

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

StemUp Model Solution

Forename(s)

Candidate signature

I declare this is my own work.

A-level PHYSICS

Paper 3

Section B Medical physics

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.

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.

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

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]

Technetium-99m has a half-life of about 6 hours.

This is long enough to allow the scan (images) to take place before the activity becomes too low.

It is short enough that the patient is not exposed to excessive radiation, i.e. the patient is not left with an active source in the body for too long.

But it is too short for the Tc-99m to be stored or transported: it would decay too much, leaving too few undecayed nuclei (too little activity) 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]

Alpha or beta radiation would be absorbed in the body, causing damage to tissue without being detectable outside the body.

Gamma rays pass through the body (tissue) so they can be detected outside the body by a gamma camera.

Gamma is the least ionising radiation, so it causes the least damage to the patient's tissue.

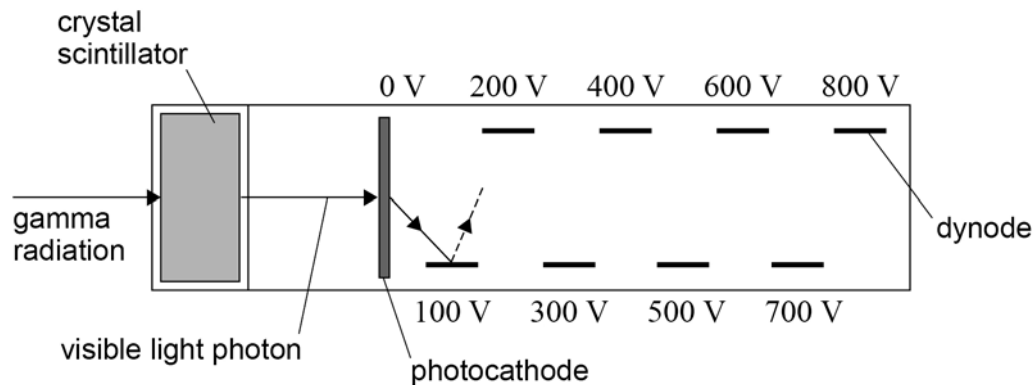
The energy (frequency) of the gamma photons is similar to medical X-rays, so a gamma (X-ray) camera can be used to detect them.



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]

Each visible light photon hitting the photocathode causes it to emit one electron (photoelectric effect).

This electron is accelerated towards the first dynode by the p.d., then to each successive dynode, which is 100 V more positive than the one before.

Each electron that collides with a dynode releases several (about 4) more electrons, so the number of electrons is multiplied at every dynode, giving a much larger current at the end.

Question 1 continues on the next page

Turn over ►



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]

$$\text{Effective half-life: } 1/T_E = 1/T_P + 1/T_B = 1/8.0 + 1/66$$

$$T_E = (0.125 + 0.0152)^{-1} = 7.1 \text{ days}$$

$$\lambda = \ln 2 / T_E = 0.693 / 7.1 = 0.097 \text{ day}^{-1}$$

$$A = A_0 e^{-\lambda t} = 3.2 \times e^{-0.097 \times 10}$$

$$A = 3.2 \times 0.379 = 1.2 \text{ GBq after 10 days}$$

$$(\text{Time to fall to 1.1 GBq: } t = \ln(3.2/1.1) / 0.097 = 11 \text{ days})$$

No: 1.2 GBq is still above 1.1 GBq (it takes 11 days), so the patient cannot be released after 10 days.



0 2

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

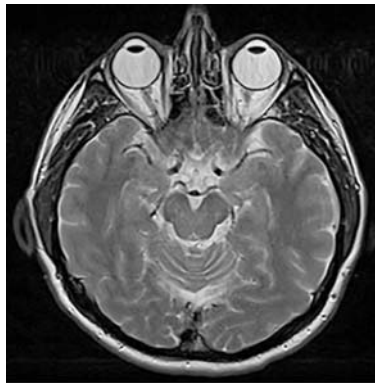
- magnetic resonance (MR)
- CT
- ultrasound
- PET.

Figure 2

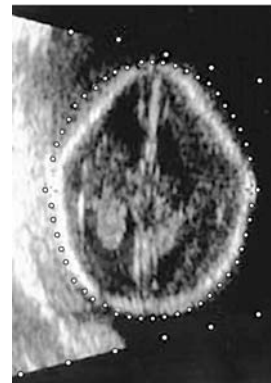
A



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 (computed tomography) scanner

Explanation The bone (skull) shows up bright with a good, clear picture, but there is a lack of detail in the soft tissue such as the brain and eyes.

B: Scanning technique MR (magnetic resonance) scanner

Explanation It has the highest resolution, with a good detailed image of soft tissue (eyes, brain), but only a dim picture of the bone.

C: Scanning technique Ultrasound scanner

Explanation It has low resolution: it shows the external boundary (outline) of the skull, as in the uterus, but lacks detail inside the skull.

4

Turn over ►



0 5

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]

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

$$\text{Intensity} = P / A = 17 / 1810 = 9.39 \times 10^{-3} \text{ W m}^{-2}$$

$$\text{Intensity level} = 10 \log (I / I_0)$$

$$= 10 \log (9.39 \times 10^{-3} / 1.0 \times 10^{-12}) = 99.7 \approx 100 \text{ dB}$$

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 perceived as quieter (less loud), even though the intensity is unchanged.

This is because the ear is most sensitive at about 3 kHz, and its sensitivity is lower at 8 kHz, so a higher intensity would be needed at 8 kHz to sound equally loud.



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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

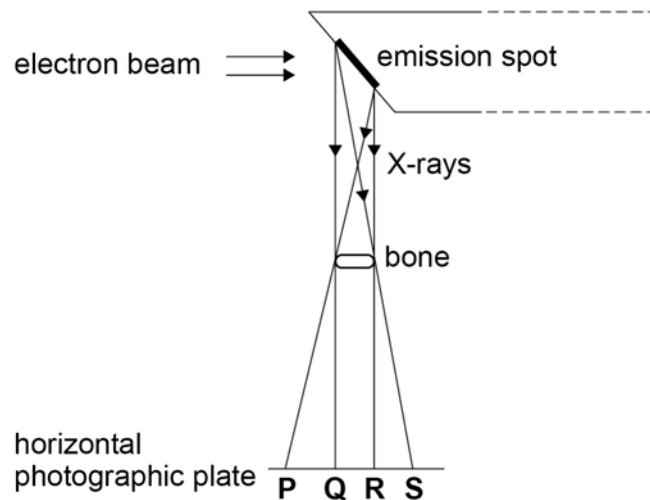


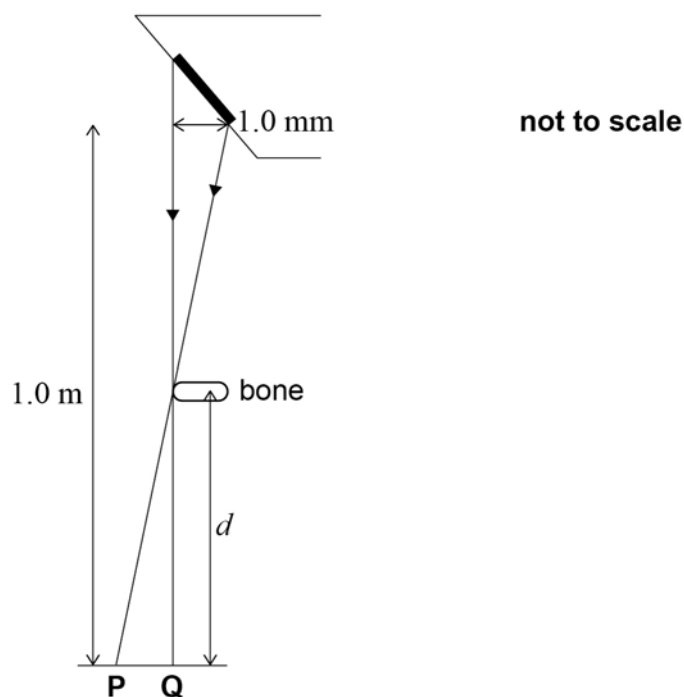
Figure 3 shows how a total shadow is produced in the region **QR** where no X-rays from any part of the emission spot can reach the photographic plate. Partial shadows are formed in regions **PQ** and **RS** where X-rays from only part of the emission spot can reach the plate.

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



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]

Similar triangles:

$$(1.0 - d) / 1.0 \times 10^{-3} = d / 0.10 \times 10^{-3}$$

$$0.10 (1.0 - d) = 1.0 d$$

$$d = 0.10 / 1.1 = 9.1 \times 10^{-2} \text{ m}$$

$$d = \underline{9.1 \times 10^{-2}} \text{ m}$$

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 hand would give the sharper image.

The chest is thicker, so parts of it are further from the plate, giving wider partial shadows (more fuzziness). It is also not uniformly thick, so the front and back cannot both be sharp at the same time.

The hand can be kept still, but the heart keeps beating (and breathing), so the chest image is blurred.

4

Turn over for the next question

Turn over ►



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.

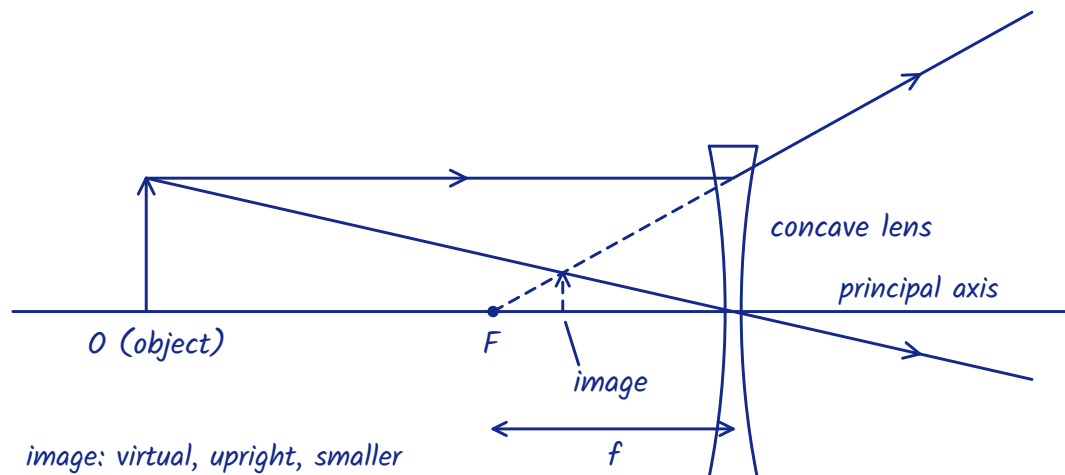
Discuss the validity of the student's statement.

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



Myopia: the eye's far point is closer than infinity, so the student cannot focus on objects further away than her far point (like O), although she can still focus near objects.

For distant objects the eye lens is too powerful, so the image is formed in front of the retina and is blurred.

A concave (diverging) lens is used. Rays from O are spread out so they appear to come from the virtual image, which is between the lens and its principal focus F , as in the diagram.

This intermediate image is closer than the eye's unaided far point (and further than its near point), so the eye can now focus it, and the final image is formed on the retina.

So the student's statement is not valid: the intermediate image is diminished (smaller than O , magnification less than 1), not enlarged.

She sees O clearly because the image is within her range of focus.

END OF QUESTIONS



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1 6



2 1 6 A 7 4 0 8 / 3 B B