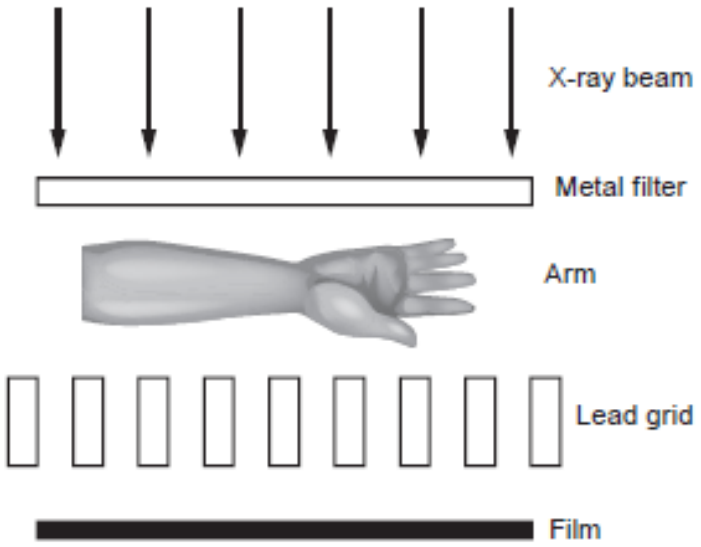
Physics

Question	Maximum Mark	Mark Awarded
#1	20	
#2	20	
#3	20	
#4	20	
Total	80	

#1

12. *(a)* When taking an X-ray image of a person's arm a metal filter is placed between the X-ray tube and the arm, and a lead grid between the arm and the film as shown.



Explain the purpose of both the metal filter and the lead grid. [4]

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(b) An X-ray tube operates at a pd of 30 kV producing a tube current of 15 mA.

(i) Calculate the number of electrons that strike the target element every second. [2]

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(ii) Calculate the force exerted by the electron beam on the target. [3]

(c) You have the choice of the following forms of medical imaging available:

MRI scan **PET scan** **ultrasound B-scan** **CT scan**

Evaluate the effectiveness of each type of imaging in detecting a cancerous tumour on a person's lung. [5]

(d) (i) Radioactive tracers can be used to measure the volume of blood in a patient. Describe one other use of radioactive tracers naming the part of the body they are diagnosing. [1]

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(ii) An isotope of sodium, Na-24, has a half-life of 15 hours and an initial activity of 160 Bq when injected into a patient. Seven hours later a sample of 5 cm^3 of blood was taken and found to have an activity of 0.12 Bq. Estimate the volume of blood in the patient. [3]

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(iii) Ultrasound of frequency 3.0 MHz was used to measure the rate of flow of blood. A shift of 0.50 kHz was detected. The measurement was taken at an angle of 30° to the direction of flow and the speed of ultrasound through the blood is 1 500 $m\,s^{-1}$. Calculate the speed of blood flow. [2]

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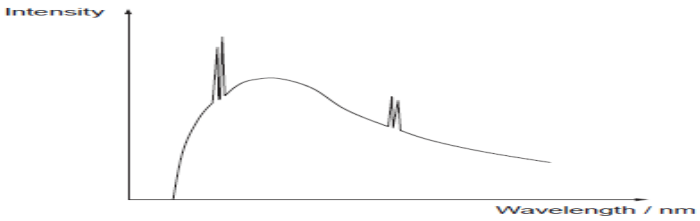
Question taken from Eduqas examination paper 842103, June 2018

#2

(a) The graph below shows the intensity spectrum for an X-ray tube.



(i) **Draw on the above diagram** an intensity spectrum for the same X-ray tube with a **higher** operating voltage. [1]

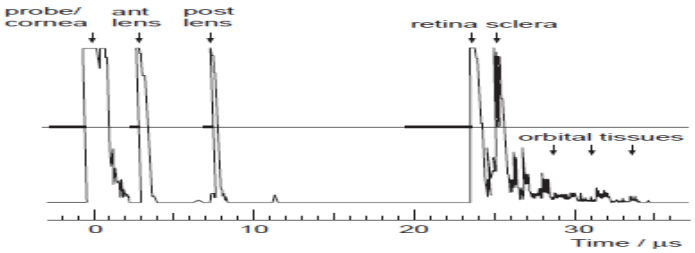
(ii) If the operating voltage of the tube is 30 000 V, determine the minimum wavelength of the X-rays produced. [2]

(iii) If the anode current is 120 mA and the X-ray tube has an efficiency of 0.450 % calculate the rate of production of heat at the anode. [2]

(iv) Explain whether it would be possible to reduce the minimum wavelength to zero. [1]

(b) (i) An ultrasound probe (A scan) can be used to determine the thickness of a lens in the human eye. Explain how a piezoelectric transducer can be used to produce ultrasound. [2]

(ii) A typical ultrasound A scan used to determine the thickness of a lens is given in the diagram below. The spike labelled 'ant lens' corresponds to the front of the lens and the spike labelled 'post lens' corresponds to the back of the lens.



Use the information in the diagram to calculate the lens thickness. The speed of ultrasound in the lens is 1640 m s^{-1}. [3]

(c) You have the choice of the following forms of medical imaging:

X-ray **ultrasound A scan** **radioactive tracer** **CT scan**

Justifying the reasons for your answer, state which of the above you would use to detect the following:

(i) A cerebral haemorrhage (bleed in the brain). [3]

(ii) An underactive thyroid gland. [2]

(d) An MRI (magnetic resonance imaging) scanner has a magnetic field that varies from 0.80 T to 1.40 T along its length. Calculate the wavelength of electromagnetic waves required to scan a slice halfway along its length **and** state which part of the electromagnetic spectrum they belong to. [4]

Question taken from Eduqas examination paper 842103, November 2020

#3

(a) Describe briefly how X-rays are produced in an X-ray tube. [2]

(b) (i) When a beam of X-rays passes through bone the X-rays are absorbed and the beam becomes attenuated. The thickness of bone needed to reduce the original intensity by 50 % is known as the half value thickness, $x_{\frac{1}{2}}$. Show that $x_{\frac{1}{2}} = \frac{\ln 2}{\mu}$ where μ is the attenuation coefficient. [3]

(ii) A beam of X-rays is used to detect a fracture in a bone. If the half value thickness for these X-rays in bone is 1.5 cm, calculate the thickness of bone that reduces the incident intensity by 60 % of the original intensity. [3]

(iii) X-ray imaging is not suitable for diagnosing brain tumours. Explain why, and suggest a more suitable technique giving your reasons. [3]

(c) An ultrasound probe can be used to check the development of an unborn baby. Explain how a piezoelectric transducer can be used to produce ultrasound. [2]

(d) The table below gives some ultrasound properties of different body tissues.

Material	Density / kg m^{-3}	Velocity / m s^{-1}	Acoustic impedance / kg m^{-2} s^{-1}
Muscle	1 075	1 590	
Fat	925	1 450	
Bone	1 908	4 080	

(i) **Complete the table** by calculating the different values for acoustic impedance. [2]

(ii) The fraction of ultrasound reflected at a boundary is given by the reflection coefficient, R, where:

$$R = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$$

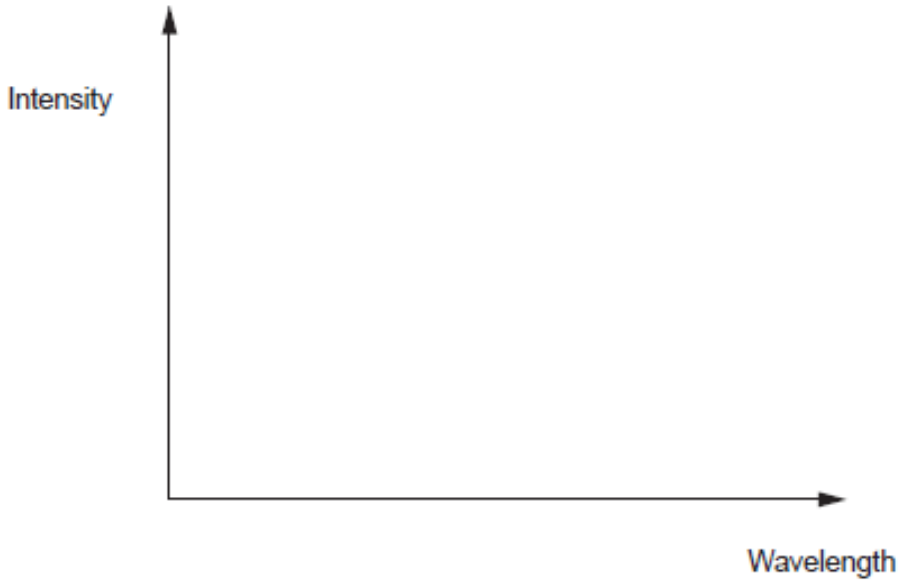
Between which **two** tissues would the greatest amount of ultrasound be reflected? Justify your answer numerically. [3]

(e) A typical MRI scanner operates with a Larmor frequency of 64 MHz. Calculate the magnetic field strength, B, that would be needed to provide this, and state which patients would **not** be able to undergo MRI scans. [2]

Question taken from Eduqas examination paper 842103, June 2017

#4

12. *(a)* (i) Sketch graphs to show how the intensity of X-rays from an X-ray tube varies with wavelength for a tube operating at two different voltages. Label the main features of the graphs and indicate which curve represents the higher voltage. [4]



(ii) The lower voltage tube operates at 20 kV. Determine the velocity with which the electrons strike the target. [2]

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(iii) Calculate the minimum wavelength of the X-ray photons produced by these electrons. [2]

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(b) (i) Ultrasound can be used to carry out either an amplitude scan (A-scan) or a brightness scan (B-scan). Explain which of these two methods you would use to determine the depth of the tumour. Justify your answer. [2]

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(ii) An ultrasound scan can be used to indicate the thickness of fat on a person's body. Typically fat has a density of $930\,kg\,m^{-3}$ and an acoustic impedance of $1.35 \times 10^{6}\,kg\,m^{-2}\,s^{-1}$. If the time delay for the ultrasound pulse is 0.040 ms. Determine the thickness of fat. [3]

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(c) (i) Explain two properties of a radioactive isotope used as a tracer in medicine. [2]

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(ii) A small volume of Human Serum Albumin (HSA) labelled with iodine-125 of activity 160 Bq is injected into the bloodstream of a patient. A sample of 0.8 cm^3 of blood was taken a few hours later and was found to have an activity of 0.025 Bq. If the half-life of iodine-125 is 60 days, calculate the volume of blood in the patient. State any assumptions you make. [3]

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(d) In a magnetic resonance imaging (MRI) scanner a large magnetic field of 1.5 T is used along with short pulses of radio waves. Dr Francis suggests that radio waves of wavelength approximately 5 m would be suitable for this MRI scanner. Determine whether or not Dr Francis is correct. [2]

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Question taken from Eduqas examination paper 842103, June 2019