AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

A-level PHYSICS

Paper 3
Section B Medical physics

Thursday 14 June 2018 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.

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.
- 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	
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4	
5	
TOTAL	

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Section B

Answer **all** questions in this section.

0 1 . 1 An endoscope is used to view an area inside the body. The endoscope contains two bundles of optical fibres.

Name each bundle and explain its use in the process.

[4 marks]

Bundle 1 : Coherent bundle, has a fixed arrangement of fibres at each end ✓

→ Used to transmit an image ✓ (each fibre is like a "pixel" in the image)

Bundle 2 : Non-coherent bundle, has a random arrangement of fibres ✓

→ Used to transmit light into the body ✓ to illuminate an area

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0 1 . 2 A single optical fibre is placed in air. The optical fibre has a core surrounded by cladding. The critical angle is 75° at the core-cladding boundary.

Complete **Figure 1** to show how the refractive index varies with radial distance from the centre of the core to the air surrounding the fibre.
Your answer should be supported by a suitable calculation.

refractive index of core = 1.6

[2 marks]

critical angle

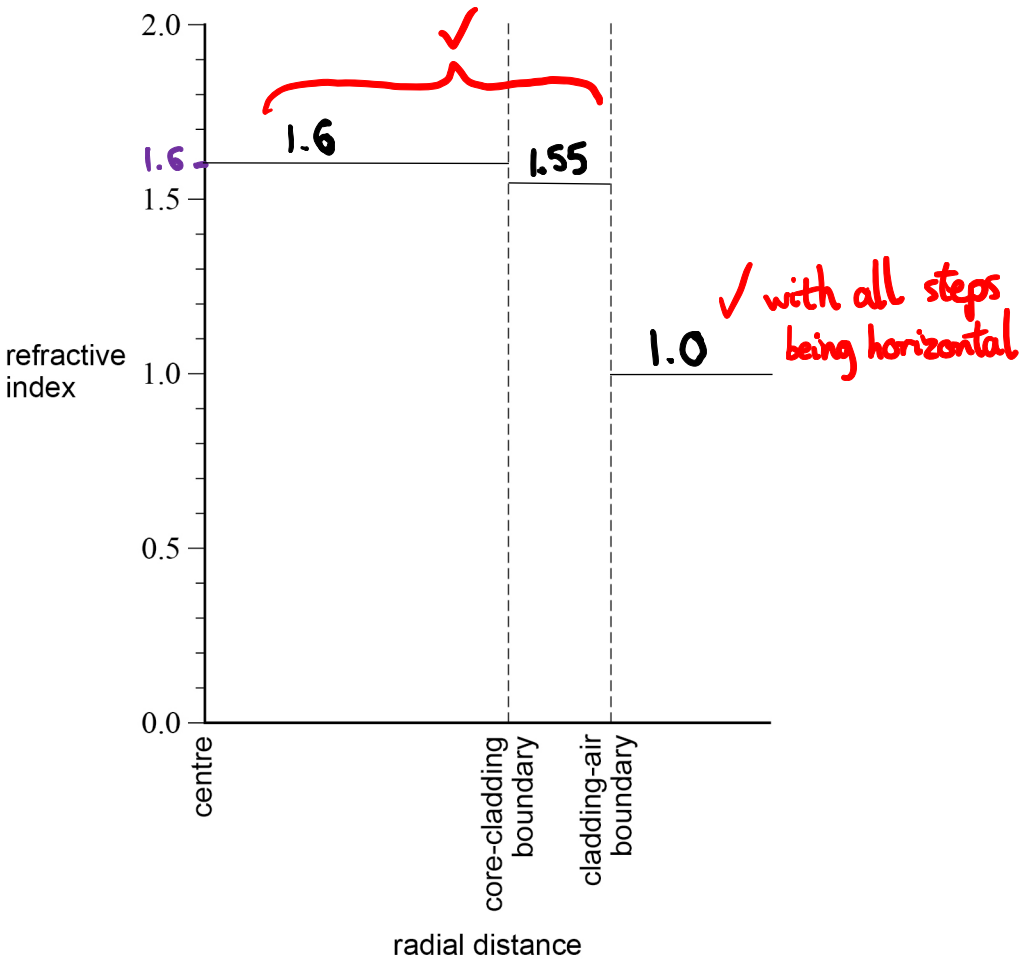
$$\sin(\theta_c) = \frac{n_r}{n_i}$$

n_r: refractive index of material the light is entering (cladding)

n_i: refractive index of incident material (core)

$$n_r = n_i \sin(\theta_c) = 1.6 \times \sin(75) = 1.55$$

Figure 1



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0 2 . 1 The fovea in a typical human eye consists of cones which have an average diameter of 1.5×10^{-6} m

An eye looks directly at two point sources of light which are 12 mm apart at a distance of 61 m from the centre of the eye lens. The fovea is at the centre of the retina a distance of 21 mm behind the centre of the eye lens.

Deduce whether the eye would be able to resolve the two images formed at the fovea.

[4 marks]

$$\frac{\text{image height}}{\text{distance from retina to lens}} = \frac{\text{object height}}{\text{distance from lens to object}}$$

$$\frac{d}{2.1\times10^{-2}} = \frac{1.2\times10^{-2}}{61} \Rightarrow d = \frac{2.1\times10^{-2}\times1.2\times10^{-2}}{61}$$

$$= 4.1\times10^{-6}\ \text{m}$$

$$\frac{4.1\times10^{-6}}{1.5\times10^{-6}} = 2.75 \text{ (times the size of the cone diameter)}$$

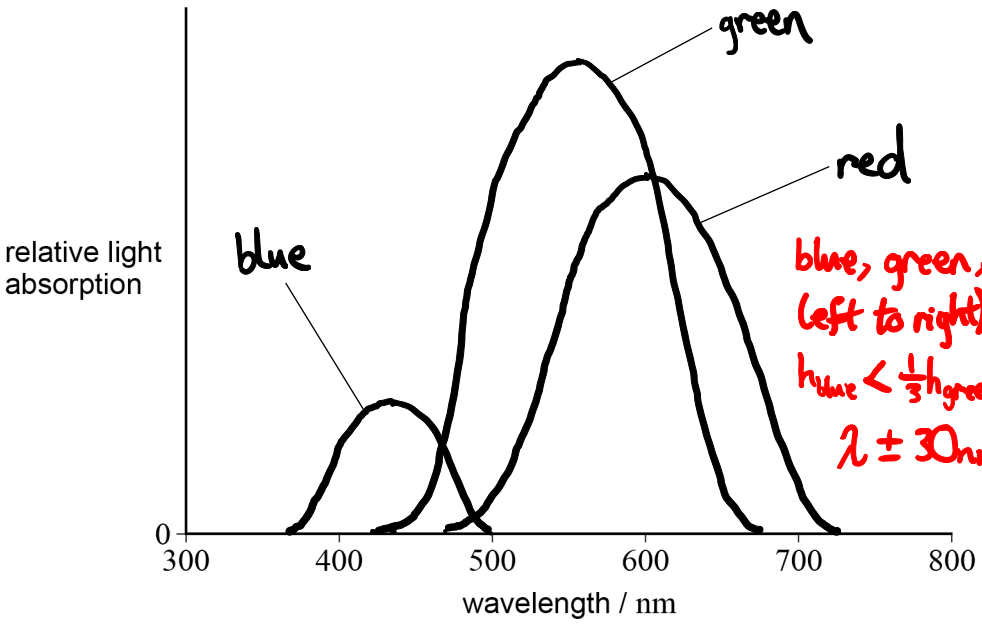
• The image separation is greater than 2 cone diameters, so it can.

0 2 . 2 Three types of cone are present at the fovea.

On **Figure 2** sketch and clearly label **three** curves to show how the relative light absorption of each type of cone varies with wavelength.

[3 marks]

Figure 2



blue, green, red (from left to right) with labels ✓

$h_{blue} < \frac{1}{3}h_{green}$, $h_{red} > \frac{2}{3}h_{green}$ ✓

$\lambda \pm 30$nm ✓

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0 3 In the past, doctors could only use a simple X-ray image to assess head injuries. A CT scan is now a preferred technique.

Discuss why the CT scan has replaced the simple X-ray image to assess head injuries, but a simple X-ray procedure is suitable for assessing other injuries.

In your answer, you should:

- describe the basic principles of a CT scanner
- discuss the advantage of the CT scan over a simple X-ray image for head injuries
- explain why a simple X-ray procedure is more suitable for assessing other injuries.

[6 marks]

Principles of a CT Scanner

- Patient is in the centre of the ring
- X-ray emitter and detector are mounted on opposite sides of the ring
- A narrow beam of X-rays is sent through the head to the detector, and the results are fed to a computer
- The emitter and detector are rotated around the ring slightly (keeping the head still) and the process is repeated
- The signals are combined in the computer from every angle to form a 2D "slice" image of the head

Advantage of CT for head injuries

- The image of tissue boundaries inside the skull is better defined
- We can identify bleeding inside the skull more easily

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Simpler X-rays of other injuries

- The patient doesn't need to keep still in a CT ring for a long time, so this is easier
- The X-ray machine is on for less time, so this is less expensive
- Simpler fractures can be identified
- The dose of ionising radiation received by the patient is lower, so this method is less harmful

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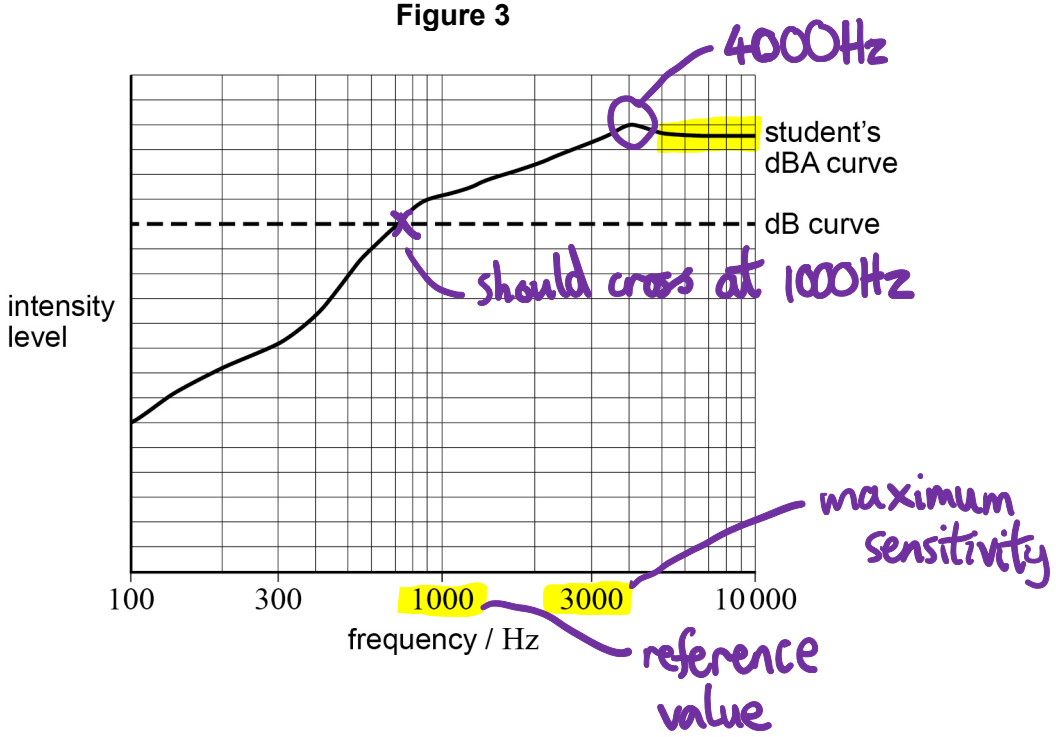
0 4 . 1 A source of constant output power is used to generate a sound which is measured using a sound meter.

The dashed line in **Figure 3** shows the intensity level curve over a range of frequencies with the meter set to the dB setting.

Figure 3



A student sketches a curve, over the same frequency range, which he thinks would be obtained when the meter is changed to the dBA setting. The curve drawn by the student is shown as the solid line in **Figure 3**.

Discuss whether the dBA curve drawn is correct.

[4 marks]

- The ear's sensitivity starts low, and increases to a maximum; the graph is convex in nature but should fall at higher frequencies rather than reaching a plateau ✓
- The 1000Hz point is a reference point ✓ and 3000Hz is the frequency of highest sensitivity (alternate ✓)
- The curves should cross at 1000Hz, not 750Hz ✓
- The maximum sensitivity on the dBA curve should be 3000Hz, not 4000Hz ✓

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0 4 . 2 Mesh barriers are set up to keep pedestrians at a safe distance from a noisy drill.
The maximum noise level which pedestrians should be subjected to is 110 dB
The drill emits sound with a power of 7.8 W and acts as a point source.
The mesh barriers are set up a distance of 2.0 m from the drill.

Discuss whether this will keep pedestrians at a safe distance from the sound source.

[4 marks]

Noise level (dB) $= 10\log(I/I_0)$

$I_0 = 1\text{pW m}^{-2}$

$I = 10^{-12} \times 10^{11} = 0.10\text{ W m}^{-2}$ ✓

$I = \frac{P}{A} = \frac{P}{4\pi r^2} \Rightarrow r = \sqrt{\frac{P}{4\pi I}}$

$= \sqrt{\frac{7.8}{4\pi \times 0.10}}$ ✓

$= 2.491\text{ m}$

$\simeq 2.5\text{ m}$ (to 2 s.f.) ✓

- The mesh barriers are closer than 2.5 m, so they are too close. ✓

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0 5 . 1 High-energy X-rays are used in the treatment of a cancer tumour inside a patient's body. The patient is given a series of scans before the treatment is started.

Discuss how these scans are used to help provide the best and safest treatment for the patient when using the high-energy X-rays.

[3 marks]

- By performing a scan first, we can locate the exact area to carry out treatment ✓
- The energy of the X-rays can be adjusted based on the size of the tumour ✓
- Computers can be used to make the X-ray position more precise ✓
- We can minimise the length of time for which the X-ray is used, ✓ reducing the dose and therefore damage to healthy cells ✓
- We can irradiate the tumour from different directions ✓ [MAX 3×✓]

0 5 . 2 Lead is commonly used as shielding when using X-rays due to its small half-value thickness.

Which statement gives the correct meaning of half-value thickness?
Tick (✓) the correct answer.

[1 mark]

The thickness of material needed to reduce the energy of an X-ray photon by half. ☐

Planck constant, speed of light

The thickness of material needed to reduce the wavelength of the photons in the X-ray beam by half. ☐

energy — $E = \frac{hc}{\lambda}$

The thickness of material needed to reduce the intensity of the X-ray beam by half. ☑ ✓

Half the thickness of material needed to stop the X-ray beam. ☐

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0 5 . 3 The half-value thickness of lead for 500 keV X-rays is 4.2×10^{-3} m

Calculate the mass attenuation coefficient of lead for 500 keV X-rays.

State an appropriate unit for your answer.

density of lead = 1.1×10^{4} kg m^{-3}

[4 marks]

Linear attenuation coefficient

$$\mu = \frac{\ln 2}{\text{half-value thickness}} = \frac{\ln 2}{4.2 \times 10^{-3}} = 165 \text{ m}^{-1}$$

mass attenuation coefficient

density

$$\mu_m = \frac{\mu}{\rho} = \frac{165 \text{ m}^{-1}}{1.1 \times 10^{4} \text{ kg m}^{-3}} = 1.5 \times 10^{-2} \text{ m}^2 \text{ kg}^{-1}$$

mass attenuation coefficient = 1.5×10^{-2} unit $\text{m}^2 \text{kg}^{-1}$ **8**

END OF QUESTIONS

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