Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
January 2003
Advanced Subsidiary Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

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

Monday 13 January 2003 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			
6			
7			
8			
9			
10			
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 **Figure 1** shows a single atomic nucleus that is part of a thin foil. **A**, **B** and **C** are the paths of three α–particles directed at the foil as shown. All three paths are approaching close to the nucleus.

(a) Complete the diagram carefully showing the subsequent paths of the α–particles.

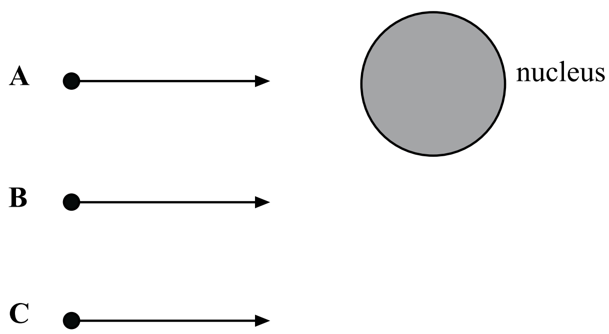

Figure 1

(3 marks)

(b) Suggest **two** pieces of scientific information that can be gained by bombarding matter with particles in this way.

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

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

Foundation Physics Electricity Formulae

$I = nAvq$

terminal p.d. $= E - Ir$

in series circuit, $R = R_1 + R_2 + R_3 + \ldots$

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

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	$-\frac{1}{3}e$	$+\frac{1}{3}$
$\bar{u}$	$-\frac{2}{3}e$	$-\frac{1}{3}$
$\bar{d}$	$+\frac{1}{3}e$	$-\frac{1}{3}$

Lepton Numbers

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

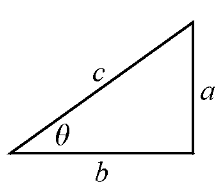
Geometrical and Trigonometrical Relationships

circumference of circle $= 2\pi r$

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

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

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



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

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

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

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

2 The list of sub-atomic particles below contains particles that are either hadrons or leptons:

electron muon neutrino neutron pi-meson proton

(a) Complete the table below by adding the names of the particles to the correct box.

Hadrons	
Leptons	

(4 marks)

(b) Underline the names of the particles that are baryons.

(2 marks)

3 **Figure 2** shows three wavefronts of light directed towards a glass block in the air. The direction of travel of these wavefronts is also shown.

Complete the diagram to show the position of these three wavefronts after partial reflection and refraction at the surface of the glass block.

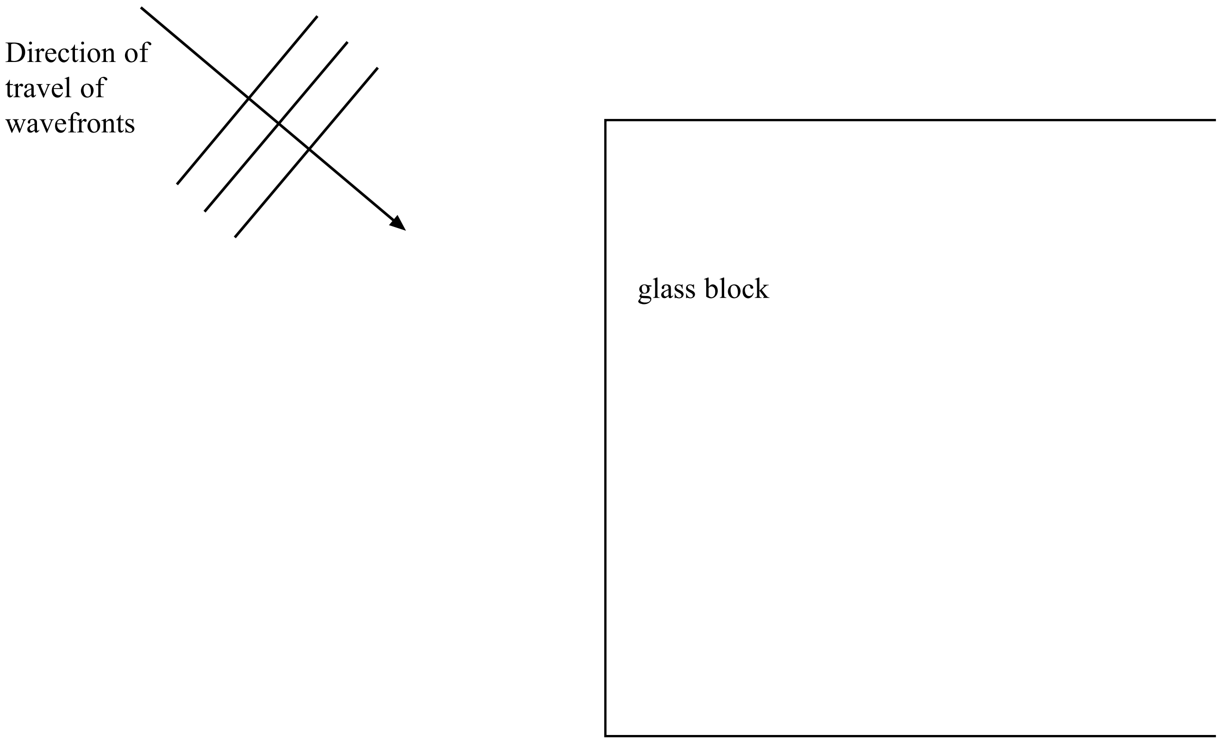


Figure 2

(3 marks)

4 **Figure 3** shows a laboratory ultrasound transmitter emitting ultrasonic waves through two slits placed 0.20 m apart. A receiver, moving along line **AB**, parallel to the line of the slits, detects regular rises and falls in the strength of the signal. A student measures a distance of 0.22 m between the first and the third maxima in the signal when the receiver is 2.5 m from the slits.

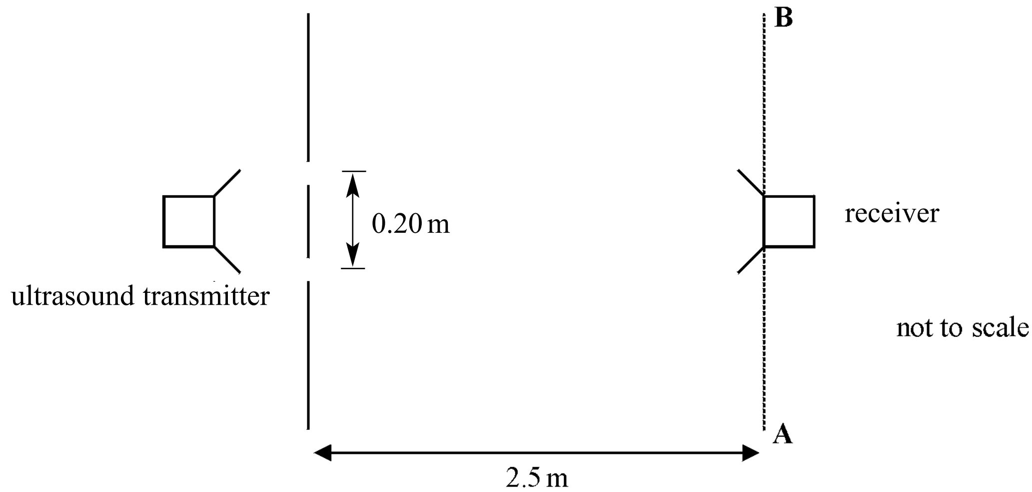


Figure 3

(a) (i) Calculate the distance between successive maxima.

Distance between successive maxima ....
(1 mark)

(ii) Calculate the wavelength of the ultrasonic waves.

Wavelength ....
(2 marks)

(b) One of the slits is now covered. No other changes are made to the experiment.

State the differences between the observations made as the receiver is moved along **AB** before and after this change. Explain the changes that you mention.

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(3 marks)

TURN OVER FOR THE NEXT QUESTION

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5 $^{228}_{90}$Th is a radioactive isotope of thorium.

(a) State for an atom of $^{228}_{90}$Th,

(i) the number of protons in the nucleus,

....

(1 mark)

(ii) the number of neutrons in the nucleus.

....

(1 mark)

(b) A sample of pure $^{228}_{90}$Th that contains 2.6×10^{21} atoms is observed to decay at an initial rate of 3.0×10^{13} Bq.

(i) State the unit of decay probability..

(1 mark)

(ii) Calculate the probability of decay for an atom of $^{228}_{90}$Th.

Probability of decay......................................

(2 marks)

25

SECTION B

Answer all questions in this section.

Total for this question: *11 marks*

6 **Figure 4** shows a stretched string driven by a vibrator. The right-hand end of the string is fixed to a wall. A stationary wave is produced on the string; the string vibrates in two loops.

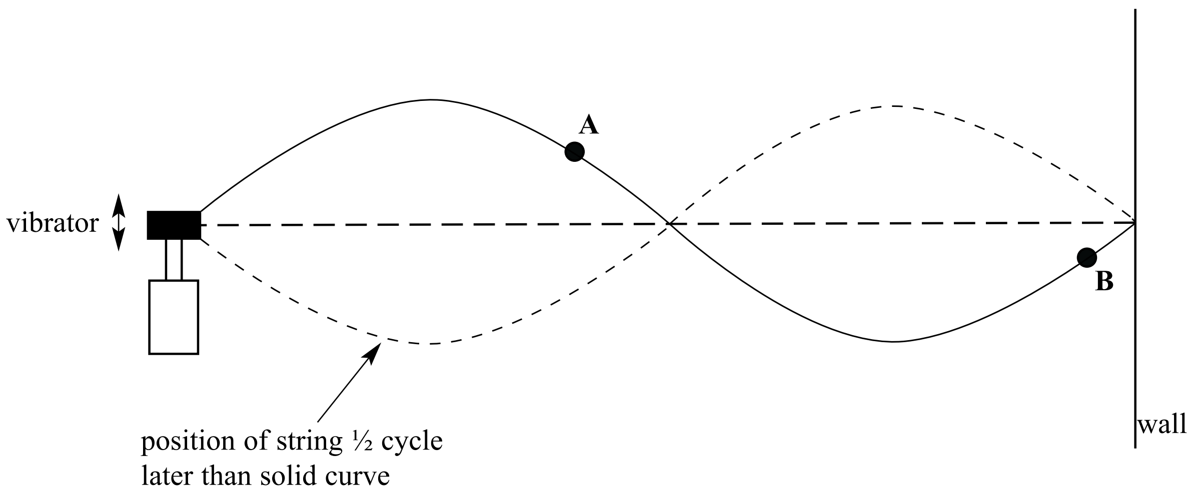

Figure 4

(a) State the physical conditions that are necessary for a stationary wave to form on the string.

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....

(3 marks)

(b) Explain how you know that the wave on the string is transverse.

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(1 mark)

(c) Compare the *amplitude* and *phase* of the oscillations of points **A** and **B** on the string.

Amplitude ....

Phase ....

(2 marks)

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(d) The length of the string is 1.2 m and the speed of the transverse wave on the string is 6.2 m s^{-1}. Calculate the vibration frequency of the vibrator.

Vibration frequency..........................

(3 marks)

(e) The frequency of the vibrator is tripled.

(i) Sketch the new shape of the stationary wave on **Figure 5**.

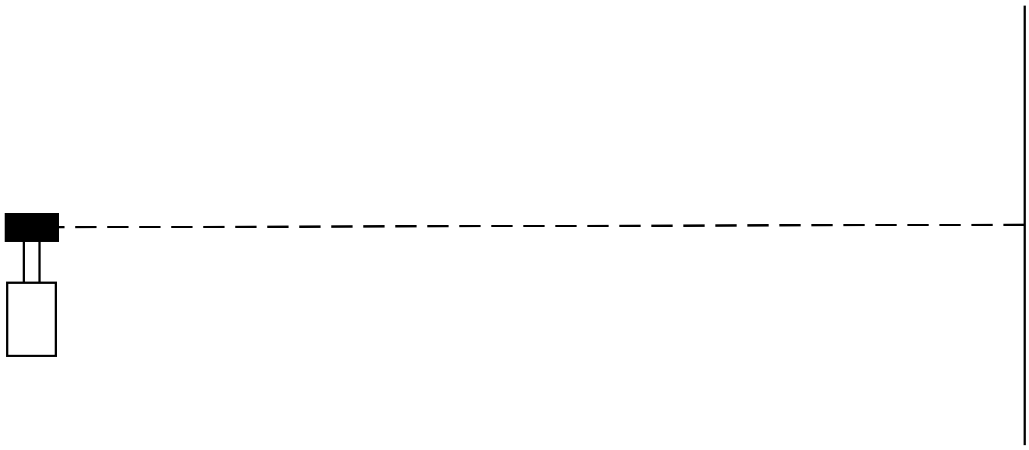

Figure 5

(ii) Show on your diagram three points P, Q and R that oscillate in phase.

(2 marks)

11

Total for this question: *11 marks*

7 A satellite orbiting the Earth receives electromagnetic signals and then re-transmits them back to Earth at a frequency of 2.3 GHz.

(a) Calculate the wavelength of the re-transmitted signal.

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

Wavelength ....

(2 marks)

(b) State the region of the electromagnetic spectrum to which these waves belong.

....

(1 mark)

(c) The satellite's signal is radiated by an antenna that resembles the satellite dishes used to receive television signals on Earth. The antenna dish is 0.60 m in diameter. Show that the angle at which the signal intensity falls to a minimum is about 12°.

(3 marks)

(d) The satellite is positioned 35 000 km from the Earth. The power received by the dish antenna on the Earth is 16 nW.

Calculate the power that would be received at the dish if the satellite were to be re-positioned at a distance of 17 500 km from Earth. Give your reasoning.

Power received ....

(2 marks)

(e) The orbit of the satellite is not perfectly circular. At one moment it has a velocity component of $2.5\,m\,s^{-1}$ towards the receiving antenna. Calculate the frequency shift that will be detected in the receiver on Earth.

Frequency shift ....

(2 marks)

(f) State whether the received frequency will be higher or lower than the transmitted frequency.

....

(1 mark)

$\overline{}$ *11*

TURN OVER FOR THE NEXT QUESTION

Total for this question: *14 marks*

8 Light of wavelength 5.9×10^{-7} m is incident on a diffraction grating (**Figure 6**). The resulting diffraction pattern is viewed on a screen 1.5 m away.

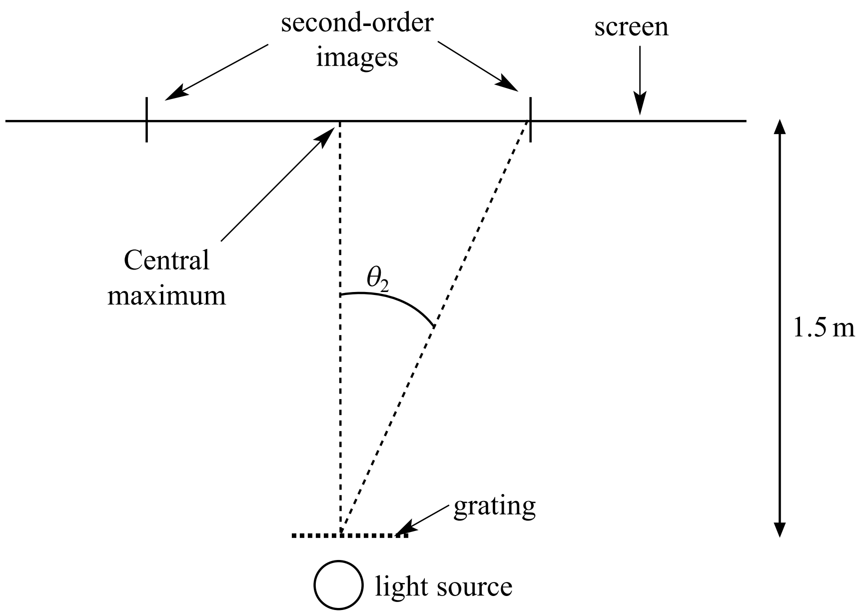

Figure 6

(a) The grating has 5.2×10^5 lines per metre. Calculate the separation between lines on the grating.

Separation ....

(1 mark)

(b) Show that the angle θ_2 at which the second-order image appears is about 38°.

(3 marks)

(c) The grating is 1.5 m away from the screen. Calculate the distance between a third-order diffracted image and the central maximum.

Distance ....

(4 marks)

(d) The light source is replaced with a source of wavelength 4.4×10^{-7} m. Describe and explain what changes will occur in the positions and numbers of the orders visible to the observer. Support your explanation with a calculation where possible.

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

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(6 marks)

14

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

9 Describe an experiment that you would carry out in order to verify that the gamma radiation from a radioactive source obeys the inverse-square law. Include in your account

- a description or labelled diagram of the apparatus
- details of the measurements that you would take
- the analysis of the data that you would carry out.

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

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(7 marks)

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

10 **Figure 7** shows the components of the transmitting stage of a simple audio-communication system prior to the signal being transmitted. The signal path is from left to right.

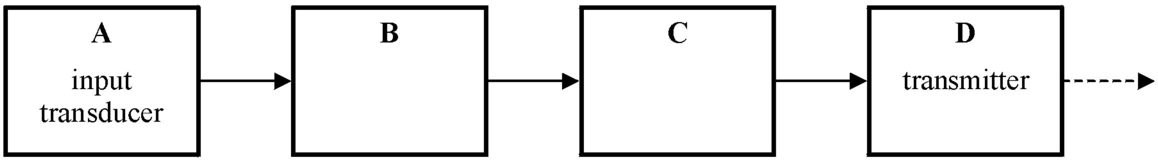

Figure 7

(a) (i) State a suitable transducer for stage **A**.

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(ii) State the name given to stage **B**.

....

(iii) State the name given to stage **C**.

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(3 marks)

(b) Describe and explain the purpose of modulation in a communication system.

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(4 marks)

7

END OF QUESTIONS