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

Friday 5 June 2020 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.

Do not write outside the box

Section B

Answer **all** questions in this section.

0 1 . 1 State and explain **two** differences between the perceived image of a brightly coloured object in bright light and the perceived image of the same object when viewed in very dark conditions.

In your answer you should refer to the visual receptors in the eye.

[5 marks]

Difference 1 There is a higher resolution in the eye in bright light and low resolution in low light. This is because the cones in the visual receptors in the eyes ~~see~~ have a nerve each

Difference 2 In the eye, the cones see in colour and the rods see in black and white. ~~Becau~~ Because bright light uses only cones and very dim light uses only rods. Therefore there is a coloured image in bright light and a black and white image in low light.

Do not write outside the box

According to some legends, in the 17th century a pirate with two healthy eyes covered one eye with a patch to keep the eye in the dark. The patch was removed when going from bright conditions outside to the very dark conditions below decks in an enemy ship.

It was necessary for the pirate to put the patch on about 45 minutes before going into the very dark conditions inside the ship.

0 1 . 2 What is the name of the process which occurs when the pirate's eye is covered by the patch?
Tick (✓) **one** box.

[1 mark]

aberration ☐

accommodation ☐

adaptation ☑

adjustment ☐

0 1 . 3 Discuss why it was necessary to wear the eye patch for 45 minutes before entering the ship.

[3 marks]

The rods in the visual eye receptors need time to adapt to the dark. The rods must regenerate rhodopsin/visual purple and reverse the effects the bleaching from light. This allows the pirates eye to see immediately in low light levels.

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0 2 A sound wave produces a maximum increase in pressure on an ear of 2.5×10^{-3} N m^{-2}.

This causes a maximum increase in pressure in the fluid of the inner ear of 5.0×10^{-2} N m^{-2}.

0 2 . 1 Explain how the ossicles contribute to this increase in pressure in the fluid of the inner ear.

[2 marks]

Ossicles act like a lever to increase the force, which increases the pressure as ~~they~~ it ~~pressure~~ is proportional to the force.

0 2 . 2 The ear's tympanic membrane can be assumed to be a circle of diameter 1.0 cm.

Calculate the area, in m^2, of the oval window.

[3 marks]

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

Area of ear drum $= \pi r^2 = \frac{\pi d^2}{4} = \frac{\pi \times (1 \times 10^{-2})^2}{4}$

$= 7.85 \times 10^{-5}$ m^2

~~Incr~~ There is an increase in pressure due to window size being smaller

$\frac{5 \times 10^{-2}}{2.5 \times 10^{-3} \times 1.5} = 13.3$

Area of oval window $= \frac{7.85 \times 10^{-5}}{13.3} = 5.9 \times 10^{6}$

area = 5.9×10^{-6} m^2

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Do not write outside the box

0 3 X-ray photons can be used to treat cancerous tumours in radiotherapy.
Some photons are absorbed by healthy tissue before they reach the tumour.

Photons with a range of energies are generated in an X-ray machine.

Table 1 shows the linear attenuation coefficient of brain tissue for photons of energy 100 keV and 500 keV.

Table 1

Energy / keV	Linear attenuation coefficient of brain tissue / cm^{-1}
100	0.15
500	0.087

0 3 . 1 Deduce whether photons of energy 100 keV or 500 keV are better for treating a brain tumour at a depth of 11 cm.

[4 marks]

Absorption equation: $I = I_0 e^{-\mu x}$

$\frac{I}{I_0} = e^{-\mu x}$

$\frac{I}{I_0} = e^{-0.15 \times 11} =$ ~~3.24×10^{-49}~~ 0.192 for 100 keV

$\frac{I}{I_0} = e^{-0.087 \times 11} = 0.384$ for 500 keV

More of the 500 keV radiation reaches the tumor so ~~this~~ 500 keV energy photons are better for treating a brain.

Do not write outside the box

0 3 . 2 Metal filters are used in X-ray machines to limit the damage to healthy tissues.
Table 2 gives data for possible filter materials.

Table 2

Energy / keV	Linear attenuation coefficient / cm^{-1}	
	Aluminium	Copper
100	0.44	3.8
500	0.23	0.73

Discuss whether it would be better to use aluminium or copper to filter the X-rays in Question **03.1**.
No calculations are required.

[2 marks]

Copper is better at removing 100keV energy, reducing damage to the cells. It removes a large percentage than Aluminium.

0 3 . 3 State and explain **one** other method used to limit exposure of healthy cells during X-ray radiotherapy.

[2 marks]

Method Lead Shielding

Explanation This method blocks X-rays from healthy tissues.

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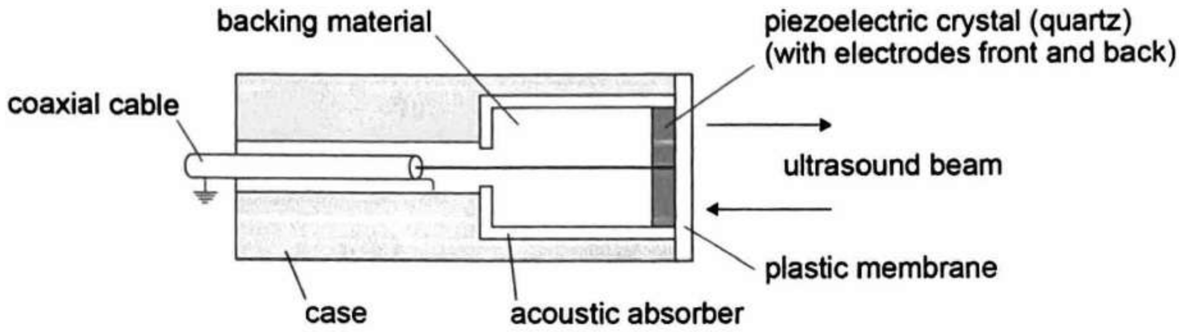
0 4 **Figure 1** shows an ultrasound transducer used to perform medical scans.

Figure 1



0 4 . 1 Explain how the transducer in **Figure 1** operates in medical diagnosis.

In your answer you should explain how

- an ultrasound pulse is produced by the transducer
- the reflected ultrasound pulse is detected by the transducer
- the transducer can both transmit a pulse and receive the reflected pulse.

[6 marks]

The ultrasound pulse is produced as follows; there is an alternating potential difference applied across the crystal. This causes the crystal to expand and contract. This creates pressure waves. The frequency of the alternating p.d is equal to that of the crystal. This is above 20 kHz. The reflected ultrasound is detected because the pressure wave in the crystal has caused the expansion / contraction which produces a p.d across the crystal.

Do not write outside the box

The transducer is able to both transmit and recieve the pulse because the short application of the alternating current produces the short pulse. There is also backing material as seen in the diagram, which dampens the vibration of the crystal. The crystal must stop vibrating before the reflection reaches it, and the backing material ensures this

0 4 . 2 Ultrasound of frequency 1.0 MHz is used to scan a person's liver.

Estimate the resolution of the scan.

speed of sound in liver tissue = 1600 m s^{-1}

[1 mark]

$$\lambda = \frac{c}{f} = \frac{1600}{1\times10^6} = 0.0016$$

resolution = 1.6 mm

Question 4 continues on the next page

0 4 . 3 Ultrasound travels from a transducer through the chest wall to an air pocket inside the lung. From the air pocket, the ultrasound is then incident on lung tissue.

Calculate the percentage of the incident ultrasound intensity that is transmitted into the lung tissue.

speed of sound in lung tissue = 1580 m s^{-1}

density of lung tissue = 1075 kg m^{-3}

speed of sound in air = 330 m s^{-1}

density of air = 1.3 kg m^{-3}

[4 marks]

$Z = \rho c$

$Z_1 = 1.3 \times 330 = 429$

$Z_2 = 1075 \times 1580 = 1.70 \times 10^6$

$\left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2 = \left(\frac{1.7\times10^6 - 429}{1.7\times10^6 + 429}\right)^2 = 0.999$

$100 - 99.9 = 0.1\ \%$

percentage = 0.1 %

0 4 . 4 Discuss whether an ultrasound scan would be suitable to investigate a tumour inside a lung.

[2 marks]

It would not be suitable because 99.9% of the ultrasound would be reflected, when going from the air inside the lungs to the lung tissue.

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END OF QUESTIONS