WJEC England A-Level Physics

3B Medical Physics

Flashcards

What device is used to produce X-rays used in diagnostic imaging?

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An evacuated rotating anode X-ray tube.

How is a continuous spectrum of X-ray radiation (bremsstrahlung) emitted using a rotating anode X-ray tube?

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Electrons are emitted from a filament when a current heats it. They are accelerated through a p.d (the tube voltage) and smash into a rotating tungsten anode resulting in some of their kinetic energy being converted into X-ray photons.

If a tube voltage of 40kV is used what will the maximum energy of the X-ray produced be?

If a tube voltage of 40kV is used what will the maximum energy of the X-ray produced be in J?

Energy gained by electron = 40keV

Maximum X ray energy = 40keV

In Joules= $40 \times 10^{3} \times 1.6 \times 10^{-19}$

$= 6.4 \times 10^{-15}$ J

How is a characteristic X-ray spectrum produced in a rotating anode X-ray tube?

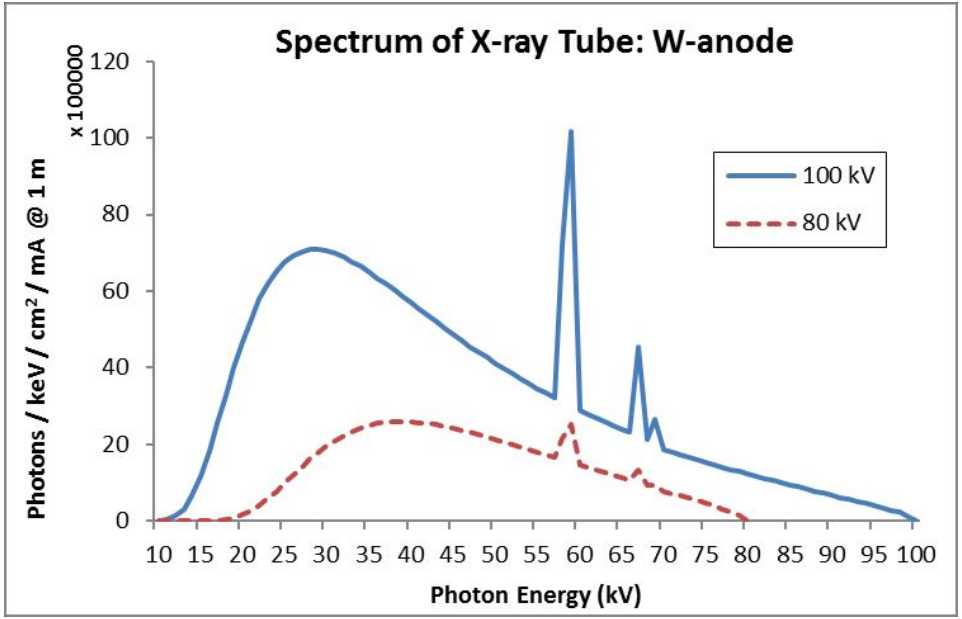
How is a characteristic X-ray spectrum produced in a rotating anode X-ray tube?

The emitted electrons cause the inner electrons in the tungsten to be ejected (ionisation). This causes outer shell electrons fall to the inner shell, releasing energy as X-ray photons. The photon energies are discrete values as the energy gaps are fixed.

What does the X-ray spectrum for a tungsten anode look like?

What does the X-ray spectrum for a tungsten anode look like?

A line spectrum superimposed on a continuous spectrum. There are peaks corresponding to the discrete photon energy values on an otherwise smooth curve.



https://www.researchgate.net/figure/Spectrum-of-an-X-ray-tube-with-a-tungsten-anode-for-2-different-tube-voltages_fig4_326785858

What precautions are taken to avoid the tungsten anode overheating?

What precautions are taken to avoid the tungsten anode overheating?

99% of the electron's K.E is converted into heat so the tungsten anode is spun at 3000 rpm and mounted on copper which is a good thermal conductor.

State 2 ways to improve the sharpness of an image formed by X-rays.

State 2 ways to improve the sharpness of an image formed by X-rays.

1. Decrease the distance from the screen to the object and increase the distance between the anode and the object.
2. Reduce the width of the focal spot (the point X-rays are emitted from) by decreasing the slope of the anode.

What problem is encountered when the focal spot is too small?

What problem is encountered when the focal spot is too small?

The anode overheats. The heating of the anode is affected by the tube voltage, the tube current and the exposure time.

How can the contrast of an X-ray image be improved?

How can the contrast of an X-ray image be improved?

An X-ray with lower energy has its attenuation more affected by changes in tissue thickness which improves the image contrast.

Why does increasing the tube voltage increase the intensity of an X-ray beam?

Why does increasing the tube voltage increase the intensity of an X-ray beam?

The electrons have more K.E so can knock out electrons from shells deeper in the tungsten atoms (so more peaks on X-ray spectrum) and the X-ray photons have a higher maximum energy.

How does increasing the current in the filament increase the intensity of the X-ray beam?

How does increasing the current in the filament increase the intensity of the X-ray beam?

More electrons are liberated per second so more x-ray photons (with the same energy as before) are produced.

How do radiographers produce clear images whilst reducing the patient's X-ray exposure to a minimum?

How do radiographers produce clear images whilst reducing the patient's X-ray exposure to a minimum?

- To improve sharpness, put the detection plate close to patient and the X-ray tube far away.
- Keep patient still as moving makes blurry images.
- Place lead collimator grid between film and patient to stop scattered radiation reducing image contrast.
- Use intensifying screens to reduce exposure time.

How do intensifying screens help develop images quickly?

How do intensifying screens help develop images quickly?

They contain crystals that absorb X-rays and re-emit the energy as visible light photons which hit the film in the correct place, developing the image quickly.

What do each of the terms represent in the equation $I=I_0e^{-\mu x}$?

What do each of the terms represent in the equation $I=I_0e^{-\mu x}$?

I=intensity of X-ray beam, Wm^{-2}

I_0=initial intensity of X-ray beam, Wm^{-2}

μ= the material's linear attenuation coefficient,m^{-1}

x=distance from the surface,m

The linear attenuation coefficient of a kidney is $21m^{-1}$. How far will the X-ray travel in the kidney before its intensity is 60% of the original intensity?

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$$I=I_0e^{-\mu x}$$

$0.6I_0=I_0e^{-21x}$	The intensity is 60% I_0 so $I=0.6\ I_0$
$0.6=e^{-21x}$	Divide both sides by I_0
$\ln(0.6)=-21x$	Take natural logs of both sides
$\ln(0.6) / -21 =x$	Divide through by -21
$0.024m=x$ (2sf)	

True or false? Elements with low atomic numbers show up better on X-rays.

True or false? Elements with low atomic numbers show up better on X-rays.

False, higher atomic numbers show up better e.g. barium is X-ray opaque and can be used as an artificial contrast medium to allow differentiation between tissues.

What are the properties of the X-ray produced for a computed tomography (CT) scan?

What are the properties of the X-ray produced for a computed tomography (CT) scan?

Narrow and monochromatic.

The computer forms an image by how much attenuation has been caused in each section of the body.

What are the advantages of X-ray imaging?

What are the advantages of X-ray imaging?

- Good resolution and clear images of bones.
- CT scans are quicker than MR scans.
- CT scanners are cheaper than MR scanners.

What are the disadvantages of X-ray imaging?

What are the disadvantages of X-ray imaging?

- X-rays are ionising, damage cells and can lead to cancer.
- Fluoroscopy leads to a high radiation dose.
- Unsuitable for pregnant women.
- Patient must remain still.

What are ultrasound waves?

What are ultrasound waves?

Sound waves with a frequency greater than 20,000 Hz (above the range of human hearing).

What happens when an ultrasound wave meets a boundary between 2 different materials?

What happens when an ultrasound wave meets a boundary between 2 different materials?

Some of it is reflected and some is transmitted and will refract (when the angle of incidence isn't 0°). The amount of reflection depends on the different in acoustic impedance (Z) between the materials.

The speed of sound in air is $340ms^{-1}$ and air's density is $1.2kgm^{-3}$. Calculate the acoustic impedance of air.

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$$Z = 1.2 \times 340 = 408kgm^{-2}s^{-1}$$

Complete the sentence: If 2 materials have the same impedance then ….. reflection occurs.

Complete the sentence: If 2 materials have the same impedance then ….. reflection occurs.

If 2 materials have the same impedance then no reflection occurs.

‘Ultrasound waves are attenuated when they travel through a material’
What is attenuation?

‘Ultrasound waves are attenuated when they travel through a material’ What is attenuation?

When the waves are absorbed and scattered. The higher the frequency of a wave, or impedance of a material, the more attenuation the wave undergoes.

What is a transducer?

What is a transducer?

A device which converts one form of energy into another.

What do piezoelectric crystals do when they are deformed?

What do piezoelectric crystals do when they are deformed?

Produce a potential difference (the piezoelectric effect), as the change in their structure moves the centres of symmetry of their electric charges.

What happens when you apply a voltage across a piezoelectric crystal?

What happens when you apply a voltage across a piezoelectric crystal?

The crystal deforms - if the voltage is alternating then it vibrates at the same frequency.

True or false? A piezoelectric crystal can only act as a transmitter of ultrasound.

True or false? A piezoelectric crystal can only act as a transmitter of ultrasound.

False.

It can act as both a receiver (converting ultrasound to alternating p.d) and a transmitter (converting alternating p.d into ultrasound).

What is the relationship between the thickness of the crystal and the wavelength it produces?

What is the relationship between the thickness of the crystal and the wavelength of the ultrasound it produces?

The crystal thickness is half the wavelength of the ultrasound.

Why is the piezoelectric crystal in ultrasound devices heavily damped?

Why is the piezoelectric crystal in ultrasound devices heavily damped?

To produce short pulses and increase the resolution of the device.

Why is a coupling medium needed between the ultrasound transducer and the body?

Why is a coupling medium needed between the ultrasound transducer and the body?

The acoustic impedance of the body is very different to air so most ultrasound energy is reflected. The coupling medium (oil or gel) has an impedance closer to body tissue (impedance matching) so more ultrasound is transmitted.

How are the uses for amplitude (A) scans and brightness (B) scans different?

How are the uses for amplitude (A) scans and brightness (B) scans different?

Both are ultrasound scans but B scans are used to create images and A scans are used to measure distances e.g. the depth of an eyeball.

In an A-scan how do reflected ultrasound pulses appear on the cathode ray oscilloscope (CRO) screen?

In an A-scan how do reflected ultrasound pulses appear on the cathode ray oscilloscope screen?

As vertical deflections.

What is the process of amplifying weaker pulses that have travelled further called?

What is the process of amplifying weaker pulses that have travelled further called?

Time gain compensation.

In which direction does the electron beam sweep across the CRO screen in an A-scan? What direction is it for a B scan?

In which direction does the electron beam sweep across the CRO screen in an A-scan? What direction is it for a B scan?

Horizontally for A scans and vertically down for B scans.

State a use of A scans and uses of B scans.

State a use of A scans and uses of B scans.

A: Monitoring a baby's growth in the uterus by measuring its head diameter.

B: Prenatal foetus scanning and echocardiograms to see how the heart is functioning in real time.

How is the amplitude of the reflected pulses displayed in a B scan?

How is the amplitude of the reflected pulses displayed in a B scan?

As the brightness of a spot.

What array of transducers can be used to produce a 2D image in a B scan?

What array of transducers can be used to produce a 2D image in a B scan?

A linear array.

State 5 advantages of ultrasound scans.

State 5 advantages of ultrasound scans.

1. No known hazards or side effects.
2. No exposure to ionising radiation.
3. Can obtain real-time images of soft tissues.
4. Ultrasound devices are portable and cheap.
5. Scan is quick, non invasive and the patient can move.

State 3 disadvantages of ultrasound scans.

State 3 disadvantages of ultrasound scans.

1. Ultrasound can't penetrate bone so the brain can't be imaged (skull in the way) and fractures can't be detected.
2. Ultrasound can't pass through air spaces in the body (mismatched impedance) so can't produce images from behind the lungs.
3. Low resolution.

Where does the patient lie during magnetic resonance imaging?

Where does the patient lie during magnetic resonance imaging?

In the centre of a superconducting magnet that is cooled by liquid helium.

What effect does the uniform magnetic field generated have on protons in the body?

What effect does the uniform magnetic field generated have on protons in the body?

They align themselves with the magnetic field lines.

What is the difference between a parallel and antiparallel alignment of protons in a magnetic field?

What is the difference between a parallel and antiparallel alignment of protons in a magnetic field?

A parallel alignment is when the proton's spin axis is parallel to the magnetic field lines whereas antiparallel is when the spin axis points in the opposite direction to the lines.

What is the effect on protons when smaller electromagnets (gradient field coils) have their magnetic field superimposed onto the main field?

What is the effect on protons when smaller electromagnets (gradient field coils) have their magnetic field superimposed onto the main field?

Variations in magnetic field strength are created across the patient so protons will have different precession frequencies depending on their location and will absorb different frequencies of radiation. Precession frequency is the angular frequency of the protons' wobble about the magnetic field lines, it is proportional to the magnetic field strength.

How can the contrast of an MRI scan image be controlled?

How can the contrast of an MRI scan image be controlled?

Vary the time between radio wave pulses to enhance the difference in response from each tissue type e.g. rapid pulses enhance the response of fatty tissue.

What are the advantages of MR scanning?

What are the advantages of MR scanning?

- No known side effects.
- Non ionising so won't damage living cells.
- Images can be formed from all orientations.
- High quality images of soft tissue with good resolution.
- Contrast can be adjusted.
- Real time images.

What are the disadvantages of MR scans?

What are the disadvantages of MR scans?

- Poor bone imaging compared to CT.
- Noisy and time consuming.
- Claustrophobic.
- Dangerous with pacemakers/metal implants.
- Costs millions of pounds.

What is a medical tracer?

What is a medical tracer?

A radioactive substance used to show organ/tissue function. They are usually a gamma emitting radioisotope bound to a metabolite like water or glucose. The movement of the tracer is mapped and used to form images.

Name 3 gamma-emitting medical tracers.

Name 3 gamma-emitting medical tracers.

Medical Tracer	Where it is used in body	Radiation emitted	Half life	Energy of gamma radiation/ keV
Iodine-131	Thyroid	Beta and gamma	8 days	360
Technetium-99m	Range of organs	Gamma	6 hours	140
Indium-111	Antibodies and blood	Gamma	2.8 days	170 or 250

Each tracer is picked to go to a particular organ e.g. the thyroid gland naturally uses iodine

Technetium-99m's physical half life is too short to be practically transported. How do hospitals overcome this problem?

Technetium-99m's physical half life is too short to be practically transported. How do hospitals overcome this problem?

Molybdenum-technetium generators. Molybdenum has a 66 hour half life so is better for transport. Within the generator aluminium oxide is bonded strongly to molybdenum. The molybdenum decays to technetium-99m which doesn't bond as strongly so can be washed out with saline solution and used as a tracer.

What are the 5 main parts of a gamma camera and their functions?

What are the 5 main parts of a gamma camera and their functions?

1. Lead shield- stops other radioactive sources entering the camera.
2. Lead collimator- lead with vertical holes so only gamma rays parallel to the holes can go through.
3. Sodium iodide crystal- scintillates when gamma ray hits it.
4. Photomultiplier tubes- converts light from scintillator to electric current as electrons released from photocathode in each tube when light is incident via photoelectric effect.
5. Circuit-collects signals and sends them to computer.

How can radiation be used in treating cancer?

How can radiation be used in treating cancer?

- Carefully focused X-ray beams (ionising radiation) are rotated around patient so that they kill tumour cells whilst causing minimal damage to healthy tissue.
- Implants with beta emitters placed inside/beside tumour to damage it by ionisation.

What is the absorbed dose?

What is the absorbed dose?

The absorbed dose is the amount of radiation energy absorbed per kg of tissue.

What is the Gray (Gy)?

What is the Gray (Gy)?

The unit of an absorbed dose where

$1Gy = 1J/kg$.

What is the Sievert (Sv)?

What is the Sievert (Sv)?

The unit used for equivalent and effective dose.

What is the equivalent dose H?

What is the equivalent dose H?

H = The absorbed dose D x radiation weight factor WR

What is the effective dose E?

What is the effective dose E?

E = The equivalent dose H x tissue weight factor WT

What is a collimator?

What is a collimator?

A collimator is used to produce a parallel beam, such as of gamma radiation.

What are scintillations?

What are scintillations?

Scintillations are when crystals give out flashes of UV radiation or light after being struck by a high energy particle.

What are photomultipliers?

What are photomultipliers?

Photomultipliers are arrangements of electrodes that allow the photoelectric effect to happen. Each have different voltages so electrons emitted are multiplied to produce a bigger current.

How do positron emission tomography (PET) scans work?

How do positron emission tomography (PET) scans work?

- Inject patient with metabolite containing a positron emitting radiotracer with short half life.
- Positrons emitted collide with electrons in organs and annihilate to form gamma ray photons.
- Gamma ray detectors record the emission and a computer builds a map of the emissions.

What are the advantages and disadvantages of PET scans?

What are the advantages and disadvantages of PET scans?

- Radioactivity distribution shows metabolic activity.
- Brain activity can be seen.
- Can monitor spreading of tumours.
- Ionising radiation can damage cells.
- Machine is expensive and large.