Medical Physics

Ultra sound

Sound wave of frequency greater than 20 KHz

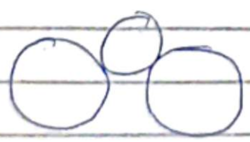
How to generate Ultrasound?

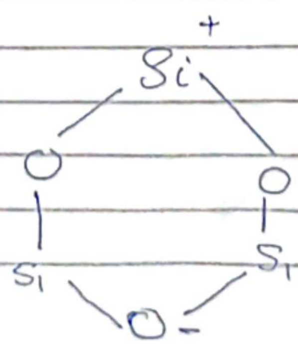
For the generation of Ultrasound Quartz crystal or piezo electric trans dur is used.

Transducer is a device which converts one form of energy to other.

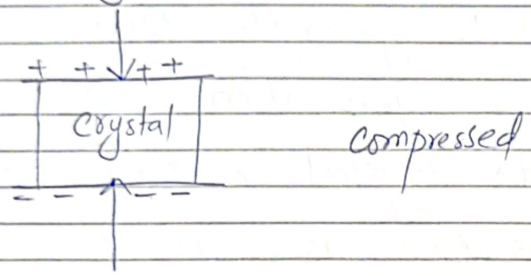
Example microphone → converts sound to electrical

Quartz crystal

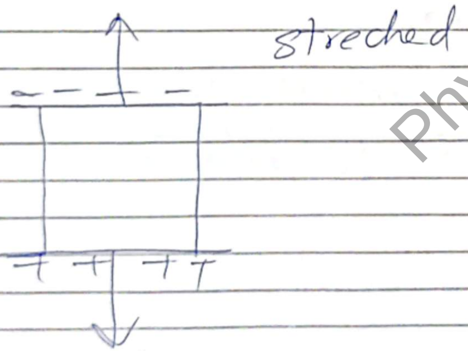




When this crystal is compressed one side become positive and other negative

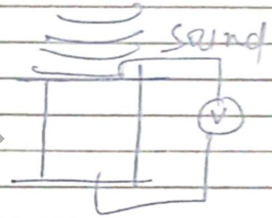


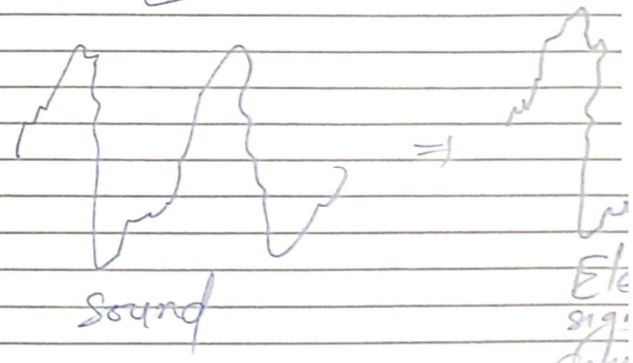
Compression ⟶ Electric field or potential generated



potential generated in opposite direction

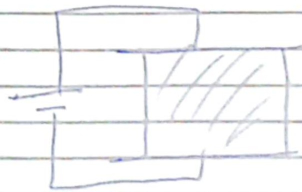
If compressed and streched periodically or sound w[...] is incident ~~then~~ the electrical wave is gene[...]





Ele[...] sig[...] gene[...]

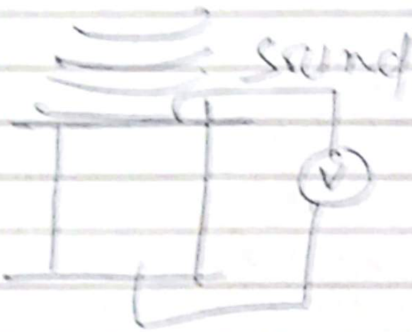
If

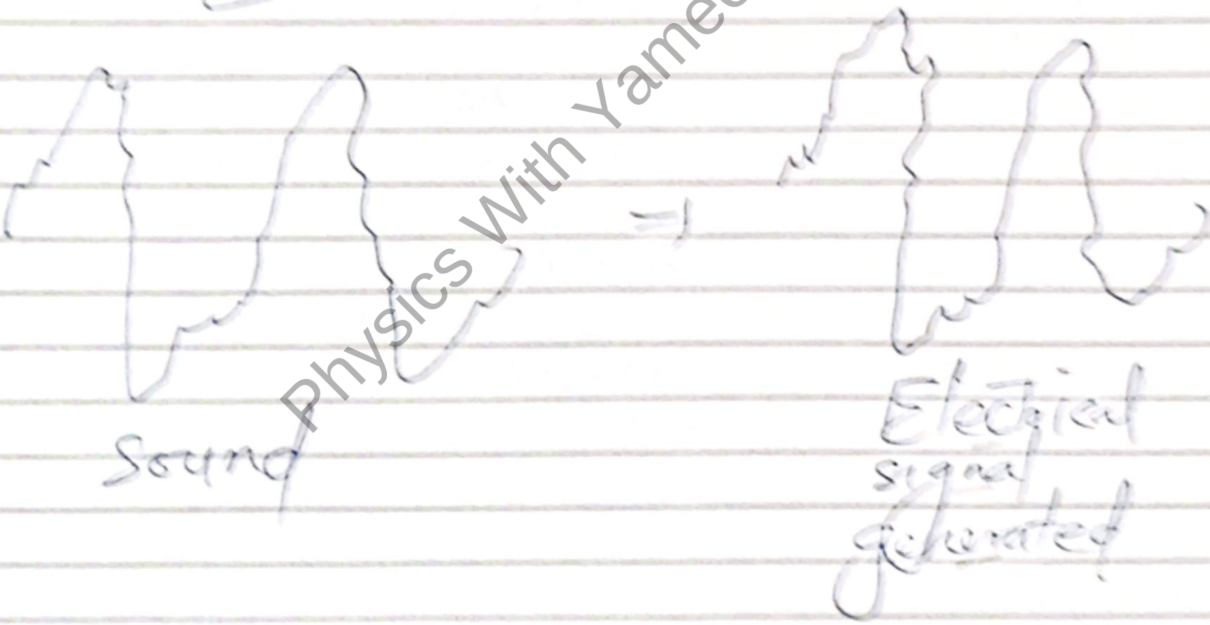


Compressi[...]

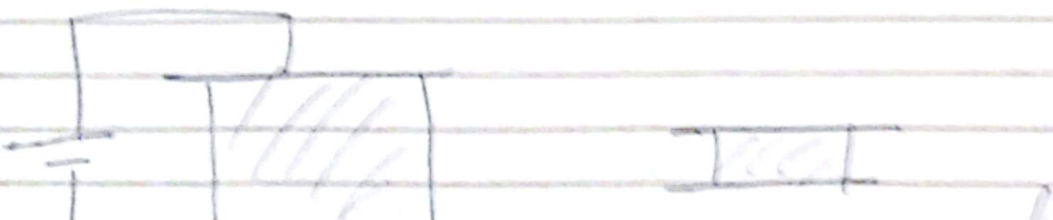
Electrical to mechanica[...]

If compressed and stretched periodically or sound wave is incident ~~then~~ the electrical wave is generated

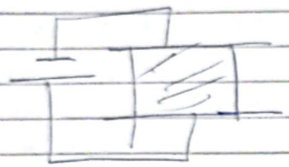




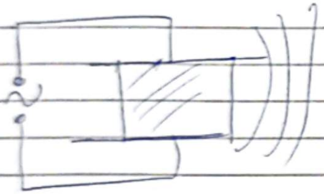
It



Electrical to mechanical

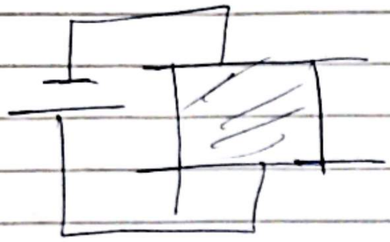


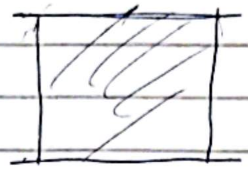
Streched



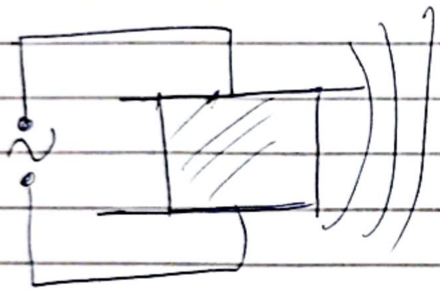
streched and compressed periodically so sound wave of Same frequency as AC signal is generated

Alternating voltage of frequency greater than 20KHz is applied accross piezo electric transducer. Natural frequency of piezo electric tranducer is greater than 20KHz so it resonates and generates sound of the same frequency as at Input is applied electrical wave When input signal is applied quartz crystal stretches and compresses & sound is produced





streched



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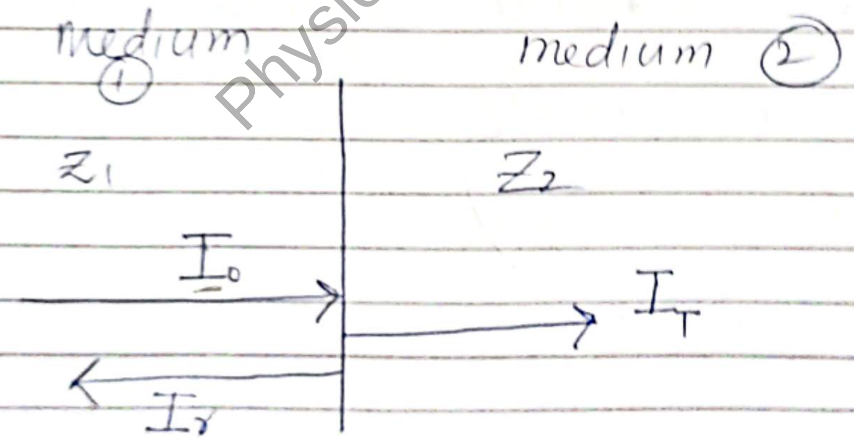
When electrical wave input signal is applied quartz crystal stretches and compresses & sound is produced.

Specific Acoustic Impedance

product of density of medium and speed of ultrasound in that medium.

$$Z = \rho c$$

ρ = density of medium
c = speed of ultrasound.



I_0: Intensity of incident wave
I_r = reflected intensity

I_T : transmitted intensity

$$I_0 = I_r + I_T$$

$$\frac{I_r}{I_0} = \alpha \qquad 0 \leq \alpha \leq 1$$

α : fraction of intensity that is reflected back

α depends on impedences of medium ① and medium ②

$$\alpha = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$$

If diff in Z_1 and Z_2 is large

α will be greater,

more reflection less transmission

$$\frac{I_r}{I_o} = \alpha \qquad I_r = \alpha I_o$$

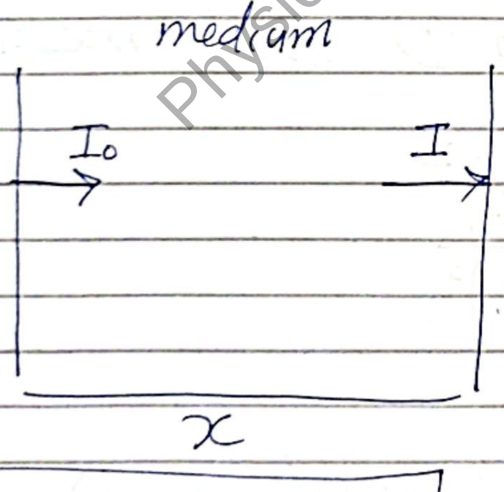
$$I_T = I_o - I_r$$

$$= I_o - \alpha I_o$$

$$I_T = (1-\alpha) I_o$$

Attenuation of Ultrasound

Loss in amplitude of Ultrasound as it travells in medium.



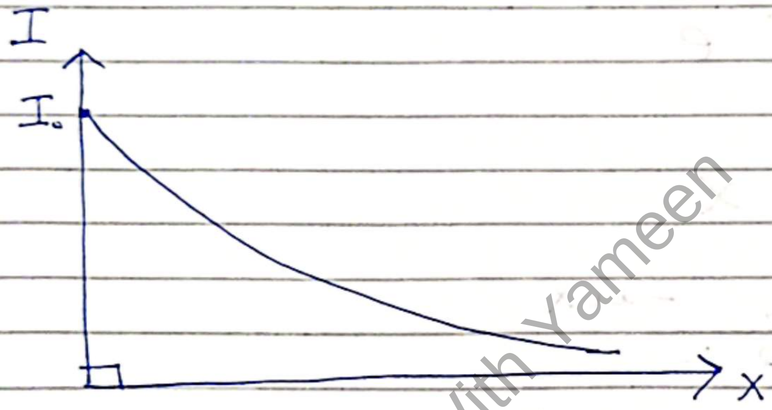
$$\boxed{I = I_o e^{-\mu x}}$$

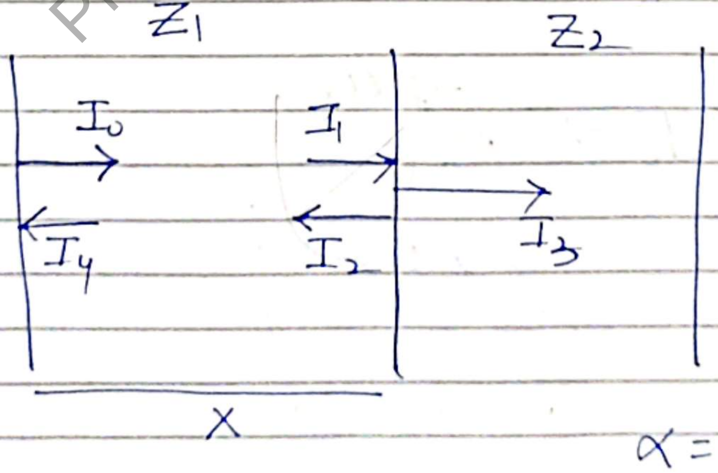
x: distance travelled in medium

μ: linear absorption Coefficient of the medium

Unit: m^{-1} as $x \to m$

if $x \to cm$ $\mu \to cm^{-1}$

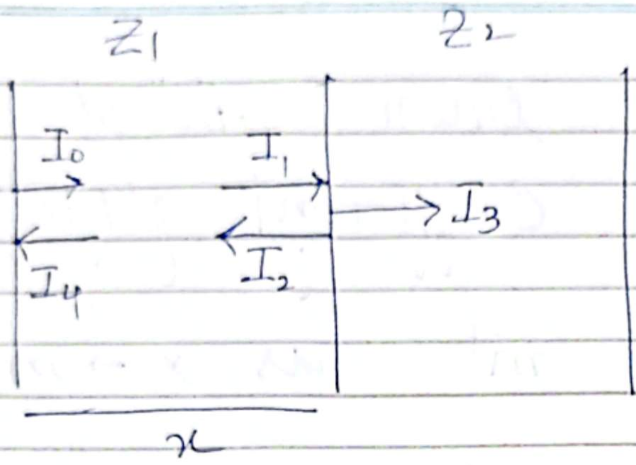




$$\alpha = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$$

express $\frac{I_4}{I_0}$?

$$\alpha = \frac{I_2}{I_1}$$



$$I_1 = I_0 e^{-\mu x}$$

$$I_2 = I_1 \alpha$$

$$I_4 = I_2 e^{-\mu x}$$

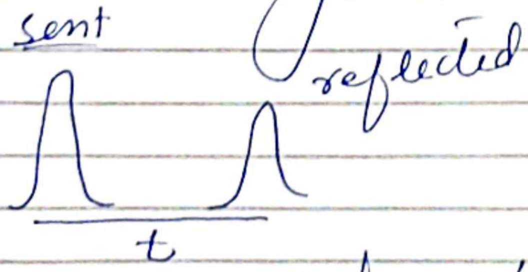
$$I_4 = I_1 \alpha e^{-\mu x}$$

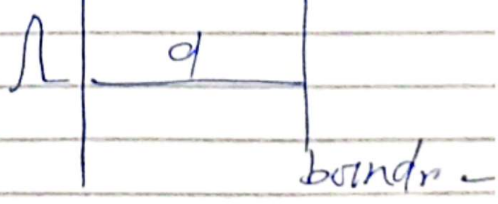
$$I_4 = I_0 e^{-\mu x} \alpha e^{-\mu x}$$

$$I_4 = I_0 \alpha e^{-2\mu x}$$

$$\boxed{\frac{I_4}{I_0} = \alpha e^{-2\mu x}}$$

A sound of pulse is sent into the body. Gell is used as coupling medium. Pulse is reflected from boundry. It is received by the Ultrasound probe. The received pulse is processed. Intensity of this pulse gives information about nature of boundry and time delay gives information about depth of boundry





$$2d = vt$$

$$d = \frac{vt}{2}$$

X-rays

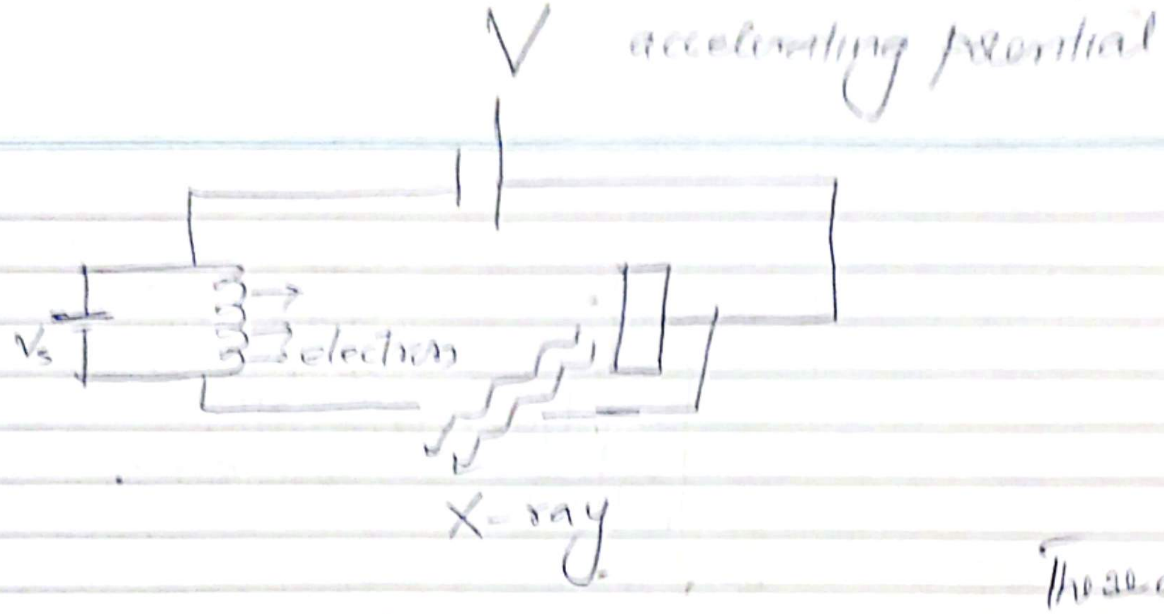
X rays are electromagnetic waves whose wave length ranges from 10^{-8} m to 10^{-11} m.

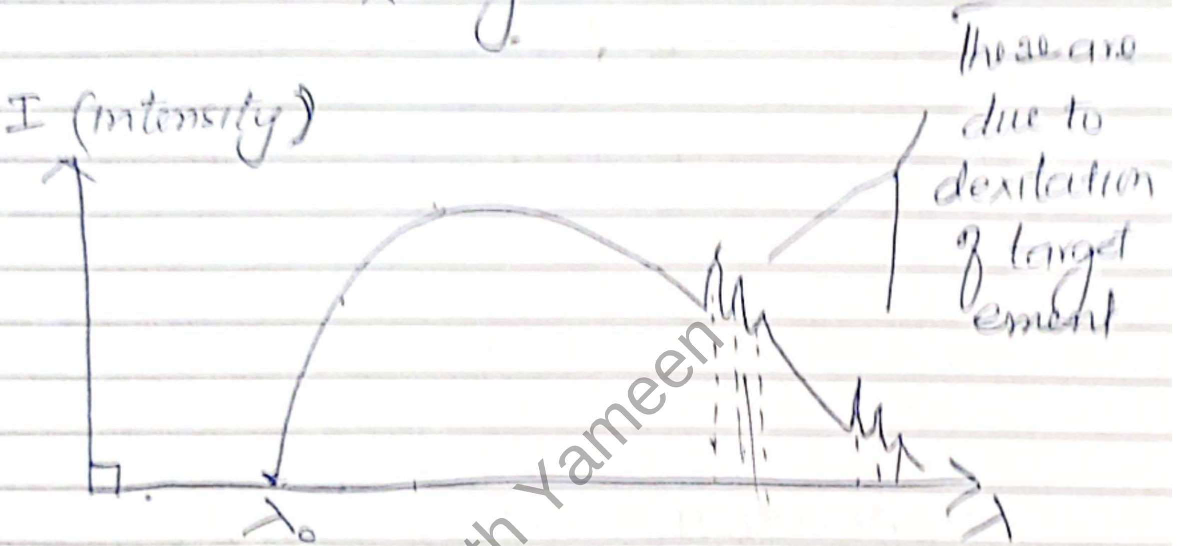
How x-rays are produced?

Fast moving electrons are incident on metal target where these electrons lose there kinetic energy in the form of X-ray photons.
So X-ray photons are produced by deceleration of charged particles (electrons)
As there is a range of deceleration so there will be range of X-ray photon

continues

wave length





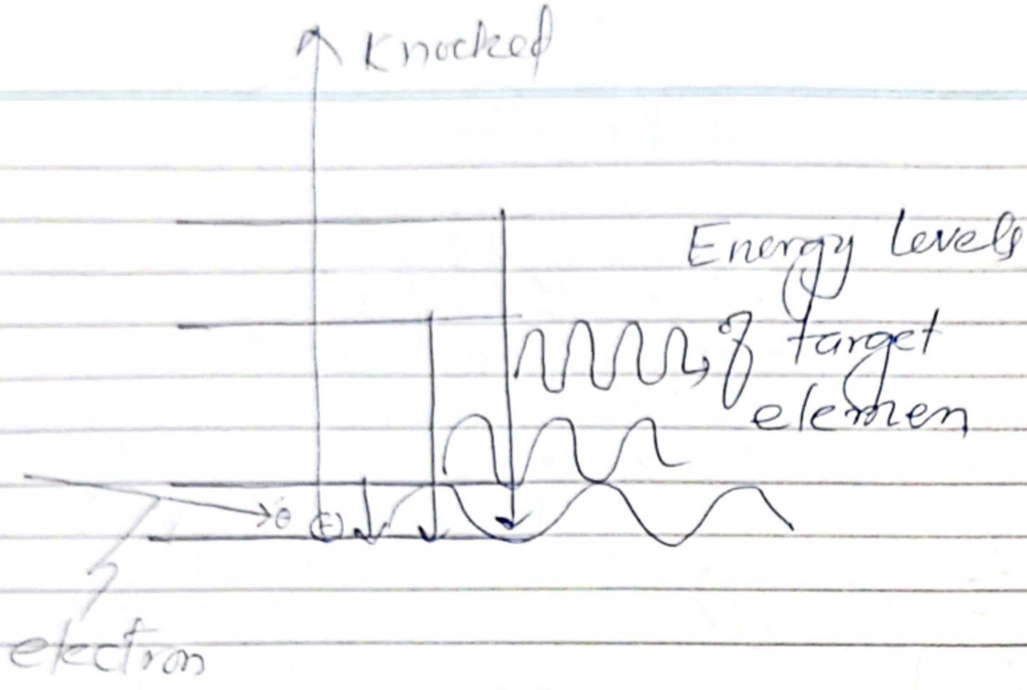
λ_0: Sharp cutt off wave length
this corresponds when
electron loses all of
it energy in collision

$$eV = \frac{hc}{\lambda_0}$$

eV: kinetic energy of electron

$$\lambda_0 = \frac{hc}{eV}$$

Minimum wavelength of X ray



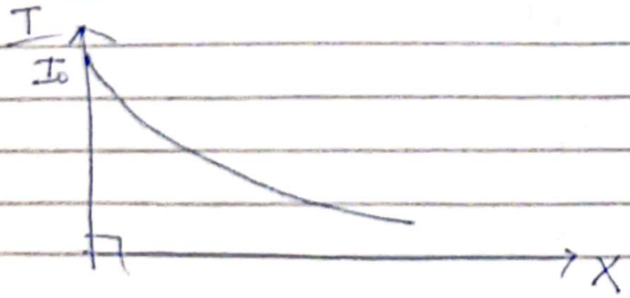
Attenuation of X-ray

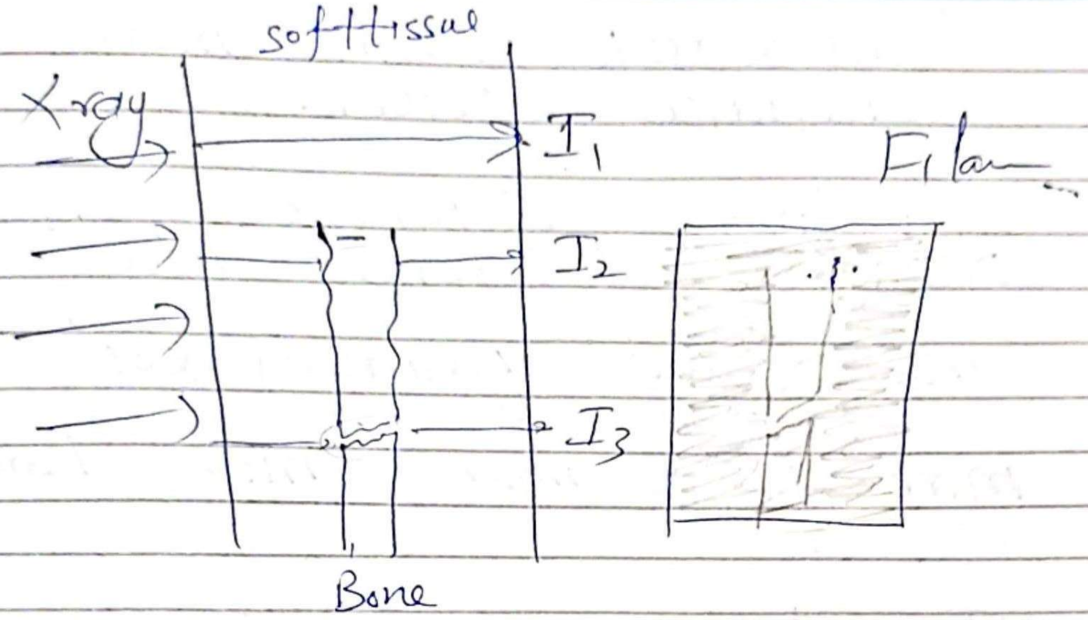
I_0 ———————— I

x

$$I = I_0 e^{-\mu x}$$

* When X-ray travells in a medium it's intensity decreases





X-ray image has Two properties

(1) <u>Constrast</u>

Difference in Degree of blackness and whitness

(2) Resolution

How clearly edges are visible

Hardness of X-ray

penetration power of X-ray

Hard x-ray mean more penetration power.

Hardness depends on potential difference b/w anode and filament coil

more p.d mean more hardness.

Intensity of x-ray can be controlled by controlling Filament Voltage (V_s)

CT- Scan

Computed tomography

* this gives us 3-D image

CT Scan is multiple x-rays taken at different angles These images are given to Computer to form 3-D image.

X-rays of a slice are taken from different angles to form 2-D image of the slice. This process is repeated for multiple slices to form 3-D image of the structure.

section

2	5
7	8

Voxeles parts of section

Number inside are pixel.

2, 5, 7, 8 → example

X

2	5
7	8

7
15

sum=22

⇒

7	7
15	15

(a)

2	5
7	8

⇒

10	5
7	10

(b)

7	10	5

sum=22

In memory (a)+(b)

17	12
22	25

result of two directions

$$\begin{bmatrix} 2 & 5 \\ 7 & 8 \end{bmatrix}$$

$$\begin{bmatrix} 9 & 13 \end{bmatrix}$$

$$\begin{bmatrix} 9 & 13 \\ 9 & 13 \end{bmatrix} \quad c$$

add in result of previous 2

$$\begin{bmatrix} 17 & 12 \\ 22 & 25 \end{bmatrix} + \begin{bmatrix} 9 & 13 \\ 9 & 13 \end{bmatrix}$$

$$\begin{bmatrix} 26 & 25 \\ 31 & 38 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 5 \\ 7 & 8 \end{bmatrix}$$

$$\begin{bmatrix} 2 \\ 12 \\ 8 \end{bmatrix}$$

ysum = 22

2	12
12	8

add in previous

26	25
31	38

+

2	12
12	8

28	38
44	46

28	37
43	46

Now how to get original pixel number

Background reading = total number in any direction
22 in this example

Step 1

Subtract background reading

28	37
43	46

− 22

6	15
21	24

Step 2

Divide by 3

2	5
7	8

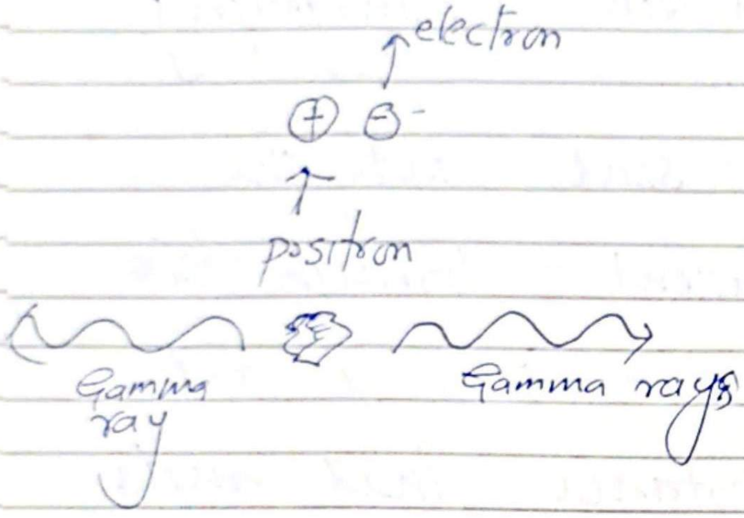
original

PET Scanning

Positron emission tomography.

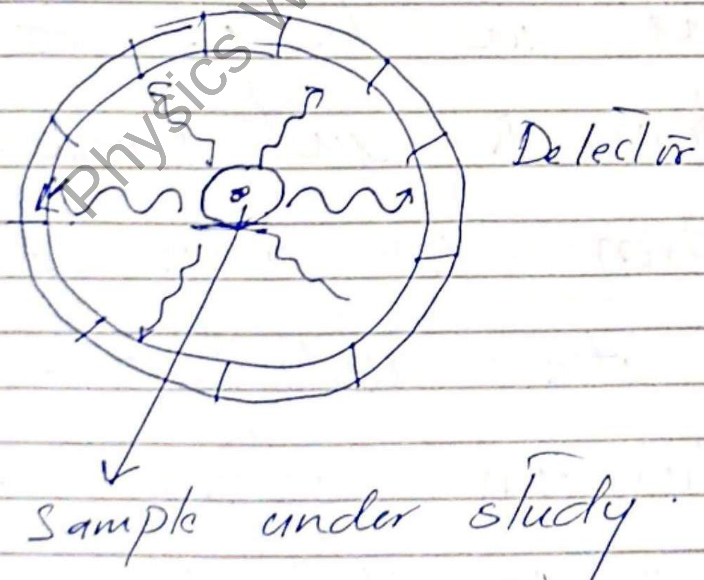
A tracer is sent into the body of patient through ~~blo~~ injection. tracer is a radio active substance that emits positron (Beta positive)

positron interact with electron present in body. As positron is anti particle of electron so when a particle and its anti particle meet annihilation occurs and mass is converted to energy in the form of Gamma. two Gamma rays are emitted in opposite direction to conserve momentum.



$$e^- + e^+ \rightarrow \gamma + \gamma$$

These gamma rays are detected on detector



These gamma rays are used to find location of

effected area and Image of effected area is formed.
arrival times of Gamma rays are processed and Image of tracer concentration is formed.

~~Energy~~

<u>Positron</u>

mass $\Rightarrow$ mass of electron $= 9.11 \times 10^{-31}\,kg$

Charge $\Rightarrow$ $+e$ $= 1.6 \times 10^{-19}\,C$

<u>Energy of one Gamma ray</u>

$E = mc^2$ $\qquad$ m = mass converted into energy

$m = m_e + m_{positron}$

$m = 9.11 \times 10^{-31} + 9.11 \times 10^{-31}$

$m = 18.22 \times 10^{-31}\,kg$

$$E = mc^2$$

$$E = 18.22 \times 10^{-31} \times (3 \times 10^8)^2$$

$$E = 1.64 \times 10^{-13} J$$

In electron volt

$$eV = 1.6 \times 10^{-19} J$$

$$E = 1024875 \ eV$$

$$E = 1025 \ keV$$

energy of one gamma ray

$$E = \frac{1025}{2} keV$$

$$\boxed{E = 512 \ keV}$$

Wave length of Gamma ray?

$$E = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{E}$$

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{512 \ eV}$$

$$\lambda = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{512 \times 1.6 \times 10^{-19} \times 1000}$$

$$\lambda = 2.42 \times 10^{-12} m$$

$$\boxed{\lambda = 2.4 \ pm}$$

Example of Tracer

$${}^{18}_{9}F \longrightarrow {}^{18}_{8}O + {}^{0}_{1}e$$

The End!