



Please write clearly in block capitals.

Centre number

--	--	--	--	--

Candidate number

--	--	--	--

Surname

StemUp Model Solution

Forename(s)

Candidate signature

I declare this is my own work.

A-level PHYSICS

Paper 3

Section B Medical physics

Tuesday 17 June 2025

Morning

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	
TOTAL	



J U N 2 5 7 4 0 8 3 B B 0 1

stemup.co.uk

15M/Jun25/G4006/E6

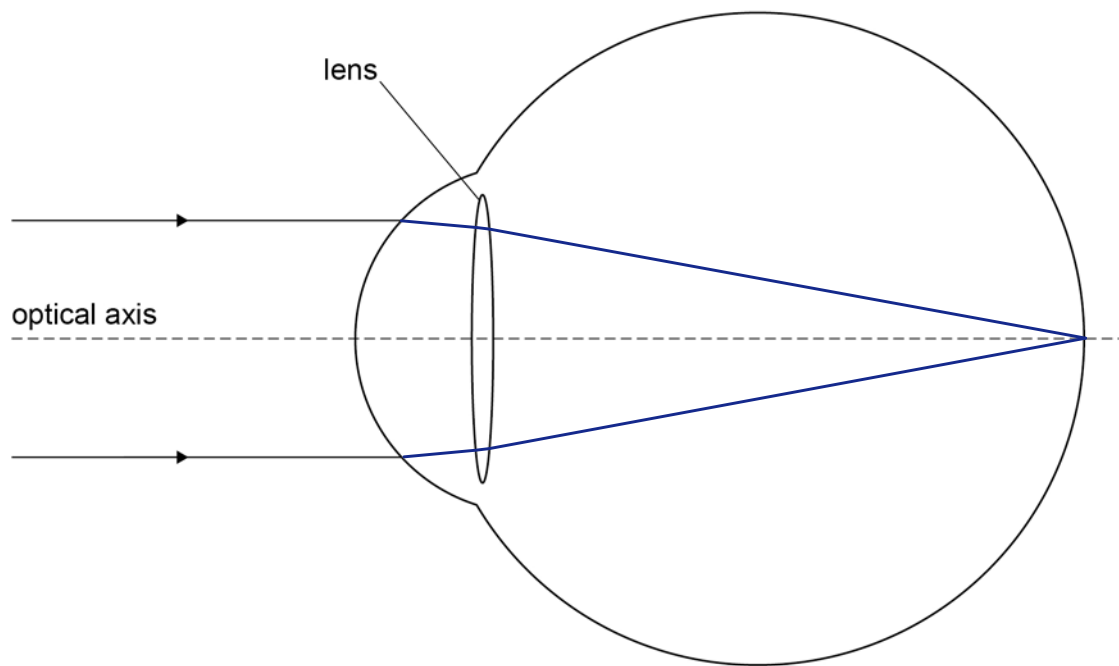
7408/3BB

There are no questions printed on this page

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**



Section BAnswer **all** questions in this section.**0 1 . 1****Figure 1** shows a simplified diagram of an eye that has no sight defects. The eye is viewing a distant point object.Complete, on **Figure 1**, the paths of the two rays to the back of the eye.**[2 marks]****Figure 1****0 1 . 2**

Accommodation is the ability of the eye to change its optical power.

Which part of the eye enables accommodation?

Tick (✓) **one** box.**[1 mark]**

cornea

☐

iris

☐

lens

☒**Question 1 continues on the next page****Turn over ►**

The accommodation amplitude A , in dioptres, is given by

$$A = \frac{1}{d_1} - \frac{1}{d_2}$$

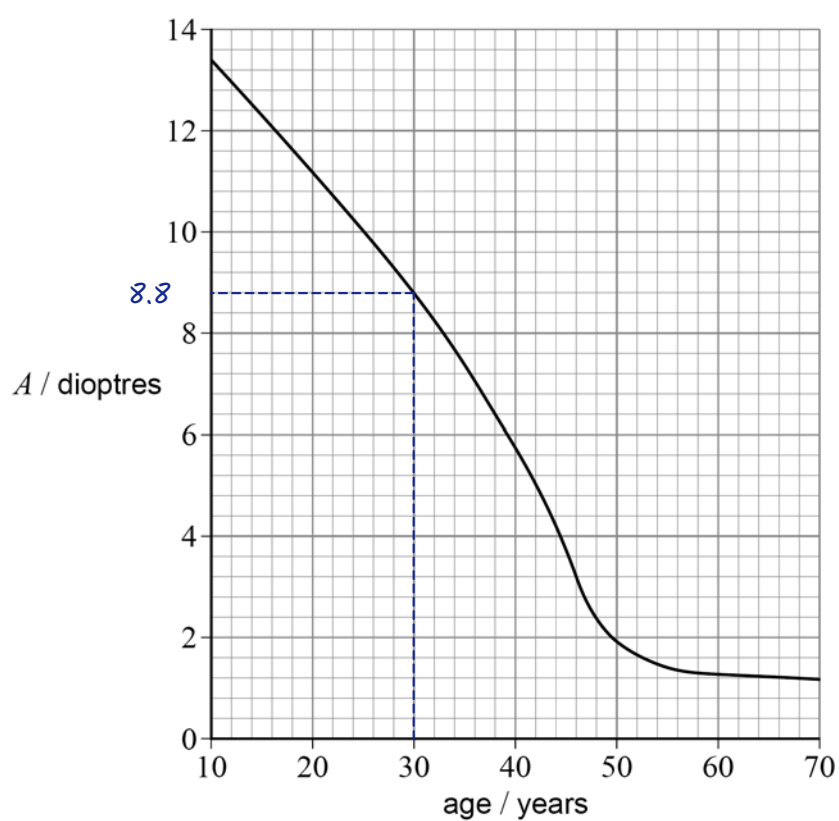
where

d_1 is the distance, in m, from the eye to its near point

d_2 is the distance, in m, from the eye to its far point.

Figure 2 shows how the value of A varies with age for a typical person.

Figure 2



0 1 . 3

An eye of a typical 30-year-old person has a far point at infinity.
The focal length of the eye when viewing an object at its far point is 23 mm.

Calculate the focal length of the eye when viewing an object at its near point.

[4 marks]

From Figure 2, at age 30: $A = 8.8$ dioptres

Far point at infinity, so $1/d_2 = 0$ and $A = 1/d_1$

$$d_1 = 1 / 8.8 = 0.114 \text{ m} = 114 \text{ mm}$$

Far point: $1/f = 1/u + 1/v$, $1/23 = 1/\infty + 1/v$, so $v = 23 \text{ mm}$

(lens to retina distance stays 23 mm)

Near point: $1/f = 1/u + 1/v = 1/114 + 1/23$

$$1/f = 0.00877 + 0.04348 = 0.05225 \text{ mm}^{-1}$$

$$f = 1 / 0.05225 = 19.1 \text{ mm}$$

focal length = 19.1 mm

0 1 . 4

For a typical person, the far point remains at infinity as the person's age increases.
Some studies suggest that hypermetropia increases with age.

Explain how **Figure 2** supports this suggestion.

[2 marks]

Figure 2 shows that A decreases with age. Since the far point stays at infinity, d_2 does not change ($1/d_2 = 0$), so $A = 1/d_1$ and d_1 must increase.

So the near point moves further away from the eye with age: the eye cannot focus on nearby objects, as light from them is focused behind the retina, which is hypermetropia.



0 2

Technetium- ^{99m}Tc is produced from the decay of molybdenum-99 (^{99}Mo). In hospitals, ^{99m}Tc is extracted from a molybdenum-technetium generator.

^{99}Mo is put into the generator at time $t = 0$

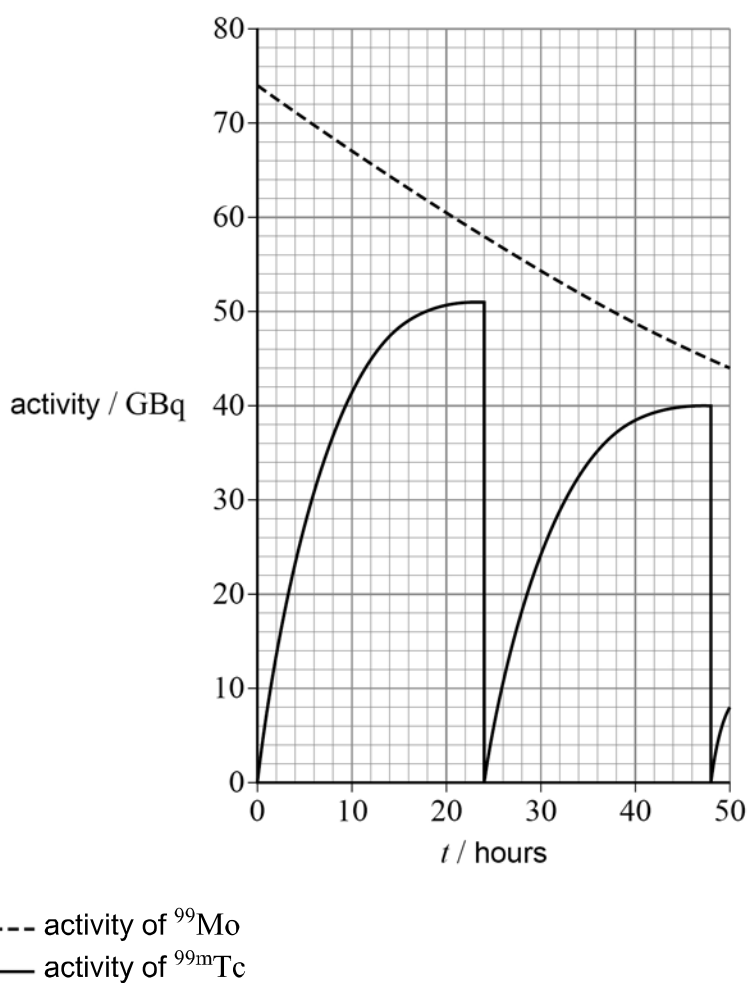
As ^{99}Mo decays, the amount of ^{99m}Tc increases to a maximum at $t = 24$ hours.

^{99m}Tc is extracted from the generator at regular intervals.

At each extraction, the activity of ^{99m}Tc in the generator falls to zero and then increases again.

Figure 3 shows how the activities of ^{99}Mo and ^{99m}Tc in the generator vary with t when extractions are made at $t = 24$ hours and $t = 48$ hours.

Figure 3



0 2 . 1 Show that about 6×10^{15} nuclei of ^{99}Mo decay between $t = 0$ and $t = 24$ hours.

decay constant for $^{99}\text{Mo} = 2.8 \times 10^{-6} \text{ s}^{-1}$

[2 marks]

From Figure 3: $A_0 = 74 \text{ GBq}$ at $t = 0$ and $A = 58 \text{ GBq}$ at $t = 24 \text{ h}$

Change in activity = $74 \times 10^9 - 58 \times 10^9 = 16 \times 10^9 \text{ Bq}$

$A = \lambda N$, so $\Delta N = \Delta A / \lambda = 16 \times 10^9 / 2.8 \times 10^{-6}$

$\Delta N = 5.7 \times 10^{15}$ (about 6×10^{15} nuclei decay)

0 2 . 2 90% of the ^{99}Mo nuclei decay to form $^{99\text{m}}\text{Tc}$ nuclei. The other 10% decay to form different nuclei.

Estimate the number of $^{99\text{m}}\text{Tc}$ nuclei that are extracted from the generator at $t = 24$ hours.

[3 marks]

Half-life of $^{99\text{m}}\text{Tc} = 6.0 \text{ hours} = 6.0 \times 3600 = 2.16 \times 10^4 \text{ s}$

$\lambda = \ln 2 / T_{1/2} = 0.693 / 2.16 \times 10^4 = 3.2 \times 10^{-5} \text{ s}^{-1}$

From Figure 3, activity of $^{99\text{m}}\text{Tc}$ at $t = 24 \text{ h}$: $A = 51 \text{ GBq}$

$N = A / \lambda = 51 \times 10^9 / 3.21 \times 10^{-5}$

$N = 1.6 \times 10^{15}$ nuclei extracted

number = 1.6×10^{15}

Question 2 continues on the next page

Turn over ►



0 2 3

Information about heart function can be obtained from a multi-gated acquisition (MUGA) scan or from a transthoracic echocardiogram (TTE) scan. Heart specialists use these scans to diagnose a range of heart conditions.

In a MUGA scan, a patient is injected with a compound containing ^{99m}Tc which binds to red blood cells.

Using images of the red blood cells, a precise reading can be made of blood flow rate through the heart.

A TTE is an ultrasound scan of the heart.

Images of the heart are seen on a monitor as a transducer is moved across the surface of the patient's chest.

Compare the MUGA method of investigating heart function with the TTE method of investigating heart function.

In your answer you should:

- outline how an image of the red blood cells is obtained during a MUGA scan
- explain the advantages that a MUGA scan and a TTE scan have in common
- compare the strengths and weaknesses of a MUGA scan and a TTE scan.

[6 marks]

MUGA: the patient is injected with a compound containing ^{99m}Tc , which binds to the red blood cells and acts as a tracer. ^{99m}Tc is a gamma emitter, so gamma photons are emitted from the blood wherever it is in the heart.

The image is obtained using a gamma camera. A lead collimator only lets through gamma photons travelling parallel to its holes, so each part of the image corresponds to one part of the heart. The photons hit a scintillator (sodium iodide crystal), producing flashes of light which are detected by an array of photomultiplier tubes, where electrons are multiplied at dynodes to give electrical pulses. A computer uses the positions and sizes of the pulses to build up the image, gated to the patient's ECG so images are taken at the same points in each heartbeat.

Advantages in common: both methods are non-invasive (no surgery, apart from the injection for MUGA), and the patient does not need an anaesthetic. Both are outpatient procedures, and both produce (2D)



images giving a moving / animated view of the heart working. Both can be used during stress testing, as the patient does not have to keep completely still.

Strengths and weaknesses: MUGA gives quantitative as well as qualitative information, since the image intensity is related to the number of red blood cells in each region, so it gives a precise and reproducible value for blood flow (e.g. ejection fraction). TTE gives mainly qualitative information, and interpretation of TTE images can be subjective and not reproducible, as it depends on the operator.

However, MUGA uses ionising gamma radiation, so there is a risk of cell damage and cancer, whereas TTE uses non-ionising ultrasound, which has no known side effects. TTE also costs less and takes less time, as no radioactive tracer needs to be prepared and injected and there is no waiting for it to circulate.



0 3 . 1

State what is meant by the threshold of hearing for a person with good hearing.

[2 marks]

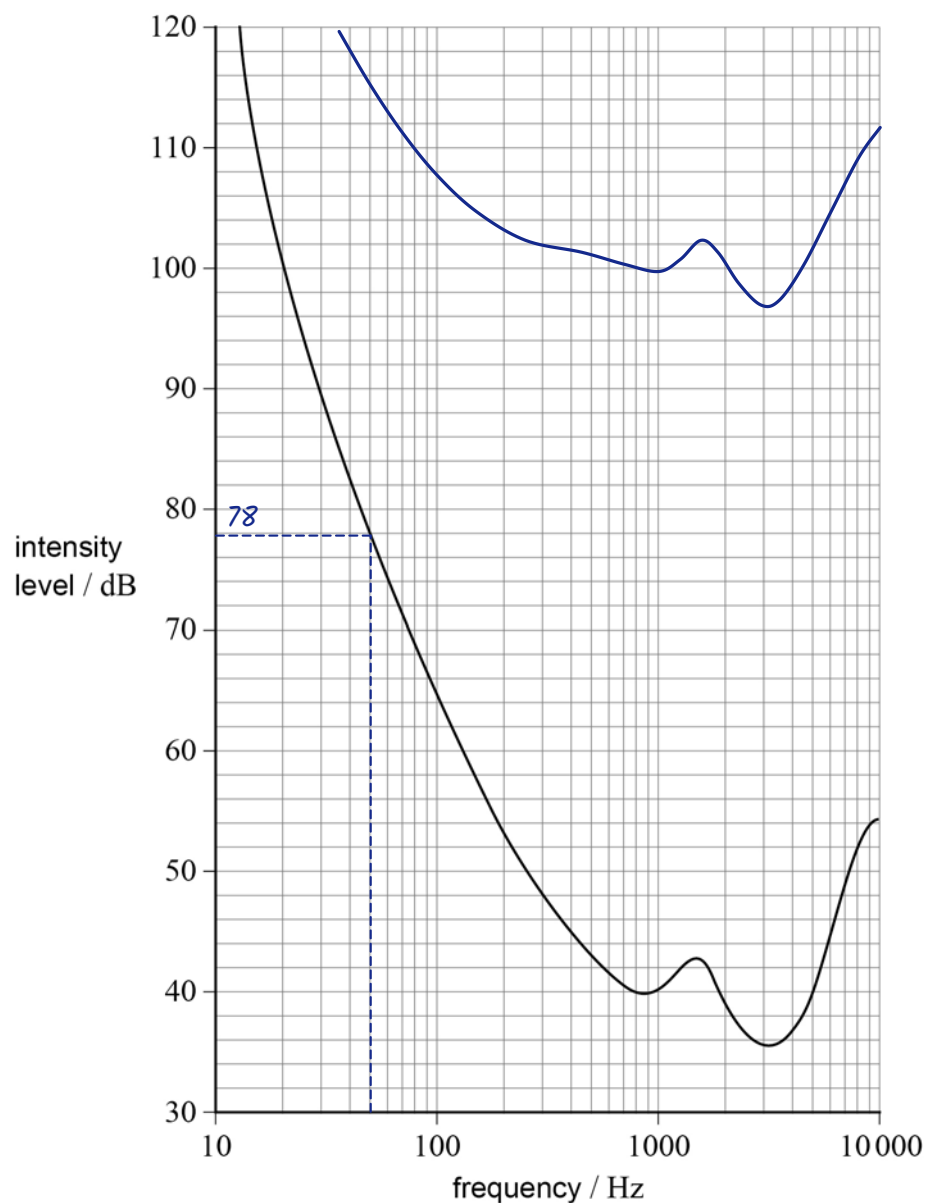
The threshold of hearing is the minimum intensity of sound that a normal ear can hear,

at a frequency of 1 kHz ($I_0 = 1.0 \times 10^{-12} \text{ W m}^{-2}$).

In a hearing test, a person is found to have good hearing.

Figure 4 shows the equal loudness curve produced in the test.

Figure 4



- 0 3 . 2** The eardrum of the person being tested has a cross-sectional area of 60 mm^2 .

Calculate the power that is incident on the eardrum when the frequency is 50 Hz.

[3 marks]

From Figure 4, at 50 Hz: intensity level = 78 dB

$$\text{intensity level} = 10 \log (I / I_0), \quad 78 = 10 \log (I / 1.0 \times 10^{-12})$$

$$I = 1.0 \times 10^{-12} \times 10^{7.8} = 6.3 \times 10^{-5} \text{ W m}^{-2}$$

$$\text{Area} = 60 \text{ mm}^2 = 60 \times 10^{-6} \text{ m}^2 = 6.0 \times 10^{-5} \text{ m}^2$$

$$\text{Power} = I \times A = 6.31 \times 10^{-5} \times 6.0 \times 10^{-5}$$

$$\text{Power} = 3.8 \times 10^{-9} \text{ W}$$

power = 3.8×10^{-9} W

- 0 3 . 3** Sketch, on **Figure 4**, an equal loudness curve that passes through 100 dB at 1 kHz.

[2 marks]

7

Turn over for the next question

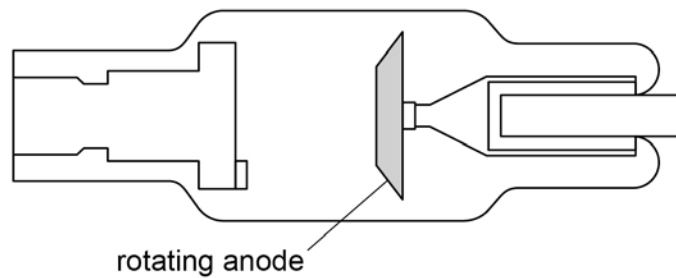
Turn over ►



0 4

Figure 5 shows a rotating-anode X-ray tube used to produce an image of a bone.

Figure 5



0 4

. 1

X-rays originate from a region on the rotating anode known as the focal spot.

Explain:

- one advantage of using a small focal spot
- why the focal spot should not be too small.

[2 marks]

A small focal spot gives a sharper image, as it reduces the penumbra (geometric unsharpness), so finer detail can be seen.

If the focal spot is too small, the heat from the electron beam is concentrated on a small area, so the anode would overheat (its temperature rises too quickly).



0 4 . 2

State and explain **three** methods used to limit exposure of the patient's healthy cells to X-rays during a diagnostic procedure.

[3 marks]

1 *Use a lead collimator / diaphragm (set aperture) to limit the beam to the target area: lead is highly attenuating, so less of the surrounding body tissue is exposed.*

2 *Use an aluminium filter: it absorbs the low-energy (soft) X-rays that would not reach the detector, so unnecessary exposure of healthy cells to soft X-rays is reduced.*

3 *Use an intensifying screen / flat panel detector: it gives an adequate image from a lower intensity beam, so the exposure time for healthy cells is minimised.*

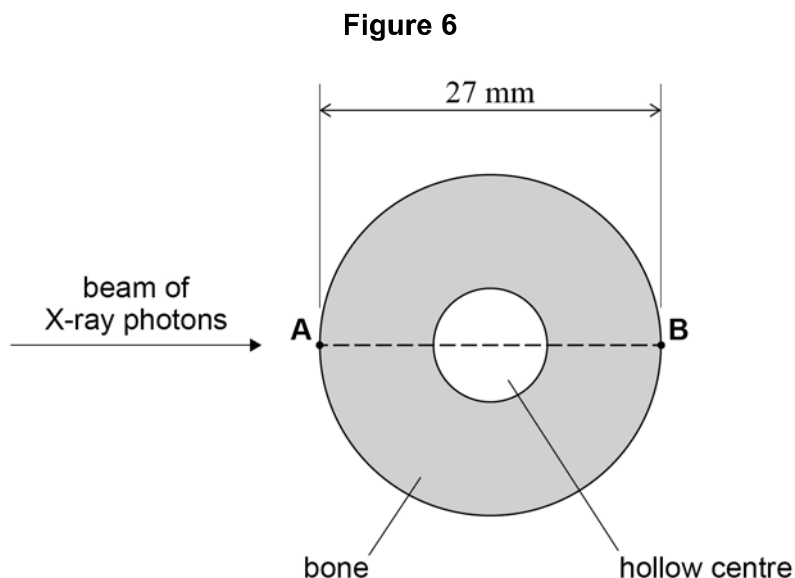
Question 4 continues on the next page

Turn over ►



0 4 . 3

Figure 6 shows a scale diagram of a cross-section through a human bone called a femur.



A dashed line has been drawn from point **A** to point **B** through the centre of the femur. Along **AB** the femur has a circular cross-section with an external diameter of 27 mm. The femur has a hollow centre.

A beam of X-ray photons is incident on the femur at **A** in the direction **AB**. For these photons, the half-value thickness of bone is 15 mm.

Determine, using the scale diagram in **Figure 6**, the percentage of the X-ray photons incident on **A** that emerge at **B**.

[3 marks]

On the diagram: $AB = 45 \text{ mm}$, hollow centre = 15 mm

Hollow centre = $15 \times 27 / 45 = 9.0 \text{ mm}$

Thickness of bone along AB: $x = 27 - 9.0 = 18 \text{ mm}$

$\mu = \ln 2 / x_{1/2} = 0.693 / 15 = 4.62 \times 10^{-2} \text{ mm}^{-1}$

$I / I_0 = e^{-\mu x} = e^{-0.0462 \times 18} = 0.435$

Percentage emerging = $0.435 \times 100 = 44 \%$

percentage = 44 %

END OF QUESTIONS



There are no questions printed on this page

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**





[illegible]

[illegible]

[illegible]

There are no questions printed on this page

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**

Copyright information

For confidentiality purposes, all acknowledgements of third-party copyright material are published in a separate booklet. This booklet is published after each live examination series and is available for free download from www.aqa.org.uk

Permission to reproduce all copyright material has been applied for. In some cases, efforts to contact copyright-holders may have been unsuccessful and AQA will be happy to rectify any omissions of acknowledgements. If you have any queries please contact the Copyright Team.

Copyright © 2025 AQA and its licensors. All rights reserved.



20



256A7408/3BB