Mark schemes

1.

(a) There will be many answers possible and examiners must use their professional judgement. These answers may include:

- Using scan before treatment to locate the precise position / size of the tumour
- Using X-rays of the correct energy for the depth/size of the tumour
- Using a computer to position X-ray relative to patient / target the tumour
- Minimising time of use
- Irradiating tumour from different directions
- Less damage caused to healthy cells

✓ ✓ ✓ for three relevant answers

3

(b) The thickness of material needed to reduce the intensity of the X-ray beam by half ✓

1

(c) $\mu = \ln 2 / \text{half thickness}$ ✓

$\mu = 165$ ✓

$\mu_m = \mu / \rho = 1.5 \times 10^{-2}$ ✓ unit $m^2\ kg^{-1}$ ✓

Unit mark is independent of the numerical answer or indeed a lack of any numerical working.

3rd mark is ecf.

4

[8]

2. Points to consider:

For the basic principles of the CT scan

- Patient lies in centre of ring
- X-ray tube is mounted on one side of the ring with array of detectors mounted on the other side of the ring opposite the X-ray tube.
- Narrow beam of X-rays in a short pulse sent through the head and the signals from the array of detectors are fed into a computer.
- The X-ray tube and detectors are rotated about the patient's head and pulses of X-rays are sent through the patient's head from different directions.
- The signals from the detectors are then added together and a 2D image of that slice of the head is produced by the computer.

For advantages of CT for head injuries

- Better defined image of tissue boundaries inside skull
- Possible to identify bleeding inside skull

For simple X-rays

- Cheaper and easier for patient
- Allows simple fractures to be identified
- Less harmful as patient dose is less than that of CT scan

6 marks will clearly explain the basic principles of the CT scan. They will explain using this scan to assess head injuries. They will give good reasons for the use of basic X-rays in certain situations.

5 marks will clearly explain some of the basic principles of the CT scan. They will give some explanation for using this scan to assess head injuries. They will give good reasons for the use of basic X-rays in certain situations.

4 marks will explain some of the basic principles of the CT scan. They will give some explanation for using this scan to assess head injuries. They will give some explanation for the use of basic X-rays in certain situations.

3 marks will address at least two of the bullet points

2 marks will address at least one of the bullet points

1 mark will have any sensible comment

0 marks has no relevant Physics.

[6]

3. (a) Attempt to use $I = I_0 e^{-\mu x}$ ✓$_1$

Alternative approach for first two marks

Use of $x_{1/2} = \frac{\ln 2}{\mu}$ ✓$_1$

Two correct answers

100 keV

$\left(\frac{I}{I_0} = e^{-\mu x} = e^{-0.15 \times 11} =\right) 0.19$

100 keV

$\left(x_{1/2} = \frac{\ln 2}{\mu} = \frac{\ln 2}{0.15} =\right) 4.6 \text{ cm}$

500 keV

$\left(\frac{I}{I_0} = e^{-\mu x} = e^{-0.087 \times 11} =\right) 0.38$ ✓$_2$

500 keV

$\left(x_{1/2} = \frac{\ln 2}{\mu} = \frac{\ln 2}{0.087} =\right) 8.0 \text{ cm}$ ✓$_2$

More of the 500 keV radiation reaches the tumour so is to be preferred or less radiation is absorbed by brain ✓$_3$

Less damage to surrounding tissue. ✓$_4$

If use 100/500 keV for I_0 do not award ✓$_1$ or ✓$_2$

4

(b) Copper better at removing 100 keV (damage cells) ✓

Remove a larger <u>percentage</u> or <u>fraction</u> of the 100 keV radiation than the 500 keV ✓

Allow ecf argument if (a) specifies 100 keV should be preferred.

2nd marking point implies first (with metal identified)

2

(c) Any one from:

Method: Use of scans to locate the tumour ✓
Reason: Allows accurate targeting of the beam✓

Method: Multiple beam or rotating beam ✓
Reason: X-rays are spread out so each part receives a lower dose ✓

Method: (Fine) collimated beam ✓
Reason: X-rays don't spread beyond the size of the tumour / filter ✓

Method: lead shielding ✓
Reason: to block X-rays from healthy tissues ✓

Reason mark depends on method mark and must match.
Do NOT credit techniques that are only applicable to X-ray imaging.

2

[8]

4. (a)

$\frac{1-d}{10^{-3}} = \frac{d}{0.1\times10^{-3}}$ ✓

$d = \frac{0.1\times10^{-3}}{1.1\times10^{-3}} = 9.1 \times 10^{-2}$ ✓ (m)

Allow alternative methods
Condone 1 SF

2

(b) (Hand)

Chest is thicker so parts will be further away from plate (increasing fuzziness) ✓

Chest is thicker and not uniformly thick (each part producing a shadow producing an unsharp image) / front and back can't both be focussed at the same time ✓

Can keep hand still but not heart so heart will be blurred ✓

Max 2
Condone can't stop breathing

2

[4]

5. (a) Points to consider:

The risk comes as X-rays are ionising radiation: the photons could ionise cells causing mutations / cancer.

Use of lead diaphragm plates to define beam so that only the area to be investigated is exposed to the X-rays – limits exposure to ionising photons.

Use of aluminium filter in path of beam to remove a large percentage of the low energy photons which are not needed for the image to be produced – reduces ionising photons which could be absorbed by the body.

(Anode voltage) selected to produce best energy photons for imaging – limits the photons required to produce a suitable image.

When using film, use of intensifying screens – give exposure in shorter time limits exposure.

Use of grid between the patient and image receptor to stop scattered X-rays blurring the image – thus stopping the need for further X-ray and further exposure.

6 marks will clearly explain the risk involved. They will then mention three ways of minimising the exposure and discuss these.

5 marks will clearly explain the risk involved. They will then mention three ways of minimising the exposure and discuss 2 of these.

4 marks will mention the risk involved. They will mention at least two ways of minimising the exposure and may discuss both or discuss one of these together with explaining the risk involved.

3 marks will mention the risk involved. They will mention at least two ways of minimising the exposure and may discuss one of these or explain the risk involved

2 marks will mention the risk and may state one way of limiting exposure or state and discuss either.

1 mark will have any sensible comment.

0 marks has no relevant Physics.

6

(b) Ultrasound is non-ionising / has no known adverse effects ✓

Ultrasound can be used for better definition image between tissue and blood ✓

Allow credit for converse arguments re. not X-rays

2

(c) correct sub of numbers in the equation

$$6.25\times10^{-4}=\left(\frac{Z-1.64\times10^{6}}{Z+1.64\times10^{6}}\right)^{2}$$ ✓

As Z decreases, the negative root is needed

$$-2.5\times10^{-2}=\left(\frac{Z-1.64\times10^{6}}{Z+1.64\times10^{6}}\right)$$ ✓

rearrange equation

$1.025\ Z = 1.64 \times 10^6 – 4.1 \times 10^4$ ✓

correct answer

1.56×10^6 (kg m^{-2} s^{-1}) ✓

Candidates who ignore the negative root can get three marks max for arranging the equation correctly and getting 1.72 by using the positive root.

Basic rule -1 for each error.

Last two marks for working can be given for wrong values above that point.

4

[12]

6. (a) Smooth curve/continuous spectrum is due to the deceleration of the electrons / transfer their kinetic energy to X-ray photons ✓$_1$

Maximum energy limited by kinetic energy / accelerating voltage of electrons. ✓$_2$

Electrons are decelerated by different amounts so a continuous spectra is emitted. ✓$_3$

Spikes/discrete/characteristic spectra due to electrons knocking inner electrons from atoms. ✓$_4$

Outer electrons drop down to fill the gaps left behind. ✓$_5$

Emitting X-ray photons (with the energy lost) by the electrons moving downwards (producing specific energies only/discrete spectrum) ✓$_6$

(Max 4)

Bremsstrahlung is not expected but is allowed for smooth curve or continuous spectrum.

Condone acceleration for deceleration in ✓$_1$ and ✓$_3$

If candidates are missing inner and outer but would otherwise gain ✓$_4$ and ✓$_5$ award one mark ✓$_{45}$

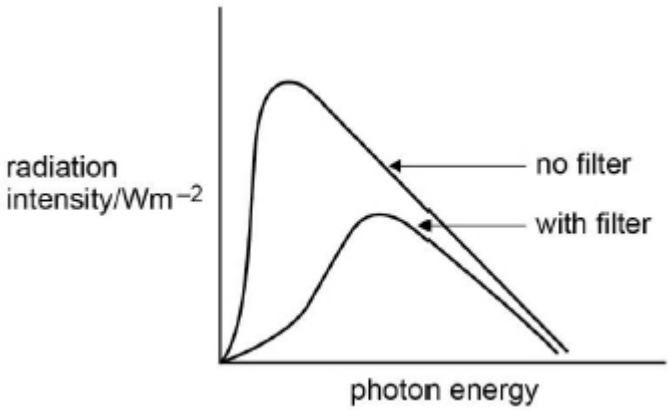
1
1
1
1

(b) Peak **and** final point moves to the right ✓

Intensity larger at all points (except 0,0) and location of spikes remain the same ✓

1
1

(c) Peak moves to the right, start at 0,0 end at or before end of existing curve, curve at or below at all points ✓



Ignore spikes even if incorrectly placed (penalised in question (b))

Be tolerant of shape if marking criteria are met.

1

[7]