**2001**

(a) (i) Identify the purpose of a coherent bundle of optical fibres in an endoscope. **1**

(ii) An optical fibre consists of a central core surrounded by cladding. Describe the role of the core and cladding. **2**

(b) The table shows information relating to the transmission of sound through some types of body tissue.

| *Tissue* | *Acoustic impedance* ($\times 10^6$ kg m$^{-2}$ s$^{-}$ | *Density* (kg m$^{-3}$) | *Velocity of sound* (m s$^{-1}$) |
|---|---|---|---|
| Muscle | 1.70 | 1040 | 1630 |
| Fat | 1.38 | 945 | 1460 |
| Bone | 7.80 | 2560 | 3050 |

(i) Identify ONE property of ultrasound. **1**

(ii) Justify why, in an ultrasound scan, a boundary between muscle and bone would show up more clearly than would a boundary between muscle and fat. **3**

(c) You have conducted a first-hand investigation to demonstrate the Doppler effect. Describe your investigation and conclusions. **4**

(d) 'CAT scans provide more information than X-rays, so they should be used whenever possible.' Discuss this statement. **6**

(e) Explain why MRI can be used to detect cancerous tissues. **8**

**2002**

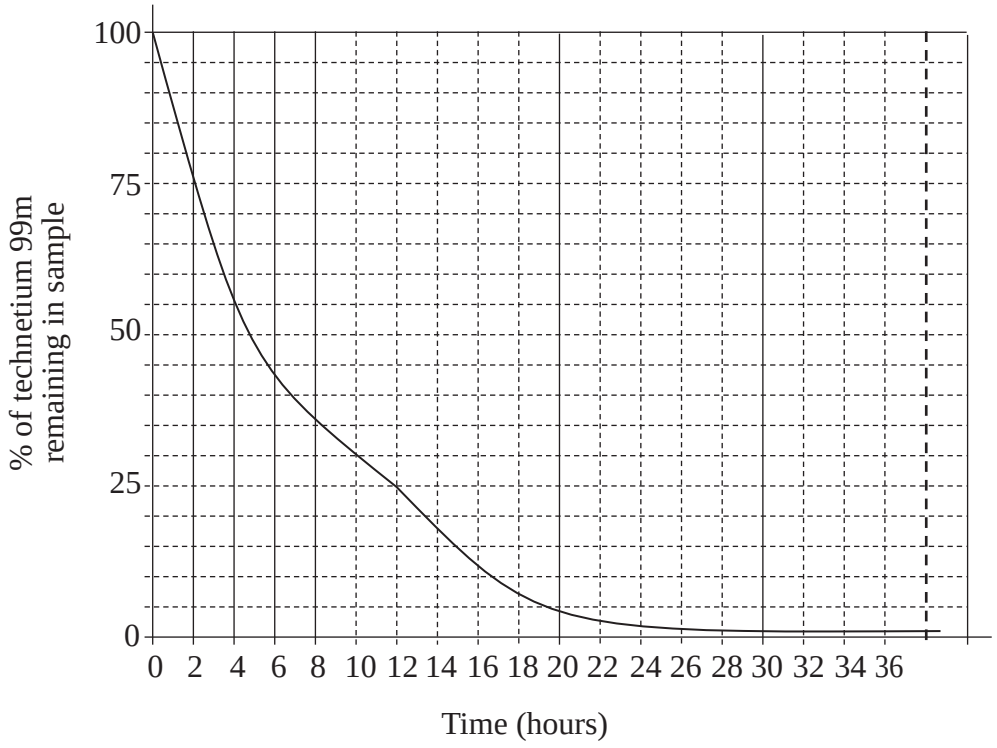
**Question 29 — Medical Physics** (25 marks)

(a) (i) Briefly describe how an endoscope works. **2**

(ii) Explain how a computed axial tomography (CAT) scan is produced. **4**

(b) Technetium 99m is an artificial isotope which is frequently used to obtain a scan of the human body.

(i) Using the graph, determine the half life of technetium 99m. **1**




(ii) A patient is given an injection containing $6.0 \times 10^{-18}$ kg of technetium 99m. The scan is taken four hours after the injection. **2**

How much technetium 99m remains undecayed when the scan is taken? (Give your answer in kilograms.)

(iii) Propose reasons why scans are best taken between two and five hours after injection of this radioisotope. **3**

**Question 29 continues on page 31**

Question 29 (continued)

(c) The diagrams shown are an MRI of the human upper arm, an X-ray of a human hand and a CAT scan of the human pelvis (hip bone) as seen in cross-section from above.

MRI of human upper arm
Procedure time: 30–60 minutes

X-ray of human hand
Procedure time: 5 minutes

CAT scan of human pelvis (hipbone)
Procedure time: 40 minutes

(i) Identify TWO advantages of MRI scans over CAT scans. **2**

(ii) A patient is brought into a hospital out-patients ward complaining of a severe headache. He explains that he hit his head while playing football. The doctor thinks that the patient may be suffering from a fractured skull. **2**

Explain why the doctor would order an X-ray to confirm the diagnosis of a fractured skull.

(iii) The patient, now diagnosed with a fractured skull, complains of other symptoms that may indicate that he is suffering from brain damage. **2**

Suggest ONE additional scan which may be required to confirm this diagnosis. Justify your choice.

(d) Assess the impact of medical applications based on ultrasound and the magnetic field of particles within the body on modern society. **7**

**2003**

**Question 29 — Medical Physics** (25 marks)

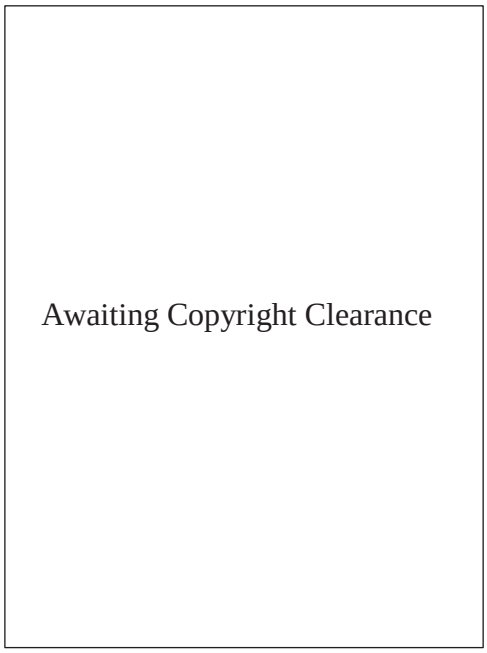
(a) (i) Identify the property of the hydrogen nucleus that makes it useful in **1**

magnetic resonance imaging.

(ii) Describe how X-rays are produced when electrons strike the anode in an X-ray tube. **2**

(b) Outline the production of gamma rays and their use in the diagnostic procedure of positron emission tomography (PET). **3**

(c) This question refers to the bone scan of a person with cancer, and a chest X-ray of a healthy person.




Bone-scan image


X-ray image

(i) Compare how radiation is used to produce a bone scan image and an X-ray image. **3**

(ii) Describe how a bone scan is able to provide information that an X-ray cannot provide. **2**

**Question 29 continues on page 35**

Question 29 (continued)

(d) The table below shows the speed of sound in, and density of, several different tissues.

| *Tissue* | *Speed of sound in tissue* (m $s^{-1}$) | *Density* (kg $m^{-3}$) |
|---|---|---|
| Fat | 1450 | 952 |
| Blood | 1570 | 1025 |
| Kidney | 1560 | 1038 |
| Liver | 1550 | 1065 |
| Muscle | 1580 | 1076 |

(i) Calculate the acoustic impedance of kidney tissue. **1**

(ii) Ultrasound travelling through kidney tissue in the body encounters a different type of tissue. Identify the type of tissue that will result in the greatest proportion of the incident pulse being reflected at the boundary between the kidney and the other tissue. Justify your choice. **2**

(iii) Describe the properties of ultrasound that led to its use in the measurement of bone density. **3**

(e) An understanding of the properties of electrons, and our ability to control their behaviour, have played key roles in the development of CAT scans and positron emission tomography imaging technologies. **8**

Justify this statement with reference to the production and display of images used for medical diagnosis.

**2004**

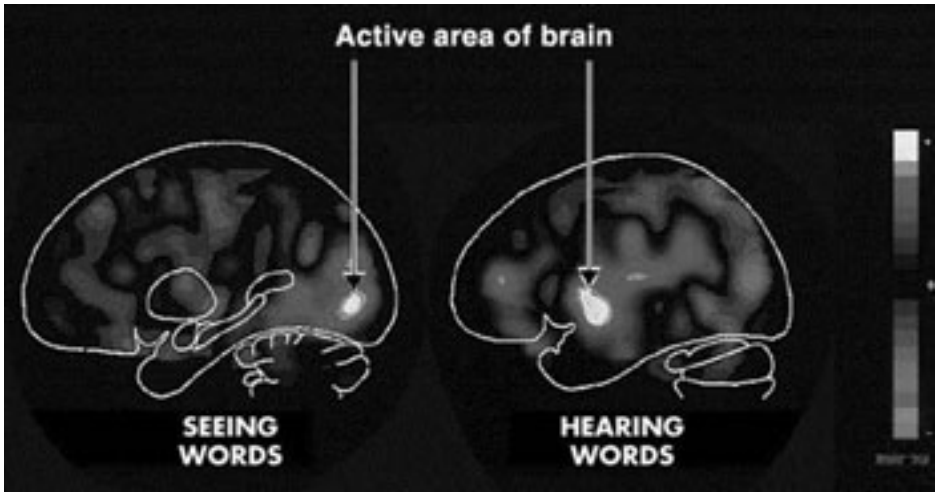
(a) (i) Describe how the piezoelectric material used in an ultrasound transducer can be made to vibrate to produce compressions and rarefactions in body tissues. **1**

(ii) Examine the following image showing the heads of unborn twins. **3**


Describe how the image of the heads of the twins was produced.

(b) Different medical imaging technologies are used to enhance the information available to scientists and doctors.

(i) The following PET images of the brain show the active areas when the same words were seen on a video screen (left image) and heard through earphones (right image). To produce these images, glucose tagged with the radioisotope F-18 was first injected into the person's body. **3**




With reference to these images and the role of the tagged glucose, evaluate how PET imaging technology is changing our understanding of the way the brain functions.

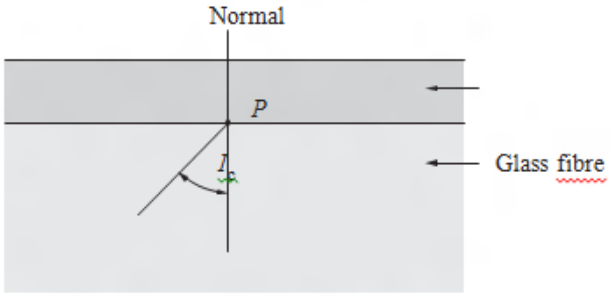
(ii) Identify the imaging technology used to obtain blood flow characteristics of blood moving through the heart, and describe the principle that enables information about the movement of blood to be measured. **3**

(c) Nobel Prizes are awarded annually 'to those who . . . have conferred the greatest benefit to mankind' (quote from Alfred Nobel's will). The following table shows information about some people who have received Nobel Prizes, and the reasons for their award. **7**

| *Award* | *Recipients* | *Citation (reasons for award)* |
|---|---|---|
| 1956 Nobel Prize for Physics | William Bradford Shockley<br>Walter Houser Brattain<br>John Bardeen | 'for their researches on semiconductors and their discovery of the transistor effect' |
| 1972 Nobel Prize for Physics | John Bardeen<br>Leon Neil Cooper<br>John Robert Schrieffer | 'for their jointly developed theory of superconductivity, usually called the BSC-theory' |
| 2003 Nobel Prize for Physics | Alexei Abrikosov<br>Vitaly Ginzburg<br>Anthony Leggett | 'for their pioneering contributions to the theory of superconductors and superfluids' |
| 2003 Prize for Medicine | Peter Mansfield<br>Paul Lauterbur | 'for their discoveries concerning magnetic resonance imaging' |

With reference to the physical processes upon which MRI depends, assess the impact of advances in knowledge about semiconductors and superconductors on the development of magnetic resonance imaging.

(d) (i) During your study of medical physics you carried out a first-hand investigation of the transfer of light by optical fibres. The diagram below shows part of the cross-section of an optical fibre, with the critical angle labelled. **2**




Sketch the diagram in your answer booklet and show a ray of light that is totally internally reflected at the point *P* in the fibre.

(ii) The photograph shows a normal endoscopic image of the transverse part of the large intestine. **3**

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Describe how the optical fibres in an endoscope are used to produce an image such as the one shown.

(iii) Describe how an endoscope could be used to obtain tissue samples from inside the large intestine, and outline why the endoscope is of particular use in this procedure. **3**

**2005**

Question 25- Medical physics (25 marks)

(a) (i) The images show a person's heart before and after a medical procedure. Describe how radioactive isotopes have been used to identify the abnormality and confirm its correction. **2**

(ii) The table provides examples of some radioactive isotopes and their properties. **2**

| *Radioactive source* | *Radiation emitted* | *Half-life* |
|---|---|---|
| $^{11}C$ | Gamma | 20.30 minutes |
| $^{99}Tc$ | Gamma | 6.02 hours |
| $^{201}Tl$ | Gamma | 3.05 days |
| $^{131}I$ | Gamma | 8.04 days |
| $^{137}Cs$ | Alpha | 30.17 years |
| $^{238}U$ | Alpha | $4.47 \times 10^9$ years |

Which radioactive isotope from the table would most likely be used to investigate the abnormality shown in the image above? Justify your choice.

(b) (i) The acoustic impedance of fat is $1.38 \times 10^6 \text{ kg m}^{-2} \text{ s}^{-1}$.

The acoustic impedance of bone is $7.80 \times 10^6 \text{ kg m}^{-2} \text{ s}^{-1}$.

What percentage of the incident intensity of an ultrasound wave is reflected as it crosses from fat into bone?

(ii) Compare the physics involved in producing X-ray images with that used for endoscopies.

(c) The images demonstrate advances in the use of ultrasound as a tool in medical diagnosis. Describe advances in technology that have enabled the improvements shown in these images, and discuss current issues that have arisen from these advances.

(d) (i) The following diagram shows the constituent parts of an MRI system. **2**

State the functions of the superconducting magnet assembly and the radio frequency (RF) coils in the MRI system.

(ii) The use of MRI may be improved by the introduction of gadolinium into the body. **2**

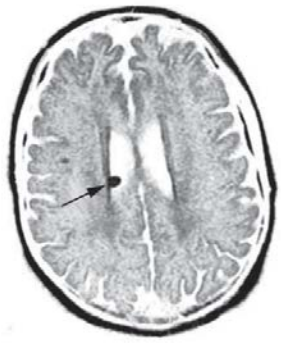
**$T_1$ curves for tissues *A* and *B* without gadolinium in the body**

**$T_1$ curves for tissues *A* and *B* with gadolinium in the body**

Explain why gadolinium has been introduced.

(iii) The arrow indicates an abnormality that has been detected in one hemisphere of the brain.

**MRI brain scan**



Identify the advantages of MRI over a CAT scan in detecting this abnormality.

**2006**

Question 29- Medical physics (25 marks)

(a) The acoustic impedance and density of a number of different types of body tissue, ultrasound gel and air are shown in the table:

| *Material* | *Acoustic impedance* ($kg\,m^{-2}\,s^{-1}$ x c | *Density* ($kg\,m^{-3}$) |
|---|---|---|
| Fat | 1.38 | $9.25 \times 10^2$ |
| Skin | 1.52 | $1.00 \times 10^3$ |

| | | |
|---|---|---|
| Ultrasound gel | 1.54 | $1.01 \times 10^3$ |
| Air | 0.0004 | 1.3 |

(i) Calculate the velocity of sound in fat tissue. **2**

(ii) Ultrasound gel is used to overcome the excessive reflection from the skin during a scan. **3**

Explain why this is necessary, justifying your response with calculations.

(b) During your study of Medical Physics you identified data sources, and gathered, processed and presented information to explain why MRI scans can be used to detect abnormalities in the body.

(i) Describe the criteria you would use to determine the reliability of a data source for this purpose. **3**

(ii) Explain why MRI scans can be used to detect cancerous tissues. **3**

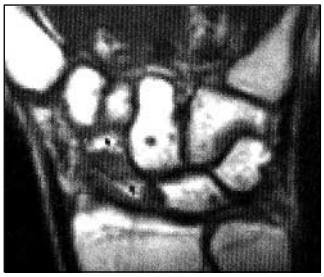
(c) Advances in our understanding of the electromagnetic spectrum have allowed scientists to investigate the human body in more detail. **7**

Assess the impact of these advances on the development of medical technologies.

(d) Bones can be viewed with a range of different medical imaging techniques. The images shown below were obtained using three different techniques.

*A*

*B*



*C*

(i) The images shown above are an X-ray, a CAT scan and a bone scan **1**

(in no particular order).

Identify the images labelled *A*, *B* and *C*.

(ii) Compare the advantages and disadvantages of CAT scans to X-ray images. **3**

(iii) Contrast the information provided by bone scans with that obtained by CAT scans and X-ray images. **3**

**2007**

(a) Ultrasound imaging depends on the fact that different materials have different acoustic impedances. The density and acoustic impedance of fat and muscle are shown.

| | *Density* (kg $m^{-3}$) | *Acoustic impedance* (kg $m^{-2}$ $s^{-1}$ × $10^6$ |
|---|---|---|
| Fat | $9.25 \times 10^2$ | 1.38 |
| Muscle | $1.073 \times 10^3$ | 1.70 |

(i) Calculate the fraction of ultrasound intensity that is transmitted as it passes from fat into muscle. **2**

(ii) Explain how a piezoelectric crystal can act as both a source and detector of ultrasonic waves. **3**

(b) (i) In your study of Medical Physics you performed an investigation to identify the function of the components of MRI equipment. The following information is from the *Australian Twin Registry Newsletter*, 2006.

**MRI: How does it work?**
Unlike conventional radiography Computed Tomography (CT) scans, which make use of potentially harmful X-rays passing through a patient to generate images, MRI is based on the magnetic properties of atoms within the tissue. A powerful magnet generates a magnetic field roughly 10,000 times stronger than the Earth's. A very small percentage of hydrogen atoms within the body will line up with this field. Radio waves are passed through the person's body then "bounce back" depending on how many lined up atoms they meet. The subtle differences in how the radio waves bounce back provide the information needed to construct the image.

Australian Twin Registry

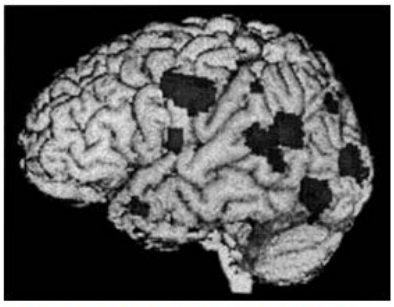
Assess the information provided in this article in terms of its scientific accuracy. **4**

(ii) Why is ultrasound imaging NOT used for investigating the function and structure of the brain? **2**

(c) Assess the effects on the lives of individuals and the wider community of the production and use of X-rays, CAT scans and MRI. **7**

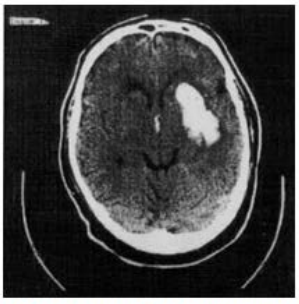
(d) (i) Compare the advantages and disadvantages of CAT and PET scans in investigating the structure and function of the brain with reference to the images shown. **3**

*Image A*



Dark areas show abnormal brain activity function.

*Image B*



White area shows the result of a stroke.

Osteoporosis is a degenerative disease in which there is a gradual loss of minerals in the bone. This leads to decreased bone strength and an increased chance of bone fractures.

(ii) With reference to the images shown, compare TWO imaging techniques which can be used to diagnose osteoporosis. **4**

**2008**

(a) (i) Account for the production and detection of ultrasound waves by the transducer of an ultrasound machine. **3**

(ii) Explain what happens to ultrasound waves as they travel through body tissues and return to the transducer. **3**

(b) (i) Outline TWO uses of endoscopy. **2**

(ii) Using diagrams, distinguish between the coherent and incoherent bundles of optical fibres and their roles in endoscopy. **3**

(iii) Outline ONE advantage of endoscopy over alternative surgical procedures. **1**

(c) (i) Contrast the advantages of bone scans with the advantages of X-ray images when examining bones. **3**

(ii) Describe how X-rays are produced. **2**

(iii) Describe the properties of a radiopharmaceutical substance that make it suitable for producing a bone scan. **2**

(d) Explain how different medical imaging techniques use tomography to improve our diagnostic abilities. **6**

**2009**

(a) (i) In X-ray images, the small intestine is not normally visible. Explain how the use of a contrast medium, for example a barium meal, allows the small intestine to be seen. **(2 marks)**

(ii) Using text and a labelled diagram, explain how X-rays are produced for medical imaging. **(4 marks)**

(b) (i)Given the velocity of sound in blood is 1.53 × 103 m s–1, and blood has a density of 1.05 × 103 kg m–3, calculate the acoustic impedance of blood. **(1 marks)**

(ii) Ultrasound can pass from blood into a variety of materials. What happens to the incident pulse when it passes into materials of increasing acoustic impedance? **(1 marks)**

(iii) Explain how a piezoelectric crystal can be used as a producer and receiver of ultrasound waves. **(4 marks)**

(c) (i) "Have a CAT scan – live longer!" **4**

Can the claim made in this statement be justified? In your answer refer to the properties and uses of CAT scans.

(ii) In this PET image a chemical tracer has been used to measure glucose metabolism in a patient. Explain how this image has been produced, including the physics involved. **3**

(d) Describe the sequence of events and associated processes of physics by which an image is produced using magnetic resonance imaging. **6**

**2010**

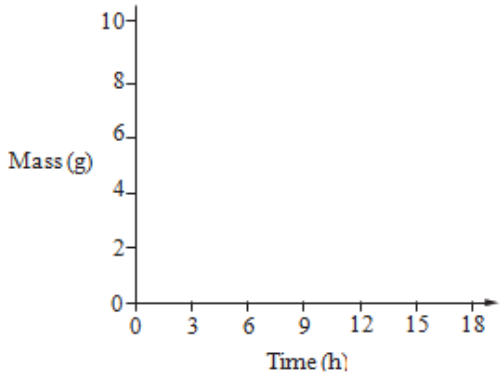
Answer parts (a)–(c) in a writing booklet.

(a) Describe how an X-ray image of the bones in the hand is produced. **3**

(b) (i) What is ONE advantage and ONE disadvantage of using a radioisotope with a 6 hour half-life for medical imaging? **2**

(ii) The half-life of Tc–99m is 6 hours. **2**

Copy the following set of axes into your writing booklet, and draw a graph to show how the mass of a 10 g sample of Tc–99m changes over 18 hours.




c)

(i) Why is hydrogen the most commonly targeted element in the magnetic resonance imaging process? **2**

(ii) Describe how energy from the radio frequency oscillator of a magnetic resonance imaging machine interacts with hydrogen to obtain information about the inside of the body. **3**

Answer parts (d)–(e) in a SEPARATE writing booklet.

(d) (i) The acoustic impedance of air is 400 kg $m^{-2}$ $s^{-1}$. **3**

| *Tissue* | *Density* (kg $m^{-3}$) | *Velocity of sound* (m $s^{-1}$) |
|---|---|---|
| Muscle | 1076 | 1580 |
| Bone | 1912 | 4080 |
| Brain | 1025 | 1540 |

Calculate the intensity of the reflected ultrasound at the interface between chest muscle and air as a proportion of the incident intensity.

(ii) Describe how the Doppler effect is used in ultrasound imaging and outline information that a Doppler ultrasound scan can provide about blood flow in the heart. **4**

(e) A cancer specialist has access to ultrasound, CAT and PET scanners. **6**

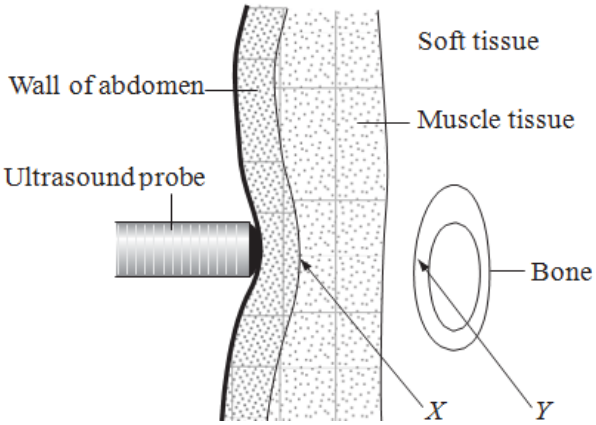
Which of these technologies is the most appropriate to detect a 3 mm brain tumour? Justify your choice.

**2011**

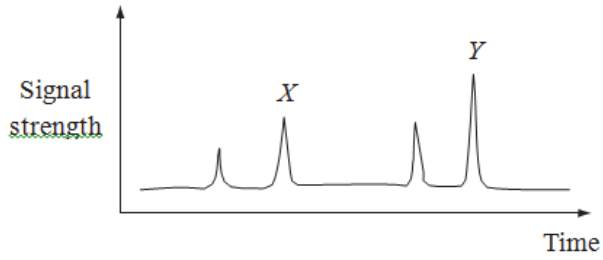
**Question 32 — Medical Physics** (25 marks)

Answer parts (a)–(b) in Section II Answer Booklet 1.

An ultrasound probe fires a pulse of ultrasound into the abdomen as shown in the diagram.




Analysis of the reflected sound produced the following scan.




(a) (i) Identify the type of scan and the information that can be obtained from it. **2**

(ii) The peaks *X* and *Y* correspond to the ultrasound reflected from the muscle tissue and bone respectively. Explain why the signal strength at *Y* is greater than at *X*. **2**

(iii) The acoustic impedance of the abdomen wall adjacent to the muscle is $1.56 \times 10^6$ kg m$^{-2}$ s$^{-1}$. If muscle tissue has a density of $1.04 \times 10^3$ kg m$^{-3}$ and an acoustic velocity of 1580 m s$^{-1}$, calculate the percentage of the incident ultrasound pulse that is reflected at boundary *X*. **3**

(b) (i) Explain how X-rays are produced in an X-ray tube. **3**

(ii) The photographs *A* and *B* show scans of the same part of the body. **3**

Answer parts (c)–(e) in Section II Answer Booklet 2.

(c) Explain why MRI is an effective tool for diagnosing brain tumours. **3**

(d) With reference to coherent and incoherent bundles of fibres, explain how an endoscope is used to observe internal organs. **3**

(e) *An increased understanding of the properties of radioactive isotopes has been important in the development of medical technologies used to analyse bodily processes.* **6**

Justify this statement.