Surname		Other Names	
Centre Number			Candidate Number				
Candidate Signature									

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General Certificate of Education
June 2004
Advanced Subsidiary Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

PHYSICS (SPECIFICATION B) PHB2
Unit 2 Waves and Nuclear Physics

Monday 14 June 2004 Afternoon Session

In addition to this paper you will require:
- a calculator;
- a ruler.

Time allowed: 1 hour 30 minutes

Instructions
- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions in **Section A** and **Section B** in the spaces provided.
- Do all rough work in this book. Cross through any work you do not want marked.
- All working must be shown, otherwise you may lose marks.
- A *Formulae Sheet* is provided on page 3. Detach this perforated page at the start of the examination.

Information
- The maximum mark for this paper is 75.
- Mark allocations are shown in brackets.
- Marks are awarded for units in addition to correct numerical answers, and for the use of appropriate numbers of significant figures.
- You are expected to use a calculator where appropriate.
- You will be assessed on your ability to use an appropriate form and style of writing, to organise relevant information clearly and coherently, and to use specialist vocabulary where appropriate.
- The degree of legibility of your handwriting and the level of accuracy of your spelling, punctuation and grammar will also be taken into account.

Advice
- You are advised to spend about 30 minutes on **Section A** and about 1 hour on **Section B**.

For Examiner's Use			
Number	Mark	Number	Mark
A			
6			
7			
8			
9			
10			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

Section A

Answer **all** questions in this section

There are 25 marks in this section

1 **Figure 1** shows the wavefronts of a progressive wave from an earthquake passing from the Earth's mantle into its core.

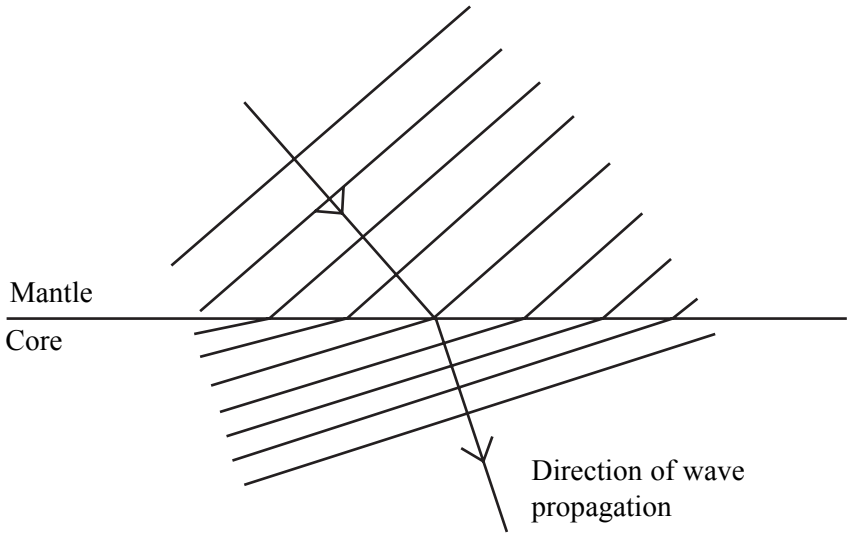

Figure 1

(a) State the name of the phenomenon which occurs at the mantle-core boundary.

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(1 mark)

(b) State how the speed of the wave changes as it crosses the boundary. With reference to **Figure 1**, explain your answer.

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(2 marks)

Detach this perforated page at the start of the examination.

Foundation Physics Mechanics Formulae

moment of force $= Fd$

$v = u + at$

$s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

$s = \frac{1}{2}(u + v)t$

for a spring, $F = k\Delta l$

energy stored in a spring $= \frac{1}{2}F\Delta l = \frac{1}{2}k(\Delta l)^2$

$T = \frac{1}{f}$

Foundation Physics Electricity Formulae

$I = nAvq$

terminal p.d. $= E - Ir$

in series circuit, $R = R_1 + R_2 + R_3 + ...$

in parallel circuit, $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$

output voltage across $R_1 = \left(\frac{R_1}{R_1 + R_2}\right) \times$ input voltage

Waves and Nuclear Physics Formulae

fringe spacing $= \frac{\lambda D}{d}$

single slit diffraction minimum $\sin\theta = \frac{\lambda}{b}$

diffraction grating $n\lambda = d\sin\theta$

Doppler shift $\frac{\Delta f}{f} = \frac{v}{c}$ for $v << c$

Hubble law $v = Hd$

radioactive decay $A = \lambda N$

Properties of Quarks

Type of quark	Charge	Baryon number
up u	$+\frac{2}{3}e$	$+\frac{1}{3}$
down d	$-\frac{1}{3}e$	$+\frac{1}{3}$
$\overline{\text{u}}$	$-\frac{2}{3}e$	$-\frac{1}{3}$
$\overline{\text{d}}$	$+\frac{1}{3}e$	$-\frac{1}{3}$

Lepton Numbers

Particle	Lepton number L		
	L_e	L_μ	L_τ
e^-	1		
e^+	−1		
ν_e	1		
$\overline{\nu}_e$	−1		
μ^-		1	
μ^+		−1	
ν_μ		1	
$\overline{\nu}_\mu$		−1	
τ^-			1
τ^+			−1
ν_τ			1
$\overline{\nu}_\tau$			−1

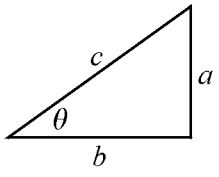
Geometrical and Trigonometrical Relationships

circumference of circle $= 2\pi r$

area of a circle $= \pi r^2$

surface area of sphere $= 4\pi r^2$

volume of sphere $= \frac{4}{3}\pi r^3$



$\sin\theta = \frac{a}{c}$

$\cos\theta = \frac{b}{c}$

$\tan\theta = \frac{a}{b}$

$c^2 = a^2 + b^2$

Turn over ▶

NO QUESTIONS APPEAR ON THIS PAGE

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(c) Suggest how the answer to part (b) supports the theory that the Earth's core is mainly liquid metal and the mantle mostly solid rock.

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(1 mark)

2 (a) With the aid of a clearly labelled diagram explain how a sound wave in air transmits energy away from its source.

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(3 marks)

(b) Unlike sound waves, transverse waves can be *polarised*. Give **one** example of a transverse wave and draw a diagram to show how it can be plane polarised. State a method of polarising a wave of the type you have chosen.

Example transverse wave.....

Method of polarisation.....

(3 marks)

3 Electron capture may occur inside a radioactive atom to stabilise its nucleus. The electron combines with a proton to form a neutron.

(a) Complete the equation below for electron capture in argon-37.

$$^{37}_{18}\mathrm{Ar} + {}^{\cdots\cdots}_{\cdots\cdots}\mathrm{e} \rightarrow {}^{\cdots\cdots}_{\cdots\cdots}\mathrm{Cl} + \cdots\cdots$$

(3 marks)

(b) How does the quark substructure of the neutron compare with that of the proton?

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(3 marks)

4 (a) State the conditions necessary for a stationary wave to be produced.

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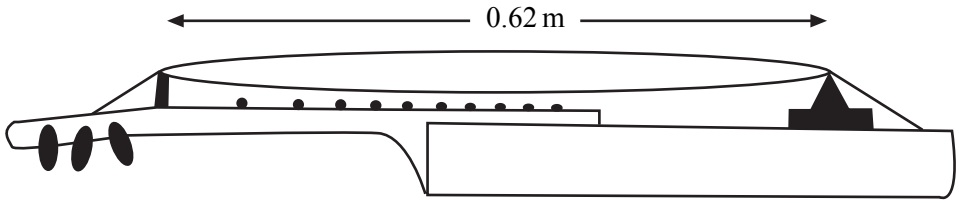
(3 marks)

(b) **Figure 2** shows a stationary wave on a stretched guitar string of length 0.62 m.



Not to scale

Figure 2

The speed of transverse waves along the string is 320 m s^{-1}. Calculate the frequency of the note being played.

Frequency…….

(3 marks)

5 Fill in the blanks in the following table which shows some of the characteristics of several types of electromagnetic radiation.

Radiation type	**Typical wavelength in air/ m**	**Radiation source**
Radio waves	1.5×10^{3}	High frequency alternating current
	5.0×10^{-4}	Hot bodies
Visible light		Excited atoms
	5.0×10^{-13}	

(3 marks)

25

Turn over ▶

SECTION B

Answer **all** questions in the spaces provided

Total for this question: *11 marks*

6 Iodine-123 is a radioisotope used medically as a tracer to monitor thyroid and kidney functions. The decay of an iodine-123 nucleus produces a gamma ray which, when emitted from inside the body of a patient, can be detected externally.

(a) Why are gamma rays the most suitable type of nuclear radiation for this application?

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(2 marks)

(b) In a laboratory experiment on a sample of iodine-123 the following data were collected.

time/h	0	4	8	12	16	20	24	28	32
count-rate /counts s^{-1}	512	410	338	279	217	191	143	119	91

Why was it unnecessary to correct these values for background radiation?

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(2 marks)

(c) On the axes provided in **Figure 3**, complete the graph of count-rate against time. *(2 marks)*

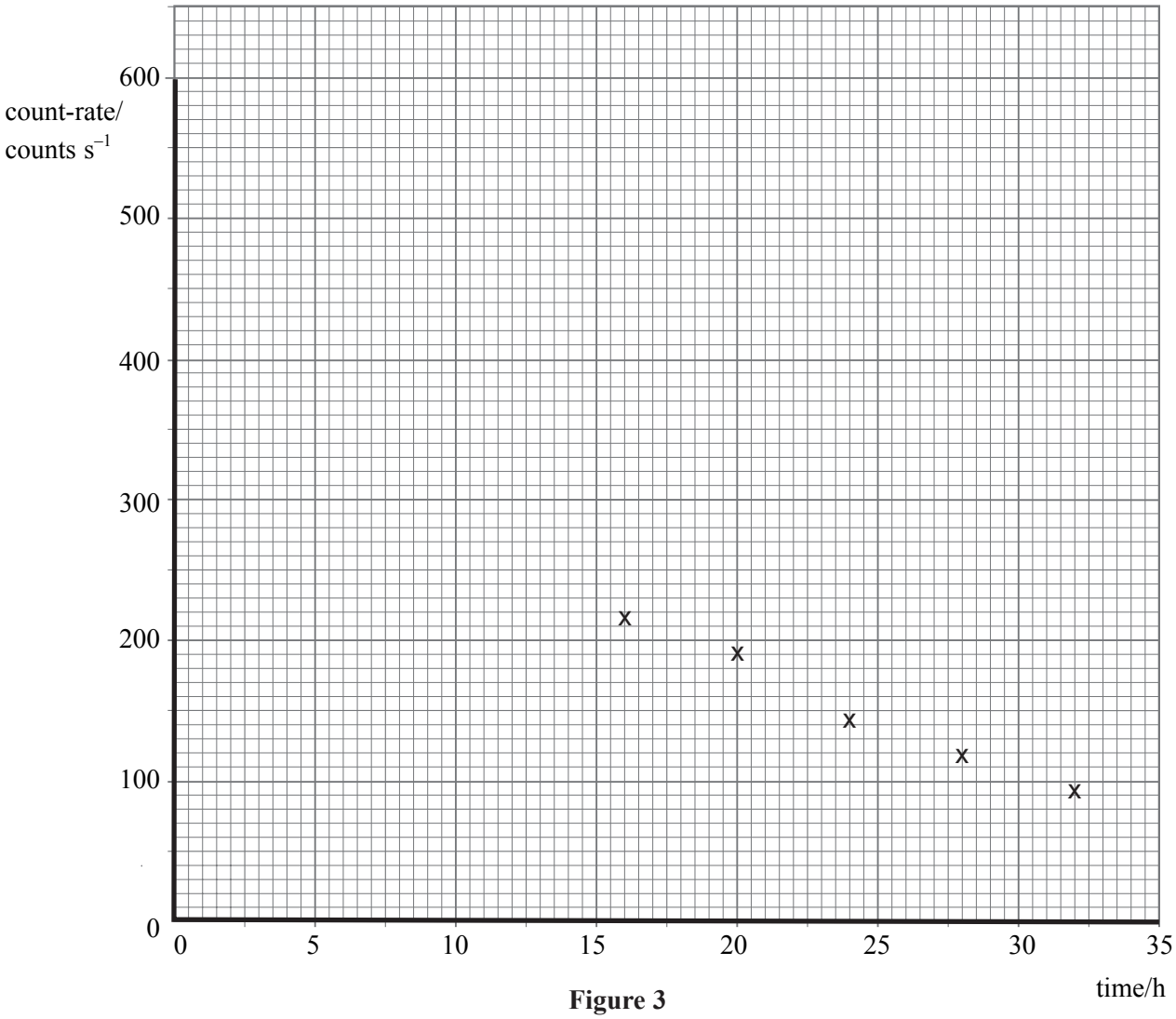

Figure 3

(d) Use your graph to find an accurate value for the half-life of iodine-123.
Show clearly the method you use.

Half-life……..
(3 marks)

(e) Give **two** reasons why radioisotopes with short half-lives are particularly suitable for use as a medical tracer.

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(2 marks)

11

Turn over ▶

Total for this question: *14 marks*

7 It is believed that the Universe is expanding with the galaxies receding from each other. **Figure 4** shows some of the experimental data which support Hubble's Law. Each point on the scatter diagram represents a galaxy: v is the recession speed of a galaxy and d is its distance from Earth.

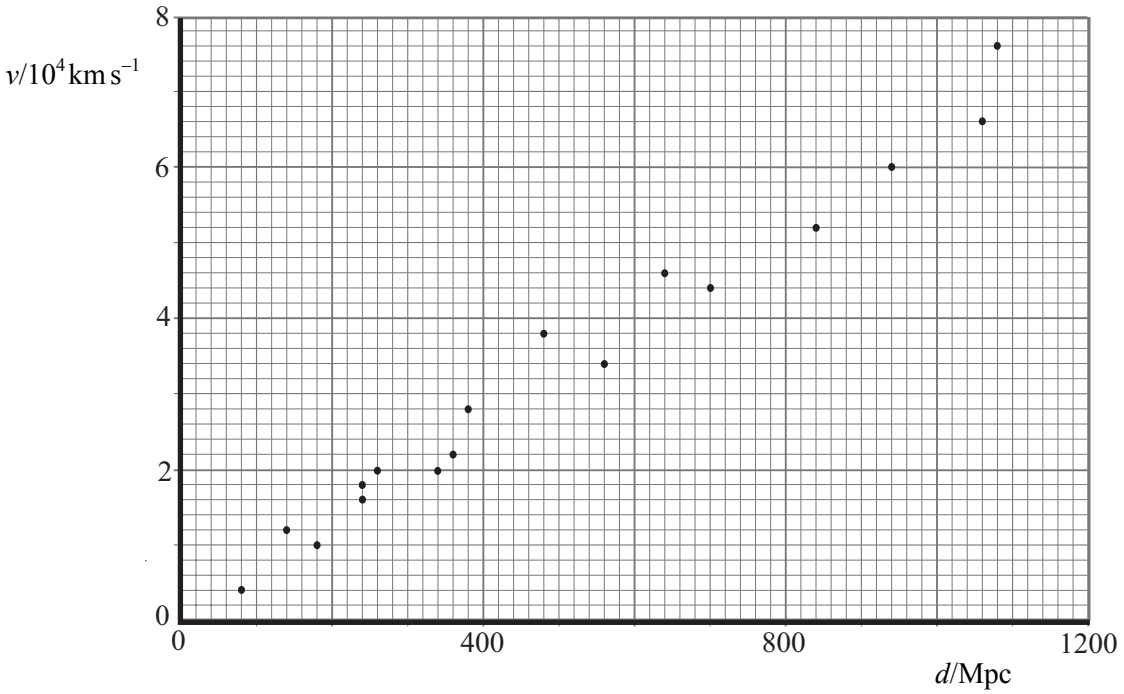

Figure 4

(a) Use the data in **Figure 4** to show that the Hubble constant H is about 65 km s^{-1} Mpc^{-1}.

(3 marks)

(b) A galaxy which can be seen in the constellation of Ursa Major has a recession speed of 17 000 km s^{-1}. **Calculate** its distance from Earth in Mpc.

Distance from Earth…….Mpc
(2 marks)

(c) An estimate for the age of the Universe can be found by assuming that recession speeds have been constant since the Big Bang. The age, *T*, of the Universe is given by the time it has taken for a given galaxy, travelling at speed *v*, to recede a distance *d* from ours. Hence

$$T = \frac{d}{v} = \frac{1}{H}$$

Use the above equation to estimate the age of the Universe in years.

1 light-year $= 9.5 \times 10^{15}$ m
1 pc $= 3.3$ light-years
1 year $= 3.2 \times 10^{7}$ s

Age of the universe……..years
(3 marks)

(d) The recession speed of a galaxy can be measured by comparing its emission spectral lines with those from an equivalent light source on Earth. Explain why this comparison enables the recession speed to be calculated and describe how the measurements are used to find the recession speed.

Two of the 6 marks in this question are for the quality of your written communication.

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(6 marks)

14

Total for this question: *10 marks*

8 (a) On the axes provided in **Figure 5** carefully sketch a graph showing the variation of light intensity in the diffraction pattern produced when parallel light of wavelength λ is incident on a narrow slit of width b. *(3 marks)*

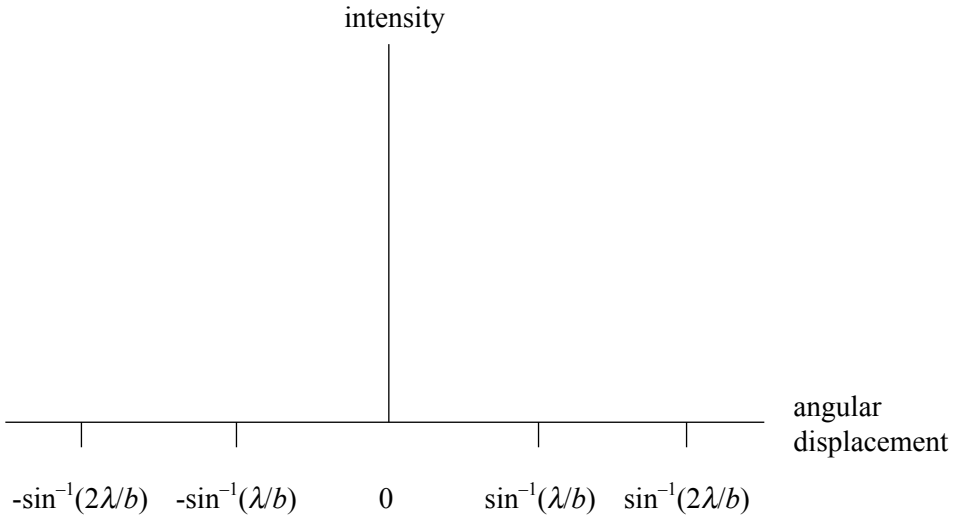

Figure 5

(b) Monochromatic parallel light is incident on a single slit of width 0.30 mm. The resulting diffraction pattern has a first minimum at a diffraction angle of 0.12°. Show that the wavelength of the light is about 6.3×10^{-7} m.

(2 marks)

QUESTION 8 CONTINUES ON THE NEXT PAGE

(c) The slit in part (b) is replaced by a diffraction grating with 5.00×10^5 lines m^{-1}. The light source is unchanged.

(i) Calculate the diffraction angle for the **second order** maximum.

Diffraction angle .....

(3 marks)

(ii) State **two** differences between the new diffraction pattern and that seen in part (b).

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(2 marks)

10

Total for this question: ***7 marks***

9 By the end of this year it is expected that 85% of the population of the United Kingdom will be able to receive Digital Audio Broadcasts (DAB).

(a) The base bandwidth of these broadcasts depends on the frequency response of the human ear.

(i) State the normal frequency range for human hearing.

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(1 mark)

(ii) State the highest frequency that has to be transmitted for high-fidelity broadcasting of an orchestral concert.

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(1 mark)

(b) Before it can be broadcast in digital form the output from a microphone has to be *sampled*.

(i) Explain the term *sampling* and sketch a graph to show the conversion of the microphone output voltage into digital form.

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(2 marks)

(ii) What would be the minimum sampling frequency for the broadcast referred to in part (a)(ii)?

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(1 mark)

(c) State **two** advantages of DAB compared with FM and AM audio broadcasting.

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(2 marks)

7

Total for this question: *8 marks*

10 By the end of twentieth century several hundred subatomic particles had been observed in experiments using particle accelerators and bubble chambers. Write an account of the *classification* of these particles. Your answer should include references to fundamental particles and stability.

Two of the 8 marks for this question are for the quality of your written communication.

(8 marks)

8

END OF QUESTIONS