AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname ____________________

Forename(s) ____________________

Candidate signature ____________________
I declare this is my own work.

A-level
PHYSICS

Paper 3
Section B Medical physics

Time allowed: The total time for both sections of this paper is 2 hours. You are advised to spend approximately 50 minutes on this section.

Materials
For this paper you must have:
- a pencil and a ruler
- a scientific calculator
- a Data and Formulae Booklet
- a protractor.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 35.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
TOTAL	

J U N 2 1 7 4 0 8 3 B B 0 1

IB/M/Jun21/E6

7408/3BB

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Section B

Answer **all** questions in this section.

0 1 A hospital uses the radioactive isotope technetium-99m as a tracer. Technetium-99m is produced using a Molybdenum-Technetium generator on site at the hospital.

0 1 . 1 Explain why the value of the half-life of technetium-99m:

- makes it suitable for use as a tracer
- means that it must be produced in a generator on site.

[4 marks]

The half life of Tc-99m is 6 hours. This is long enough for a scan to take place. but short enough so as not to expose the patient to an excessive amount of radiation. must be produced on site because the half life is too short to keep stored or transport with enough undecayed nuclei to be useful.

0 1 . 2 Technetium-99m emits **only** gamma rays.

Explain why this makes technetium-99m suitable for use as a tracer.

[4 marks]

Other types of radiation cause damage to tissue without being detectable. Some gamma rays pass through the body and so can be detected externally. Gamma rays are the least ionising so they cause the least damage to tissue. The energy of gamma rays is similar to X-rays so an X-ray camera can be used for detection.

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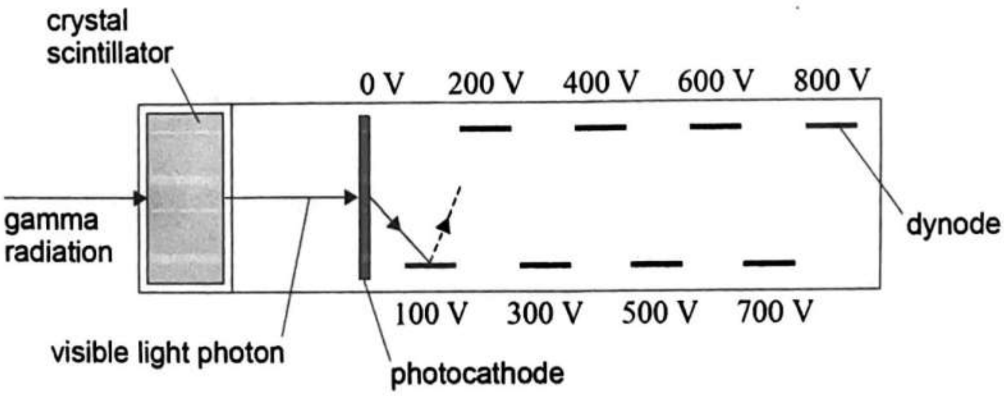
0 1 . 3 A gamma camera can be used to form images when using a tracer. **Figure 1** shows a photomultiplier tube from a gamma camera.

Figure 1



At the crystal scintillator, each photon of gamma radiation leads to the emission of one visible light photon.

Describe how the current produced by the photocathode is amplified in the photomultiplier tube.

[3 marks]

An electron is emitted from the photocathode. It is accelerated towards the positive dynodes. When an electron collides with a dynode, more electrons are released. These are accelerated towards the next dynode and so on.

Question 1 continues on the next page

0 1 . 4 Iodine-131 is a medical tracer that can be detected using a gamma camera.

Iodine-131 has a physical half-life of 8.0 days.

A patient is injected with iodine-131 that has an initial activity of 3.2 GBq. For this patient, the biological half-life is 66 days. For safety reasons, the patient cannot be discharged from hospital until the activity due to the iodine in the patient's body drops to 1.1 GBq.

Determine whether the patient can be safely released from hospital after 10 days.

[4 marks]

The biological half-life is significantly greater than the physical half life and so it can be ignored.

$$\lambda = \frac{\ln 2}{8} = 0.087 \text{ days}.$$

$$t = -\frac{\ln\left(\frac{1100}{3200}\right)}{0.097} = 12 \text{ days}.$$

Hence, the patient cannot be safely released from hospital after 10 days because the activity of the iodine drops to 1.1 GBq after 12 days.

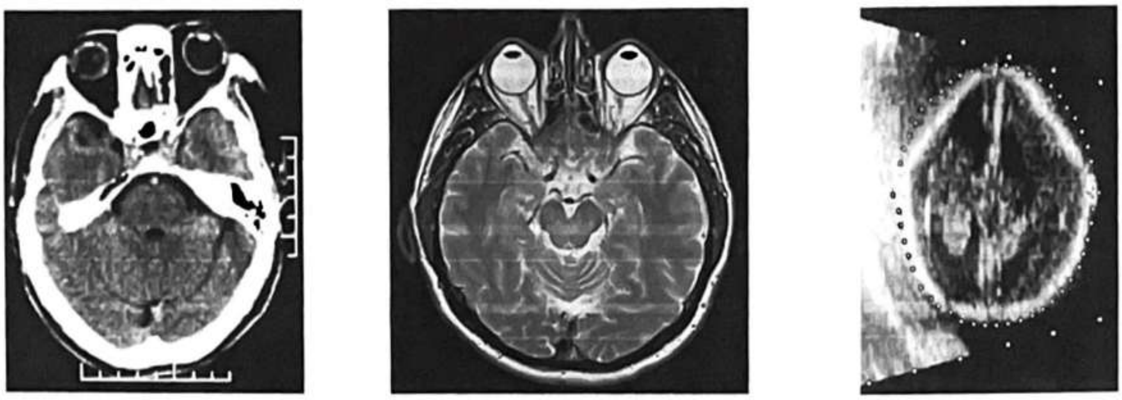
15

0 2 **Figure 2** shows scanned images of three different human heads.
Each image used **one** of the following scanning techniques:

- magnetic resonance (MR)
- CT
- ultrasound
- PET.

Figure 2

A **B** **C**



Identify the scanning technique used for each image.
Go on to explain how the features of each image enabled you to identify the type of scan.

[4 marks]

A: Scanning technique CT

Explanation bright image of bone but lacking detail in soft tissue.

B: Scanning technique MR

Explanation high resolution image of soft tissue, bone appears very dim.

C: Scanning technique ultrasound.

Explanation low resolution image, showing mainly external boundaries

4

Turn over ▶

0 3 . 1 A point source of sound has a power of 17 W.

Calculate, in dB, the intensity level at a distance of 12 m from the source.

[3 marks]

$A = 4\pi r^2 = 4\pi \times 12^2 = 1810 m^2$

$I = \frac{P}{A} = \frac{17}{1810} = 9.49 \times 10^{-3} Wm^{-2}$

$I = 10 \log\left(\frac{9.49 \times 10^{-3}}{10^{-12}}\right) = 100$ dB.

intensity level = 100 dB

0 3 . 2 The frequency of a sound is increased from 3.0 kHz to 8.0 kHz with no change in intensity.

One change in the sound perceived by a person with normal hearing is an increase in pitch.

Explain **one** other change to the sound perceived by the person as the frequency is increased from 3.0 kHz.

[2 marks]

The sound would be quieter because the ear is most sensitive at 3kHz.

5

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0 4 In an X-ray machine, X-rays are emitted from an emission spot on a tungsten target.

Figure 3

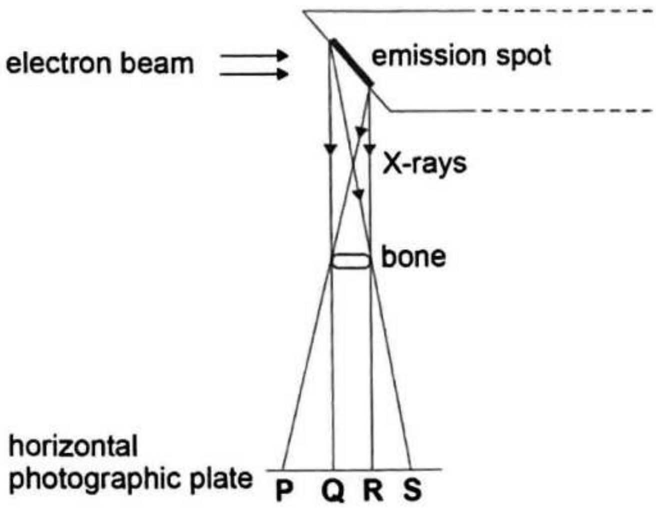
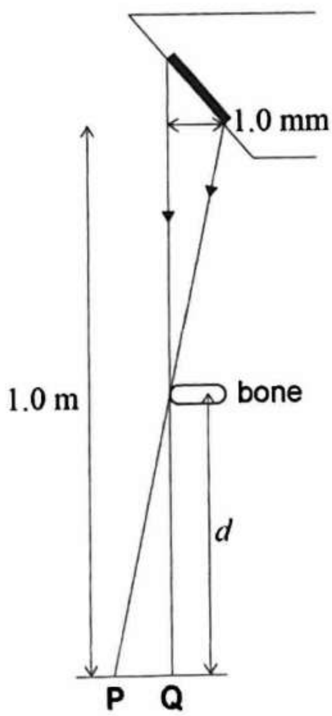


Figure 3 shows how a total shadow is produced in the region **QR** where no X-rays from any part of the emission spot can reach the photographic plate. Partial shadows are formed in regions **PQ** and **RS** where X-rays from only part of the emission spot can reach the plate.

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

Figure 4



not to scale

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0 4 . 1 To produce a sharp image of a bone, the partial shadow in region **PQ** must be no more than 0.10 mm wide.

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

[2 marks]

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

$$d = \frac{0.1\times10^{-3}}{1.1\times10^{-3}} = 9.1\times10^{-2}\ \text{m}.$$

$d =$ 9.1×10^{-2}. m

0 4 . 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]

The image of the hand will be sharper because the chest is thicker so some parts of it will be further away from the plate. Also, it is easy to keep a hand still whereas a heart will continue to beat and so will be blurred.

4

Turn over for the next question

0 5 . 1 Which would be a correct lens prescription for a person with hypermetropia and astigmatism?

Tick (✓) **one** box.

[1 mark]

−2.00	+0.50	75	☐
+2.00	−0.50	75	☑
−2.00	+0.50	255	☐
+2.00	−0.50	255	☐

0 5 . 2 A student views an object **O** and cannot see it clearly unaided.
The student is diagnosed with myopia and is prescribed a suitable correcting lens.
Using the correcting lens, an intermediate image is formed that can be viewed clearly by the student.

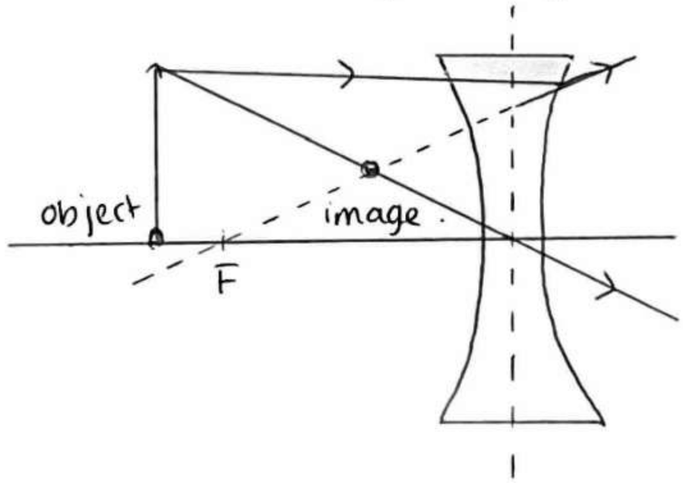
The student states that she can see **O** more clearly because the intermediate image is enlarged.

Discuss the validity of the student's statement.
In your answer you should:

- describe how myopia affects vision
- draw a labelled ray diagram of the correcting lens, showing how the intermediate image of **O** is formed
- explain how the correcting lens enables the student to see clearly.

[6 marks]

Space for diagram



In myopia, the far point of the eye is closer than infinity and so the person cannot focus on objects further away than the far point. (can focus on nearby objects). The student is incorrect because the magnification factor is less than 1. Using a concave lens, an image is formed on the retina. This image is closer than the eye's far point.

7

END OF QUESTIONS