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| Surname | | Other Names | |
| Centre Number | | Candidate Number | |
| Candidate Signature | | | |

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General Certificate of Education
 June 2006
 Advanced Level Examination



ASSESSMENT and
 QUALIFICATIONS
 ALLIANCE

PHYSICS (SPECIFICATION A)
Unit 6 Nuclear Instability: Medical Physics Option

PHA6/W

Thursday 15 June 2006 9.00 am to 10.15 am

For this paper you must have:

- a calculator
- a pencil and ruler

Time allowed: 1 hour 15 minutes

Instructions

- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- Answer the questions in the spaces provided.
- Show all your working.
- Do all rough work in this book. Cross through any work you do not want marked.

Information

- The maximum mark for this paper is 40. This includes up to 2 marks for the Quality of Written Communication.
- The marks for questions are shown in brackets.
- A *Data sheet* is provided on pages 3 and 4. You may wish to detach this perforated sheet at the start of the examination.
- You are expected to use a calculator where appropriate.
- You are reminded of the need for good English and clear presentation in your answers. Questions indicated on the paper should be answered in continuous prose. Quality of Written Communication will be assessed in these answers.

| For Examiner's Use | | | |
|----------------------------------|------|--------|------|
| Number | Mark | Number | Mark |
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| Total (Column 1) → | | | |
| Total (Column 2) → | | | |
| Quality of Written Communication | | | |
| TOTAL | | | |
| Examiner's Initials | | | |

Data Sheet

- A perforated *Data Sheet* is provided as pages 3 and 4 of this question paper.
- This sheet may be useful for answering some of the questions in the examination.
- You may wish to detach this sheet before you begin work.

Data Sheet

| Fundamental constants and values | | | | Mechanics and Applied Physics | | Fields, Waves, Quantum Phenomena | |
|--|----------------|-------------------------|-----------------------------------|--|---|----------------------------------|--|
| Quantity | Symbol | Value | Units | | | | |
| speed of light in vacuo | c | 3.00×10^8 | m s^{-1} | $v = u + at$ | $g = \frac{F}{m}$ | | |
| permeability of free space | μ_0 | $4\pi \times 10^{-7}$ | H m^{-1} | $s = \left(\frac{u+v}{2}\right)t$ | $g = -\frac{GM}{r^2}$ | | |
| permittivity of free space | ϵ_0 | 8.85×10^{-12} | F m^{-1} | $s = ut + \frac{at^2}{2}$ | $g = -\frac{\Delta V}{\Delta x}$ | | |
| charge of electron | e | 1.60×10^{-19} | C | $v^2 = u^2 + 2as$ | $V = -\frac{GM}{r}$ | | |
| the Planck constant | h | 6.63×10^{-34} | J s | $F = \frac{\Delta(mv)}{\Delta t}$ | $a = -\frac{(2\pi f)^2 x}{g}$ | | |
| gravitational constant | G | 6.67×10^{-11} | $\text{N m}^2 \text{kg}^{-2}$ | $P = Fv$ | $v = \pm 2\pi f \sqrt{A^2 - x^2}$ | | |
| the Avogadro constant | N_A | 6.02×10^{23} | mol^{-1} | $\text{efficiency} = \frac{\text{power output}}{\text{power input}}$ | $x = A \cos 2\pi ft$ | | |
| molar gas constant | R | 8.31 | $\text{J K}^{-1} \text{mol}^{-1}$ | $\omega = \frac{v}{r} = 2\pi f$ | $T = 2\pi \sqrt{\frac{m}{k}}$ | | |
| the Boltzmann constant | k | 1.38×10^{-23} | J K^{-1} | $a = \frac{v^2}{r} = r\omega^2$ | $T = 2\pi \sqrt{\frac{l}{g}}$ | | |
| the Stefan constant | σ | 5.67×10^{-8} | $\text{W m}^{-2} \text{K}^{-4}$ | $I = \sum mr^2$ | $\lambda = \frac{\omega s}{D}$ | | |
| the Wien constant | α | 2.90×10^{-3} | m K | $E_k = \frac{1}{2} I\omega^2$ | $d \sin \theta = n\lambda$ | | |
| electron rest mass | m_e | 9.11×10^{-31} | kg | $\omega_2 = \omega_1 + at$ | $\theta \approx \frac{\lambda}{D}$ | | |
| (equivalent to $5.5 \times 10^{-4}u$) | | | | $\theta = \omega_1 t + \frac{1}{2} at^2$ | $n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$ | | |
| electron charge/mass ratio | e/m_e | 1.76×10^{11} | C kg^{-1} | $\omega_2^2 = \omega_1^2 + 2a\theta$ | $n_2 = \frac{n_2}{n_1}$ | | |
| proton rest mass | m_p | 1.67×10^{-27} | kg | $\theta = \frac{1}{2} (\omega_1 + \omega_2)t$ | $\sin \theta_c = \frac{1}{n}$ | | |
| (equivalent to 1.00728u) | | | | $T = I\alpha$ | $E = hf$ | | |
| proton charge/mass ratio | e/m_p | 9.58×10^7 | C kg^{-1} | $\text{angular momentum} = I\omega$ | $hf = \phi + E_k$ | | |
| neutron rest mass | m_n | 1.67×10^{-27} | kg | $W = T\theta$ | $hf = E_1 - E_2$ | | |
| (equivalent to 1.00867u) | | | | $P = T\omega$ | $\lambda = \frac{h}{p} = \frac{h}{mv}$ | | |
| gravitational field strength | g | 9.81 | N kg^{-1} | $\text{angular impulse} = \text{change of angular momentum} = Tt$ | $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$ | | |
| acceleration due to gravity | g | 9.81 | m s^{-2} | $\Delta Q = \Delta U + \Delta W$ | | | |
| atomic mass unit | u | 1.661×10^{-27} | kg | $\Delta W = p\Delta V$ | | | |
| (1u is equivalent to 931.3 MeV) | | | | $pV^\gamma = \text{constant}$ | | | |
| Fundamental particles | | | | $\text{work done per cycle} = \text{area of loop}$ | | | |
| Class | Name | Symbol | Rest energy /MeV | $\text{input power} = \text{calorific value} \times \text{fuel flow rate}$ | | | |
| photon | photon | γ | 0 | $\text{indicated power as (area of } p-V \text{ loop)} \times (\text{no. of cycles/s}) \times (\text{no. of cylinders})$ | | | |
| lepton | neutrino | ν_e | 0 | $\text{friction power} = \text{indicated power} - \text{brake power}$ | | | |
| | | ν_μ | 0 | $\text{efficiency} = \frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$ | | | |
| | electron | e^\pm | 0.510999 | $\text{maximum possible efficiency} = \frac{T_H - T_C}{T_H}$ | | | |
| | muon | μ^\pm | 105.659 | | | | |
| mesons | pion | π^\pm | 139.576 | | | | |
| | | π^0 | 134.972 | | | | |
| | kaon | K^\pm | 493.821 | | | | |
| | | K^0 | 497.762 | | | | |
| baryons | proton | p | 938.257 | | | | |
| | neutron | n | 939.551 | | | | |
| Properties of quarks | | | | | | | |
| Type | Charge | Baryon number | Strangeness | | | | |
| u | $+\frac{2}{3}$ | $+\frac{1}{3}$ | 0 | | | | |
| d | $-\frac{1}{3}$ | $+\frac{1}{3}$ | 0 | | | | |
| s | $-\frac{1}{3}$ | $+\frac{1}{3}$ | -1 | | | | |
| Geometrical equations | | | | | | | |
| arc length = $r\theta$ | | | | | | | |
| circumference of circle = $2\pi r$ | | | | | | | |
| area of circle = πr^2 | | | | | | | |
| area of cylinder = $2\pi rh$ | | | | | | | |
| volume of cylinder = $\pi r^2 h$ | | | | | | | |
| area of sphere = $4\pi r^2$ | | | | | | | |

Data Sheet

| <p>magnitude of induced e.m.f. = $N \frac{\Delta\Phi}{\Delta t}$</p> <p>$I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$</p> <p>$V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$</p> | <p>$E = mc^2 = \frac{m_0c^2}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$</p> <p>$l = l_0 \left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}$</p> <p>$t = \frac{t_0}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$</p> | <p>Medical Physics</p> <p>power = $\frac{1}{f}$</p> <p>$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ and $m = \frac{v}{u}$</p> <p>intensity level = $10 \log \frac{I}{I_0}$</p> <p>$I = I_0 e^{-\mu x}$</p> <p>$\mu_m = \frac{\mu}{\rho}$</p> | | | | | | | | | |
|---|--|--|---------|---------------|-----|-----------------------|--------------------|-------|-----------------------|--------------------|--|
| <p>Mechanical and Thermal Properties</p> <p>the Young modulus = $\frac{\text{tensile stress}}{\text{tensile strain}} = \frac{F}{A} \frac{l}{e}$</p> <p>energy stored = $\frac{1}{2} Fe$</p> <p>$\Delta Q = mc \Delta\theta$</p> <p>$\Delta Q = ml$</p> <p>$pV = \frac{1}{3} Nmc^2$</p> <p>$\frac{1}{2} mc^2 = \frac{3}{2} kT = \frac{3RT}{2N_A}$</p> | <p>Astrophysics and Medical Physics</p> <table border="1"> <thead> <tr> <th>Body</th> <th>Mass/kg</th> <th>Mean radius/m</th> </tr> </thead> <tbody> <tr> <td>Sun</td> <td>2.00×10^{30}</td> <td>7.00×10^8</td> </tr> <tr> <td>Earth</td> <td>6.00×10^{24}</td> <td>6.40×10^6</td> </tr> </tbody> </table> <p>1 astronomical unit = 1.50×10^{11} m</p> <p>1 parsec = 206265 AU = 3.08×10^{16} m = 3.26 ly</p> <p>1 light year = 9.45×10^{15} m</p> <p>Hubble constant (H) = $65 \text{ km s}^{-1} \text{ Mpc}^{-1}$</p> <p>angle subtended by image at eye</p> <p>$M = \frac{\text{angle subtended by image at eye}}{\text{angle subtended by object at unaided eye}}$</p> <p>$M = \frac{f_o}{f_c}$</p> <p>$m - M = 5 \log \frac{d}{10}$</p> <p>$\lambda_{\text{max}} T = \text{constant} = 0.0029 \text{ m K}$</p> <p>$v = Hd$</p> <p>$P = \sigma AT^4$</p> <p>$\frac{\Delta f}{f} = \frac{v}{c}$</p> <p>$\frac{\Delta \lambda}{\lambda} = -\frac{v}{c}$</p> <p>$R_s \approx \frac{2GM}{c^2}$</p> | Body | Mass/kg | Mean radius/m | Sun | 2.00×10^{30} | 7.00×10^8 | Earth | 6.00×10^{24} | 6.40×10^6 | <p>Electronics</p> <p>Resistors</p> <p>Preferred values for resistors (E24) Series: 1.0 1.1 1.2 1.3 1.5 1.6 1.8 2.0 2.2 2.4 2.7 3.0 3.3 3.6 3.9 4.3 4.7 5.1 5.6 6.2 6.8 7.5 8.2 9.1 ohms and multiples that are ten times greater</p> <p>$Z = \frac{V_{\text{rms}}}{I_{\text{rms}}}$</p> <p>$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$</p> <p>$C_T = C_1 + C_2 + C_3 + \dots$</p> <p>$X_C = \frac{1}{2\pi fC}$</p> |
| Body | Mass/kg | Mean radius/m | | | | | | | | | |
| Sun | 2.00×10^{30} | 7.00×10^8 | | | | | | | | | |
| Earth | 6.00×10^{24} | 6.40×10^6 | | | | | | | | | |
| <p>Nuclear Physics and Turning Points in Physics</p> <p>force = $\frac{eV_p}{d}$</p> <p>force = Bev</p> <p>radius of curvature = $\frac{mv}{Be}$</p> <p>$\frac{eV}{d} = mg$</p> <p>work done = eV</p> <p>$F = 6\pi\eta rv$</p> <p>$I = k \frac{I_0}{x^2}$</p> <p>$\frac{\Delta N}{\Delta t} = -\lambda N$</p> <p>$\lambda = \frac{h}{\sqrt{2meV}}$</p> <p>$N = N_0 e^{-\lambda t}$</p> <p>$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$</p> <p>$R = r_0 A^{\frac{1}{3}}$</p> | <p>Alternating Currents</p> <p>$f = \frac{1}{T}$</p> <p>Operational amplifier</p> <p>$G = \frac{V_{\text{out}}}{V_{\text{in}}}$ voltage gain</p> <p>$G = -\frac{R_f}{R_1}$ inverting</p> <p>$G = 1 + \frac{R_f}{R_1}$ non-inverting</p> <p>$V_{\text{out}} = -R_f \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} \right)$ summing</p> | <p>www.theallpapers.com</p> | | | | | | | | | |

Turn over for the first question

SECTION A: NUCLEAR INSTABILITYAnswer **all** of this question.

- 1 (a) Calculate the radius of the ${}_{92}^{238}\text{U}$ nucleus.

$$r_0 = 1.3 \times 10^{-15} \text{ m}$$

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(2 marks)

- (b) At a distance of 30 mm from a point source of γ rays the corrected count rate is C . Calculate the distance from the source at which the corrected count rate is $0.10 C$, assuming that there is no absorption.

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(2 marks)

- (c) The activity of a source of β particles falls to 85% of its initial value in 52 s. Calculate the decay constant of the source.

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(3 marks)

- (d) Explain why the isotope of technetium, $^{99}\text{Tc}_m$, is often chosen as a suitable source of radiation for use in medical diagnosis.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

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(3 marks)

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| 10 |
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Turn over for the next question

SECTION B: MEDICAL PHYSICS

Answer **all** questions.

- 2 (a) State and explain **two** physical properties of the light produced by a laser which makes it different from the light produced by a filament lamp.

property 1.....

.....

.....

property 2.....

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.....

(3 marks)

- (b) An endoscope may use light from a filament lamp and light from a laser.

State

- (i) the use of the light from a filament lamp,

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.....

- (ii) a use of the light from a laser.

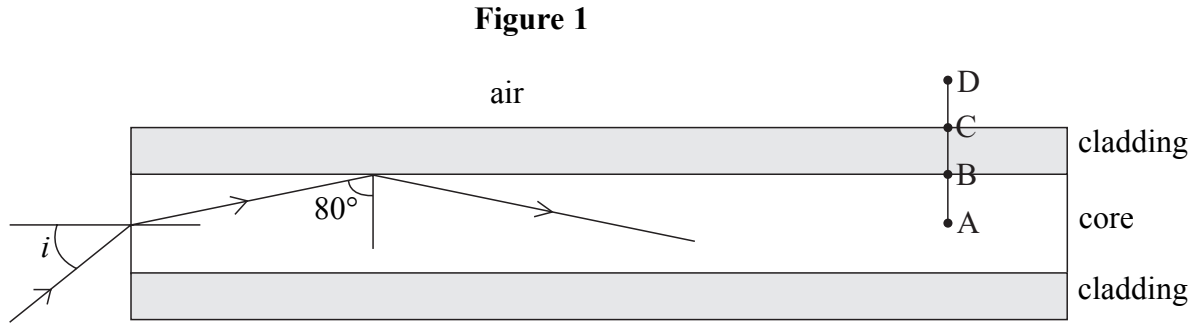
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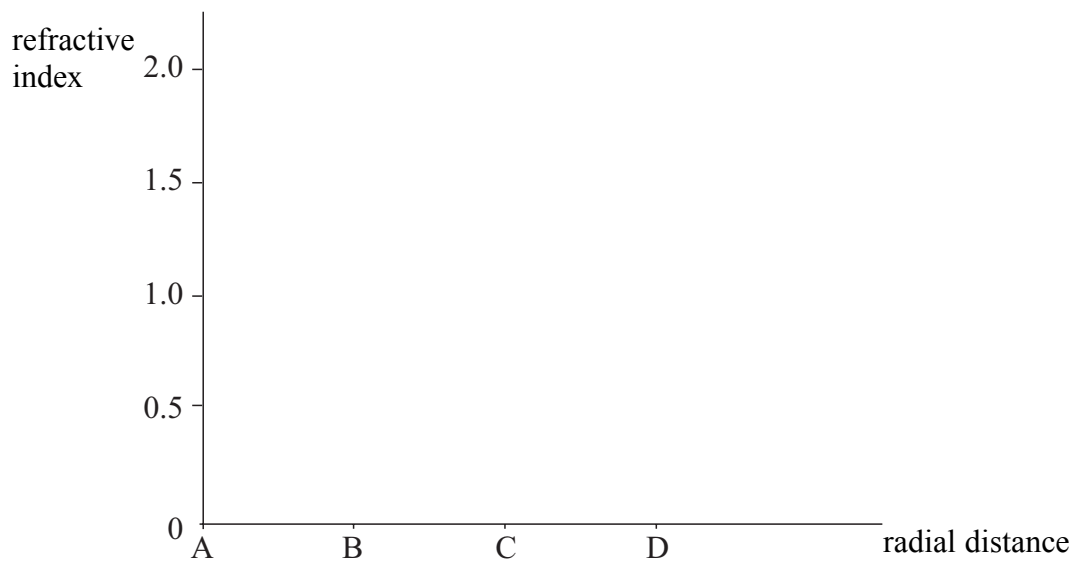
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(2 marks)

- (c) **Figure 1** shows a cross-section through an optical fibre used in an endoscope. The core is made from glass of refractive index 1.5.



- (i) Complete the graph below to show how the refractive index changes with radial distance along the line ABCD in **Figure 1**.



- (ii) Calculate the value of the angle of incidence, i , shown in **Figure 1**.

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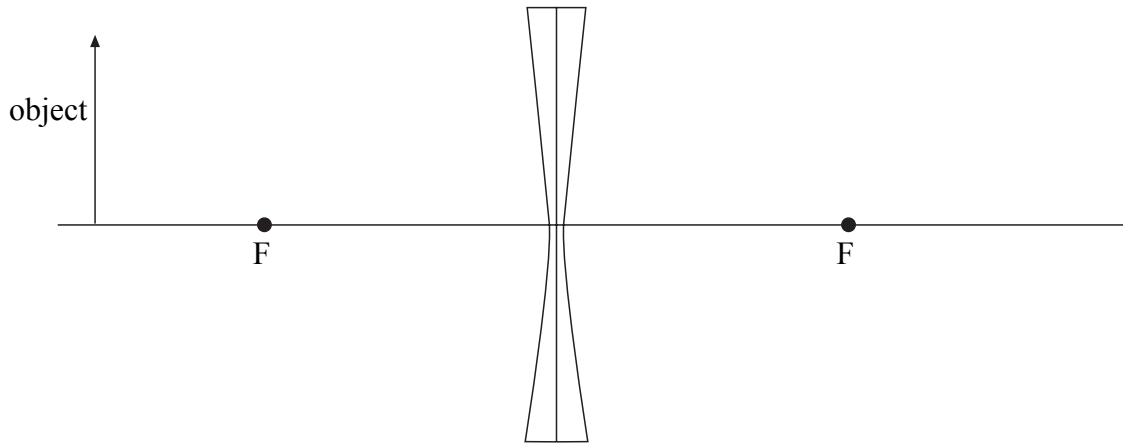
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(4 marks)

- 3 (a) The diverging lens in **Figure 2** forms an image of the object. Complete **Figure 2** by drawing a ray diagram to show the formation of the image. Label the image.

Figure 2



(2 marks)

- (b) A diverging spectacle lens of power -3.0 D is used to correct a defect of vision. When used to view a real object, the image is formed 0.21 m from the lens.

- (i) State the defect of vision.

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- (ii) Calculate the distance of the object from the lens.

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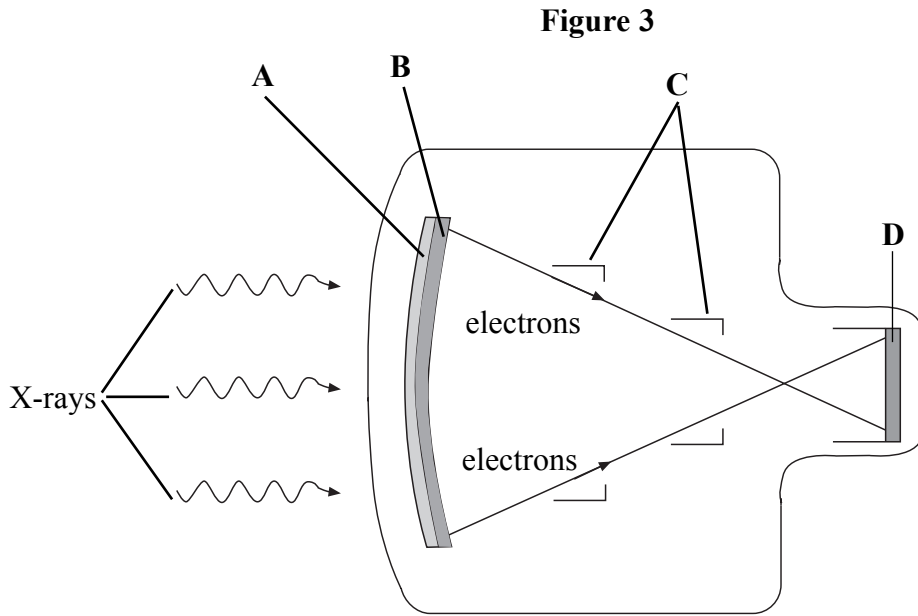
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(3 marks)

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| 5 |
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4 **Figure 3** shows the design of an X-ray image intensifier.



The main components are labelled **A** to **D**. Name each component and state its purpose in the process of image intensification.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

A.....

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B.....

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C.....

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D.....

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(8 marks)

5 (i) State the **two** physical properties of a material which determine its acoustic impedance.

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(ii) Under what condition is ultrasound strongly reflected at a boundary between two types of material?

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(iii) State where a coupling medium or gel is used in an ultrasound scan and explain why it is necessary.

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(6 marks)

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| 6 |

Quality of Written Communication (2 marks)

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| |
| 2 |

END OF QUESTIONS