Hz to 20kHz
② Minimum time to hear two sounds $t = 0.1$ sec

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④ If the pressure amplitude in a sound wave is tripled, by what factor its intensity will increase?

a) 3. b) 6 c) 9 d) $\sqrt{3}$

<u>Hint</u>;

Intensity of sound $\propto$ Amplitude

$\therefore I \propto A^2$

$\therefore I' \propto (3A)^2$

$\propto 9A^2$

⑤ Which of the following sound will be audible to human being?

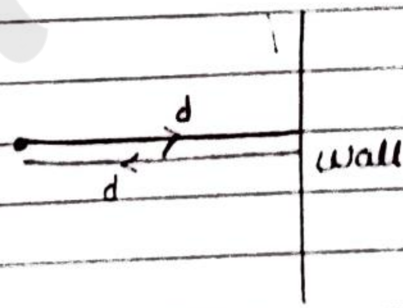
(a) 5 Hz (b) 27000 Hz (c) 5000 Hz (d) 50000 Hz

[Range of audible sound to human being - 20 Hz to 20 kHz]

⑥ The minimum distance between source of sound and reflector wall is [$v = 330\ ms^{-1}$ (velocity of sound in air)]

(a) 8.5 m (b) 16.5 m (c) 31 m (d) 62 m.

⇒ Hint



$v = \frac{s}{t} = \frac{2d}{t}$

$\therefore d = \frac{v \cdot t}{2}$

$= \frac{330 \times 0.1}{2}$

$= 16.5 m$

⑦ For two sound waves with phase differences of $60°$, path difference will be

a) 2λ b) $\frac{\lambda}{2}$ (c) $\lambda/3$ (d) $\lambda/6$

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Hint

$$\Delta\phi = \frac{2\pi}{\lambda}\Delta x \qquad \left[\text{here,}\ \Delta\phi = 60^\circ = \pi/3 \text{ radian}\right]$$

$$\therefore \Delta x = \frac{\lambda\Delta\phi}{2\pi}$$

$$= \frac{\lambda}{2\pi} \times \frac{\pi}{3} = \frac{\lambda}{6}$$

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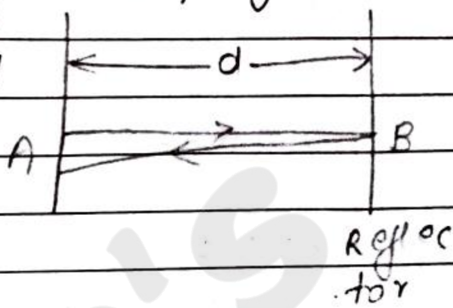
short questions with answer:-

(1) Why echo cannot be heared in a small room? [2069 set A]

Ans Echo is heared due to the reflection of sound from a reflector (like a tall building). If t is the time taken by sound to move from A to B and then come at A then, the velocity of sound will be,



$$v = \frac{\text{total distance}}{\text{time taken}}$$

$$= \frac{d+d}{t} = \frac{2d}{t}$$

$\therefore d = \frac{v \cdot t}{2} = \frac{332 \times 0.1}{2} = 16.6\ m \simeq 17\ m$ where $t = 0.1$ sec = minimum time taken to hear two sounds by human ear.

Thus, the echo will not be heard in a small room (of length less than 17 meters).

(2) A radio station broadcasts at 800 kHz. What will be the wavelength of the wave? [2069 set B]

Ans we know that

$$v = f \cdot \lambda$$

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

$$\therefore \lambda = \frac{3 \times 10^8}{800 \times 10^3} = 375\ m$$

here
$v = c = 3 \times 10^8\ ms^{-1}$ = velocity of light and radiowave
f = frequency = 800 kHz $= 800 \times 10^3$ Hz

Thus, the wavelength of the radio wave is 375 meters.

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(3) Distinguish between light waves and sound waves. [2068]

Ans: The main differences between light waves and sound waves are as follows:-

S.N	Light waves	Sound waves.
1.	Light waves are transverse waves.	Sound waves are the longitudinal waves in gas.
2.	Light waves can be polarized	Sound waves cannot be polarized
3	Light ~~waves~~ can move in vaccum with velocity $3\times10^8 ms^{-1}$.	Sound needs medium for propagation and cannot move in vaccum.
4.	Velocity of light is independent of temperature change.	Velocity of sound increases with the increase in temperature ($v\propto\sqrt{T}$)
5.	Velocity of light in air is almost $3\times10^8 ms^{-1}$.	Velocity of sound in air is $332 ms^{-1}$ at S.T.P.

(4) Can two person on moon hear the sound of one another? Explain [2068]

Ans: No, two person cannot hear the sound of one another on moon because moon has no atmosphere and sound wave needs medium for its propagation.

(5) Which types of wave propagated in liquids? [2063]

Ans: The wave formed on the liquid surface are the combination of longitudinal & transverse waves and known as ripples. On the bottom of liquids the waves are longitudinal.

(6) What is principle of superposition of waves? [2068]

Ans: It states that the sum of the displacement produced by interfering waves is equal to the displacement of the resultant wave. Mathematically it's written as

$$y = y_1 + y_2 + y_3 + \dots + y_n$$

(7) Do sound waves undergo reflection, refraction and polarization phenomena? (2062)

Ans Sound waves undergo reflection and refraction but do not undergo polarization because sound waves in gases are longitudinal waves and polarization occurs in transverse waves only.

(8) What are the differences between longitudinal and transverse waves?

Ans Following are the main differences between longitudinal and transverse waves:-

S.N	Longitudinal waves	Transverse wave
1.	It is formed in a series of compressions and rarefactions.	It is formed in series of crest and trough.
2.	The particles of the medium vibrate along the propagation of wave.	The particles of the medium vibrate perpendicular to the propagation of wave.
3.	It cannot be polarized.	It can be polarized.
4.	The pressure and density are maximum at compression and minimum at rarefaction.	Pressure and density are unchanged.

- 15th ~~mangsir~~ Poush

ch – Mechanical Waves.

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(2) Velocity of sound in a medium:

If E is the modulus of elasticity of the medium having density ρ then the velocity of sound in the medium is given by

$$v = \sqrt{\frac{E}{\rho}} \quad - (1)$$

from eqn (1) we get

(i) velocity of sound in solid

$v = \sqrt{\frac{Y}{\rho}}$ – (2) when $E = Y$ = young's modulus of elasticity of solid.

for example;

$Y = 2 \times 10^{11}\ Nm^{-2}$

$\rho = 7800\ kgm^{-3}$

$\therefore$ for eqn (2) velocity of sound in steel

$$v = \sqrt{\frac{2 \times 10^{-11}}{7800}}$$

$= 5064\ ms^{-1}$

(ii) ~~Velocity of sound in liquid~~

(ii) velocity of sound in liquid:

$v = \sqrt{\frac{K}{\rho}}$ – (3) ; where, $E = K$ = Bulk modulus of elasticity of liquid

from eqn (3), velocity of sound in water will be

$v = \sqrt{\frac{2.04 \times 10^{9}}{1000}}$; $K = 2.04 \times 10^{9}$

$= 1428\ ms^{-1}$

$V = 3\times10^{?}$

Sound 132 (1 sec)

$\gamma = \frac{C_P}{C_V}$

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(iii) velocity of sound in air (gas):-

$$V = \sqrt{\frac{\gamma \cdot P}{\rho}}$$

$$= \sqrt{\frac{1.4\times(1.013\times10^5)}{1.293}}$$

$$= 332\ ms^{-1}.$$

where $\gamma = 1.4$ for air

$\rho = 1.293\ kg\ m^{-3}$ → density of air at STP

$P = 1.013\times10^5\ Nm^{-2}$

Newton's formula for velocity of sound in a gas:-

Newton assumed that sound moves in a gas under isothermal conditions (i.e temprature of compression or rarefaction remain constant).

∴ For 1 mole of ideal gas

$$PV = RT$$

$$\therefore PV = \text{constant} \quad -(1)\text{; because } T = \text{constant for isothermal process.}$$

Differentiating both side of eqn (1), we get

$$PdV + VdP = 0$$

$$P = -\frac{VdP}{dV} = \frac{(-dP)}{\left(\frac{dV}{V}\right)} = \frac{\text{Stress}}{\text{Volume strain}} = K = \text{Bulk modulus of gas.} \quad -(2)$$

[Stress ∝ strain

$\frac{F}{A} = Y\left(\frac{\Delta V}{V}\right)$

For gas

$\frac{F}{A} = K\left[\frac{\Delta V}{V}\right]$]

for gas $E = K$ $\quad V = \sqrt{\frac{E}{\rho}} = \sqrt{\frac{K}{\rho}}$

$$\therefore V = \sqrt{\frac{K}{\rho}}$$

$$\therefore V = \sqrt{\frac{P}{\rho}} \quad \text{--- (3) [from eqn (2)]}$$

For air at STP

$P = 1.013\times10^5\ Nm^{-2}$

$\rho = 1.293\ kg\ ms^{-3}$.

from eqn (3)

$$V = \sqrt{\frac{1.013\times10^5}{1.293}}$$

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$= 280\,ms^{-1}$

But the actual or experimental of sound in air at STP is $332\,ms^{-1}$ This means that the newton ~~velocity~~ formula for velocity of sound i.e $v = \sqrt{\frac{P}{\rho}}$ must be corrected. This correction was done by Laplaces.

Imp # Laplaces formula for velocity of sound in a gas:-

Leplaces corrected newton's formula for velocity of sound in gas by assuming that sound moves in the gas under adiabatic condition (not isothermal).

Adiabatic gas equation is

$$PV^{\gamma} = \text{constant} \quad \text{---} \; (1)$$

where $\gamma = \frac{C_P}{C_V}$ = adiabatic constant

Differentiating both side of eqn (1) we get,

$$dP \cdot V^{\gamma} + (\gamma V^{\gamma - 1} dV) P = 0.$$

$$\gamma P = \frac{-dP V^{\gamma}}{V^{\gamma - 1} \cdot dV}$$

$$= \frac{-dP \cdot V}{dV}$$

$$= \frac{(-dP)}{\frac{dV}{V}} = \frac{\text{Stress}}{\text{volume strain}} = K \quad \text{---} \; (2)$$

where, K is Bulk modulus of gas

$$\therefore V = \sqrt{\frac{K}{\rho}}$$

$$\therefore \boxed{V = \sqrt{\frac{\gamma P}{\rho}}} \quad \text{---} \; (3)$$

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Eqn (3) is Laplaces formula for velocity of sound in a gas
For air

$\gamma = 1.4$

$P = 1.013 \times 10^5 \ Nm^{-2}$

$\rho = 1.293 \ kgm^{-3}$.

In eqn (3) $v = \sqrt{\frac{1.4 \times 1.013 \times 10^5}{1.293}}$

$= 332 \ m/s$.

- 6th Poush, Tuesday

* Effect of change of pressure, temprature, humidity on the velocity of sound in air (or gas):-

(Numerical base)

(i) Effect of <u>temprature</u> change on velocity of sound in air (or gas):-

Laplace's formula for velocity of sound in air (or gas) is given by

$$v = \sqrt{\frac{\gamma P}{\rho}} \quad \text{---} \ (1)$$

for 1 mole of ideal gas $PV = RT$, therefore,

$$\therefore P = \frac{RT}{V} \quad \text{---} \ (2)$$

from eqn (2) eqn (1) gives,

$$v = \sqrt{\frac{\gamma}{\rho}\left(\frac{RT}{V}\right)}$$

$$v = \sqrt{\frac{\gamma RT}{\left(\frac{m}{V}\right)}} \quad \left[\therefore \text{density} = \rho = \frac{m}{V}\right]$$

$$v = \sqrt{\frac{\gamma RT}{m}}$$

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$N_A = 6.023 \times 10^{23}\ mol^{-1}$

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$V \propto \sqrt{T}$

$$\therefore \boxed{\frac{V_2}{V_2} = \sqrt{\frac{T_1}{T_2}}} \quad \text{.. (3)}$$

(ii) Effect of pressure change on velocity of sound in air (or gas):-
Laplace's formula for velocity of sound in air (or gas) is given by

$$V = \sqrt{\frac{\gamma P}{\rho}} \quad \text{---- (1)}$$

For mass 'm' of a gas,

$PV = mrT$; where $r = \frac{R}{M}$ = specific gas constant or gas constant per unit mass

$$P = \frac{mrT}{V} = \rho rT$$

$$\therefore \frac{P}{\rho} = rT \quad \text{— (2)}$$

If temperature 't' is constant then, from eqn (2) for the given gas;

$$\frac{P}{\rho} = \text{constant}.$$

Therefore from eqn (1) there will be no effect of pressure change on velocity of sound, in air or gas,

(iii) Effect of humidity on velocity of sound in air (or gas):-
Laplace's formula for velocity of sound in air or gas is given by we know that

$$V = \sqrt{\frac{\gamma P}{\rho}}$$

$$\therefore V \propto \frac{1}{\rho}$$

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[short question]

The increase in humidity (i.e. presence of water vapour in atmospheric air) decreases the density of air. Therefore from eqn (1) velocity of sound will increase when humidity increase.

Numerical:-

(1) calculate the temprature at which the velocity of sound in air increases by 50% to that of the velocity of sound in air at STP. [Take $V_0 = 332\ ms^{-1}$ if not given, $T_0 = 273$]

Given

Temprature (T) = ? at which $v = V_0 + 50\%$ of V_0
$\therefore\ = 1.5V_0$

Soln,

$$\frac{v}{V_0} = \sqrt{\frac{T}{T_0}}$$

Squaring on both side, we get

$$\frac{v^2}{V_0} = \frac{T}{T_0}$$

$$\text{or, } T = T_0\left(\frac{v}{V_0}\right)^2$$

$$\text{or, } T = 273 \times \left(\frac{1.5\cancel{V_0}}{\cancel{V_0}}\right)^2$$

$$\text{or, } T = 273 \times 2.25$$
$$= 614.25\ K$$

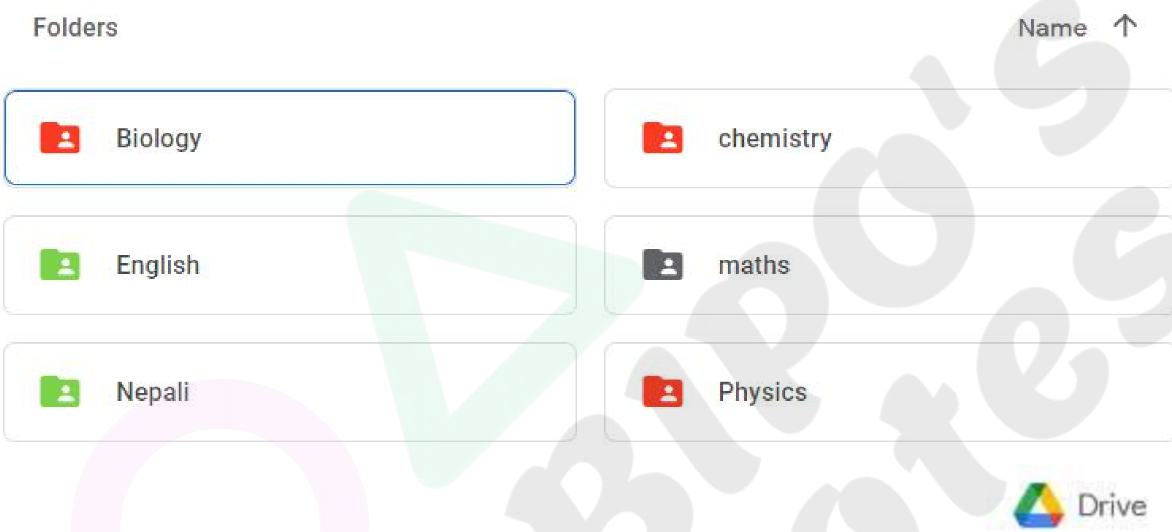
$\therefore$ the temprature at which the velocity of sound in air increase by 50% is 614.25 K.

Teacher's Signature..............

Bipin Khatri

(Bipo)

Class 12 complete notes and paper collection.



Feedbacks:

admin@bipinkhatri.com.np | bipinkhatri.ram@gmail.com

Contact:

@im.bipo   www.bipinkhatri.com.np   @im.bipo

Bipo's notes