

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

A-level PHYSICS

Paper 3

Section B Medical physics

Monday 3 June 2019

Afternoon

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.

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.

For Examiner's Use

Question	Mark
1	
2	
3	
4	
TOTAL	

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.



J U N 1 9 7 4 0 8 3 B B 0 1

Section BAnswer **all** questions in this section.**0 1**

Car drivers must be able to

- read a speedometer from a distance of 50 cm
- read a number plate from a distance of 20.5 m.

A driver has an unaided far point of 55 cm and an unaided near point of 25 cm.

0 1 . 1

Identify the driver's eye defect.

Tick (✓) **one** box.**[1 mark]**

Astigmatism	
Hypermetropia	
Myopia	✓



0 1 . 2

Figure 1 shows the position of a number plate at a distance of 20.5 m in front of the driver's unaided eye.

Figure 2 shows the same situation and the position of a corrective lens.

Complete both ray diagrams to show how and where the image of the number plate is formed in each case.

Add a suitable lens to **Figure 2**.

[4 marks]

Figure 1

Without corrective lens

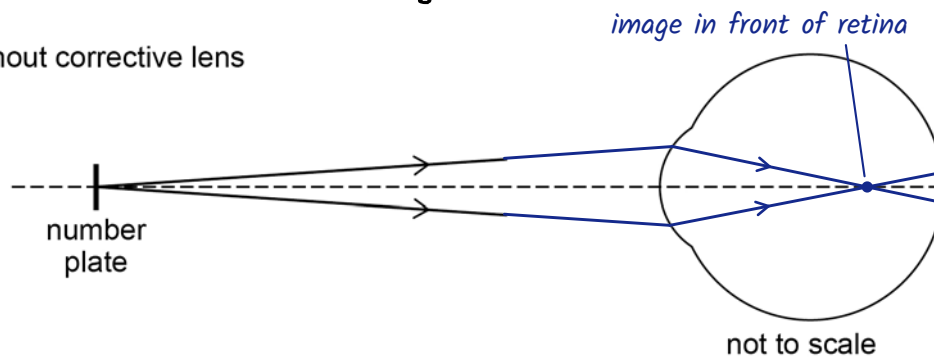
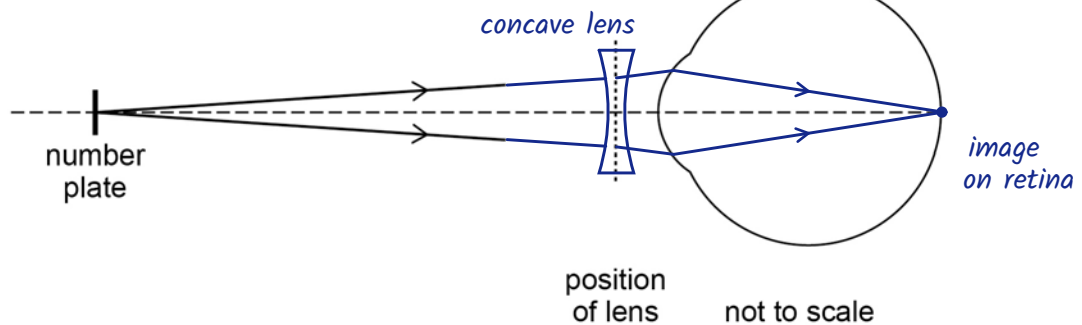


Figure 2

With corrective lens



Question 1 continues on the next page

Turn over ►



0 1 . 3

An optician considers the use of **three** different lenses, **A**, **B** and **C**, for use by the driver when driving.

Power of **A** = -2.18D

Power of **B** = -1.77D

Power of **C** = $+1.95\text{D}$

Deduce which lens is suitable.

Support your answer with calculations.

[5 marks]

Lens C (+1.95 D) is converging (convex): wrong type for myopia, reject C.

$P = 1/f = 1/u + 1/v$ (real is positive, virtual image v negative)

Lens to see number plate: $u = 20.5\text{ m}$, image at far point $v = -0.55\text{ m}$

$P = 1/20.5 + 1/(-0.55) = 0.049 - 1.818 = -1.77\text{ D}$

(lens to correct far point: $P = 1/\infty + 1/(-0.55) = -1.82\text{ D}$)

Lens B, $P = -1.77\text{ D}$:

number plate: $1/v = -1.77 - 1/20.5 = -1.82$, $v = -0.55\text{ m} = -55\text{ cm}$

image at the far point (55 cm), so the number plate can be seen.

speedometer: $1/v = -1.77 - 1/0.50 = -3.77$, $v = -0.265\text{ m} = -27\text{ cm}$

27 cm is beyond the near point (25 cm), so it can be seen.

Lens A, $P = -2.18\text{ D}$:

number plate: $1/v = -2.18 - 1/20.5 = -2.23$, $v = -0.45\text{ m} = -45\text{ cm}$

speedometer: $1/v = -2.18 - 1/0.50 = -4.18$, $v = -0.24\text{ m} = -24\text{ cm}$

24 cm is closer than the near point (25 cm): A cannot focus on it.

(With B: aided far point $u = 1/(1/0.55 - 1.77) = 20.8\text{ m}$ and

aided near point $u = 1/(1/0.25 - 1.77) = 0.45\text{ m}$, so 0.50 m and 20.5 m are in range.)

Lens B (-1.77 D) is suitable: it is the only lens with which both the

number plate and the speedometer can be seen (lens A cannot focus on

the speedometer, lens C is convex).



Turn over for the next question

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ANSWER IN THE SPACES PROVIDED**

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0 5

0 2

Three customers, **P**, **Q** and **R**, are sitting in a café listening to music from a loudspeaker.

Customer **P** is 11 m from the loudspeaker. At the position of customer **P**, the sound intensity is $3.4 \times 10^{-8} \text{ W m}^{-2}$.

0 2

1

Customer **P** moves to a distance of 7.0 m from the loudspeaker.

Calculate the sound intensity at the new position of customer **P**.
Assume that the loudspeaker is a point source.

[2 marks]

$$I \propto 1/r^2 \text{ so } I_2 = I_1 \times (r_1/r_2)^2$$

$$I_2 = 3.4 \times 10^{-8} \times (11 / 7.0)^2$$

$$= 3.4 \times 10^{-8} \times 2.47 = 8.4 \times 10^{-8} \text{ W m}^{-2}$$

sound intensity = 8.4×10^{-8} W m^{-2}

0 2

2

The sound intensity level is 65 dB at the position of customer **Q** and 42 dB at the position of customer **R**.

Calculate the ratio $\frac{\text{sound intensity at the position of Q}}{\text{sound intensity at the position of R}}$.

[2 marks]

$$IL = 10 \log(I / I_0) \text{ so } I = I_0 \times 10^{IL/10}$$

$$I_Q = 10^{-12} \times 10^{6.5} = 3.16 \times 10^{-6} \text{ W m}^{-2}$$

$$I_R = 10^{-12} \times 10^{4.2} = 1.58 \times 10^{-8} \text{ W m}^{-2}$$

$$\text{ratio} = (3.16 \times 10^{-6}) \div (1.58 \times 10^{-8}) = 10^{6.5 - 4.2} = 10^{2.3}$$

$$= 200 \text{ (2 s.f.)}$$

ratio = 200



0 2 . 3

Customer **Q** perceives the loudness of the sound differently to customer **R**.

Discuss whether the use of intensity level or intensity is more appropriate to compare the perceived loudness.

[2 marks]

Intensity level is more appropriate. It uses a logarithmic scale (in dB), which matches the logarithmic response of the human ear, so it relates to perceived loudness; intensity is a linear scale.

0 2 . 4

Customers **P**, **Q** and **R** move to the same distance from the loudspeaker.

Customer **P** is 80 years old and has hearing loss due to her age.

Customer **Q** is 35 years old and has hearing loss due to working in an extremely noisy environment.

Customer **R** is 35 years old and has no hearing loss.

The hearing defects of **P** and **Q** affect their perception of the music being played.

Describe how their perceptions are different from that of **R**.

[3 marks]

P and Q would both hear the music at a lower volume (quieter) than R at all frequencies, as their thresholds of hearing are raised.

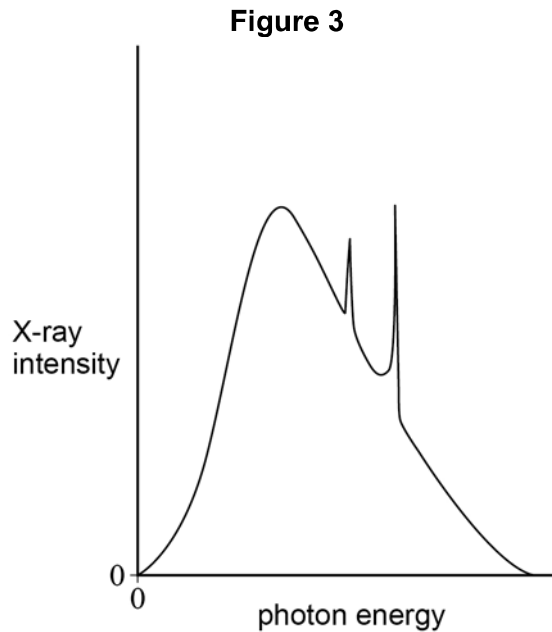
P (age-related loss) would experience most hearing loss at high frequencies compared to R, so high notes sound much quieter or are not heard.

Q (noise-induced loss) would experience most hearing loss at and around 4 kHz compared to R, so sounds near 4 kHz seem much quieter.



0 3

Figure 3 shows the X-ray spectrum produced in a medical X-ray machine at a particular anode potential difference (pd).



0 3 . 1

In an X-ray tube, electrons collide with a tungsten target.

Explain how the continuous spectrum and the characteristic spectra are produced by these electron collisions.

[4 marks]

Continuous spectrum *Electrons are decelerated by the target nuclei and transfer their kinetic energy to X-ray photons (bremsstrahlung).*

Electrons are decelerated by different amounts, so a continuous range of photon energies is emitted.

Maximum photon energy is limited by the kinetic energy of the electrons (eV, set by the anode pd).

Characteristic spectra *The electrons knock inner electrons (e.g. K shell) out of the tungsten atoms.*

Outer electrons drop down to fill the gaps left behind.

Each electron moving down emits an X-ray photon of a specific energy (difference in energy levels), giving the discrete spikes.

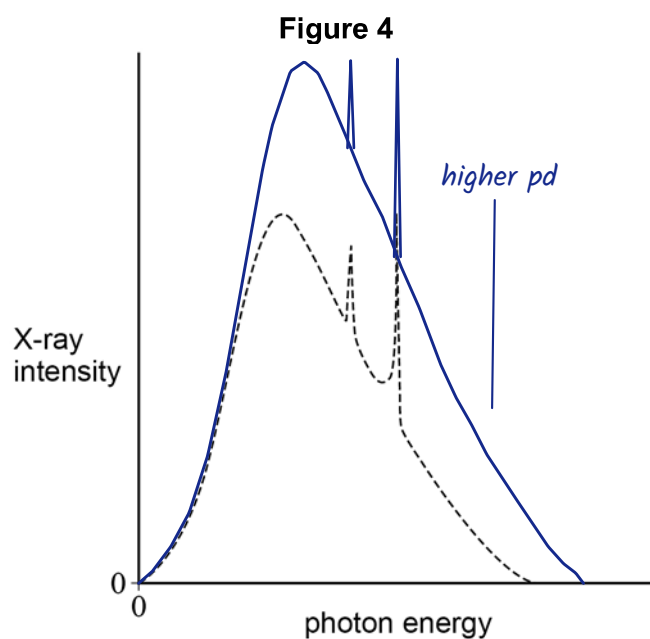


0 3 . 2

The dashed line on **Figure 4** shows the X-ray spectrum for the initial anode pd.

Sketch on **Figure 4** the X-ray spectrum produced when the anode pd is increased.

[2 marks]



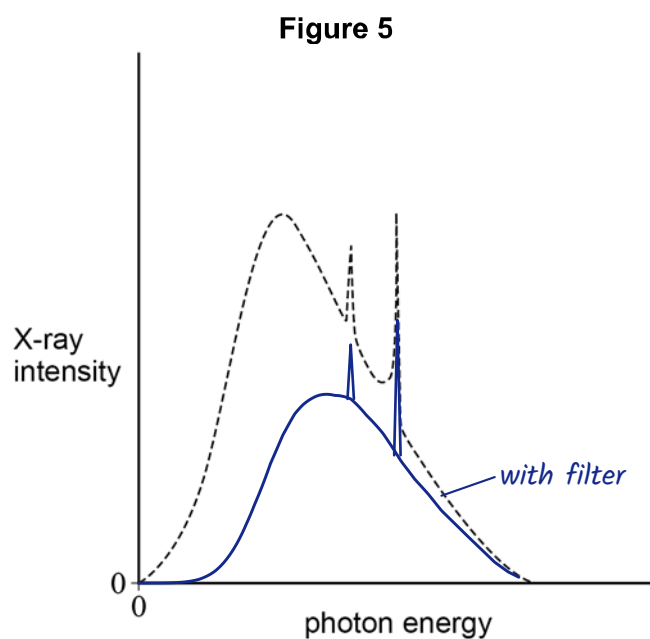
0 3 . 3

In the medical X-ray machine, the X-rays produced with the initial anode pd are now passed through an aluminium filter.

The dashed line on **Figure 5** shows the X-ray spectrum for the initial anode pd.

Sketch on **Figure 5** the X-ray spectrum of the X-rays that emerge from the filter.

[1 mark]



7

Turn over ►



0 4

Ultrasound is commonly used in medical procedures.

0 4 . 1

An ultrasound A-scan is used to find the length l of an eye as shown in **Figure 6**. **Figure 7** shows the simplified A-scan for the eye. A short pulse of ultrasound is transmitted at time $t = 0$

The average speed of ultrasound in the eye = 1560 m s^{-1} .

Figure 6

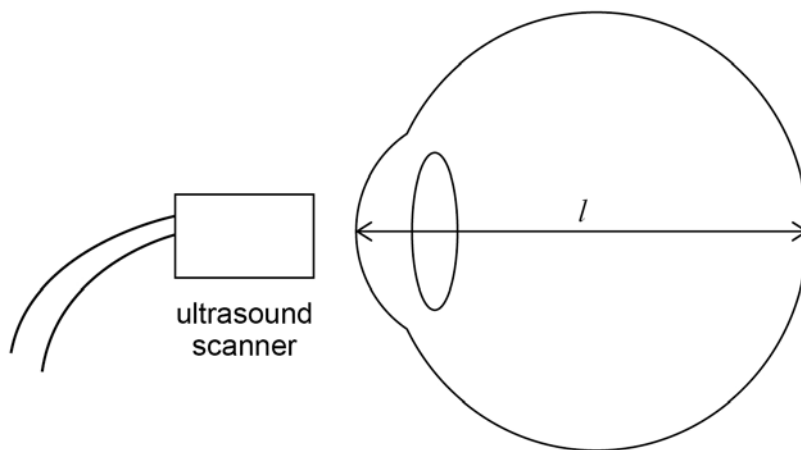
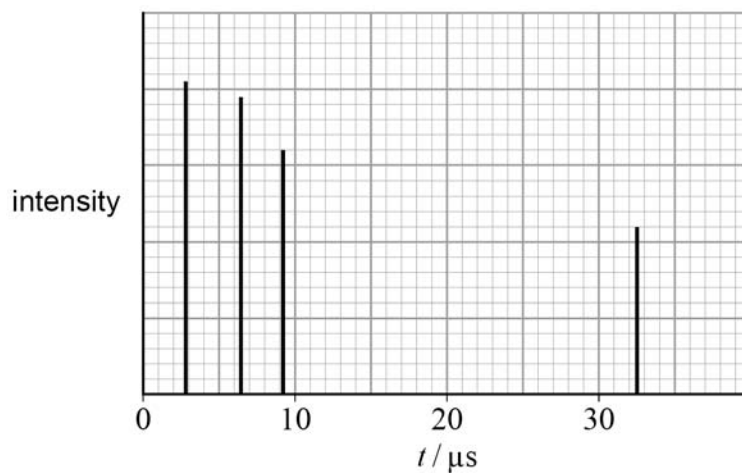


Figure 7



Calculate l .

[3 marks]

$$\text{time between first and last echoes: } t = 32.5 - 3.0 = 29.5 \mu\text{s} = 29.5 \times 10^{-6} \text{ s}$$

$$s = vt = 1560 \times 29.5 \times 10^{-6} = 4.6 \times 10^{-2} \text{ m (there and back)}$$

$$l = s / 2 = 4.6 \times 10^{-2} / 2 = 2.3 \times 10^{-2} \text{ m}$$

$$l = \underline{2.3 \times 10^{-2}} \text{ m}$$



0 4 . 2

Amniocentesis is a procedure where a tube is inserted into a uterus to remove some cells and fluid from around a foetus. For the procedure to be carried out safely the positions of the needle, foetus and placenta must be determined accurately.

Discuss whether an A-scan or a B-scan should be used for amniocentesis.

In your answer, you should:

- outline the differences between an A-scan and a B-scan
- describe the advantages and disadvantages of each type of scan
- explain why your chosen scan should be used for this procedure.

[6 marks]

An A-scan uses a single transducer (one sensor) sending pulses along one line. The echoes are shown as a graph, where the intensity determines the amplitude of each peak and the time gives the depth of each boundary.

A B-scan uses multiple sensors (an array of transducers) or a moving probe. The intensity of each echo determines the brightness of a dot, building up a 2D cross-sectional image.

A-scan advantages: good for accurately determining distances when a limited number of surfaces lie along a straight line, e.g. the length of an eye. Disadvantages: it only produces a graph; with complex structures it is difficult to identify which surface produced which echo, and the structures may not lie along one line.

B-scan advantages: it produces a picture, a 2D cross-section rather than a single line, so structures are identified more easily, including features not along one line, and it can be viewed in real time. Disadvantage: it is harder to determine distances accurately along a straight line.

The B-scan should be used for amniocentesis. The needle, foetus, uterus and placenta are complex structures that do not lie along a straight line, so an image is needed to identify them and to guide the needle safely in real time. On an A-scan graph they could not easily be

Question 4 continues on the next page

Turn over ►



identified, so the A-scan is not suitable.

Both scans use ultrasound, which is non-ionising, so either is safe for the foetus; the B-scan is chosen because it shows the positions accurately.

9

END OF QUESTIONS



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