

# AQA Physics A Level

## 10.5 X-ray imaging

### Flashcards

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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?



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

Electrons are emitted from a filament when a current heats it and accelerated through a p.d (the tube voltage), they smash into a rotating tungsten anode so some of their kinetic energy is 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) so outer shell electrons fall to the inner shell releasing energy as X-ray photons whose energies are discrete values as the energy gaps are fixed.

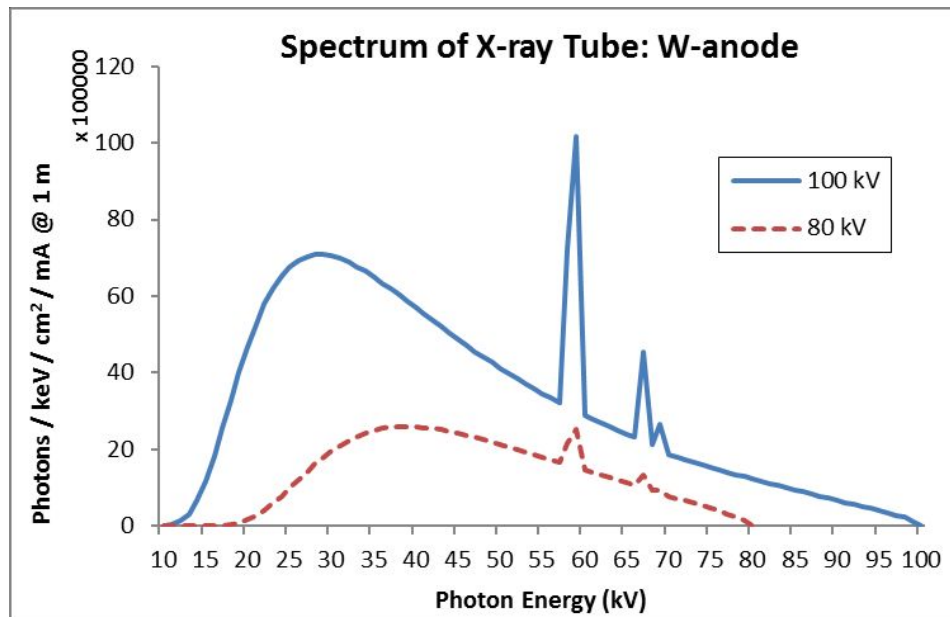


What does the X-ray spectrum for a tungsten anode look like?



# 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](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

- Decrease the distance from the screen to the object and increase the distance between the anode and the object.
- 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, tube current and 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 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 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 detection plate close to patient and 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  $I = I_0 e^{-\mu x}$  ?



What do each of the terms represent in the equation

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

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

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

$\mu$  = the material's linear attenuation coefficient,  $\text{m}^{-1}$

$x$  = distance from the surface,  $\text{m}$



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



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

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

$$0.6I_0 = I_0 e^{-21x}$$

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

$$0.024\text{m} = x \text{ (2sf)}$$



What is meant by half value thickness  
( $x_{1/2}$ ) ?





What is meant by half value thickness ( $x_{1/2}$ ) ?

The thickness of material needed to reduce the intensity of radiation to half its original value in metres.



What equation links the linear attenuation coefficient with half value thickness?



What equation links the linear attenuation coefficient with half value thickness?

$$x_{1/2} = \ln 2 / \mu$$



What is the mass attenuation coefficient  
( $\mu_m$ )?



What is the mass attenuation coefficient ( $\mu_m$ )?

A measure of how much radiation is absorbed per unit mass.

$$\mu_m = \mu / \rho$$

Where  $\mu$  is the linear attenuation coefficient and  $\rho$  is density.



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.



How does a flat panel detector (FTP)  
create a digital X-ray image?





# How does a flat panel (FTP) detector create a digital X-ray image?

- X-rays are fired at patient with FTP detector behind them, FTP detector has scintillator material which makes light with intensity proportional to the energy of the X-ray photon that hit it.
- Photodiode pixels in FTP detector generate a voltage proportional to the light's intensity when it hits them.
- A thin-film transistor reads the digital signal for each pixel to create an image.



State 4 advantages of FTP detectors over photographic detection.



State 4 advantages of FTP detectors over photographic detection.

- Lighter and more compact so more convenient as can be transported.
- Higher resolution and less distortion.
- Image is easily copied, shared and stored.
- Lower exposure required for clear images.



Fluoroscopy is used to form videos, how does it work?



## Fluoroscopy is used to form videos, how does it work?

- X-rays go through the body to a fluorescent screen which emits light.
- The light causes electrons to be emitted from a photocathode which are accelerated by a p.d and focused onto a viewing screen.
- Image intensifiers reduce the body's radiation dose.



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, 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 be still.

