AQA

Please write clearly in block capitals.

Centre number | 7 | 7 | 5 | 7 | 2 | Candidate number | 4 | 7 | 0 | 9 |

Surname Matheson

Forename(s) Lewis

Candidate signature

I declare this is my own work.

A-level PHYSICS

Paper 3
Section B Medical physics

ALevelPhysicsOnline.com

Thursday 15 June 2023 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.

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

Section B

Answer **all** questions in this section.

0 1 Brachytherapy is used to treat small tumours. In this technique a sealed radioactive source is placed inside a patient's body next to the tumour.

Explain **one** advantage of using beta radiation rather than gamma radiation in brachytherapy.

[2 marks]

Beta is less penetrating ✓ ∴ ionisation is concentrated in the tumour and the surrounding healthy tissue is less affected. ✓

2

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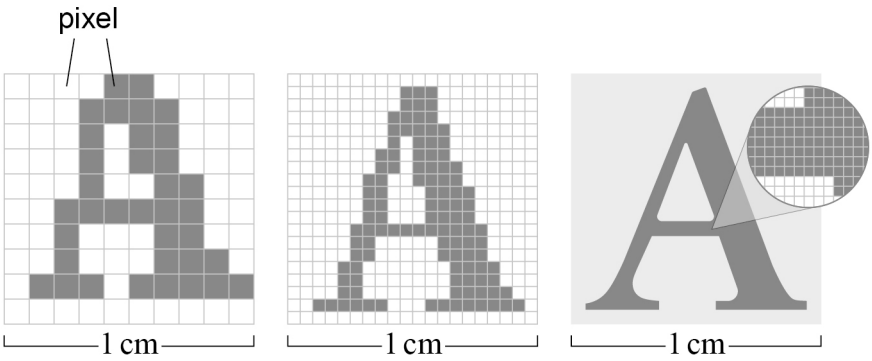
0 2 Electrophoretic screens are used in handheld electronic devices.

The screen contains individual squares known as pixels. Pixels can be changed independently from light to dark to create the shapes of letters and numbers. An external light source is needed in order to read the screen.

Figure 1 shows a letter formed by three electrophoretic screens that have different pixel line densities. Pixel line density is the number of pixels along a $1.0\ \text{cm}$ length of the screen.

Figure 1



0 2 . 1 A particular screen is designed so that two dark pixels separated by one light pixel cannot be resolved as separate images by the eye when viewed from a distance of $0.50\ \text{m}$.

Determine, in pixels per cm, the minimum pixel line density required for this screen.

typical diameter of cones in a human eye at the fovea $= 1.5\ \mu\text{m}$
typical length of the human eye $= 21\ \text{mm}$

[3 marks]

$$\frac{2 \times 1.5 \times 10^{-6}}{21 \times 10^{-3}} = \frac{d}{0.5} \checkmark \qquad d = \frac{0.5 \times 2 \times 1.5 \times 10^{-6}}{21 \times 10^{-3}}$$

$$d = 7.143 \times 10^{-5}\ \text{m} \checkmark$$

$$\frac{1}{7.143 \times 10^{-5}} = 1.4 \times 10^{4}\ \text{pixels m}^{-1}$$

pixels per cm = 140 ✓

Question 2 continues on the next page

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0 2 . 2 On a different electrophoretic screen, two dark pixels separated by one light pixel can just be resolved at a particular distance when the external light source is bright.

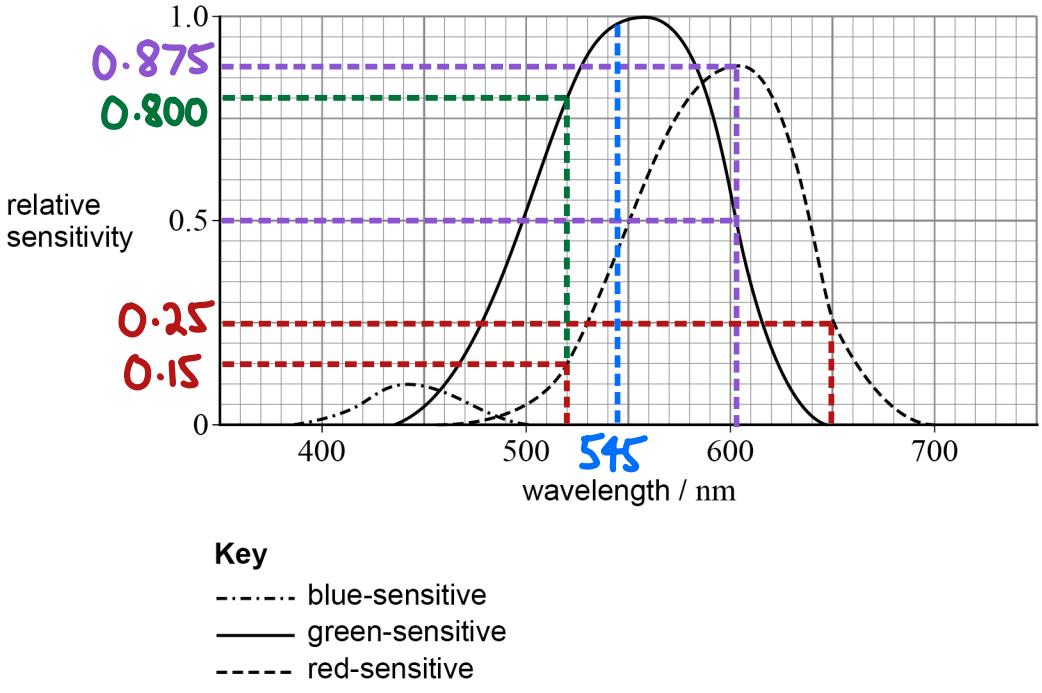
Explain why these pixels cannot be resolved at the same distance when the intensity of the external light source is reduced.

[3 marks]

Pixels are viewed by rods not cones ✓, and multiple rods share a nerve ✓. To resolve, there must be one unstimulated receptor between the stimulated receptors ∴ cannot distinguish at low light intensities. ✓

Figure 2 shows the spectral response of the three different types of cone in a human eye.

Figure 2



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0 2 . 3 The eye is illuminated by light of wavelength 603 nm.

Show that the response of a red-sensitive cone is approximately double the response of a green-sensitive cone.

[1 mark]

$$\frac{\text{Red}}{\text{Green}} = \frac{0.875}{0.50} = 1.75 \checkmark \approx 2$$

0 2 . 4 Other types of screen use blue, green and red pixels to produce coloured images.

Table 1 shows the wavelength of the light emitted by each pixel when it is turned on.

Table 1

Pixel	Wavelength / nm
blue	450
green	520
red	650

On one screen, the blue pixels are turned off.
When the green pixels and the red pixels are turned on, they emit light with the same intensity. A human eye that has the spectral response shown in **Figure 2** responds to this light.

Determine, in nm, the **single** wavelength of light that will produce the same response in the same human eye as the light emitted from the green and red pixels.

[3 marks]

At 520 nm Green = 0·80 Red = 0·15
At 650 nm Green = 0·00 Red = 0·25
Total Green = 0·80 Red = 0·40 ✓

∴ Green is double the value of red ✓

This occurs just below 550 nm

wavelength = 545 ✓ nm

10

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0 3 . 1 Define sound intensity.

[1 mark]

Power of sound per unit area. ✓

0 3 . 2 The intensity level, in dB, of a sound is I.

Let this be I_1

What is the intensity level of a sound with double the intensity? $\therefore \frac{I}{I_0} = 2$

Tick (✓) **one** box.

[1 mark]

$I_1 = 10 \log (I/I_0)$

$I + 2$	
$I + 3$	✓ ✓
$I + 7$	
$2I$	
$3I$	
I^2	

$\Delta I = 10(\log 2 - \log 1)$

$\Delta I = 10 \times 0.301 = 3.01$

$I_2 = I_1 + 3.01$

0 3 . 3 The amplitude of the pressure wave at the oval window of an ear is 20 times greater than at the tympanic membrane.

Calculate the ratio $\frac{\text{force on oval window}}{\text{force on tympanic membrane}}$.

$20 P_{TM} = P_{OW}$

area of oval window $= 5.9 \times 10^{-6}$ m^2
area of tympanic membrane $= 7.2 \times 10^{-5}$ m^2

$\frac{P_{OW}}{P_{TM}} = 20$

[2 marks]

$P = \frac{F}{A}$

$F = P \cdot A$

$\frac{F_{OW}}{F_{TM}} = \frac{P_{OW} \cdot A_{OW}}{P_{TM} \cdot A_{TM}} = \frac{20 \times 5.9 \times 10^{-6}}{7.2 \times 10^{-5}} = 1.64$ ✓

ratio = 1.6 ✓

4

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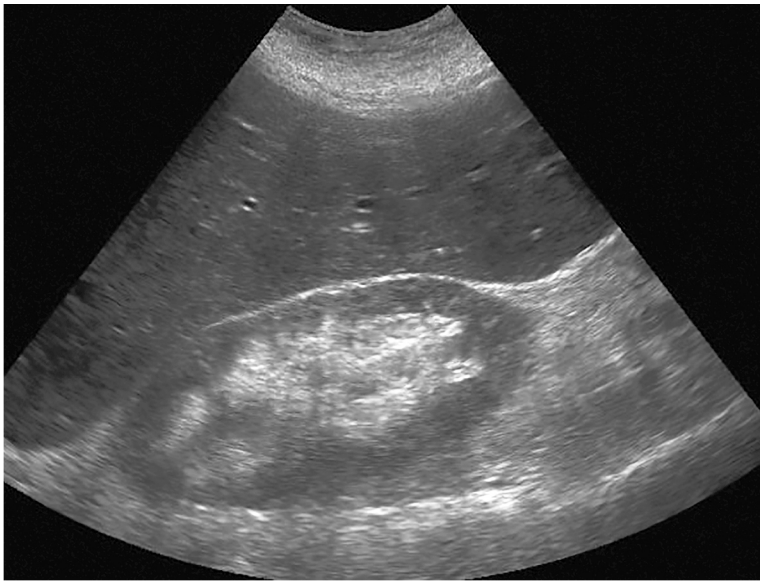
0 4 Different ultrasound techniques are used to investigate the health of a patient's kidneys.

0 4 . 1 **Figure 3** shows the results of an ultrasound scan of a kidney using one technique.

Figure 3



Identify the type of ultrasound scan used to produce **Figure 3**.

Explain your answer.

[1 mark]

B scan, as it is an image not a graph. ✓

Question 4 continues on the next page

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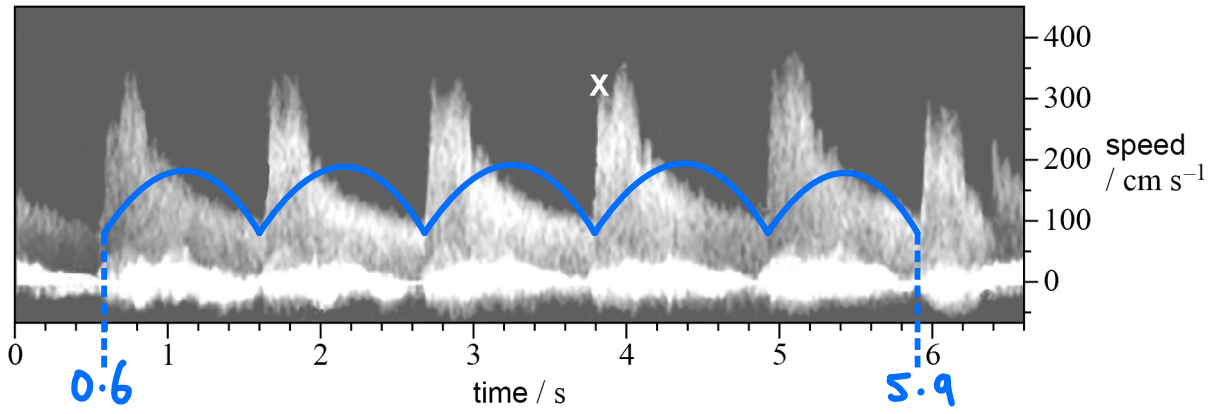
Another ultrasound technique is used to measure the speed of blood flow in one of the kidney's blood vessels.

Figure 4 shows an image formed using this technique. It shows how the speed of flow through the blood vessel varies with time.
Point **X** shows this speed at one instant of time.

Figure 4



0 4 . 2 Determine the patient's heart rate in beats per minute.

[3 marks]

5 ✓ beats in (5·9 − 0·6) seconds

$\frac{5}{5.3}$ = 0·943 beats s^{-1}

× 60 ✓ = 56·6 bpm

heart rate = 57 ✓ beats per minute

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0 4 . 3 An ECG was made for the patient in Question **04.2**.

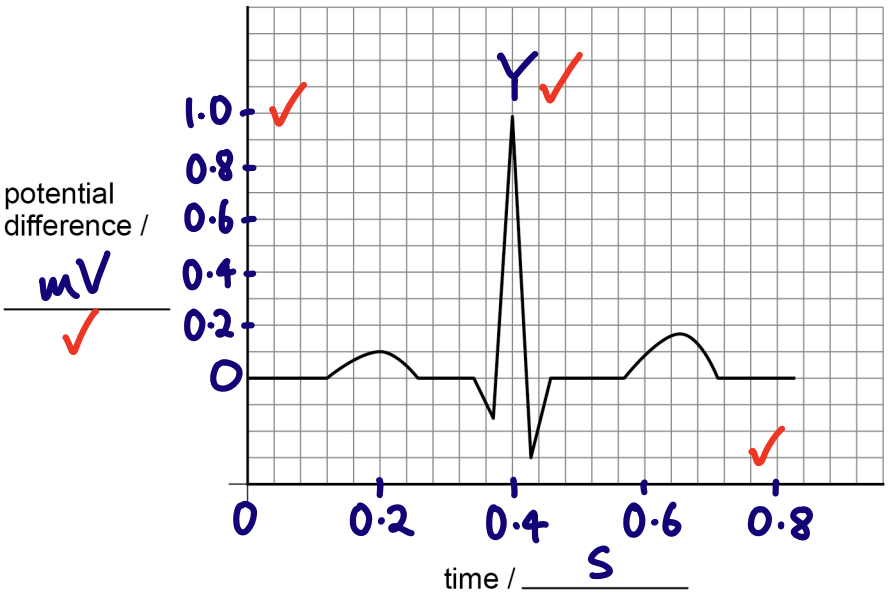
Figure 5 shows one heartbeat from the ECG.

Annotate **Figure 5** to show:

- units on both axes
- scales on both axes
- point **Y** that corresponds to point **X** on **Figure 4**.

[4 marks]

Figure 5



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0 4 . 4 A backing gel is used between an ECG pad and the skin of the patient.
The gel is sticky. This property ensures that the pad is securely attached to the skin.

Explain:

- one other reason why the backing gel is needed
- one other property of the backing gel
- how the skin is prepared for the pad to be applied.

[3 marks]

- It is needed to improve the electrical contact. ✓
- Gel needs to have a low electrical resistance. ✓
- Skin is shaved to remove hairs. ✓

11

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Turn over for the next question

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0 5 . 1 **Figure 6** shows an X-ray image of a chest on photographic film.
Figure 7 shows a diagram of a horizontal cross-section of the chest along the dashed line in **Figure 6**.

Figure 6

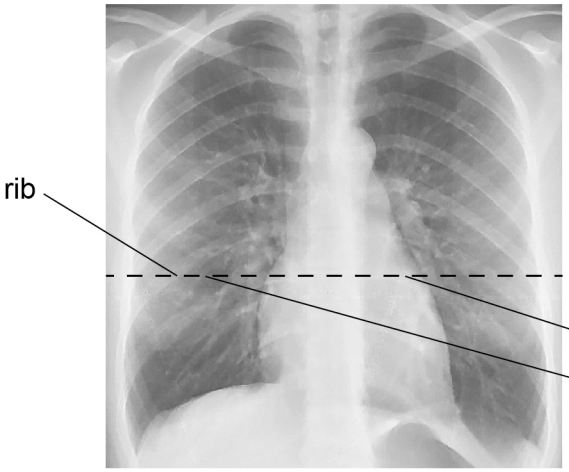
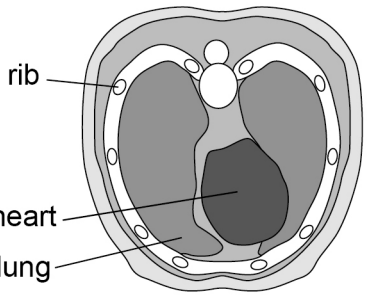


Figure 7



Discuss the half-value thicknesses of the labelled body parts relative to each other.

In your answer you should:

- explain how the intensity of the X-rays affects the brightness of the image
- explain how the thickness of the labelled parts affects the intensity of the X-rays
- compare the relative half-value thicknesses of the labelled body parts.

[6 marks]

Brightness: Film is darkened by X-rays ∴ a darker film is due to a greater intensity of X-rays. Heart brighter than ribs which are brighter than the lungs ∴ lungs allow more X-rays through and heart allows the least. ✓

Thickness: Tissue decreases the intensity of X-rays exponentially. ✓ Lungs are the thickest, followed by the heart and then the ribs. ✓

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Half-value thickness: This is the thickness of tissue needed to halve the intensity of X-rays. A large $x_{1/2}$ means more X-rays transmitted through the same thickness. ✓

Rib is bone ∴ a small $x_{1/2}$ as it is the most dense. Lungs have the largest $x_{1/2}$ as they are the least dense. ✓

Heart is the brightest as $x_{1/2}$ is a medium value but the organ is thick. Ribs are slightly dimmer as $x_{1/2}$ is the smallest but they are very thin. Lungs are darkest, as although they are the thickest, $x_{1/2}$ is very large. ✓

0 5 . 2 The stomach is not clearly visible in **Figure 6**.

Explain the method used to improve the image of the stomach on X-ray photographic film.

[2 marks]

A barium meal is ingested before the X-ray. ✓ This improves contrast of image because barium has a high attenuation coefficient. ✓

8

END OF QUESTIONS

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