Centre Number

Candidate Number

Rewarding Learning

ADVANCED
General Certificate of Education
2019

Life and Health Sciences

Assessment Unit A2 3
assessing

MV18

Medical Physics

[AZ031]
FRIDAY 31 MAY, AFTERNOON

Time

1 hour 45 minutes, plus your additional time allowance.

Instructions to Candidates

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
Write your answers in the spaces provided in this question paper.
Answer **all eight** questions.

Information for Candidates

The total mark for this paper is 100.
Figures in brackets printed at the end of each question indicate the marks awarded to each question or part question.
You may use an electronic calculator.
Quality of written communication will be assessed in question **1(ii)**.

1 A patient is to be injected with the radioactive tracer technetium-99.

(i) What is the medical purpose of this particular radioactive tracer?   [1 mark]

_____

_____

(ii) Discuss the benefits and risks to the patient of this medical procedure.   [8 marks]

In your discussion you should include:

- the type of radiation emitted by technetium-99
- the properties of technetium-99 which make it suitable for this medical procedure
- the advantage of using a radioactive tracer
- an evaluation of the risks to the patient
- the precautions the patient needs to take immediately after the procedure

Quality of written communication will be assessed in this question.

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2 **Table 2.1** shows data for some radioisotopes.

Table 2.1

Isotope	Half-life / days		
	$T_{Physical}$	$T_{Biological}$	$T_{Effective}$
^{90}Sr	1.1×10^4	1.8×10^4	
^{32}P	14.3	1155	14.1
^{131}I	8	135	7.55

The rate of decrease of radiation exposure is affected by both the radioactive half-life, $T_{Physical}$, and biological half-life, $T_{Biological}$, giving an effective half-life, $T_{Effective}$, for the isotope in the body.

(a) Explain why it is important that a patient has minimal exposure to a radioisotope.   [2 marks]

_____

_____

Phosphorus, ^{32}P, and strontium, ^{90}Sr, are **both taken up by bone**.

(b) (i) **Describe and explain** the effects this will have, if any, on the radioactive half-life, $T_{Physical}$, and on the biological half-life, $T_{Biological}$. [2 marks for each]

$T_{Physical}$ _____

_____

_____

_____

$T_{Biological}$ _____

_____

_____

_____

From the examples shown in **Table 2.1**, it can be observed that sometimes biological half-life is the dominant influence and sometimes physical half-life is the dominant influence.

Equation 2.1 below is used to calculate the effective half-life for a radioisotope.

$$\frac{1}{T_{Effective}} = \frac{1}{T_{Physical}} + \frac{1}{T_{Biological}}$$ **Equation 2.1**

(ii) Using data from **Table 2.1**, calculate the effective half-life, $T_{effective}$, for ^{90}Sr.   [3 marks]

   You are advised to show your working.

   Effective half-life for ^{90}Sr = _____ days

(iii) Evaluate which of the two radioisotopes, ^{90}Sr or ^{32}P, would be safer to use in bone scans.   [3 marks]

   _____

   _____

   _____

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3 Under normal circumstances the human body maintains a constant temperature called core temperature.

A lowering of body temperature is known as hypothermia and a raising of body temperature is known as hyperthermia.
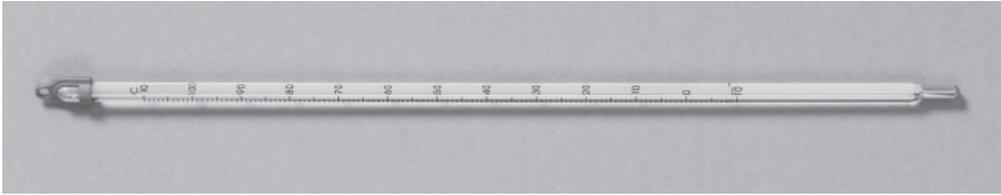
(a) (i) What is the value of the core temperature?
[1 mark]

_____ °C

(ii) What are the temperatures above and below which the human body can no longer stay alive?
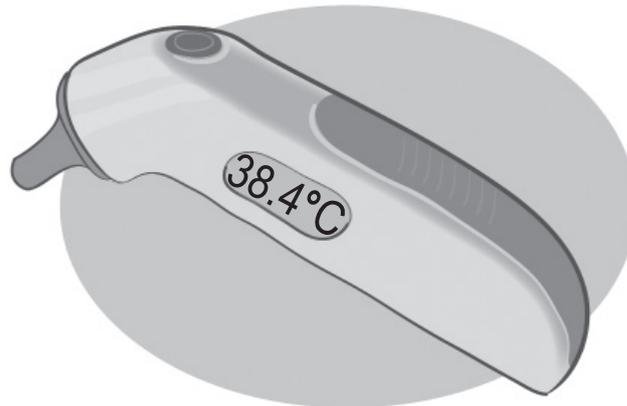[2 marks]

Above _____ °C   Below _____ °C

(b) Fig. 3.1 below shows 3 different types of thermometer which can be used to measure body temperature.

Mercury in glass thermometer

Digital thermometer

Electronic thermometer

Fig. 3.1

(i) Complete **Table 3.1** to give one method of use and one limitation for each of these thermometers. Write your answers in the blank boxes below. [6 marks]

Table 3.1

Type of Thermometer	Method of use	Limitation
Mercury in glass thermometer		
Digital thermometer		
Electronic thermometer		

(ii) Mercury in glass thermometers are no longer commonly used by medical professionals to measure body temperature. Suggest a reason why they are considered unsafe to use for this purpose. [1 mark]

_____

_____

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4 The heart consists of four chambers which receive and expel blood 60–80 times per minute. The rate at which a normal heart beats is affected by factors such as activity and stress.

(a) (i) A basic first aid course requirement is that a candidate can measure the heart rate of a patient who is at rest.

Describe a simple procedure to measure heart rate that could be carried out by the candidate using a stopwatch.   [5 marks]

Your answer should include the steps that must be taken to ensure the results are accurate and reliable.

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(ii) Suggest a non-medical reason why a patient may have a resting heart rate below the normal value.
[1 mark]

_____

An electrocardiogram (ECG) works by measuring pulses of electric current flowing in the heart. These electrical impulses are then recorded as special tracings on strips of graph paper as seen in **Fig. 4.1**.

Fig. 4.1

Long QT syndrome is a genetic heart condition which causes problems with the electrical activity of the heart.

It causes short episodes of abnormally fast heart rhythm which last for about a minute.

This can be triggered by stimuli such as stress, sudden noises, strenuous exercise and even sleeping.

(b) (i) State **two** other medical abnormalities which may be detected through the use of an electrocardiogram.
[2 marks]

1. _____

_____

2. _____

_____

(ii) Describe the limitations of an ECG when used to determine if a patient has long QT syndrome.
[2 marks]

_____

_____

_____

_____

5 **Fig. 5.1** shows a simplified X-ray tube used in the production of conventional X-rays and CT scans.

high voltage supply

target

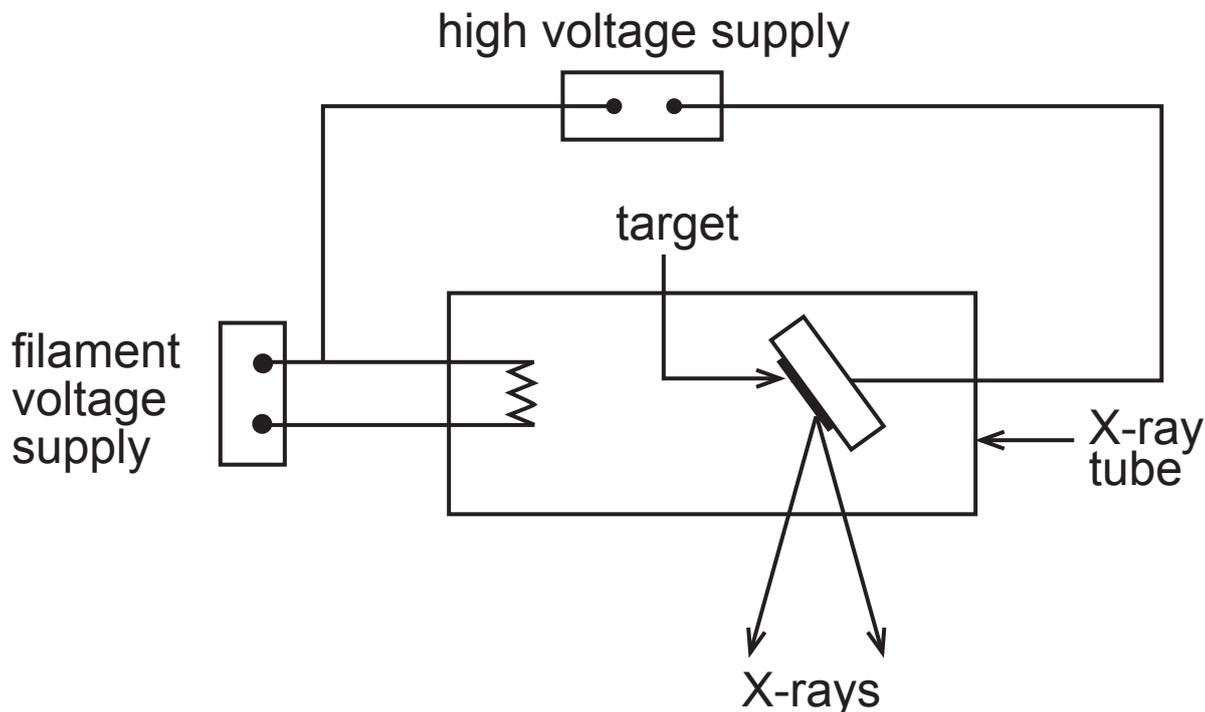filament voltage supply

X-ray tube

X-rays

Fig. 5.1

(a) (i) **Table 5.1** lists some possible properties of X-rays. Tick the appropriate boxes to indicate the correct properties of X-rays.   [3 marks]
One example has been provided.

Table 5.1

Properties	
High energy wave	✓
Low frequency	
Cause ionisation of matter	
Has a relative charge of −1	
Can travel in a vacuum	
Part of the electromagnetic spectrum	
Can only travel a few centimetres in air	

(ii) Describe what happens in an X-ray tube in order to produce X-rays suitable for medical use.   [6 marks]

_____

_____

_____

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_____

(b) (i) State one similarity and one difference between the **images** produced in conventional X-ray scans and in CT scans.   [1 mark for each]

Similarity _____

_____

Difference _____

_____

(ii) Briefly describe the difference between the equipment involved in CT scans and conventional X-ray scans.   [2 marks]

_____

_____

_____

(iii) Patients are often asked to wear a lead apron before having a dental X-ray. Suggest a reason why.
[1 mark]

_____

6   A technician carried out an experiment to determine the activity of a radioactive source, **A**. The results collected from this experiment are shown in **Table 6.1** below.

Table 6.1

Reading	Number of counts in 2 minutes
1	287
2	300
3	298

(a) (i)   Activity is measured in becquerels, Bq.

What is the meaning of **1 Bq**?   [1 mark]

_____

(ii)   Using all the results in **Table 6.1**, calculate the activity when source **A** is present. Give your answer to 3 significant figures.   [3 marks]

You are advised to show your working.

Activity = _____ Bq

The technician then recorded the counts for the background radiation over the same period of time and calculated the background activity to be 0.37 Bq.

(iii) What is background radiation?   [1 mark]

_____

_____

(iv) Calculate the activity of radioactive source, **A**.
[1 mark]

Activity = _____ Bq

(b) (i) In another experiment the half-life of a radioactive source, **B**, is found to be 77.3 days. Show that the decay constant is $1.04 \times 10^{-7}\,s^{-1}$.   [3 marks]

You must show your working.

(ii) If the activity of source **B** at the time of the experiment was 85.4 Bq, calculate the activity 100 days later.   [4 marks]

You are advised to show your working.

Activity = _____ Bq

7 **(a) (i)** What is ultrasound?   [1 mark]

_____

_____

(ii) Outline how ultrasound is used in medical diagnostics. [2 marks]

_____

_____

_____

(b) (i) State the frequency range used for the medical imaging of breast tissue.   [1 mark]

_____

(ii) Explain why the frequency range stated in **(b)(i)** is used.   [2 marks]

_____

_____

(iii) Explain why the frequency range stated in **(b)(i)** is unsuitable for ultrasound imaging of a deep structure, such as a kidney.   [1 mark]

_____

_____

(iv) What is the purpose of a coupling agent between the skin and ultrasound probe?   [1 mark]

_____

MRI scans are becoming increasingly common.

(c) (i) What do the letters MRI mean?   [1 mark]

_____

(ii) Which part of the electromagnetic spectrum is used in an MRI scan?   [1 mark]

_____

(iii) Explain why a patient who has had a cardiac pacemaker fitted, may not have an MRI scan of the heart.   [2 marks]

_____

(iv) Suggest a reason why babies are usually not given an MRI scan.   [1 mark]

_____

8 **(a)** In a B-scan, a 2.2 MHz ultrasound beam travels at a speed of 1.5 km s^{-1} through soft tissue.

If the specific acoustic impedance of soft tissue is 1.63 × 10^6 kg m^{-2} s^{-1}, calculate the density of the soft tissue.   [4 marks]

You are advised to show your working.

Density = _____ kg m^{-3}

The specific acoustic impedance for some materials is provided in **Table 8.1**.

Table 8.1

Material	Specific acoustic impedance/kg m^{-2} s^{-1}
Skin	1.63 × 10^6
Oil	1.43 × 10^6
Fat	1.38 × 10^6
Bone	7.78 × 10^6
Muscle	1.70 × 10^6

(b) (i) Calculate the intensity reflection coefficient at the fat–muscle interface.   [3 marks]

You are advised to show your working.

Intensity reflection coefficient = _____

(ii) Between which two materials, listed in **Table 8.1**, will the most ultrasound energy be lost by reflection at the interface between the materials?   [3 marks]

Explain your answer.

Materials: _____

Explanation: _____

_____

(iii) State what will happen to the ultrasound energy lost as the ultrasound passes through a layer of tissue. [1 mark]

_____

_____

(c) (i) Compare the visual output and uses of ultrasonic A-scans and B-scans.   [2 marks]

_____

_____

(ii) Which type of ultrasonic scan requires the operator to move the probe continuously across the surface of the skin?   [1 mark]

_____

(iii) In an A-scan of a tumour the time taken between the reflected pulses from each surface of the tumour is 60 μs. If the speed of ultrasound in the tumour is 1500 m s^{-1}, calculate the diameter of the tumour. [5 marks]

You are advised to show your working.

diameter = _____ m

_____

This is the end of the question paper

_____

Sources:

Q3(b) ..... Source: Principal Examiner

Q4(a)(i) ..© AlexanderZam / Getty Images