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BY

Asst. Prof. Tarun Kumar Gautam

(B.Tech, M.Tech, PhD (P))

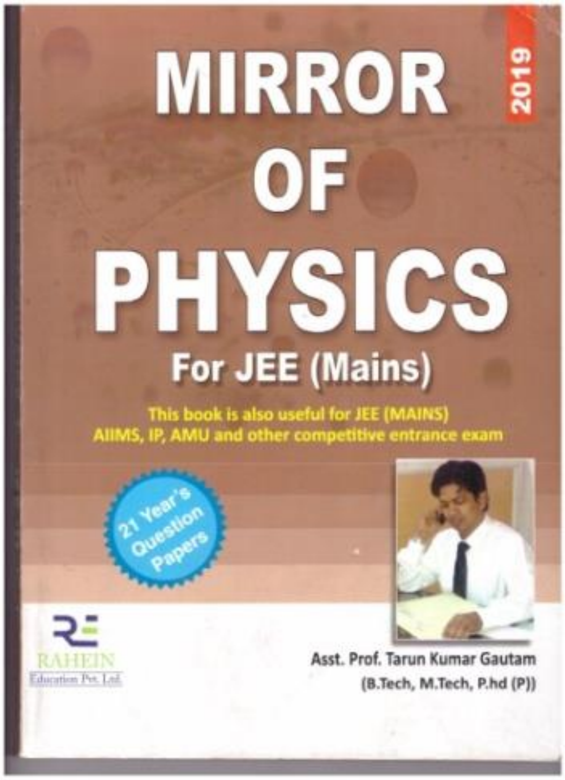
Currently working in Jamia Hamdard, (HSC), Delhi

Working on Nano Technology with Rise University, USA

Author of 8 books regarding Physics and Engineering Subject.

Ex-Faculty of Rajshree Institute of Management & Technology (RMIT), Braeilly, Uttar Prdesh

Ex-Faculty of Assistant professor in Krishna Engineering Collage (KEC), Ghaziabad, Uttar Prdesh
Member of Educational Project in University of Petroleum and Energy Studies (UPES), UK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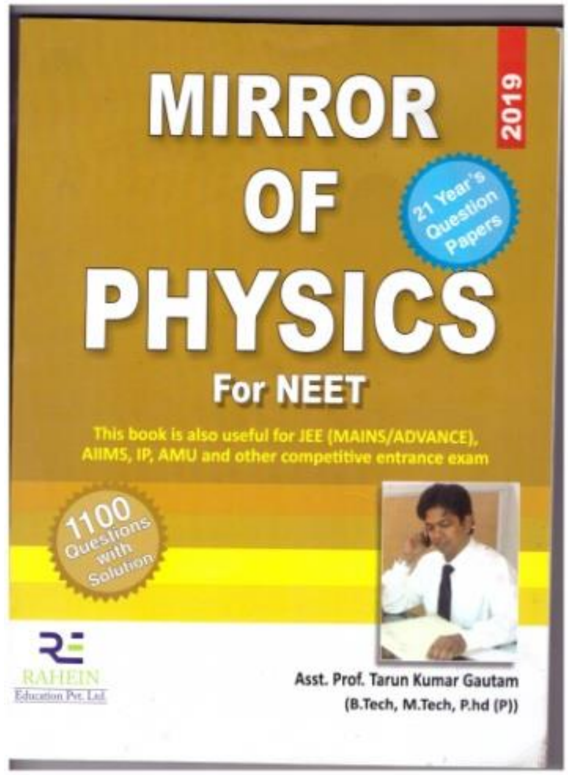
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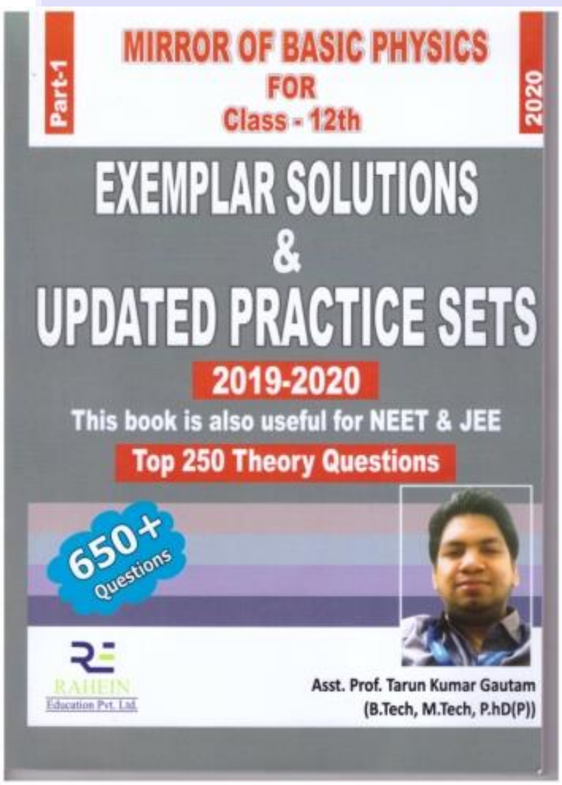
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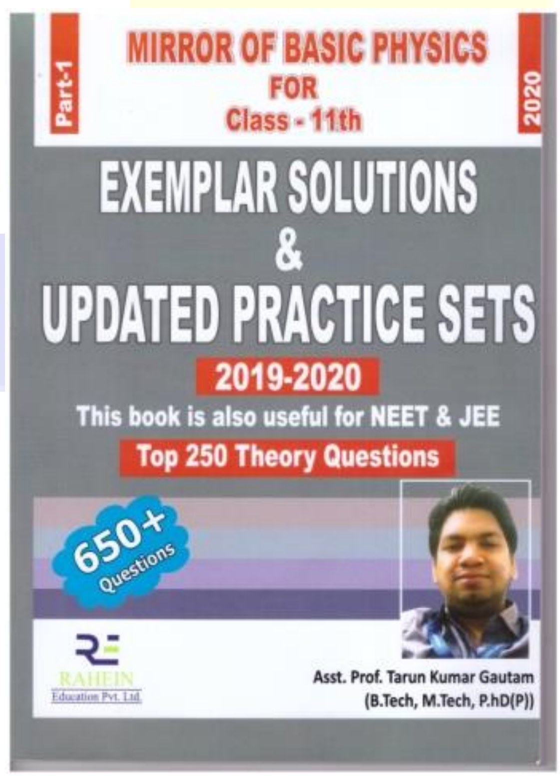
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Chapter - 15

[Waves]

* Wave Motion

It is mean of transferring energy and momentum from one point to another without any actual transportation of matter between there points.

Thus, in wave motion, disturbance travels through some medium but the medium doesn't travel along with the disturbance.

Two types of machenical waves

1) Transverse wave Motion
2) Longitudnal wave Motion

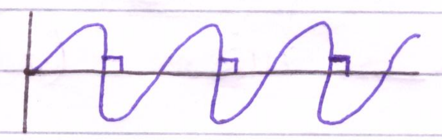
* Transverse Wave Motion

It is the that motion in which individual particles of medium execute Simple Harmonic Motion about their mean position in a direction of perpendicular to the direction of propagation of wave motion.

Ex- Movement of Membrane of Tabla.

Ex- Movement of rope.

Transverse wave Motion



* Longitudnal Wave Motion

It is the wave Motion in which individual

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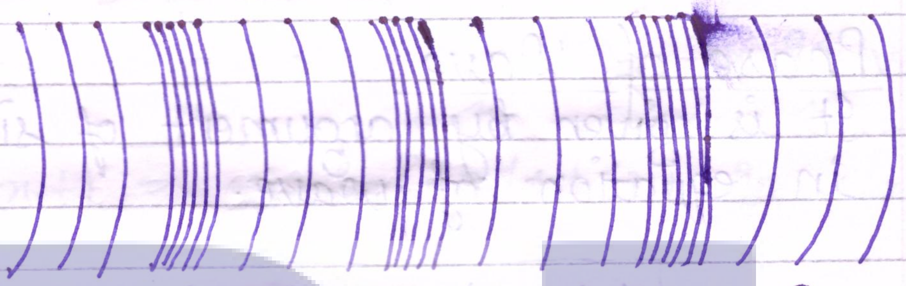
particles of medium execute Simple Harmonic motion about its mean position along the same direction along which wave is propagated as :

C → Compression , R → Rarefraction



Wave Function
Function which describe mathmatically the motion of wave pulse are called 'Wave Function'.

$$\boxed{y = f(t)}$$

Periodic Wave Function
It is wave which repeats itself after a fixed interval of time is called 'Periodic Wave Function'

$$\boxed{y(x,t) = y[x, (t + mT)]}$$

$$\sin\theta = \sin(\theta + \pi)$$

Harmonic Wave Function
The Harmonic waves corresponds to Periodic Motion. It is called "Harmonic Wave Function"

$$\rightarrow \quad y(x,t) = r \sin\left[\frac{2\pi}{\lambda}(vt-x) + \phi_0\right]$$

$$\rightarrow \quad y(x,t) = r \cos\left[\frac{2\pi}{\lambda}(vt-x) + \phi_0\right]$$

* Phase of Wave

It is given by argument of sine or cosine in equation of wave.

$$\boxed{\phi(x,t) = \frac{2\pi}{\lambda}(vt-x) + \phi_0}$$

$$\boxed{\begin{aligned} y &= a \sin\phi \\ y &= a \cos\phi \end{aligned}}$$

* Relation Between Particle Velocity & Wave Velocity

Equation of Wave

$$\rightarrow \quad y(x,t) = r \sin\left[\frac{2\pi}{\lambda}(vt-x) + \phi_0\right]$$

if initial phase $\phi_0 = 0$

then,

$$y(x,t) = r \sin\left[\frac{2\pi}{\lambda}(vt-x)\right]$$

velocity of particle : $u(x,t)$

$$u(x,t) = \frac{dy(x,t)}{dt}$$

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$$\boxed{u(x,t) = r\cos\left[\frac{2\pi}{\lambda}(vt - x)\right] \times \frac{2\pi}{\lambda} \times v}$$

Particle acceleration :

$$a(x,t) = \frac{d[u(x,t)]}{dt}$$

$$a(x,t) = \frac{d}{dt}\left[r\cos\left[\frac{2\pi}{\lambda}(vt-x)\right] \times \frac{2\pi}{\lambda}\cdot v\right]$$

$$a(x,t) = -r\sin\left[\frac{2\pi}{\lambda}(vt-x)\right]\frac{2\pi}{\lambda}\cdot v \times \frac{2\pi}{\lambda}\cdot v$$

$$a(x,t) = -r\sin\left[\frac{2\pi}{\lambda}(vt-x)\right] \times \frac{4\pi^2}{\lambda^2} \times v^2$$

$$a(x,t) = -y\,\frac{4\pi^2}{\lambda^2} \times v^2$$

$$a(x,t) = -y \times 4\pi^2 \left(\frac{v}{\lambda}\right)^2$$

$$a(x,t) = -y \times 4\pi^2 \times \nu^2$$

$$\boxed{a(x,t) = -y \times \omega^2}$$

Note : $\omega^2 = 2\pi\nu = (2\pi\nu)^2$

$$\omega^2 = 4\pi^2 \times \nu^2 \quad \Rightarrow \quad v = \lambda\cdot\nu$$

$$\boxed{\frac{v}{\lambda} = \nu}$$

then,

$$a(x,t) = -y \times 4\pi^2 \times \nu^2$$

$$a(x,t) = -y\,\omega^2$$

Note :

① $y(x,t) = r \sin\left[\frac{2\pi}{\lambda}(vt - x) + \phi_0\right]$

② velocity of particle ⇒ $u(x,t) = \frac{-dy}{dt}$

$$u(x,t) = r\cos\left[\frac{2\pi}{\lambda}(vt-x)\right] \times \frac{2\pi}{\lambda} \cdot v$$

③ Accelaration of particle

$$a(x,t) = \frac{du}{dt}$$

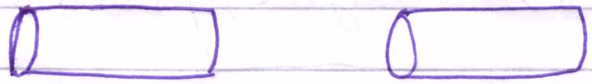
$$a(x,t) = -r\sin\left[\frac{2\pi}{\lambda}(vt-x)\right] \times \frac{4\pi^2}{\lambda^2} \times v^2$$

$$a(x,t) = -y\omega^2$$

④ $\omega = 2\pi\nu = \frac{2\pi}{T}$

⑤ $v = \lambda\nu$

Organ Pipe



Standing wave in closed organ pipe

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

1) Ist Normal mode of vibration

$n = 1$, $\lambda_1 = \frac{4L}{(2\times1-1)} = \frac{4L}{1}$

$$\boxed{L = \frac{\lambda_1}{4}}$$

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$$\boxed{\nu_1 = \frac{v}{\lambda_1} = \frac{v}{4L}}$$ Fundamental Note or Isoharmonic

(ii) <u>IInd Normal Mode of Vibration</u>

$n = 2, \ \lambda_2 = \frac{4L}{(2\times2-1)} = \frac{4L}{3}$

$$\boxed{\nu_2 = \frac{v}{\lambda_2} = \frac{3v}{4L}}$$

(iii) <u>IIIrd Normal mode of Vibration</u>

$n = 3$

$\lambda_3 = \frac{2\times 2L}{3} = \frac{4L}{5}$

$\nu_3 = \frac{v}{\lambda_3} = \frac{5v}{4L} = 5\times\left[\frac{v}{4L}\right] = 5\nu_1$

$\nu_3 = 5\nu_1$

$$\boxed{\nu_n = (2n-1)\nu_1}$$

<u>Standing wave in open Organ pipe</u>

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

(i) Ist Normal Mode of <u>Vibration</u>

$n = 1, \ \lambda_1 = \frac{2L}{1}$ $\boxed{L = \frac{\lambda_1}{2}}$

$$\boxed{\nu_1 = \frac{v}{\lambda_1} = \frac{v}{2L}}$$ fundamental note or Isoharmonic

(ii) IInd normal mode of vibration

$n = 2, \lambda_2 = \frac{2L}{2} = L$

$\nu_2 = \frac{V}{\lambda_2} = \frac{V \times 2}{L \times 2} = 2\left[\frac{V}{2L}\right] = 2\nu_1$

$\boxed{\nu_2 = 2\nu_1}$

Second Harmonic or first overtone

(iii) IIIrd Normal mode of vibration

$n = 3, \lambda_3 = \frac{2L}{3}$

$\nu_3 = \frac{V}{\lambda_3} = \frac{3V}{2L} = 3 \times \left[\frac{V}{2L}\right] = 3 \times \nu_1$

$\boxed{\nu_3 = 3\nu_1}$

$\boxed{\nu_n = n\nu_1}$

Standing wave in String

$y_1 = r \sin(\omega t - Kx)$

$y_2 = r \sin(\omega t + Kx - \pi) = -r \sin(\omega t + Kx)$

$y = y_1 + y_2$

$y = r[\sin(\omega t - Kx) - \sin(\omega t + Kx)]$

$\boxed{y = -2r\omega t \cos x \sin Kx}$

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

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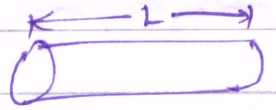
at end point :-



$x = L,\ y = 0$

$\sin kL = 0$

$\sin kL = \sin n\pi$

$kL = n\pi$

$\frac{2\pi}{\lambda} \cdot L = n\cancel{\pi}$

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

Ist Mode of vibration

$n = 1,\quad \lambda_1 = \frac{2L}{1} = 2L$

$$\boxed{\nu_1 = \frac{v}{\lambda_1} = \frac{v}{2L}} \longrightarrow v = \sqrt{\frac{T}{m}}$$

$T \rightarrow$ Tension, $m \rightarrow$ mass

$$\boxed{\nu_1 = \frac{1}{2L}\sqrt{\frac{T}{m}}}$$ called "fundamental note or Isoharmonic"

IInd Mode of vibration

$n = 2,\quad \lambda_2 = \frac{2L}{\cancel{2}} = L$

$\nu_2 = \frac{v}{\lambda_2} = 2\frac{1}{2L}\sqrt{\frac{T}{m}} = 2 \times \nu_1$

$$\boxed{\nu_2 = 2\nu_1}$$

Second Harmonic or Ist Overtone

$$\boxed{\nu_n = n\nu_1}$$