Types of rectification

- Half-wave (single diode)
- Full-wave (multiple diode)

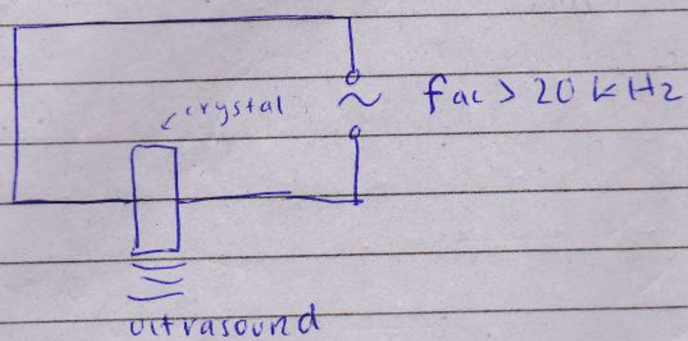
MEDICAL PHYSICS

Medical imaging

- Ultrasonograph (USG): In colloquial way people call it video xray, which is wrong.
Sound waves of frequency greater than 20 kHz is called ultrasound. Infrasound is sound with frequency less than 20 Hz. Audible sound is 20 Hz - 20 kHz. They have the same speed.
Generally used ultrasound frequency is 5 MHz. The higher the frequency, the better the imaging.
This is because $v = \lambda f$, $\lambda = v/f$, so when f increases λ decreases, so we can image structures of size equivalent to λ. So, in higher f, we can image smal structures.

Piezoelectric effect, transduction: Quartz is a piezoelectric crystal. Sound waves travel in compressions and rarefactions. The waves disturb the crystal such that the crystal also undergoes strain. Vibrates / compresses and rarefacts. ~~So when~~ This creates +ve & -ve poles on the crystal. So when a high voltage is fed to the crystal, it oscillates fast producing ultrasound.

This is piezoelectric effect when sound waves compress and rarefact a crystal to produce an oscillating pd.

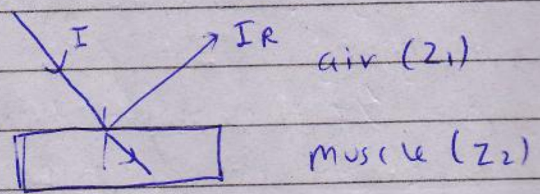


Crystal oscillates with frequency of ac source.

Specific acoustic impedence of a medium 'Z' is defined as $Z = \rho c$, where ρ is density of medium and c is speed of sound in that medium.

SI unit of $Z = \frac{kg}{m^3} \times \frac{m}{s} = kg\,m^{-2}s^{-1}$

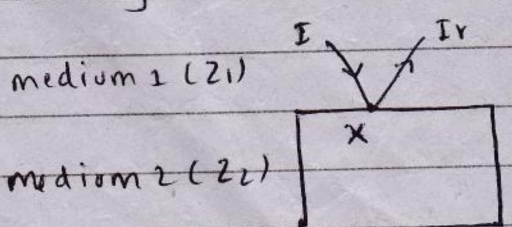
It characterizes how the medium responds to sound waves.



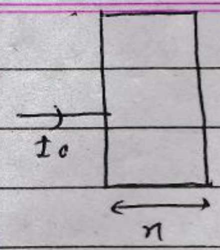
Sound waves are incident at air-muscle boundary.
(not muscle-air boundary)

Image from ultrasound depends on intensity of reflected wave while that of x-ray depends on intensity of transmitted wave.

Intensity reflection coefficient $= I_r / I$



$$\frac{I_r}{I} = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2$$



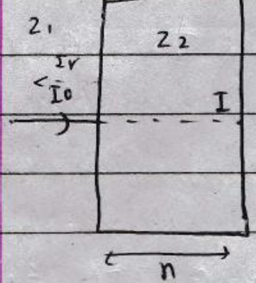
The medium attenuates the wave by:

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

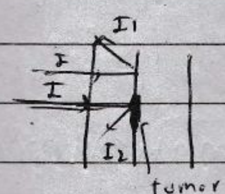
where μ is linear ~~attenuation~~ absorption/attenuation coefficient

Attenuation is the gradual loss in power / intensity / amplitude of a wave as it travels distance.

μ varies with medium.



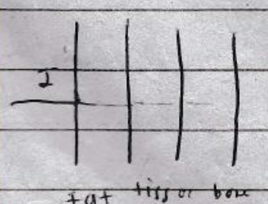
$$\frac{I_r}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2} \qquad I = I_0 e^{-\mu n}$$



Here tumor reflects back very differently.

The time delay between transmission and detection gives the idea of depth of tumour inside body / other body structures. This is automatically adjusted by computers.

The time delay between the transmission of the ultrasound pulse and its reception at the probe gives impression of the depth of structures.



There is a difference in intensities reflected from various boundaries, which is analyzed by a computer to determine depth and make image.

MEDICAL PHYSICS...

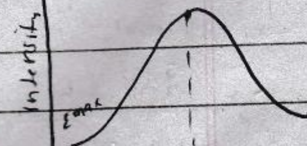
Main principles behind use of ultrasound to obtain diagnostic information about internal body structures.

- Pulses of ultrasound are produced by a piezoelectric crystal (transducer). These pulses are sent into the body using a coupling medium (gel.). Ultrasound is reflected from the boundaries between the structures. These reflected pulses are received at the transducer. Intensity of these reflected pulses gives the information about the nature of the boundary. Time delay between the pulses received from different boundaries gives the information about the depth of structures inside the body. Computer generates the image on the basis of intensities received at different times.

High frequency / short wavelength ultrasound is preferred as structures within shorter distances corresponding to wavelength can be resolved.

~~Absor~~

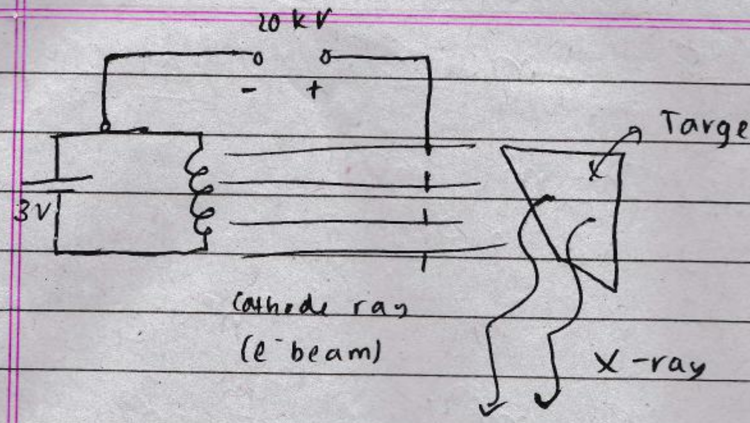
X-ray



- Wavelength of approx. 10^{-10} m. 1 Å (Armstrong)
- For an electron accelerated with p.d. V,

$eV = \frac{1}{2}mv^2 \therefore v = \sqrt{2eV/m}$

Now as we make V very large e/m decreases (relativistic correction), so v never exceeds speed of light.

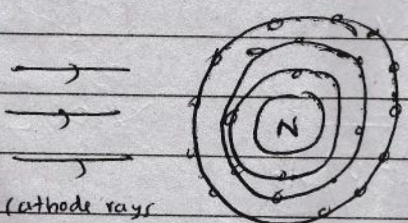


Cathode ray is stream of fast moving e^-.
kV is accelerating potential.

The target is generally of Molybdenum or Tungsten (high melting point)
When 3V is supplied to Filament, it gets heated and thermo-ionic emission takes place and e^- get released in a cloud form near filament. 20kV is used to accelerate it.

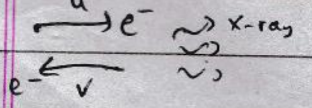
Relativistic correction: $m = \dfrac{m_0}{\sqrt{1 - v^2/c^2}}$

Where m_0 is actual mass and m is relativistic mass for a moving object.
So when something moves at speed of light, its mass is ∞.



The cathode rays gets ~~reflecte~~ retarded from coloumbian field of e^- in nucleus. (High at. wt coz more e^-]

Now from classical theory, when e^- are deflected, X-ray radiation is emitted.



$nhf = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$, where hf is energy of X-rays.

This X-ray is continuous. The X-ray spectra that is obtained have continuous wavelength (all wavelengths). Bcoz accelerated e^- have different retardation and variance in energies.

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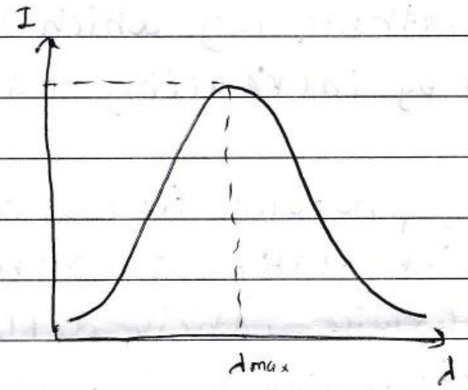
MEDICAL PHYSICS...

X-ray

- Continuous spectrum
- Characteristic spectrum

Generally, target material is rotated, so e^- don't hit at only one point and melt the target.



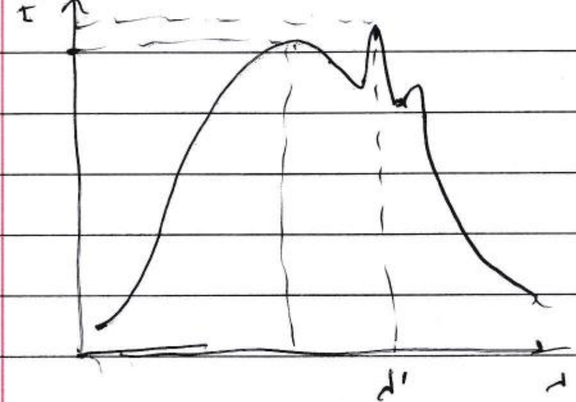
Continuous spectrum
(All wavelengths emitted)

From quantum mechanics, when an e^- jumps between quantum/energy levels, it emits a photon (X-ray)

$$f = \frac{E_2 - E_1}{h}$$

When a nucleon jumps between energy levels, it releases a γ-ray photon as nucleon energy is higher.

Most X-ray photons emitted are of wavelength λ_{max}.



Characteristics medium

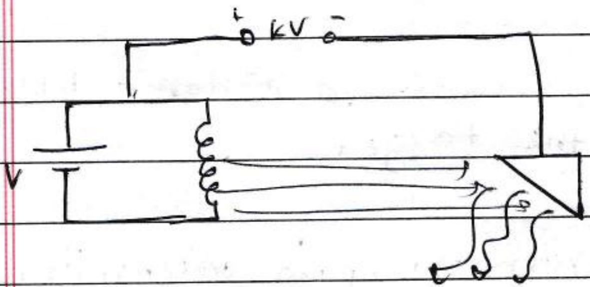
The peaks represent characteristics medium of target.
λ_1 is acheived at an accelerating potential, specific to target. Let's say for molybdenum, 30 kV.

This arises because of retardation between target electrons and cathode ray.

If magnitude of retardation is high, X-ray frequency is high. As this magnitude is continuous we obtain continuous frequency

Date: / /

Some electrons with high KE penetrate deeper into the target and thus excite the nucleus e^- of target. Upon deexcitation of those target e^-, they emit x-ray as well. This is characteistics medium.
This is why characteristics medium only ~~*~~ is seen at a certain accelerating potential.



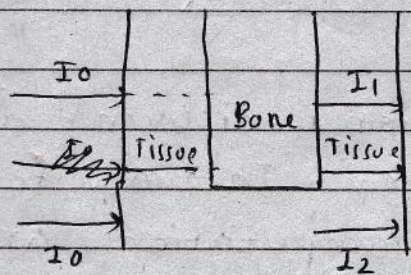
If we want more x-ray photons we need to increase intensity of cathode ray which can be done by increasing small pd. V

Generally, longer wavelength x-ray photons do not contribute to imaging and are stopped with filter. The x-ray sent into body must be parallel otherwise, their deflection would give false information of imaging on photographic plate.

Magnitude of e^- retardation is different and hence continuous spectrum is obtained.

MEDICAL PHYSICS

X-ray image



Here, X-ray follows attenuation eq^n,
$I = I_0 e^{-\mu x}$
Here $I_2 > I_1$ as bone has a larger linear attenuation coefficient.

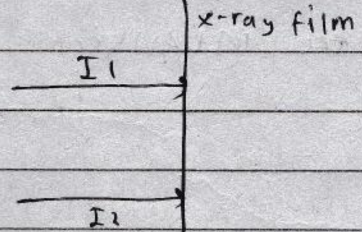


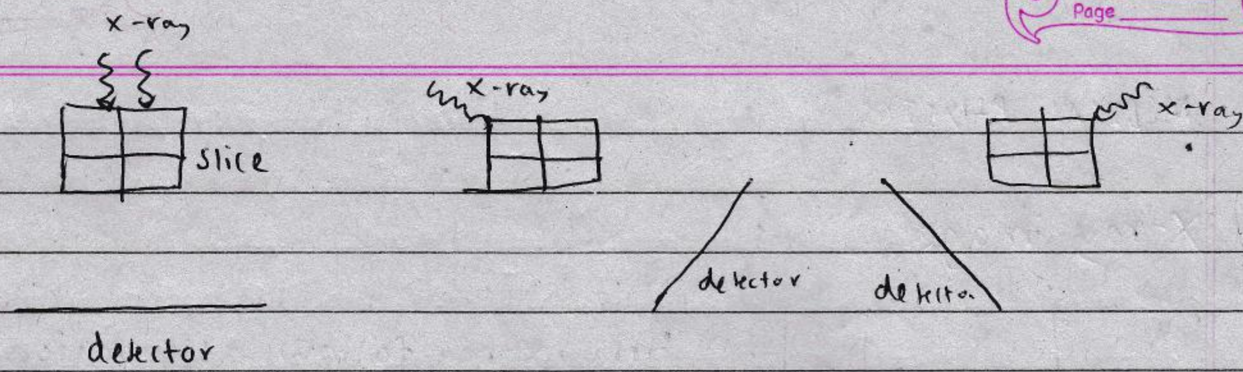
Image is said to have good contrast if there is a significant difference in ~~It a~~ blackening. This happens when there is significant difference between I_1 and I_2.

If the edges/boundaries between structures are clearly revealed image is said to have good sharpness.
Long wavelength x-rays are more likely to be absorbed by cells, so they are avioided and filtered using thin aluminum sheet.

CT-Scan (Computed Tomography)

This also uses X-ray
For instance to take scan of abdomen, the abdomen is divided into multiple cubes called slices and each slices are divided into voxels. As this is more of a 3-d scan, the X-ray intensity (dose) is much higher than normal x-ray.

p.t.o. →



In diffrent angles, x-ray attenuation is different and the detector data is fed into computer. In order to constru the image of a slice, millions of computations are required.
So, C-T scan was only possible after the invention of modern day - powerful computers.

+ Basic principles of CT scan.
In CT scanning, x-ray images of one slice is taken from different angles. This is done by rotating the x-ray tube (source) and the detector. The data of this is processed to form an image of the slice in a 2-D manner. This process is repeated for many neighbouring slices. Images of these different slices taken from different angles are combined to produce a 3-D image of the structure. Computers with large memories do the computati to construct the final 3-d image of the structure.

Computation of multiple images to form 3-d image has a lot of data which can only be computed by high memory computer.

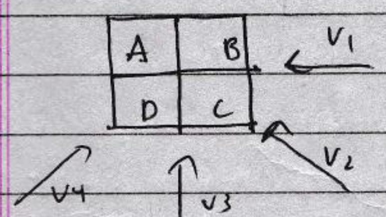
Contrast medium (oral pills) are administered into patient so that degree of blackening between two structures wit similar attenuation coeff can be sharper.

Principles behind use of X-rays for imaging

Parallel beam of x-rays is directed through body onto the detector. Different tissues attenuate x-rays by different amount and hence intensity that is transmitted through the body which falls on detector is different. Degree of blackening on the detector is different. X-ray is shadow image and different degree of blackening reveals structures.

Voxels are assigned some memory value as all voxels attenuate X-ray by different degrees.

A student creates model for CT scan with voxels having pixel readings A, B, C, D



Background reading = A+B+C+D.

The detector ~~d~~ readings are shown then summed and it is given that background count is 26

$$\begin{bmatrix} 47 & 59 \\ 44 & 32 \end{bmatrix} - 26 = \begin{bmatrix} 21 & 33 \\ 18 & 6 \end{bmatrix} \div 3 = \begin{bmatrix} 7 & 11 \\ 6 & 2 \end{bmatrix} = \begin{bmatrix} A & B \\ D & C \end{bmatrix}$$

Radioisotope in medicine (Radionuclide)

Positron Emission Tomography (PET) scan uses radionuclide. Annihilation is the complete destruction of matter which happens when a particle meets its antiparticle, in accordance with $E = mc^2$

A β particle is nothing but a high energy e^-, thus when a β particle loses energy, it becomes an e^-.

(h/λ) ~~~ ● ○ ~~~> (h/λ) . Total linear momentum is conserved.

e^- e^+

$m_e = 9.11 \times 10^{-31}$ kg

$\varepsilon = 2m_e c^2 = h/\lambda$

A positron emitting radionucleide in injected into the patient's bloodstream. The nuclei must have a short half life and mustn't hinder normal bodily functions. This is called radiotracer.

$\varepsilon = 2 \times 9.11 \times 10^{-31} \times (3 \times 10^8)^2 = 1.64 \times 10^{-13}$ J

1 MeV $= 1.60 \times 10^{-13}$ J

$\varepsilon = \dfrac{1.64 \times 10^{-13}}{2 \times 1.60 \times 10^{-13}} = \dfrac{1.02}{2} = 0.51$ MeV

Energy of γ-photon is 0.51 MeV.

The positron emitted by the radiotracer in the body, when it travels a distance of only 1mm gets annihialated.

Technetium-99 is generally used as a radiotracer as it emits γ-rays and has a half life of only 6 hours.

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

→ Tracer is a substance containing a radioactive nuclei that is absorbed by a tissue being studied.

- A particle interacting with its antiparticle so that mass of these particles is entirely converted to energy by $E = mc^2$ is annihilation.

The two γ-photons produced in annihilation of e^- positron pa[ir] travel in opp- direction. These photons are detected by the detector and arrive at different times. The detector determines the location of production of photons and the conc. of γ-photons produced from tissues. On the basis of detection of γ-photons, a powerful computer generates image.