Do not write outside the box

0 1 . 1 A patient with a suspected broken arm is going to have an X-ray image taken.

Explain the risk to the patient of exposure to X-rays.

Go on to discuss **three** ways by which the design and use of the X-ray equipment minimises this risk.

[6 marks]

0 1 . 2 The blood vessel called the aorta passes through the abdomen. A second patient with a suspected fault in the wall of the aorta can be given an ultrasound scan or an X-ray of the abdomen.

Suggest, with reasons, which is the better procedure for investigating this suspected fault.

[2 marks]

0 1 . 3 When ultrasound travels across a boundary from blood to the wall of the aorta there is a decrease in acoustic impedance across the boundary. This results in 0.0625% of the intensity of the incident ultrasound being reflected at the boundary.

Calculate the acoustic impedance of the aorta wall tissue.

acoustic impedance of blood = $1.64 \times 10^6 \text{ kg m}^{-2} \text{ s}^{-1}$

[4 marks]

acoustic impedance of aorta wall tissue = _____ $\text{kg m}^{-2} \text{ s}^{-1}$

12

Question	Answers	Additional Comments/Guidelines	Mark
01.1	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
01.2	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

Question	Answers	Additional Comments/Guidelines	Mark
01.3	correct sub of numbers in the equation $6.25 \times 10^{-4} = \left(\frac{Z-1.64\times10^{6}}{Z+1.64\times10^{6}}\right)^{2}$ ✓ As Z decreases, the negative root is needed $-2.5 \times 10^{-2} = \left(\frac{Z-1.64\times10^{6}}{Z+1.64\times10^{6}}\right)$ ✓ rearrange equation $1.025\ Z = 1.64 \text{ x}10^{6} - 4.1 \text{ x } 10^{4}$ ✓ correct answer $1.56 \text{ x } 10^{6}$ $(\text{kg m}^{-2}\ \text{s}^{-1})$ ✓	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
Total			**12**

Do not write outside the box

0 2 In the past, doctors could only use a simple X-ray image to assess head injuries. A CT scan is now a preferred technique.

Discuss why the CT scan has replaced the simple X-ray image to assess head injuries, but a simple X-ray procedure is suitable for assessing other injuries.

In your answer, you should:

- describe the basic principles of a CT scanner
- discuss the advantage of the CT scan over a simple X-ray image for head injuries
- explain why a simple X-ray procedure is more suitable for assessing other injuries.

[6 marks]

Question	Answers	Additional Comments/Guidelines	Mark
02	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
Total			**6**

Do not write outside the box

0 3 . 1 High-energy X-rays are used in the treatment of a cancer tumour inside a patient's body. The patient is given a series of scans before the treatment is started.

Discuss how these scans are used to help provide the best and safest treatment for the patient when using the high-energy X-rays.

[3 marks]

0 3 . 2 Lead is commonly used as shielding when using X-rays due to its small half-value thickness.

Which statement gives the correct meaning of half-value thickness?
Tick (✓) the correct answer.

[1 mark]

The thickness of material needed to reduce the energy of an X-ray photon by half. ☐

The thickness of material needed to reduce the wavelength of the photons in the X-ray beam by half. ☐

The thickness of material needed to reduce the intensity of the X-ray beam by half. ☐

Half the thickness of material needed to stop the X-ray beam. ☐

0 3 . 3 The half-value thickness of lead for $500\ \text{keV}$ X-rays is $4.2 \times 10^{-3}\ \text{m}$

Calculate the mass attenuation coefficient of lead for $500\ \text{keV}$ X-rays.

State an appropriate unit for your answer.

density of lead = $1.1 \times 10^{4}\ \text{kg m}^{-3}$

[4 marks]

mass attenuation coefficient = _____ unit _____

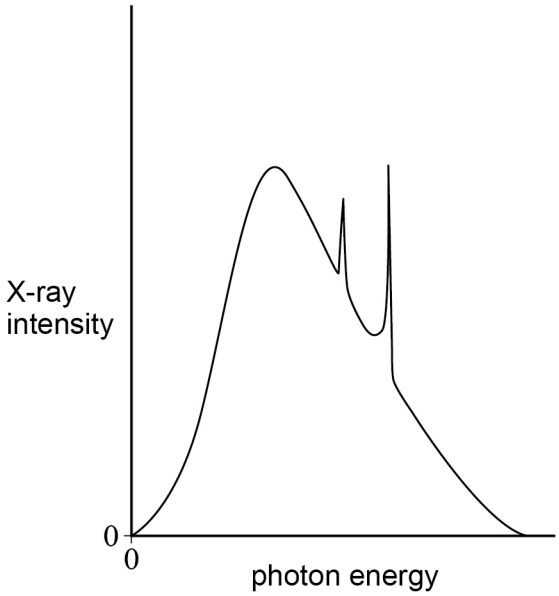
8

Question	Answers	Additional Comments/Guidelines	Mark
03.1	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
03.2	The thickness of material needed to reduce the intensity of the X-ray beam by half ✓		1
03.3	$\mu = \ln 2$ / 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
Total			**8**

Do not write outside the box

0 4 **Figure 3** shows the X-ray spectrum produced in a medical X-ray machine at a particular anode potential difference (pd).

Figure 3



0 4 . 1 In an X-ray tube, electrons collide with a tungsten target.

Explain how the continuous spectrum and the characteristic spectra are produced by these electron collisions.

[4 marks]

Continuous spectrum

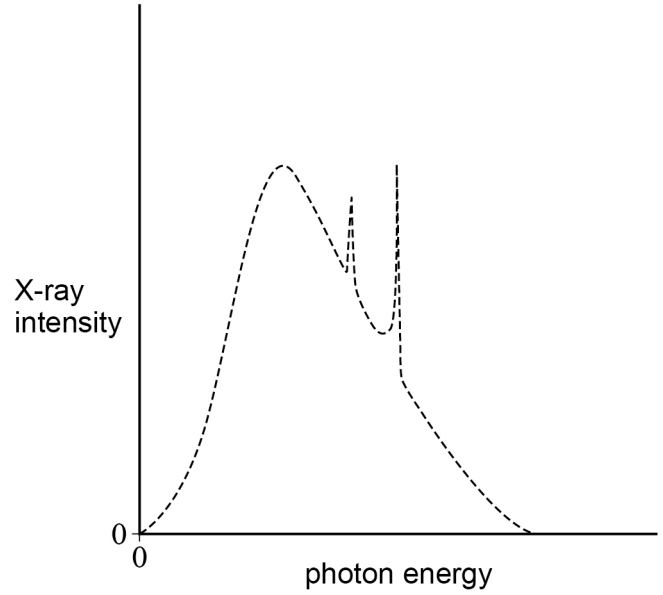
Characteristic spectra

Do not write outside the box

0 4 . 2 The dashed line on **Figure 4** shows the X-ray spectrum for the initial anode pd.

Sketch on **Figure 4** the X-ray spectrum produced when the anode pd is increased.
[2 marks]

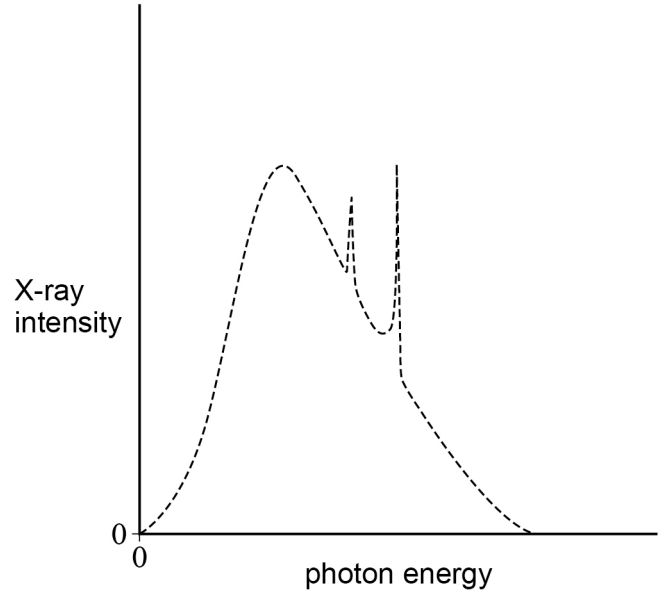
Figure 4



0 4 . 3 In the medical X-ray machine, the X-rays produced with the initial anode pd are now passed through an aluminium filter.
The dashed line on **Figure 5** shows the X-ray spectrum for the initial anode pd.

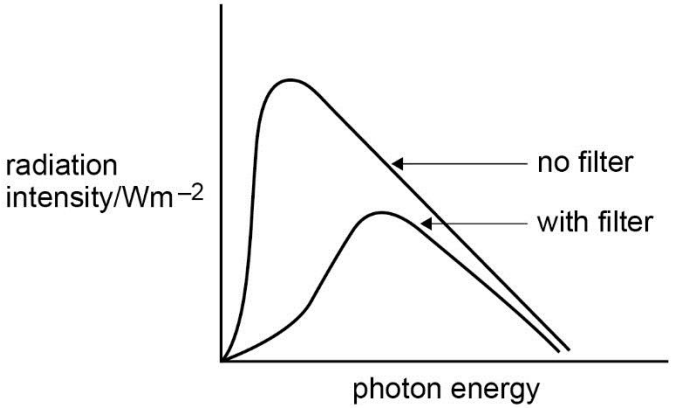
Sketch on **Figure 5** the X-ray spectrum of the X-rays that emerge from the filter.
[1 mark]

Figure 5



7

Question	Answers	Additional Comments/Guidelines	Mark
04.1	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 <u>inner electrons</u> from atoms. ✓4 <u>Outer electrons</u> 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

04.2	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
04.3	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 03.2) Be tolerant of shape if marking criteria are met.	1
Total			**7**

Do not write outside the box

0 5 X-ray photons can be used to treat cancerous tumours in radiotherapy.
Some photons are absorbed by healthy tissue before they reach the tumour.

Photons with a range of energies are generated in an X-ray machine.

Table 1 shows the linear attenuation coefficient of brain tissue for photons of energy 100 keV and 500 keV.

Table 1

Energy / keV	Linear attenuation coefficient of brain tissue / cm^{-1}
100	0.15
500	0.087

0 5 . 1 Deduce whether photons of energy 100 keV or 500 keV are better for treating a brain tumour at a depth of 11 cm.

[4 marks]

Do not write outside the box

0 5 . 2 Metal filters are used in X-ray machines to limit the damage to healthy tissues. **Table 2** gives data for possible filter materials.

Table 2

Energy / keV	Linear attenuation coefficient / cm^{-1}	
	Aluminium	**Copper**
100	0.44	3.8
500	0.23	0.73

Discuss whether it would be better to use aluminium or copper to filter the X-rays in Question **03.1**.
No calculations are required.

[2 marks]

0 5 . 3 State and explain **one** other method used to limit exposure of healthy cells during X-ray radiotherapy.

[2 marks]

Method _____

Explanation _____

8

Turn over ►

Question	Answers	Additional comments/Guidelines	Mark	AO
05.1	Attempt to use $I = I_0 e^{-\mu x}$ ✓1 Two correct answers 100 keV $\left(\frac{I}{I_0} = e^{-\mu x} = e^{-0.15\times 11} =\right) 0.19$ 500 keV $\left(\frac{I}{I_0} = e^{-\mu x} = e^{-0.087\times 11} =\right) 0.38$ ✓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	Alternative approach for first two marks Use of $x_{1/2} = \frac{\ln 2}{\mu}$ ✓1 100 keV $\left(x_{1/2} = \frac{\ln 2}{\mu} = \frac{\ln 2}{0.15} =\right) 4.6$ cm 500 keV $\left(x_{1/2} = \frac{\ln 2}{\mu} = \frac{\ln 2}{0.087} =\right) 8.0$ cm ✓2 If use 100/500 keV for I_0 do not award ✓1 or ✓2	4	1× AO3.1a 3× AO3.1b
05.2	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 03.1 specifies 100 keV should be preferred. 2nd marking point implies first (with metal identified)	2	AO3.1a

Question	Answers	Additional comments/Guidelines	Mark	AO
05.3	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	1× AO1.a 1× AO1.b
Total			**8**	

Do not write outside the box

0 6 In an X-ray machine, X-rays are emitted from an emission spot on a tungsten target.

Figure 3

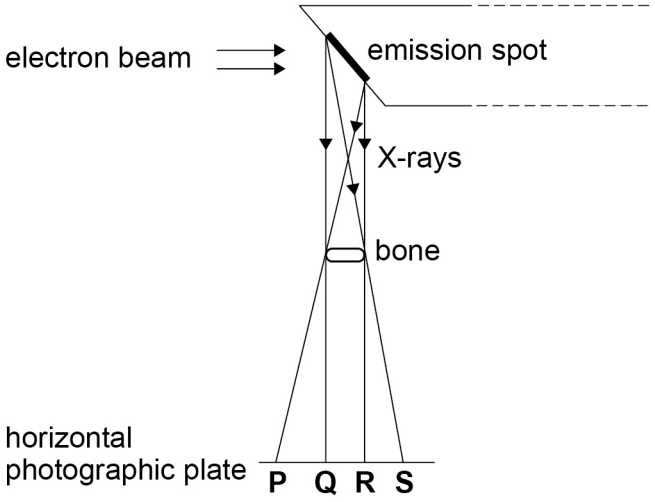
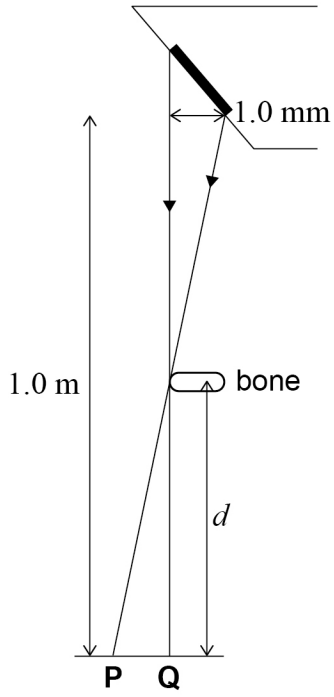


Figure 3 shows how a total shadow is produced in the region **QR** where no X-rays from any part of the emission spot can reach the photographic plate. Partial shadows are formed in regions **PQ** and **RS** where X-rays from only part of the emission spot can reach the plate.

Figure 4 shows detail of the formation of edges of the partial shadow **PQ**.
The bottom of the emission spot is $1.0\ \text{m}$ vertically above the plate.
The horizontal distance across the beam is $1.0\ \text{mm}$ at the bottom of the emission spot.

Figure 4



not to scale

Do not write outside the box

0 6 . 1 To produce a sharp image of a bone, the partial shadow in region **PQ** must be no more than $0.10\ \text{mm}$ wide.

Calculate the maximum distance d between a bone and the plate.

[2 marks]

$d =$ _____ m

0 6 . 2 Discuss whether an X-ray image of a chest or an X-ray image of a hand is likely to be sharper when exposed to the same X-ray source.

[2 marks]

_____

_____

_____

_____

_____

_____

4

Turn over for the next question

Question	Answers	Additional comments/Guidelines	Mark	AO
06.1	$\frac{1-d}{10^{-3}} = \frac{d}{0.1\times10^{-3}}$ ✓ $d = \frac{0.1\times10^{-3}}{1.1\times10^{-3}} = 9.1 \times 10^{-2}$ ✓ (m)	Allow alternative methods Condone 1 SF	2	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
06.2	(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	AO3
Total			**4**	

Do not write outside the box

0 7 . 1 An X-ray image is to be made of a broken bone.
The image can be formed on

- photographic film
- a flat panel (FTP) detector or
- an intensifying screen using fluoroscopic image intensification.

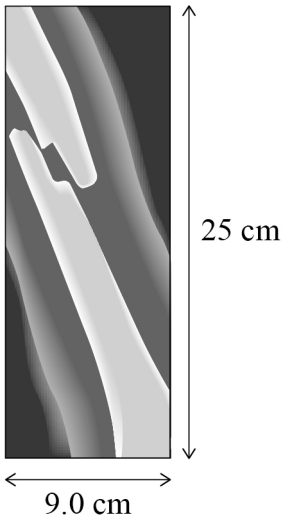
State and explain which one of these detection methods should be used in this situation.
Go on to discuss why the other two methods are less suitable.

[4 marks]

Do not write outside the box

Figure 2 shows an X-ray of a broken bone.

Figure 2



mean diameter of bone = 0.040 m

intensity of incident X-rays = 0.013 W m^{-2}

exposure time of X-ray = 0.80 s

linear attenuation coefficient of bone = 58.3 m^{-1}

Do not write outside the box

0 7 . 2 Calculate an estimate for the X-ray energy that is absorbed by the bone.

[5 marks]

energy absorbed = _____ J

0 7 . 3 State **two** reasons why the estimate of energy absorption in Question **02.2** may be greater than the actual value.

[2 marks]

1 _____

_____

_____

_____

2 _____

_____

_____

_____

11

Question	Answers	Additional comments/Guidelines	Mark	AO
07.1	Flat panel detector ✓ If flat panel detector, **max 3** from: Not moving, so fluoroscopic image intensity not required ✓ Saves a picture unlike an intensifying screen ✓ FTP digital image is easier to share or transfer unlike film ✓ Flat panel detector is more sensitive (than film) ✓ Faster than film / film is slower / doesn't have to be developed like film ✓ To minimise dose of X-rays to be used ✓ If film selected Not moving, so film is preferred to intensifying screen ✓ Saves a picture unlike an intensifying screen ✓ Minimise dose of X-rays to be used (compared to moving image with intensifying screen) ✓ If image intensifier selected Intensifying screen is more sensitive (than film) ✓ Does not need to be developed like film / real time image✓	Ignore references to resolution / image quality Treat cost / portability as neutral Do NOT accept minimise dose compare to flat panel detector Condone increases contrast (at low intensity) as an alternative to increase sensitivity If no selection is made max 2 for correct comments.	4	4 x AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
07.2	First mark is for calculating intensity (or power or energy if calculation done in a different order) transmitted through bone (allow thickness < 4 cm if justified as mean eg $r\sqrt{\pi}$ accept $r = 0.02 <$ thickness $\leq d = 0.04$) must include a factor $e^{-\mu x}$ ✓ Second mark is for calculating intensity absorbed by bone (or power or energy if calculation done in a different order) ✓ Third mark is for calculating the area of the bone ✓ Fourth mark is for converting an intensity into a power (allow ecf for incorrect intensity, including I_0, or area) ✓ Fifth mark is for converting a power into an energy (allow ecf for incorrect energy) ✓	Expected answer $I = I_0 e^{-\mu x} = 0.013 \times e^{-58.3 \times 0.04}$ ✓ $(= 0.00126)$ Absorbed intensity = $I_0 - I = 0.013 - 0.00126$ ✓ $(= 0.0117)$ Area of bone = $\sqrt{0.25^2 + 0.09^2} \times 0.04$ ✓ $(= 0.0106\ \text{m}^2)$ $P = IA = 0.0117 \times 0.0106$ ✓ $(= 0.000124)$ $E = Pt = 0.000124 \times 0.8 = 1.0 \times 10^{-4}$ ✓(J) (allow 9.9×10^{-5} or 1.1×10^{-4}) Condone rounding of answers/values as estimate asked for. Award max 4 if PoT error in final answer.	5	4 × AO2 1 × AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
07.3	Assuming bone has constant thickness / bone is rectangular/cuboid ✓ Assuming none of the X-rays are absorbed by tissue before it reaches the bone ✓	Allow any other sensible assumption that leads to a larger value For the first mark it must be clear that the distance referred to is x in the equation $I = I_0 e^{-\mu x}$ and not the mean diameter used to calculate the cross sectional areas. First mark can also be gained from an attempt to use an average value for x in **02.2** Allow some X-rays are scattered (rather than being absorbed) ✓ Treat references to X-rays reflecting as neutral	2	2 x AO3

Total			**11**	

Do not write outside the box

0 8 A patient has calcium kidney stones.
Three types of scan are available to investigate the condition:

- a magnetic resonance (MR) scan
- a CT scan
- an ultrasound scan.

Calcium kidney stones contain no water and appear similar to bone in each of the scans.

Discuss the advantages and disadvantages of each option.
In your answer you should

- refer to the relevant quality of the image obtained from each scan
- identify other factors that should be considered
- justify the type of scan you would recommend.

[6 marks]

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidelines</th><th>Mark</th><th>AO</th></tr>
<tr><td>08</td><td>
The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer.
Guidance provided in section 3.10 of the ‘Mark Scheme Instructions’ document should be used to assist in marking this question.
<table>
<tr><th>Mark</th><th>Criteria</th></tr>
<tr><td>6</td><td>Ultrasound or CT identified and justified, quality comments on all 3, at least 3 other factors. Must refer to resolution / detail for 6 marks.</td></tr>
<tr><td>5</td><td>Ultrasound or CT identified and justified, quality comments on all 3, at least 2 other factor
Must differentiate between the quality of CT and ultrasound for kidney stones.</td></tr>
<tr><td>4</td><td>Ultrasound or CT scanner identified.
Quality comments on all 3 or 2 quality comments and 1 other factor.</td></tr>
<tr><td>3</td><td>Ultrasound or CT scanner identified.
2 comments including at least 1 quality comment
Or
MR scanner identified and stated as highest resolution, with 2 quality comments and 2 others factors.</td></tr>
<tr><td>2</td><td>Any choice, with a relevant supporting argument (allow MR scanner as highest resolution provided one other relevant factor is provided).
Or
At least 3 valid comments with no choice made</td></tr>
<tr><td>1</td><td>Any valid comments (ignore MR scanner as highest resolution).</td></tr>
<tr><td>0</td><td>No relevant comments.</td></tr>
</table>
</td><td>
Points to consider:

Relevant quality
• MR scanner – low quality image of calcium / kidney stones (allow cannot see)
• CT scanner – high resolution image of kidney stone
• Ultrasound – low resolution image of kidney stone
(Allow CT scanner and Ultrasound produce good images of kidney stone but not for 6 marks)
Allow references to bone instead of kidney stone

Other factors
• (CT scanner / MRI is more expensive than ultrasound)
• Ultrasound / MRI causes no harm
• CT scanner emits ionising radiation
• Ionising radiation damages cells
• Do not have to remain still for ultrasound
• Ultrasound is fastest / real time
• MRI can cause claustrophobia

Ignore references to metal / pace maker in the body for MRI
Ignore references to 3D images

Justified choice
• Ultrasound
• Quality is good enough, (cheaper) and safe

• CT
• Best quality image of kidney stones
• (except for pregnant women and children)
</td><td>6</td><td>5 × AO3

1 × AO2</td></tr>
</table>

Do not write outside the box

0 9 . 1 **Figure 6** shows an X-ray image of a chest on photographic film.
Figure 7 shows a diagram of a horizontal cross-section of the chest along the dashed line in **Figure 6**.

Figure 6

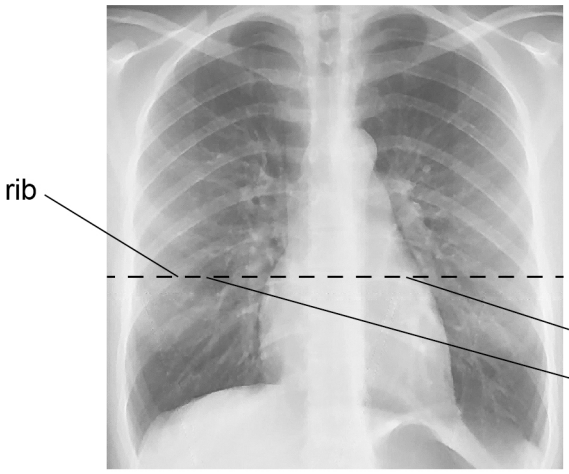
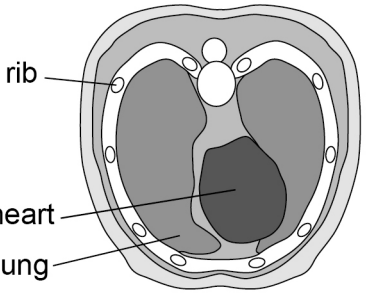


Figure 7



Discuss the half-value thicknesses of the labelled body parts relative to each other.

In your answer you should:

- explain how the intensity of the X-rays affects the brightness of the image
- explain how the thickness of the labelled parts affects the intensity of the X-rays
- compare the relative half-value thicknesses of the labelled body parts.

[6 marks]

Do not write outside the box

0 9 . 2 The stomach is not clearly visible in **Figure 6**.

Explain the method used to improve the image of the stomach on X-ray photographic film.

[2 marks]

8

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidelines</th><th>Mark</th><th>AO</th></tr>
<tr>
<td>09.1</td>
<td>The mark scheme gives some guidance as to what statements are expected to be seen in a 1- or 2-mark (L1), 3- or 4-mark (L2) and 5- or 6-mark (L3) answer.
Guidance provided in section 3.10 of the ‘Mark Scheme Instructions’ document should be used to assist in marking this question.
<table>
<tr><th>Mark</th><th>Criteria</th></tr>
<tr><td>6</td><td>All three areas covered with at least two aspects covered in some detail.
There should be at least one statement from the conclusions.
Can be awarded even if there is an error and/or parts of one aspect missing.</td></tr>
<tr><td>5</td><td>A fair attempt to analyse all three areas, with two areas discussed successfully and one are partially.</td></tr>
<tr><td>4</td><td>Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be several gaps, there should only be an occasional error.</td></tr>
<tr><td>3</td><td>One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.</td></tr>
<tr><td>2</td><td>Only one area discussed, or makes a partial attempt at two areas.</td></tr>
<tr><td>1</td><td>None of the three areas covered without significant error.</td></tr>
<tr><td>0</td><td>No relevant comments</td></tr>
</table>
</td>
<td>Ignore references to body parts other than ribs, heart, lung.

Statements can be in terms of transmission or absorption.

Area 1: Brightness
Film is darkened by X-rays.
More X-rays darker film / lighter areas have fewer X-rays.

Brightness:
Heart > ribs >> lungs
Lungs allows the most X-rays to be transmitted and are darkest.
Heart allows the fewest X-rays to be transmitted and is lightest.
Rib allows more X-rays than the heart but fewer than lungs to be transmitted and is medium brightness.

Area 2: Thickness
Thicker tissue decreases the amount of X-rays transmitted.
Reference to exponential decrease in X-rays transmitted with thickness.

Rib<< heart < lungs
Rib - very thin, so transmits more X-rays than heart.
Heart - much thicker than rib transmits less X-rays.
Lung - very thick (but transmit most X-rays).</td>
<td>6</td>
<td>2 × AO1

4 × AO3</td>
</tr>
</table>

		Area 3: Half-value thickness Half-value thickness is the thickness needed to reduce intensity by half. Larger $x_{1/2}$ increases the amount of X-rays transmitted for the same thickness. Half value thickness: Lungs >> heart > ribs Rib has smallest $x_{1/2}$ (most dense) Heart has medium $x_{1/2}$ (medium density) Lung has largest $x_{1/2}$ (least dense) **Conclusions** Ideas that: Heart brightest as it has medium $x_{1/2}$ but is thick Rib almost as bright as heart as it has smallest $x_{1/2}$ but is much thinner. Lung darkest as although thicker, it has highest $x_{1/2}$		

Question	Answers	Additional comments/Guidelines	Mark	AO
09.2	Idea of ingestion of barium meal/ contrast medium ✓ To improve contrast of image / to increase the number of X-rays absorbed (by contents of stomach) / barium is a good absorber of X-rays/ barium has high attenuation (coefficient) ✓	Do not allow any response suggesting ingestion of a radioisotope Do not award MP2 without MP1 being given. MP2: ignore 'has higher atomic number' Do not allow reference to increased reflection.	2	2 × AO2
Total			**8**	