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

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General Certificate of Education
June 2006
Advanced Subsidiary Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

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

Friday 9 June 2006 9.00 am to 10.30 am

**For this paper you must have:**
- a calculator
- a ruler

Time allowed: 1 hour 30 minutes

| For Examiner's Use | | | |
|---|---|---|---|
| Number | Mark | Number | Mark |
| A | | 7 | |
| | | 8 | |
| | | 9 | |
| | | 10 | |
| | | 11 | |
| | | 12 | |
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| Total (Column 1) → | | | |
| Total (Column 2) → | | | |
| TOTAL | | | |
| Examiner's Initials | | | |

**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 **Section A** and **Section B** in the spaces provided.
- Show all your working.
- 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.
- The marks for questions are shown in brackets. 4 of these marks will be awarded for the Quality of Written Communication.
- 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 10 and 12 should be answered in continuous prose. Quality of Written Communication will be assessed in these answers.

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

## SECTION A

Answer **all** questions in this section.

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

**1** The following are regions in the electromagnetic spectrum:

**gamma radiation**
**microwave**
**radio**
**visible light**

(a) Name the region with the highest photon energy.

..........................................................................................................................

*(1 mark)*

(b) Place these regions in order of increasing wavelength in the table below.

**increasing wavelength** →

| | | | |
|---|---|---|---|
| | | | |

*(2 marks)*

**2** Ultrasound has a number of uses in medicine and industry.

(a) State **one** medical and **one** industrial use for ultrasound.

medical use ..........................................................................................................

industrial use.........................................................................................................

*(2 marks)*

(b) State and explain whether an ultrasound wave in air can be polarised.

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*(2 marks)*

**Detach this perforated page at the start of the examination.**

## Foundation Physics Mechanics Formulae

moment of force $= Fd$

$$v = u + at$$

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

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

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

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

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

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

## Foundation Physics Electricity Formulae

$$I = nAvq$$

terminal p.d. $= E - Ir$

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

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

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 | $-\frac{1}{3}e$ | $+\frac{1}{3}$ |
| $\overline{\text{u}}$ | $-\frac{2}{3}e$ | $-\frac{1}{3}$ |
| $\overline{\text{d}}$ | $+\frac{1}{3}e$ | $-\frac{1}{3}$ |

### Lepton Numbers

| Particle | Lepton number $L$ | | |
|---|---|---|---|
| | $L_e$ | $L_\mu$ | $L_\tau$ |
| $e^-$ | 1 | | |
| $e^+$ | −1 | | |
| $\nu_e$ | 1 | | |
| $\overline{\nu}_e$ | −1 | | |
| $\mu^-$ | | 1 | |
| $\mu^+$ | | −1 | |
| $\nu_\mu$ | | 1 | |
| $\overline{\nu}_\mu$ | | −1 | |
| $\tau^-$ | | | 1 |
| $\tau^+$ | | | −1 |
| $\nu_\tau$ | | | 1 |
| $\overline{\nu}_\tau$ | | | −1 |

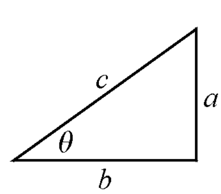
## Geometrical and Trigonometrical Relationships

circumference of circle $= 2\pi r$

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

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

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




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

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

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

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

**There are no questions printed on this page**

**3** A radioactive nucleus decays with the emission of an alpha particle and a gamma-ray photon.

(a) Describe the changes that occur in the proton number and the nucleon number of the nucleus.

proton number ..........................................................................................................

nucleon number ..........................................................................................................

*(2 marks)*

(b) Comment on the relative penetrating powers of the two types of ionizing radiation.

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*(1 mark)*

(c) Gamma rays from a point source are travelling towards a detector. The distance from the source to the detector is changed from 1.0 m to 3.0 m.

Calculate

$$\frac{\text{intensity of radiation at } 3.0\,\text{m}}{\text{intensity of radiation at } 1.0\,\text{m}}$$

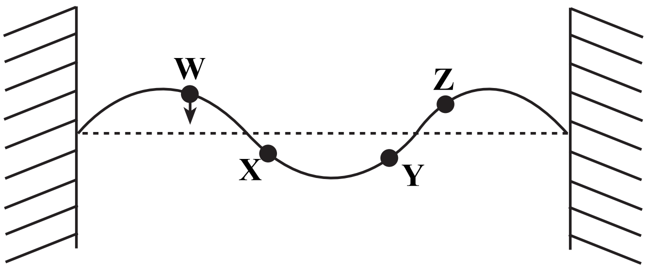
answer ......................................

*(2 marks)*

**Turn over for the next question**

**4** **Figure 1** shows the appearance of a stationary wave on a stretched string at one instant in time. In the position shown each part of the string has its maximum displacement. The arrow at **W** shows the direction in which the point **W** is about to move.

**Figure 1**




(a) (i) Mark clearly on the diagram the directions in which points **X**, **Y** and **Z** are about to move.

(ii) State the conditions necessary for a stationary wave to be produced on the string.

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*(4 marks)*

(b) In **Figure 1**, the frequency of vibration is 120 Hz.
Calculate the frequency of the fundamental vibration for this string.

frequency of the fundamental vibration.................................................

*(2 marks)*

**5** Radio waves are travelling from a transmitter to a detector. A sheet of hardboard is inserted between the detector and the transmitter without either of these being moved. When the hardboard is inserted, the intensity of the wave drops to $\frac{1}{16}$th of its original value.

(a) Calculate

$$\frac{\text{amplitude of detected wave } \textbf{after} \text{ hardboard insertion}}{\text{amplitude of detected wave } \textbf{before} \text{ hardboard insertion}}$$

answer ......................................................

*(2 marks)*

(b) Give **two** reasons for the change in intensity when the hardboard is inserted into the beam.

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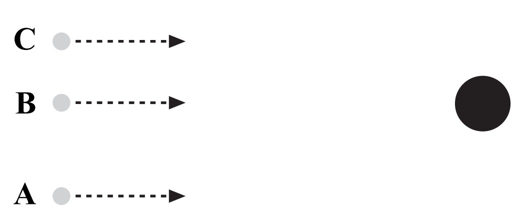
*(2 marks)*

**6** **Figure 2** shows three alpha particles approaching a gold nucleus in an alpha-particle scattering experiment. All three alpha particles have the same initial energy.

**Figure 2**




(a) State which alpha particle will be deviated through the greatest angle.

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*(1 mark)*

(b) Draw on **Figure 2** the path of the alpha particle that is deviated through the smallest angle.

*(2 marks)*

## SECTION B

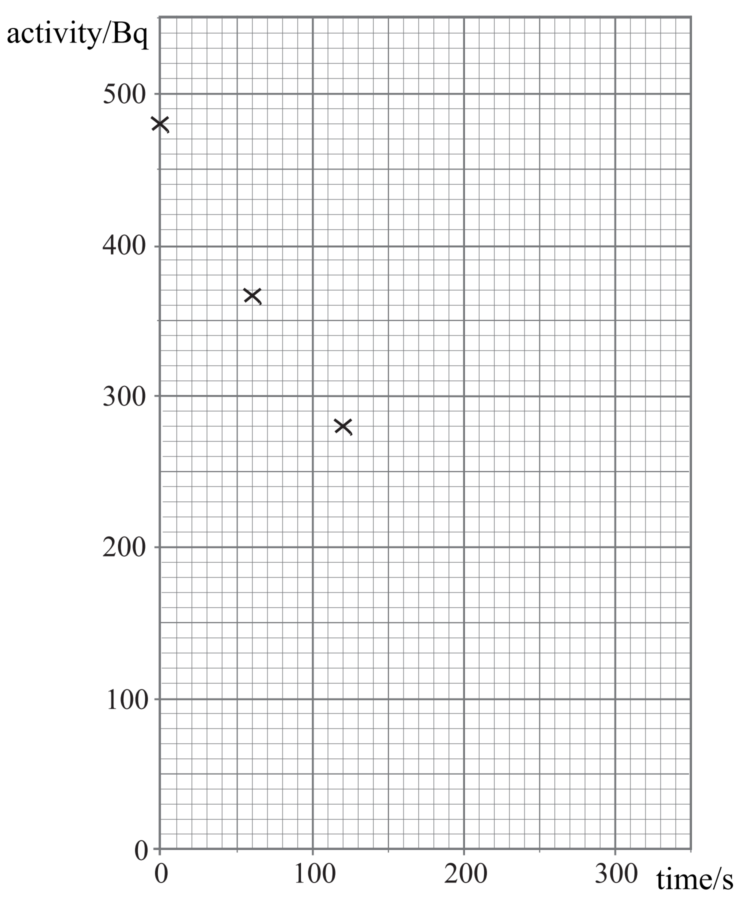
Answer **all** questions in this section.

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

**7** The table below gives the values for the activity of a radioactive isotope over a period of a few minutes.

| **time/s** | 0 | 60 | 120 | 180 | 240 | 300 |
|---|---|---|---|---|---|---|
| **activity/Bq** | 480 | 366 | 280 | 214 | 163 | 124 |

(a) Complete the graph below by plotting the remaining points and drawing an appropriate curve.




*(3 marks)*

(b) Use the graph to determine the half-life of the isotope.

half-life ......................................

*(3 marks)*

(c) Initially there were $1.1 \times 10^5$ atoms of the isotope present.
Calculate the decay probability of the isotope.

decay probability......................................

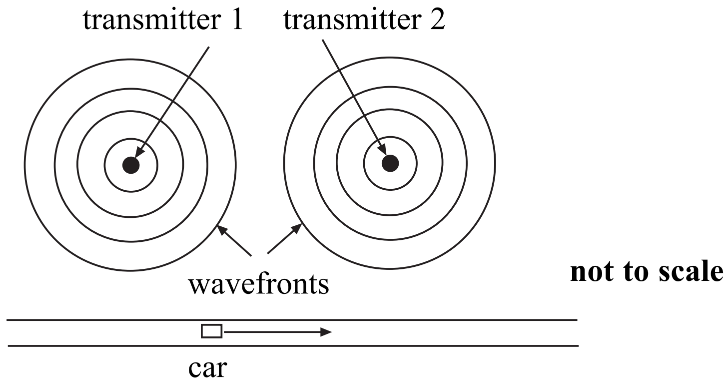
*(2 marks)*

8

**Turn over for the next question**

**8** A motorist is driving along a straight road listening to the radio. His radio is receiving signals from two transmitters both broadcasting the same programme at the same frequency and in phase. The motorist notices that the intensity of the signal varies regularly from a maximum to a minimum and back to a maximum again. **Figure 3** shows the arrangement seen from above.

**Figure 3**




(a) (i) Explain how a maximum of signal intensity occurs. You may draw on **Figure 3** to help your explanation.

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(ii) The distance travelled by the car between successive maxima is 1.7 km and the wavelength of the signals is 0.54 km. The transmitters are both 570 km from the road.

Calculate the distance between the transmitters.

distance between transmitters .............................................

*(4 marks)*

(b) The radio is tuned to a frequency of 560 kHz. The loudspeaker emits a maximum frequency of 8 kHz. Explain the significance of using these frequencies.

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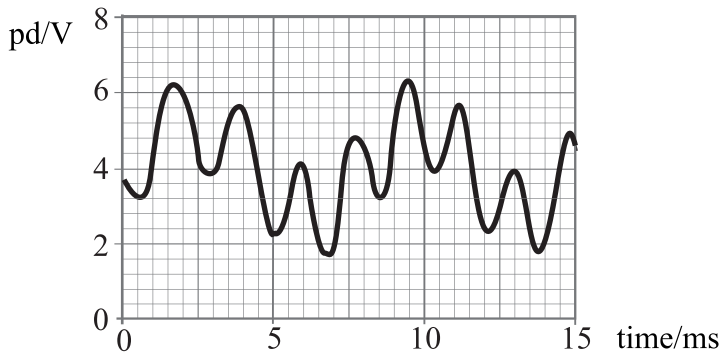
*(2 marks)*

(c) The transmitters emit an analogue signal. An alternative is to transmit the signal in a digital form.
Explain how an analogue signal such as that shown in **Figure 4** may be converted into a digital form.

**Figure 4**

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*(3 marks)*

(d) Several digital channels can be multiplexed at a transmitter.
Explain what is meant by *time division multiplexing*.

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*(3 marks)*

LEAVE MARGIN BLANK

**9** (a) State, in words, the Hubble law.

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*(2 marks)*

(b) A galaxy at a distance of $2.2 \times 10^{21}$ m is observed to be moving at a speed of $4.6 \times 10^{3}\ \text{m s}^{-1}$ relative to the Earth.

Calculate the Hubble constant in $s^{-1}$.

Hubble constant ..................................$s^{-1}$

*(2 marks)*

(c) Calculate the percentage change in the frequency of a spectral line emitted from the galaxy in part (b) when observed on Earth, compared with the same line from a terrestrial source.

speed of light, $c = 3.0 \times 10^{8}\ \text{m s}^{-1}$

percentage change in frequency.......................................%

*(2 marks)*

(d) State **two** properties of a star (other than its motion) that can be deduced from the study of the spectrum of the star.

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*(2 marks)*

8

**10** A free neutron decays into three particles.

State what these particles are, and go on to use the example of neutron decay to help you explain:

- the differences between hadrons and leptons
- the quark model of nuclear structure.

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

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*(7 marks)*

LEAVE MARGIN BLANK

**11** (a) A student stands some distance away from a wall and claps her hands. She listens to the echoes produced by the sound reflected from the wall and adjusts her rate of clapping so that each clap coincides with the echo of the previous clap. A fellow student counts the number of times she claps in 20 s.

(i) There were 47 claps in 20 s.
Calculate the time between two successive claps.

time between two successive claps ......................................

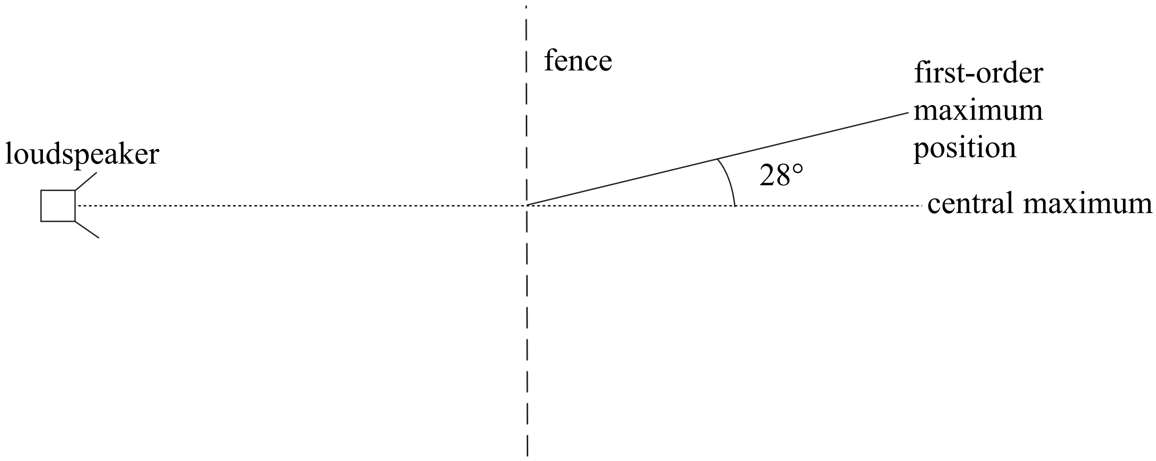
(ii) The speed of sound in the air is $340\,\mathrm{m\,s^{-1}}$.
Calculate the distance of the student from the wall.

distance from wall ...............................................................

*(3 marks)*

(b) The student goes on to carry out a diffraction experiment. She stands on one side of a fence that consists of evenly-spaced wooden strips. The fence behaves as a diffraction grating for sound waves. **Figure 5** shows the arrangement.

**Figure 5**



(i) She uses a loudspeaker to send a sound wave of frequency 2.4 kHz towards the fence.
Calculate the wavelength of this sound wave.

speed of sound in air, $v = 340\,\mathrm{m\,s^{-1}}$

wavelength ................................................

(ii) A diffracted first-order maximum is observed at an angle of 28°.
Calculate the spacing between adjacent wooden strips.

strip spacing ............................................

(iii) Determine the highest order of maximum that could be heard.

highest order ...........................................

*(6 marks)*

LEAVE MARGIN BLANK

**12** Both humans and mice use visible light in order to see. The aperture of a mouse eye is much smaller than that of a human eye, so that the resolutions of the two eyes are different.

State what is meant by resolution and the factors that affect it. Go on to compare, giving physical explanations, the likely resolutions of the eyes of humans and mice.

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

*(6 marks)*

**END OF QUESTIONS**





6