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 29 June 2017 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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TOTAL	

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Section B

Answer **all** questions in this section.

0 1 A person suffers from hypermetropia (long sight).
Use of a spectacle lens of power +2.0D allows the person to just see clearly an object placed 24 cm away from the eye.

0 1 . 1 Explain why the unaided defective eye cannot form a clearly focused image of the object placed 24 cm from the eye.

[2 marks]

- The lens is not powerful enough (cannot bend the light enough) ✓
- The light will not be able to focus at the retina ✓

0 1 . 2 An object is placed 24 cm from the spectacle lens.

Calculate the distance of the image formed from the spectacle lens.
Give your answer to a suitable number of significant figures.

[3 marks]

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

u = object distance, v = image distance, f = focal length

$$\frac{1}{0.24} + \frac{1}{v} = 2 \quad ✓$$

$$v = \left(2 - \frac{1}{0.24}\right)^{-1} = -0.46\text{m}$$

image distance = −46 ✓✓ cm

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0 1 . 3 What is the name for the position where the image is formed by the spectacle lens?
Tick (✓) the correct answer.

[1 mark]

The eye's aided far point ☐

The eye's aided near point ☐

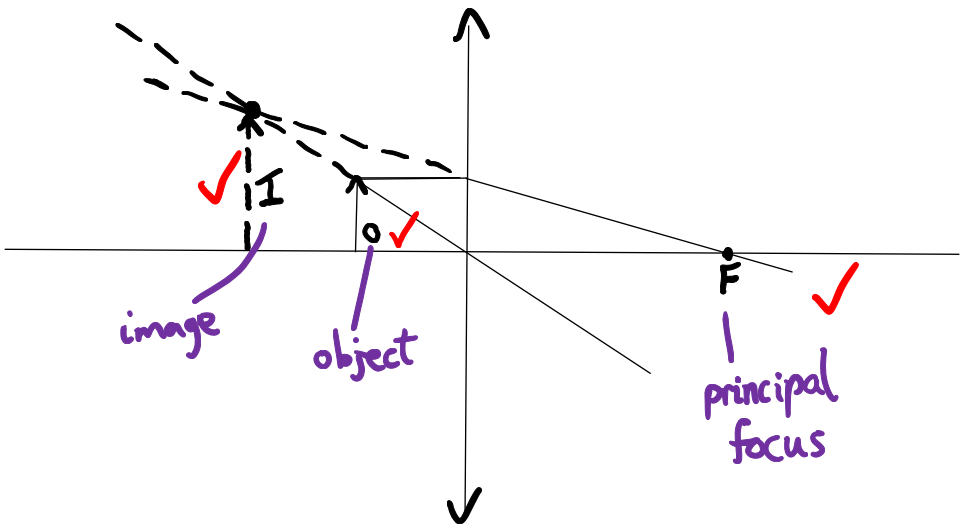
The eye's unaided far point ☐

The eye's unaided near point ☑ ✓

The person is far-sighted, so they won't be able to focus on objects that are too close.

0 1 . 4 Draw a ray diagram to show how this spectacle lens forms an image of the object placed 24 cm from the spectacle lens.
On your diagram clearly label the object, image and a principal focus of the lens.
Your diagram does not have to be drawn to scale.

[3 marks]



Turn over for the next question

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0 2 . 1 A patient with a suspected broken arm is going to have an X-ray image taken.

Explain the risk to the patient of exposure to X-rays.

Go on to discuss **three** ways by which the design and use of the X-ray equipment minimises this risk.

[6 marks]

Risk

- X-rays are ionising radiation.
- Increasing exposure to ionising radiation increases the risk of mutations (could also say cancer)

Methods to Minimise Exposure

- Using lead diaphragm plates will mean that only the area being investigated has X-rays incident
- An aluminium filter removes low-energy photons (thus reducing the ionising radiation intensity) as they cannot produce an image and are therefore not needed
- Adjusting the anode voltage produces more photons which are energetic enough to produce an image; fewer useless photons produced

Other Points

- Use intensifying screens with film, to shorten exposure
- Place a grid between the patient and image receptor to stop scattering (which would require further X-rays)

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0 2 . 2 The blood vessel called the aorta passes through the abdomen. A second patient with a suspected fault in the wall of the aorta can be given an ultrasound scan or an X-ray of the abdomen.

Suggest, with reasons, which is the better procedure for investigating this suspected fault.

[2 marks]

- Ultrasound is preferable as it is non-ionising ✓
- An ultrasound image will provide an image with a better definition between tissue and blood ✓

Question 2 continues on the next page

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0 2 . 3 When ultrasound travels across a boundary from blood to the wall of the aorta there is a decrease in acoustic impedance across the boundary. This results in 0.0625% of the intensity of the incident ultrasound being reflected at the boundary.

Calculate the acoustic impedance of the aorta wall tissue.

acoustic impedance of blood = 1.64×10^{6} kg m^{-2} s^{-1}

[4 marks]

intensity of reflected ultrasound

$$\frac{I_r}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$$

original intensity of ultrasound

acoustic impedance of second medium (after boundary)

acoustic impedance of incident medium

$$\sqrt{\frac{I_r}{I_0}} = \frac{Z_2 - Z_1}{Z_2 + Z_1}$$

as Z decreases ✓

$$-2.5 \times 10^{-2} = \frac{Z_2 - (1.64 \times 10^6)}{Z_2 + (1.64 \times 10^6)}$$ ✓

$$Z_2 = \frac{(1.64 \times 10^6) - (4.1 \times 10^4)}{1 + (2.5 \times 10^{-2})}$$ ✓

$$= 1.56 \times 10^6 \text{ kg m}^{-2} \text{ s}^{-1}$$

acoustic impedance of aorta wall tissue = 1.56×10^6 ✓ kg m^{-2} s^{-1}

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ANSWER IN THE SPACES PROVIDED

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positron emission tomography

0 3 A patient is going to have a PET scan. A small amount of radioisotope is injected into the patient's bloodstream and the patient is left to relax. The patient then lies on a horizontal table and is moved into the PET scanner. The scanner has many detectors positioned in a vertical circular pattern around the patient.

0 3 . 1 State what is meant by a radioisotope.

[1 mark]

A material with unstable nuclei, which will decay to emit ionising radiation ✓

0 3 . 2 The radionuclide used in the PET scan has a physical half-life of 110 minutes. The radionuclide is excreted from the body with a biological half-life of 185 minutes.

Show that the effective half-life of the radionuclide in the body is about 70 minutes.

[1 mark]

$$\frac{1}{T_E} = \frac{1}{T_P} + \frac{1}{T_B}$$

effective half-life; physical half-life; biological half-life

$$T_E = \left(\frac{1}{T_P} + \frac{1}{T_B}\right)^{-1} = \left(\frac{1}{110} + \frac{1}{185}\right)^{-1}$$

$$= 68.98 \text{ mins}$$ ✓

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0 3 . 3 Discuss what might be a suitable length of time for the patient to relax between injecting the radionuclide and moving the patient into the PET scanner.

[3 marks]

- 70 minutes (maybe lower but no less than 10mins), as this is near to the effective half-life ✓
- Allows the blood to carry the radionuclide around the body ✓
- The part of the body being investigated needs enough time to take up the isotope ✓

0 3 . 4 The decay of the radionuclide results in the emission of a positron. Two of the detectors, directly opposite to each other, are triggered as they each receive a gamma photon.

Explain the process in which the gamma photons are created.

[2 marks]

- A positron collides with an electron and annihilation takes place ✓
- The mass of the positron and electron is converted into energy of the photons ✓
- (The photons move away in opposite directions to conserve momentum ✓)

Question 3 continues on the next page

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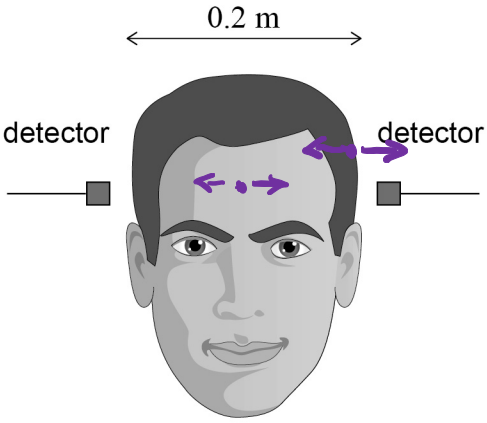
0 3 . 5 **Figure 1** shows the head of a patient that is 0.2 m across, placed centrally between two of the many detectors in a PET scanner.

Figure 1



To determine the position where the gamma photons are produced between the detectors, the scanner measures the short interval of time Δt between the triggering of the first detector and the triggering of the second detector.

Discuss, for the detector positions shown in **Figure 1**, the range of the values of Δt that the scanner must measure to perform a PET scan on the head.
Assume that the speed of the gamma photons in the head is 3×10^8 m s^{-1}. speed of light

[2 marks]

- Time taken to cross width of head
$= \frac{\text{distance}}{\text{speed}} = \frac{\text{width of head}}{\text{speed of light}}$

$= \frac{0.2}{3 \times 10^8} = 6.7 \times 10^{-10}$ s
$\simeq 7 \times 10^{-10}$ s ✓

- The time difference could be:
  - → As low as zero (two photons emitted from the centre)
  - → As high as 7×10^{-10} s (two photons emitted from one side, one hits a detector immediately and the other needs to cross the width of the head) ✓

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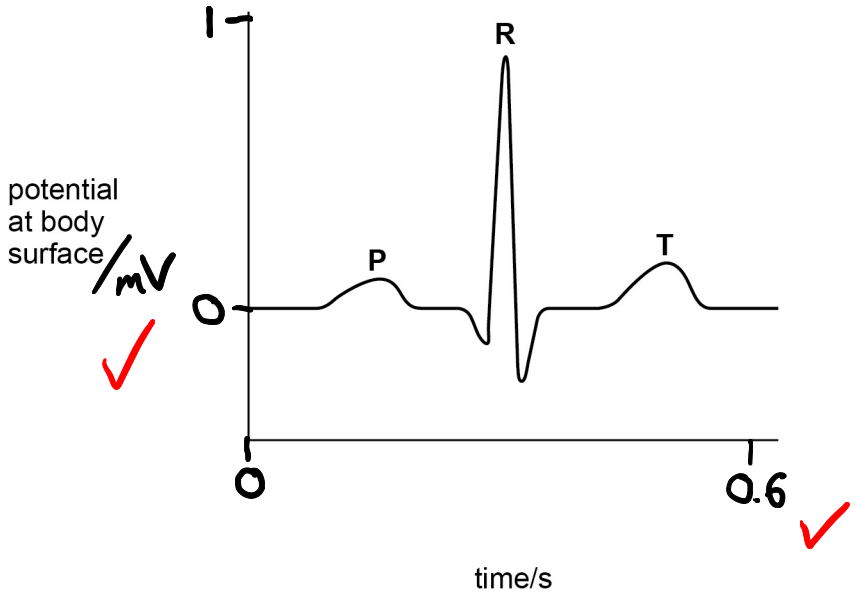
0 4 . 1 **Figure 2** shows an ECG trace for a healthy person.

Complete **Figure 2** by adding a suitable unit and scale to the potential axis, and a suitable scale to the time axis.

[2 marks]

Figure 2



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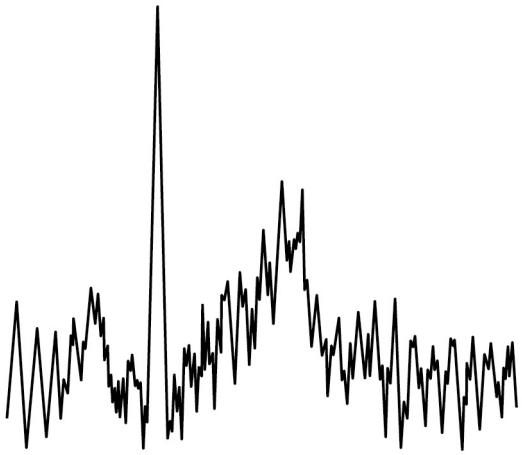
0 4 . 2 **Figure 3** shows a faulty ECG trace which was obtained for another healthy person.

Figure 3



Discuss **three** possible reasons why this faulty trace was obtained.

[3 marks]

- Electrodes are not properly attached to the patient
  → A disconnecting electrode will cause a jump in the voltage ✓
- The patient is not keeping still
  → If they move and disconnect an electrode, the voltage reading will jump ✓
- The amplifier is not low-noise
  → The noise will be scaled up with the signal, making it more significant ✓

5

END OF QUESTIONS