Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
January 2004
Advanced Subsidiary Examination

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

Monday 12 January 2004 Morning 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.
- 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.
- 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			
8			
9			
10			
11			
12			
13			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

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SECTION A

Answer **all** questions in this section.

There are **25** marks in this section.

1 **Figures 1a and 1b** each show a ray of light incident on a water-air boundary. **A**, **B**, **C** and **D** show ray directions at the interface.

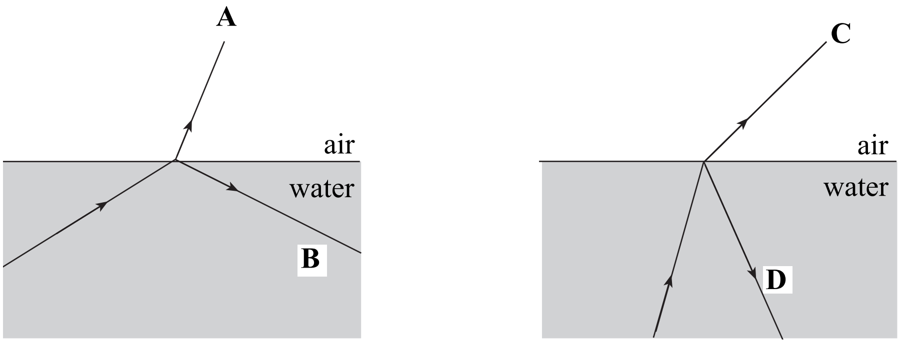


Figure 1a **Figure 1b**

(a) Circle the letter below that corresponds to a direction in which a ray **cannot** occur.

A **B** **C** **D**

(1 mark)

(b) Circle the letter below that corresponds to the direction of the faintest ray.

A **B** **C** **D**

(1 mark)

2 (a) State the quark substructure of a neutron.

....

(2 marks)

(b) Circle the terms below that can be used to describe a neutron.

antiparticle **baryon** **fundamental particle** **hadron** **lepton** **meson**

(2 marks)

3 State **two** factors that affect the fundamental frequency of a vibrating stretched string.

Factor 1 ....

Factor 2 ....

(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 $= \frac{1}{2}F\Delta l = \frac{1}{2}k(\Delta l)^2$

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

Foundation Physics Electricity Formulae

$I = nAvq$

terminal p.d. $= E - Ir$

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

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

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

Waves and Nuclear Physics Formulae

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

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

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

Doppler shift $\dfrac{\Delta f}{f} = \dfrac{v}{c}$ 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	$-\frac{1}{3}e$	$+\frac{1}{3}$
$\overline{u}$	$-\frac{2}{3}e$	$-\frac{1}{3}$
$\overline{d}$	$+\frac{1}{3}e$	$-\frac{1}{3}$

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

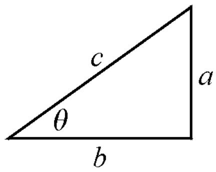
Geometrical and Trigonometrical Relationships

circumference of circle $= 2\pi r$

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

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

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



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

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

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

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

4 A square metre of the Moon's surface that is perpendicular to sunlight receives 1.4 kJ of energy every second from the Sun. Estimate the total energy radiated by the Sun every second assuming that the Sun acts as a point source.

mean distance of the Moon from the Sun = 1.5×10^{11} m

Total energy radiated ....

(3 marks)

5 Thallium (Tl) decays to a stable form of lead (Pb) with the emission of a β^- particle. Complete the equation below for this decay.

$$^{208}_{\cdots\cdots}\mathrm{Tl} \rightarrow\ ^{\cdots\cdots}_{82}\mathrm{Pb} +\ ^{\cdots\cdots}_{\cdots\cdots}\beta^- + \cdots\cdots$$

(3 marks)

6 (a) (i) State the difference between the appearance of a continuous emission spectrum and that of a line emission spectrum.

....

....

(1 mark)

(ii) State **one** laboratory source of a continuous spectrum.

....

....

(1 mark)

(b) The spectrum of the Sun consists of a continuous spectrum crossed by dark lines. State the name for this type of spectrum and explain how the dark lines arise.

Spectrum name ....

Explanation ....

....

....

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(3 marks)

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7 **Figure 2** shows an arrangement used to demonstrate the interference of sound waves. The two loudspeakers act as *coherent sources* of sound.

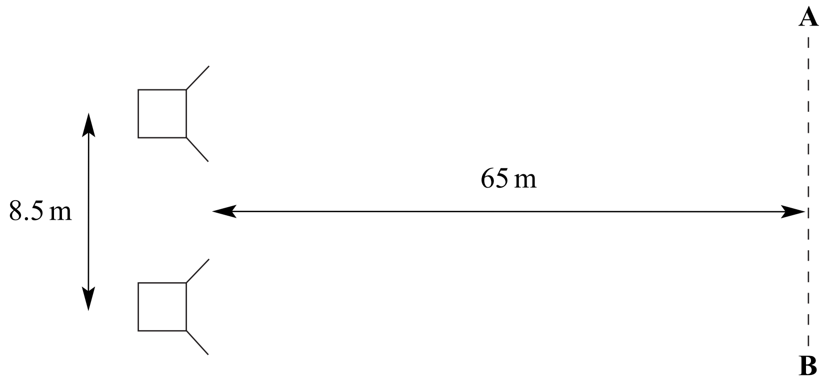

Figure 2

(a) Explain what is meant by the term *coherent sources*.

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(2 marks)

(b) In **Figure 2**, the loudspeakers are separated by 8.5 m and are emitting sound of wavelength 0.77 m. When a sound engineer walks along the line **AB**, 65 m from the loudspeakers, he observes a regular rise and fall in the sound intensity.

(i) Explain this observation.

....

....

....

(2 marks)

(ii) Calculate the distance moved along **AB** between two consecutive maxima of sound.

Distance moved ....

(2 marks)

25

SECTION B

Answer **all** questions in this section.

There are **50** marks in this section.

Total for this question: *5 marks*

8 **Figure 3** shows a hammer being struck against the end of a horizontal metal rod. A pulse of sound travels along the rod from where the hammer strikes it to the far end and back again. The sound pulse throws the hammer and rod apart when it returns. An electrical timing circuit measures the time for which the hammer and the rod are in contact.

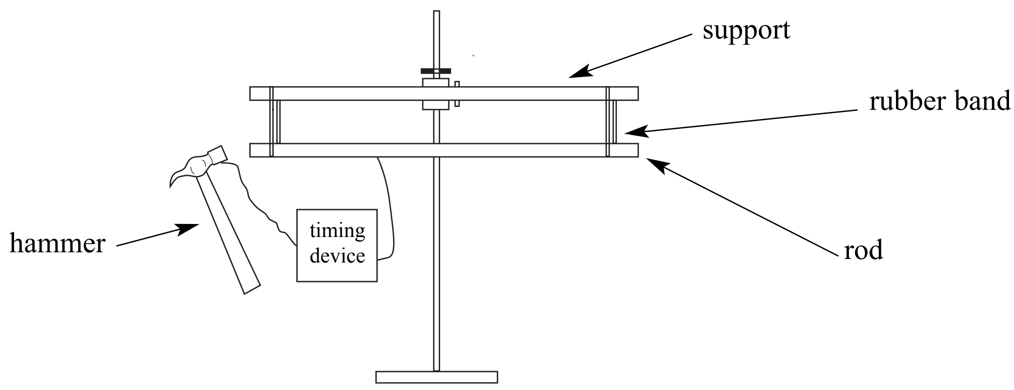

Figure 3

(a) Circle the word below that describes the type of wave that travels along the rod.

transverse **longitudinal**

(1 mark)

(b) State the name of the effect that causes the sound pulse to return to the hammer.

....

(1 mark)

(c) The rod is 0.45 m long and the time for which the hammer is in contact with the rod is 1.6×10^{-4} s. Calculate the speed of sound in the rod.

Speed of sound ....

(3 marks)

5

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Total for this question: ***9 marks***

9 (a) State and explain the benefits and drawbacks of X-rays compared with other technologies when used for medical diagnosis.

Two of the 7 marks in this question are available for the quality of your written communication.

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(7 marks)

(b) (i) State a medical diagnostic technique that overcomes **one** of the limitations of X-rays that you mentioned.

Diagnostic technique ....

(1 mark)

(ii) Explain how the diagnostic technique you stated in part (b)(i) overcomes the limitation of X-rays.

....

....

(1 mark)

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9

TURN OVER FOR THE NEXT QUESTION

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Total for this question: *6 marks*

10 **Figure 4** shows a graph of the number of radioactive nuclei remaining in a sample of material against time. The radioactive isotope decays to a non-radioactive element.

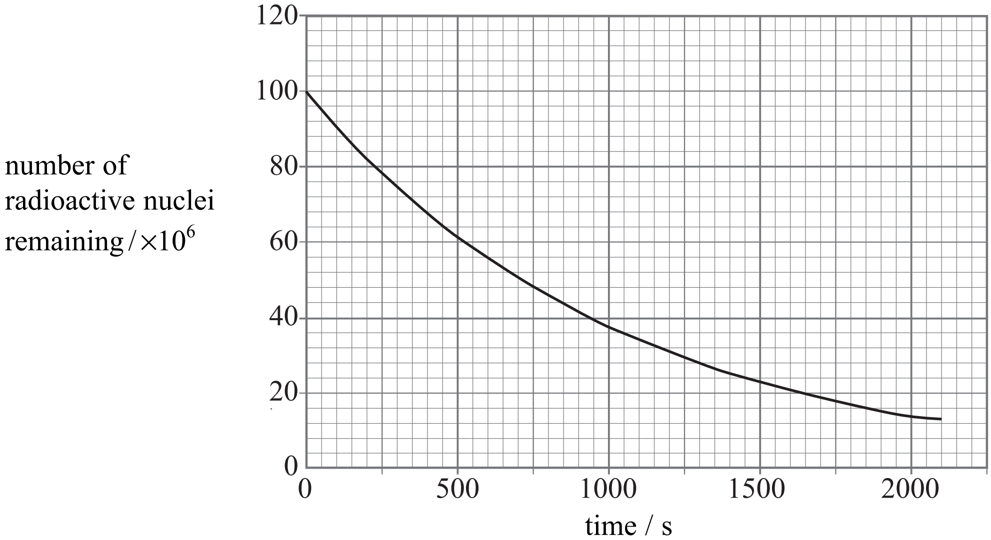

Figure 4

(a) Use the graph to show that, after a time of 500 s, about 6×10^4 nuclei are decaying every second.

(3 marks)

(b) Calculate the decay probability (decay constant) of a nucleus of the radioactive isotope in the sample.

Decay probability ....

(3 marks)

6

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Total for this question: ***8 marks***

11 A galaxy is 4.5×10^{24} m from the Earth.

(a) Show that this galaxy is likely to be moving at a speed of about 1×10^7 m s^{-1} relative to the Earth.

Hubble constant, $H = 65$ km s^{-1} Mpc^{-1}
1 parsec (pc) $= 3.1 \times 10^{16}$ m

(3 marks)

(b) The galaxy emits light of wavelength 580.0 nm as it moves away from the Earth. This light is observed on the Earth.

(i) Calculate the change in wavelength of this light due to the movement of the galaxy.

[*Hint:* $\Delta\lambda/\lambda = \Delta f/f$]

Speed of light in a vacuum, $c = 3.0 \times 10^8$ m s^{-1}

Change in wavelength ....
(3 marks)

(ii) Calculate the wavelength of the light from the galaxy when observed on the Earth.

Observed wavelength ....
(2 marks)

— 8

Total marks for this question: *8 marks*

12 A white-light source illuminates a diffraction grating that has 6.30×10^5 lines per metre. The light is incident normally on the grating.

(a) Show that adjacent lines in the grating are separated by a distance of about 0.0016 mm.

(1 mark)

(b) **Table 1** shows the diffracting angles measured from the normal for the visible spectral orders using this grating. The angles are given for the red and blue ends of each spectrum.

	First order	**Second order**	**Third order**
red	25.4°	59.0°	not possible
blue	15.0°	31.1°	50.0°

Table 1

(i) Use the value for the first order diffracting angle to calculate the wavelength of the red light.

Wavelength of the red light ....

(3 marks)

(ii) Describe carefully the appearance of the complete diffraction pattern on the screen. You may draw a sketch of the pattern to help your explanation if you choose.

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(4 marks)

8

TURN OVER FOR THE NEXT QUESTION

LEAVE MARGIN BLANK

Total for this question: ***14 marks***

13 **Figure 5** shows the Afristar satellite. Afristar orbits the Earth and is used to broadcast high quality digital signals to parts of Africa. The area over which signals can be received is called the 'footprint' of the satellite.

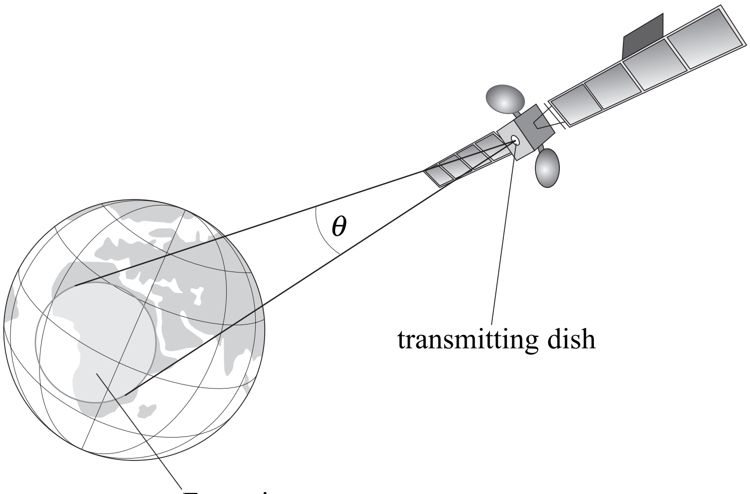

Figure 5

(a) (i) The satellite broadcasts at a frequency of 1.5 GHz. Calculate the wavelength of the transmitted signal.

speed of electromagnetic radiation, $c = 3.0 \times 10^{8}\,\mathrm{m\,s^{-1}}$

Signal wavelength ....

(2 marks)

(ii) The satellite is 36 000 km above the Earth's surface. The footprint of the satellite has an area of radius 3500 km. Calculate the angle, θ, indicated on **Figure 5** over which signals can be detected.

Angle ....

(2 marks)

(iii) Use your answers to part (i) and part (ii) to calculate the maximum diameter of the transmitting dish that is required on the satellite. Assume that the edge of the footprint corresponds to the diffraction minimum.

Diameter of satellite transmitting dish ....

(2 marks)

(iv) The radio signals are transmitted to the satellite from a ground station that also has a satellite dish. The station is 36 000 km from the satellite. Explain why this dish has a larger diameter than the dish on the satellite.

....

....

(1 mark)

QUESTION 13 CONTINUES ON THE NEXT PAGE

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(b) The satellite uses *time division multiplexing* to transmit its multi-channel digital audio services. Explain what is meant by *time division multiplexing* and go on to suggest why the satellite uses this technique.

Two of the 7 marks in this question are available for the quality of your written communication.

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(7 marks)

14

END OF QUESTIONS