Topic: Medical Physics. Date:

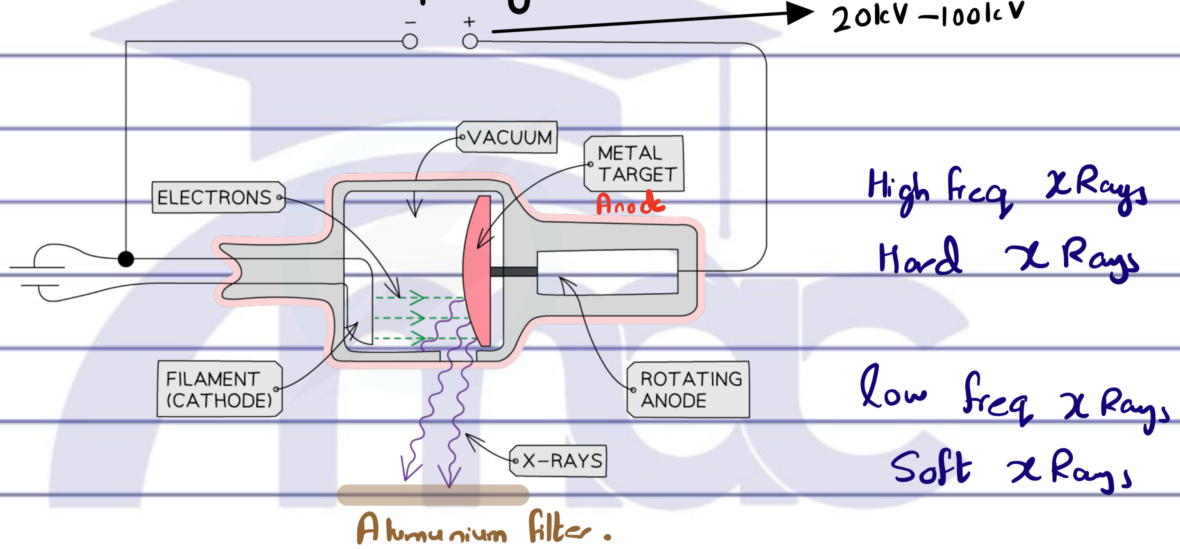
1) X Rays.
2) ultra sound
3) PET Scanning

1) Properties and Production of x Rays:

i) $\lambda = 10^{-10}$ m

ii) locate fractures in bones

iii) Can ionize matter darken photografic films.



→ Metal filament heated, thermionic emission occurs, electrons are produced, these electrons will accelerate towards the target anode. there K.E will be absorbed by the electrons of the target anode & as a result these e^- of the target anode will undergo excitation causing them to Jump from lower energy levels into higher energy levels

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When these electrons undergo de exitation they emit x Rays (Electromagnetic Radiation).

The Intensity of x Rays produced is controlled by the magnitude of tube current.

* Tube current increases ⟶ more electrons will be emitted More no of x Rays will be produced (Hence Intensity increase)

* The frequency also called hardness or penetration power of x Rays are Controlled by the potential difference supplied b/w cathode and anode.

Increasing potential difference more Electrons will gain KE and Based on $\uparrow E = hf\uparrow$ (hence if Energy increases, x Rays photons will be emitted with greater frequency).

* Since Emitted Electrons have range of K.E ∴ the x Ray photons produced also have a range of frequencies. The low frequency x Rays (also called soft x Rays) gets absorbed by the patient's body which is why an Aluminium filter is used to stop these soft x Rays from Entering the patient's body.

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If the incoming electron transfer all of its Energy to the target anode, than the x Rays produced will have the highest frequency and the shortest wavelength. This shortest wavelength is also called cut off wavelength.

Attenuation of x Rays:

It is defined as the loss in power or loss in intensity of a radiation as it passes through living matter.

Flesh (Human body)

I_o = Incident Intensity
I = Transmitted Intensity

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

x = thickness of medium (m)
μ = constant known as liniar Attenuation constant / linear Absorption constant / linear Attenation coefficient.
(m^{-1})

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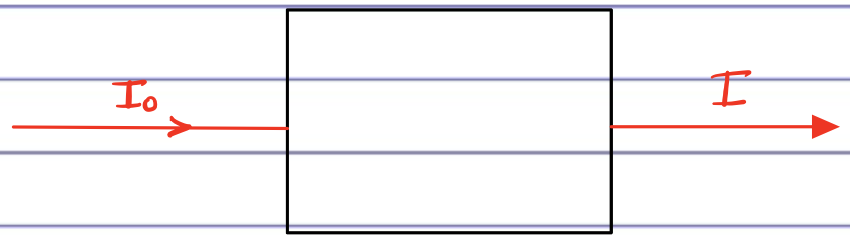
Ex



$x = 0.14m$

$\mu = 0.23m^{-1}$

Calculate fraction transmitted through flesh.

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

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

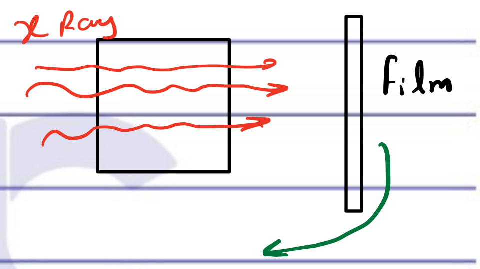
$$\frac{I}{I_0} = e^{-(0.23)(0.14)}$$

$$\boxed{\frac{I}{I_0} = 0.97}$$

≈ 97% of incident intensity is able to pass through flesh (only 3% is absorbed)

$\frac{I}{I_0}$ when close to 1 (majority gets transmitted)

Flesh xRay {Black}



High Exposure therefore it turns black.

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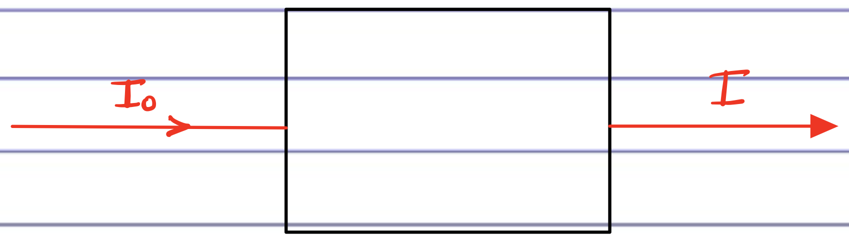


Soft tissue.

$x = 0.14\,m$

$\mu = 3.5\,m^{-1}$

Calculate fraction transmitted through soft tissue

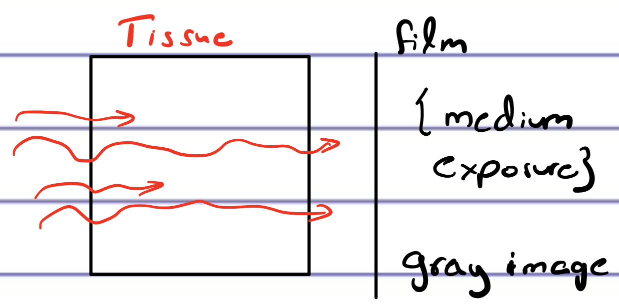
$$\frac{I}{I_o} = e^{-\mu x}$$

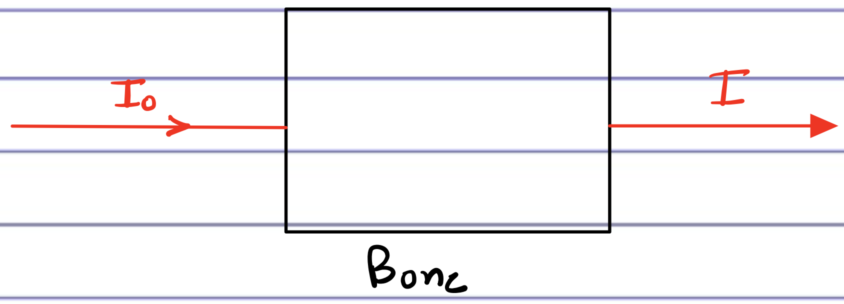
$$\frac{I}{I_o} = e^{-(3.5)(0.14)}$$

$$\frac{I}{I_o} = 0.613$$

61.3 % transmitted

39% is absorbed.





$x = 0.14\,m$

$\mu = 28\,m^{-1}$

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

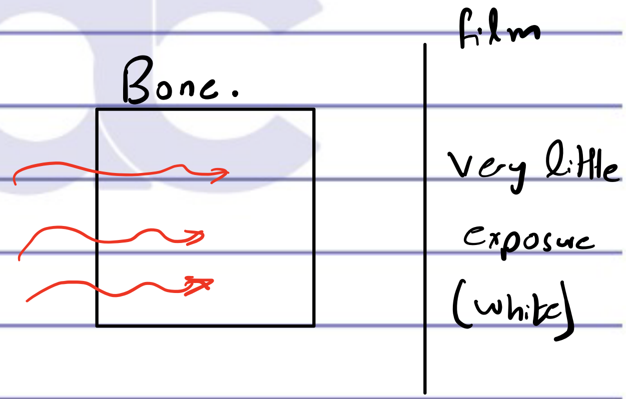
$$\frac{I}{I_0} = e^{-(28)(0.14)}$$

$$= 0.02 \qquad 2\%$$

{very little amount transmitted}

very high absorption

A good contrast can be established if x Ray image involves bone vs flesh



Bone vs flesh

↳ white Black.

{A well defined contrast is achived}

The contrast will be not be well defined b/w bone and tissue.

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Finally if $\frac{I}{I_0} \simeq$ close to 1 very little absorption
Color is black

If close to 0 very little transmission
Color is white.

→ Graph of Intensity against thickness (x) looks like for different mediums ex flesh soft tissue and bone.

Concept of Half value Thickness (HVT or $x^{1/2}$)

It is thickness of medium which causes intensity of xRay to reduce to half of its initial value.

$$x^{1/2} = \frac{0.693}{\mu}$$

μ = linear absorption constant.

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Concept of Half life ($T_{1/2}$)

Time taken for activity to reduce to half of its orignal value.

$$T_{1/2} = \frac{0.693}{\lambda}$$

Q) Quality of an image produced by an x Ray tube

It depends upon 2 factors.

① Sharpness

is defined as the ease with which the edges of a structure can be determined. A sharp image is the one in which edges are well defined.

② Contrast

Is defined as the ease with which one structure can be differentiated from the other. a good contrast is one which has a range of exposures i.e it shows area of little or no blackening as well as area of heavy blackning.

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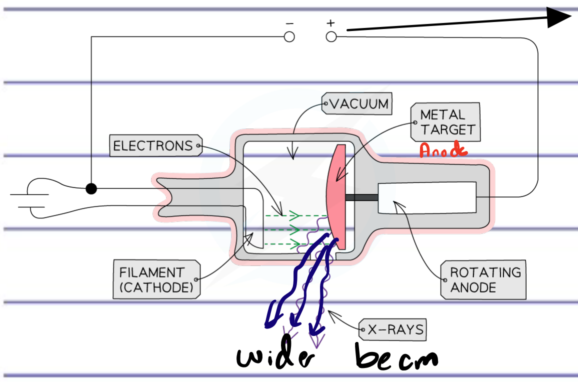
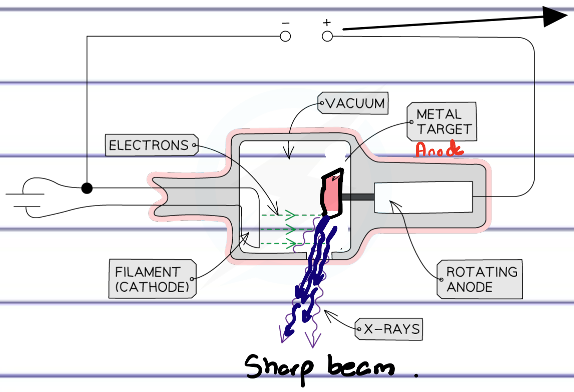
Factors that effect the sharpness of x Ray ? (Learn)

① Size of Target Anode.



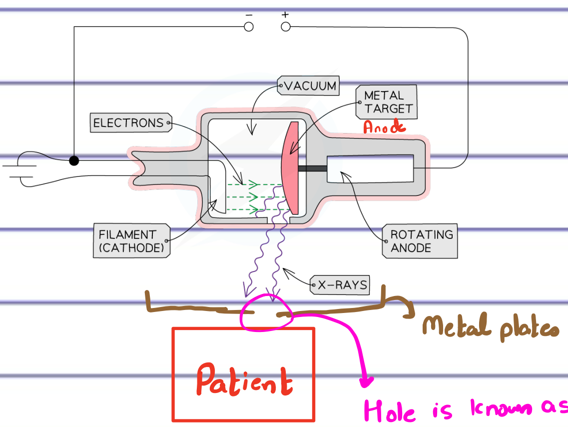


* Beam of x Ray has a greater width it is less focused or less sharp

* Beam of x Ray has a Lesser width ∴ it is more focused or more sharp

Conclusion: Reducing size of the anode increases sharpness of the x Ray beam.

② Size of the Aperture.



→ If Aperture is larged sized beam will be less focused (lack sharpness)

→ Aperture (Small sized) beam more focused (Sharpness improves)

Conclusion : Reducing the size of the apparture improves the sharpess of the beam.

Topic: ______ Date: ______

Factors which affect the contrast of the x Rays.

① Exposure time:

If you increase the exposure time (within limit)

Gray ⟶ Black

White ⟶ White (x Ray do not pass)

Contrast will improve.

② Use of back light

Black ⟶ Black

White ⟶ Back light passes through ⟶ more brighter than before & hence a good contrast is established.

③ Stomach patients

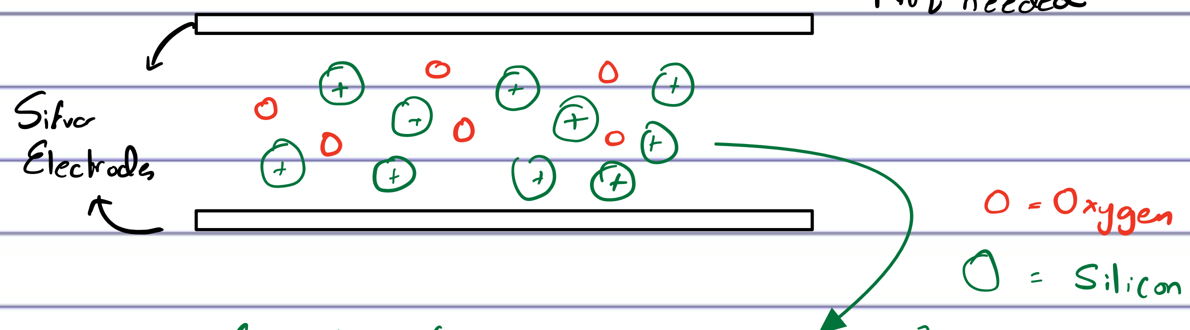
(Barium drink) ⟶ Barium is very strong absorber/Blocker of x Ray.

For creating an Artificial Contrast

Topic: Ultra sound Date:

How is Ultrasound Produced:

Device : "Ultra Sonic Transducer." Diagram Not needed



Quartz Crystal (SiO_2) {Piezo - Electric Crystals}

Silicon is in group IV
Silicon cause electropositivity

O = Oxygen is group VI
electronegativity.

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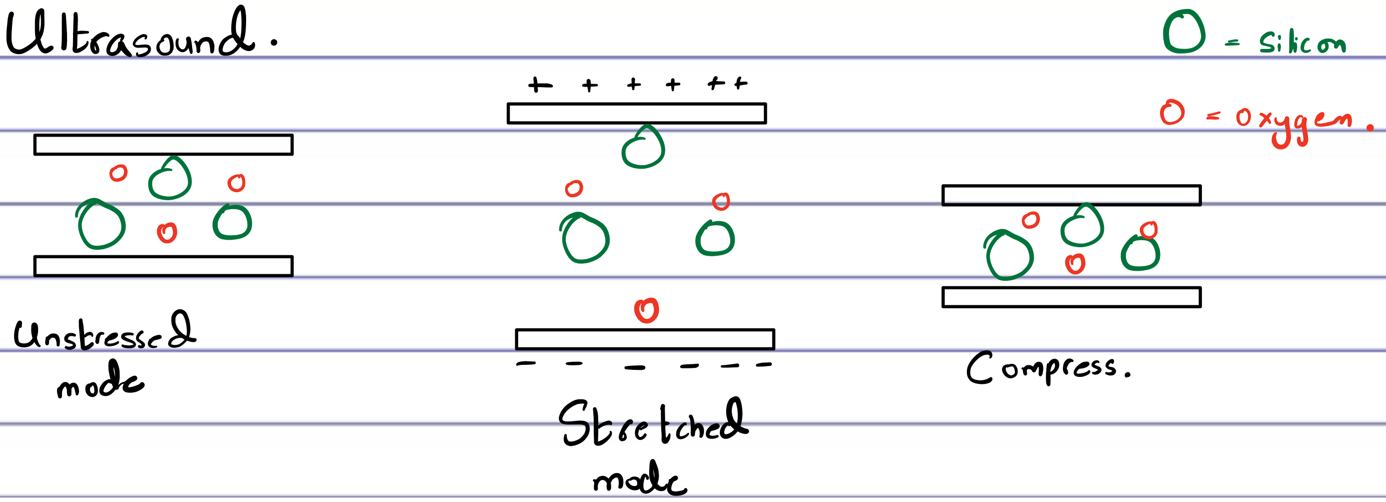
Topic: ____________ Date: ____________

Ultrasound.



The production of ultrasounds can be done by using piezo electric crystals/ Quartz crystals. The effect demonstrated above is called piezo electric effect.
In an unstressed mode the crystals are positioned such that the distribution of positive charges and negative charges are symmetrical i.e. no potential difference is generated between the two silver electrodes.
However if the crystal is compressed or stretched the centers of positive and negative charges will shift.
If vibrated continuously an alternating potential difference can be generated between the electrodes due to the shifting of the center of positive and negative charges.
Conversely if the crystal is supplied with small alternating potential difference, the crystal can be made to vibrate.
This vibration results in the production of sound waves.
The frequency of the a.c. supply is such that the vibration of the crystal produces sound in excess of 20KHz.

Q) How will we insure that Ultrasound will Enter the human body.

Concept of Specific Acoustic Impedance (Z)

Ultrasound follows laws of reflection and refraction, similar to light waves and sound waves i.e. whenever Ultrasound arrives at a boundary between two mediums, a certain fraction of it is reflected at the boundary, whereas, the other fraction gets transmitted.
The intensity reflected depends upon 2 factors.
1) Density of the medium
2) Speed of ultra sound.

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Product of these two quantaties is denoted by "z" and this quantity is denoted by symbol "Z" and this quantity is called Specific acoustic impedence (i-c)

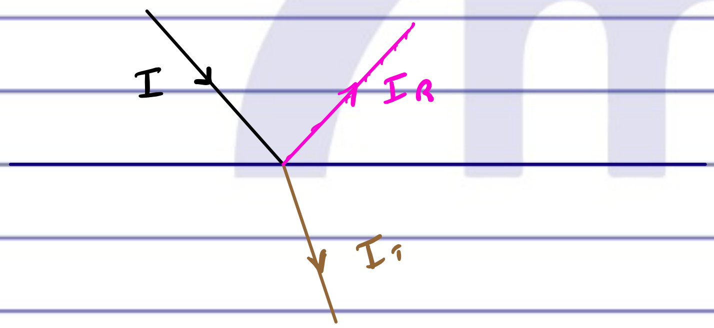
$$Z = \rho c$$

The fraction reflected $\left(\frac{I_R}{I}\right)$ Known as (intensity reflection coefficient or (α)

is given by the expression.

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

Where Z_1 and Z_2 are the values of specific Acoustic Impedence of the two mediums.



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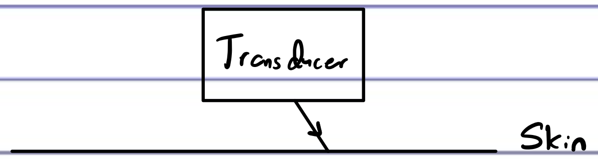
Example:

Air

$Z = 0.0004$



Soft tissue

$Z = \rho \times c$ $\quad Z = 1.3 \times 10^6$

Calculate the fraction reflected at the boundary

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

$$\frac{I_R}{I} = \frac{(1.3\times10^6 - 0.0004)^2}{(1.3\times10^6 + 0.0004)^2}$$

$$\frac{I_R}{I} = 0.999 \approx 99.9\%$$

approximately 100%

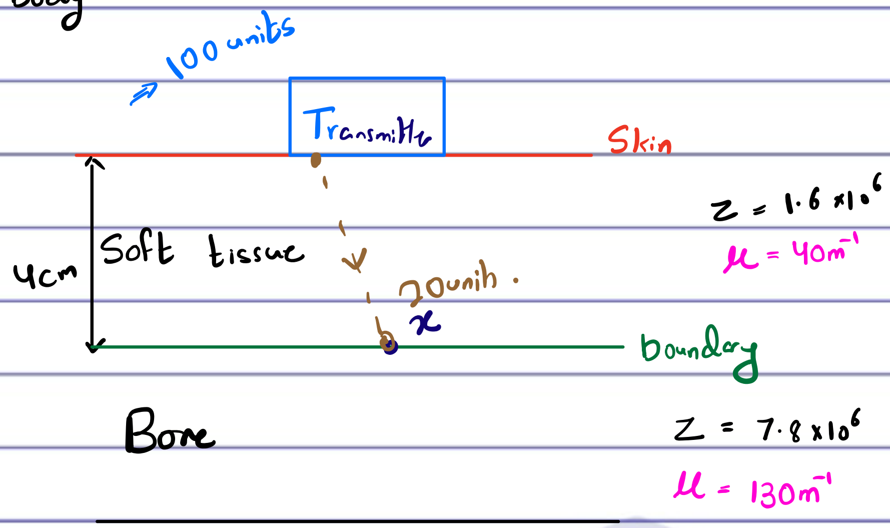
Note: Whenever values of Z have large difference

$$\frac{I_R}{I} \approx 1 \ (100\%)$$

Using this information it can be noticed that this fraction(α) is high when ultrasound enters or leaves the body (i.e. a boundary between the air and soft tissues). To reduce this fraction gel is used as a coupling medium. This information signifies that very little or no information can be gathered about regions beyond lungs or for that matter any air filled cavities.

Topic: ______ Date: ______

In Your Exams they ask you what happens inside human body



i) Calculate fraction transmitted through 4cm of soft tissue.

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

$$\frac{I}{I_0} = e^{-(40)(0.04)}$$

$= 0.2 \Rightarrow 20\%$ reaches point x

ii) Calculate fraction reflected at the soft tissue — bone boundary

$$\frac{I_R}{I} = \frac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2} = \frac{(7.8\times10^6 - 1.6\times10^6)^2}{(7.8\times10^6 + 1.6\times10^6)^2} = 0.44 = 44\%$$

Out of 20% transmitted 44% is reflected back

Topic: ________________ Date: ________________

iii) Calculate the fraction which is recieved back at the surface / Transmitter?

$0.2 \times 0.44 \times 0.2 = 0.0176$ Ans

Question (Reverse)

Thickness of soft tissue x (unknown). Given that only 0.0176 of incident intensity is received back at the surface use this information to calculate the thickness of soft tissue.

$$e^{-\mu x} \times \frac{(z_1 - z_2)^2}{(z_1 + z_2)^2} \times e^{-\mu x} = 0.0176$$

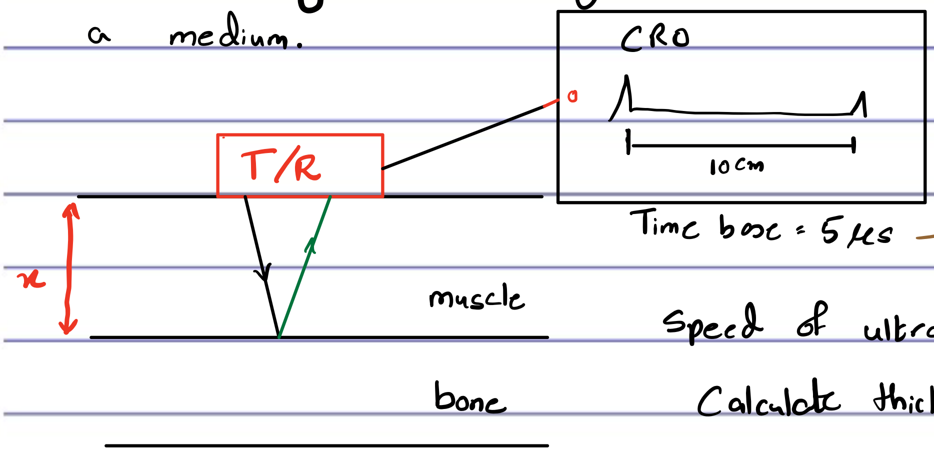
$$e^{-(40)x} \times 0.44 \times e^{-40(x)} = 0.0176$$

$$\ln e^{-80x} = \ln \frac{0.0176}{0.44}$$

$$x = 4\,cm$$

Topic: ____________ Date: ____________

Alternate way of asking Question to obtain thickness of a medium.



Time base = 5 μs → 1 cm

Speed of ultrasound = 2000 m/s

Calculate thickness of muscle

Time for pulse to go and be back

$10 \times 5 = 50 \mu s$

$d = s \times t$

$d = (2000)(50 \times 10^{-6})$

A scan

$d = 0.1\ m$ (10 cm)

$0.1 \div 2$ = Its echo. so

Thickness = 0.05 m (5 cm)

TYPES OF ULTRASOUNDS

There are basically 3 types of techniques known as the A-scan, B-scan and the Doppler ultrasound.

The A-scan basically measures the distance between different boundaries from the transducer with the transducer held in one position. A short burst of ultrasound is made to enter the body using gel as coupling medium. At each boundary between the two medium , a certain fraction of ultrasound gets reflected while a certain fraction transmitted. The reflected pulse is picked up by the transducer which now behaves as a receiver and it converts the pulse into a voltage pulse which is processed, amplified and is observed on the screen of CRO. Since the transmission of ultrasound results in a loss of intensity at each boundary where it strikes, the echoes obtained from the region deep inside the body are of low intensities. To compensate for this effort, later an echo is received, the greater is the scale through which it is amplified before it is displayed on the CRO screen. Using the distance between the two wave pulses and the speed of the ultrasound, in that particular medium, the thickness of that region can be obtained. This technique is known as A-scan. Hence A-scan makes use of the above effect to measure the thickness between various boundaries.

A B-scan is a combination of A-scan which is taken from a variety of different angles. The individual pulses obtained are gathered, analysed and processed by a computer which superimposes these multiple echoes on top of each other thereby gathering a two dimensional image. Ultrasounds are useful because they can show us real time image such as a heart-beating.

Doppler ultrasound is used to observe the circulation of blood through the blood vessels.

Ultrasound do not pose any serious threat because they do not make use of any ionising radiations. Hence, the ultrasound scanning can be done quite often without any side-effects.

N 95

Topic: CT scan   Date:

CT = Computer Tomography.

Priciple of CT scan (5 marks)

Computer Tomography makes use of ionising radiation (conventional x Rays) to obtain images a standard x Ray is a flat image i.e it doesn't give any impression about the depths hence weather an organ is near to the skin or deep inside the body is not apperent, One possible solution is to use the beam for multiple scans, from a variety of different angles, for this to happen a rotating x Ray beam is used, the beam and the detector are both made to rotate in the same sense, and same speed. It is rather difficult process hence an Algorithms are there in computer to convert these 2Ds in 3Ds

Slice = Small part of human body.

The procedure of CT Scan. (4 marks)

1) CT scan takes many images of slice of variety of different angles.
2) This builtup an image of a slice through the body.
3) Series of images of various slices are made so the superposition of these can allow a builtup of 3D image
4) This image can be rotated on a computer through varity of different angles. on a computer screen.

Topic: ____ Date: ____

Advantages

1) quick process
2) used for head injuries.
3) used in treatment of Braintumors
4) Provides good contrast in abdominal regions.

Topic: PET Scanning Date:

Positron emission tomography

Its a very different technique.

In this we actually give patient a tracer.

Tracer = very small half life.

Tracer: Substance containing radioactive nuclic which is absorbed by tissue being shielded.

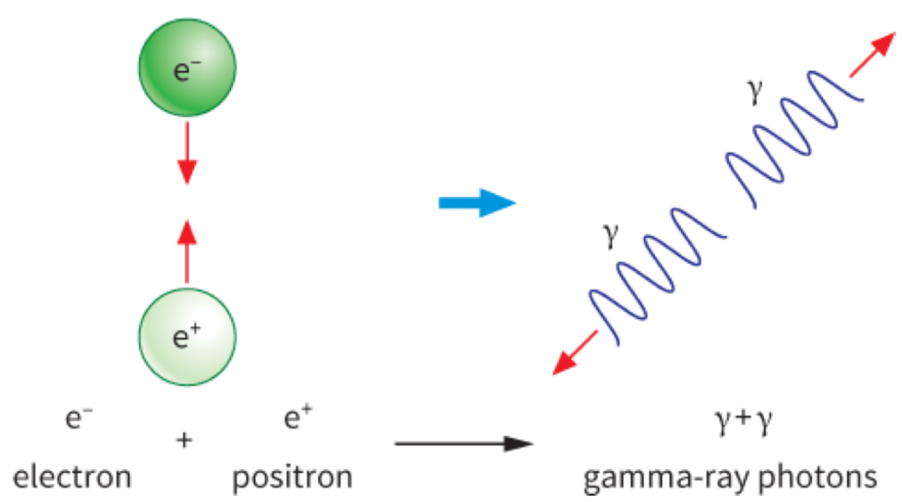
Tracer = 18 FDG = Its like glucose that emits positron.

$e^+ + e^- \xrightarrow{\text{Annahilation}}$ gamma rays.

(Antimatter) (matter)

Brain is hungry for glucose or FDG

Cancer is also hungry for glucose or FDG

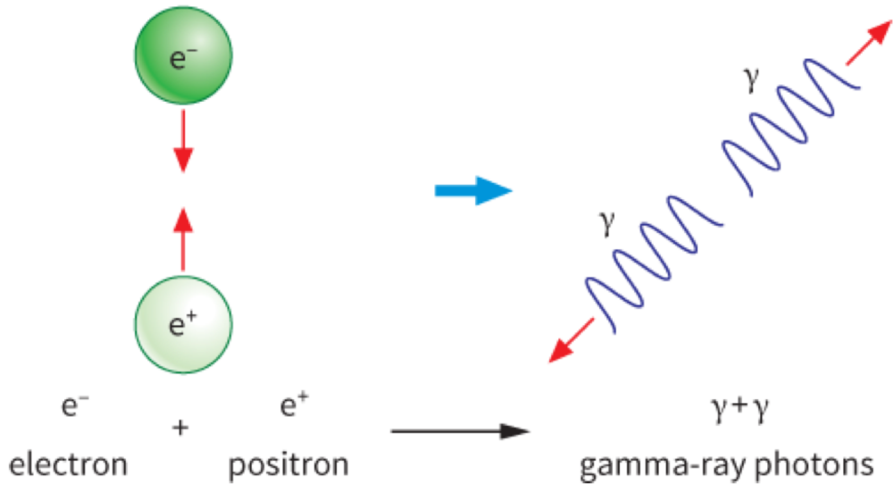


matter + Antimatter ⟶ energy.

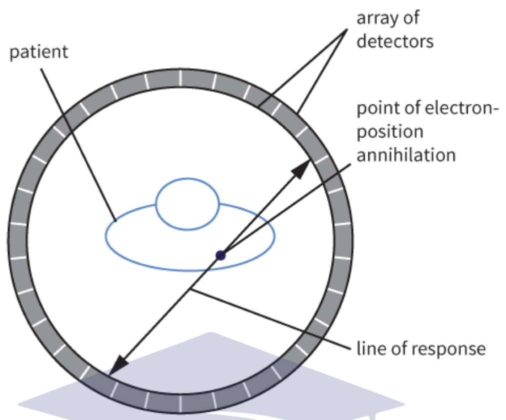
Annahilation: It is a process in which a matter and Antimatter interact there mass converts into energy.

Topic: ______________ Date: ______________

Upon Annahilations 2 gamma photons are released travelling in opposite direction.



Momentum is Conserved



Gamma photons from one Amahiltion events reach at 180°

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Topic: ____________ Date: ____________

Process of PET scanning 3 - 4 - 5 marks.

1) A tracer is given to the patient. that should be a B^+ (positron emitter) with short half life. hence it reaches the tissue that we need to image.

2) B^+/e^+ comes in contact with e^-/B^- and annahilate giving out gamma rays. (that travel in opposite direction.

3) The patient is in the scanner and gamma reaches at 180° and time delay b/w them is used to pinpoint the location, This happens millions of time to give the perfect image.

Last Concept:

Since electrons and positrons are used in annihilation.

i) Calculate total Energy for one annihilation.

$E = \Delta m c^2$

$E = 2(9.11 \times 10^{-31})(3.0 \times 10^8)^2$

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

ii) Calculate the wavelength of Each gamma photon.

$\left. E = \frac{hc}{\lambda} \right\}$ Remember this

$\frac{1.64 \times 10^{-13}}{2} = \frac{(6.63 \times 10^{-34})(3 \times 10^8)}{\lambda}$

$\lambda = 2.43 \times 10^{-12}$ m

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iii) Calculate the frequency of gamma

$v = f\lambda$

10 Positron emission tomography (PET scanning) involves the detection of gamma-radiation in order to identify the position of origin of positrons in the body.

(a) (i) Positrons are not naturally present in the body.

Explain how positrons come to be present in the body during PET scanning.

....

....

.... [2]

(ii) Explain how positrons cause the emission of gamma-radiation from the body during PET scanning.

....

....

....

.... [3]

(b) Show that the wavelength of the gamma-radiation that is detected during PET scanning is approximately 2.4 pm. Explain your reasoning.

$E = \Delta m c^2$

$\frac{E}{2} = h\left(\frac{c}{\lambda}\right)$

[4]

[Total: 9]

11 Positron emission tomography (PET scanning) obtains diagnostic information from a person. The information is used to form an image.

(a) PET scanning uses a tracer.

Explain what is meant by a tracer.

....

.... [1]

(b) PET scanning involves annihilation.

(i) Explain what is meant by annihilation.

....

.... [1]

(ii) State the names of the particles involved in the annihilation process.

.... [1]

(c) (i) Calculate the total energy released in one annihilation event in **(b)**.

energy = ... J [1]

(ii) Calculate the wavelength of each gamma photon released.

wavelength = ... m [2]

Topic: ______________ Date: ______________

(d) Explain how the gamma photons are used to produce an image.

....

....

....

....

....

.... [3]

[Total: 9]

11 **(a)** Positron emission tomography (PET scanning) makes use of a tracer containing a radioactive material that decays by positron emission.

(i) State what is meant by a tracer.

....

....

.... [2]

(ii) State the name of the particles that are emitted from the body and detected by the detectors during PET scanning.

.... [1]

(b) Explain how the particles in **(a)(ii)** are created from positrons.

....

....

....

....

.... [3]

(c) Positrons can be artificially created by a process in the laboratory that is the reverse of the process in **(b)**. This process creates both a positron and an electron moving at the same speed in opposite directions.

Suggest why two of the particles in **(a)(ii)** are needed to create one positron.

....

....

....

.... [2]

[Total: 8]

Topic: ______________________ Date: ______________________

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