Surname		Other Names	
Centre Number			Candidate Number				
Candidate Signature									

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General Certificate of Education
January 2005
Advanced Subsidiary Examination

AQA
ASSESSMENT and QUALIFICATIONS ALLIANCE

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

Wednesday 12 January 2005 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			
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 (a) State the name of the antiparticle of a positron.

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(1 mark)

(b) Describe what happens when a positron and its antiparticle meet.

.....

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(2 marks)

2 **Figure 1** shows three particles in a medium that is transmitting a sound wave. Particles **A** and **C** are separated by one wavelength and particle **B** is half way between them when no sound is being transmitted.

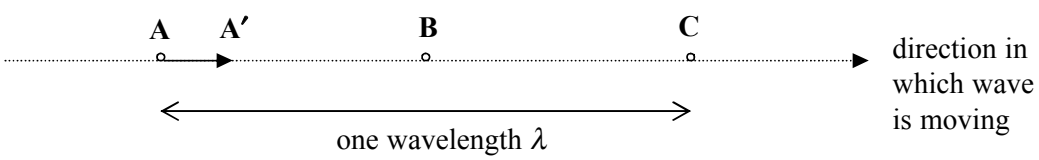

Figure 1

(a) Name the type of wave that is involved in the transmission of this sound.

.....

(1 mark)

(b) At one instant particle **A** is displaced to the point **A′** indicated by the tip of the arrow in **Figure 1**. Show on **Figure 1** the displacements of particles **B** and **C** at the same instant. Label the position **B′** and **C′** respectively. *(1 mark)*

(c) Explain briefly how energy is transmitted in this sound wave.

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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		
υ_e	1		
$\overline{\upsilon}_e$	−1		
μ^-		1	
μ^+		−1	
υ_μ		1	
$\overline{\upsilon}_\mu$		−1	
τ^-			1
τ^+			−1
υ_τ			1
$\overline{\upsilon}_\tau$			−1

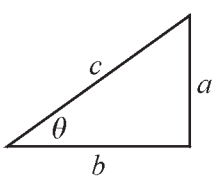
Geometrical and Trigonometrical Relationships

circumference of circle $= 2\pi r$

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

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

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



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

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

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

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

NO QUESTIONS APPEAR ON THIS PAGE

3 **Figure 2** shows an arrangement to investigate stationary (standing) waves on a stretched string.

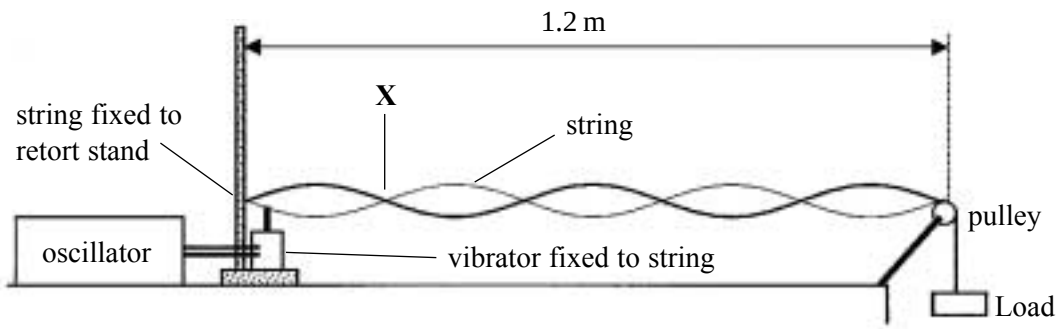


Figure 2

The stationary wave in **Figure 2** appears when the frequency of the oscillator is set at 75 Hz.

(a) State the name given to a point on the stationary wave such as **X** in **Figure 2**.

.....

(1 mark)

(b) Calculate the speed of the wave along the string.

speed of wave.....

(2 marks)

(c) Calculate the frequency that would produce a stationary wave with **two** loops on this string.

frequency.....Hz

(1 mark)

TURN OVER FOR THE NEXT QUESTION

4 Light from a laser has a wavelength of 6.30×10^{-7} m. When the laser light is incident normally on a diffraction grating the first order maximum is produced at an angle of 12°.

(a) Calculate the spacing between the lines on the grating.

spacing of lines .....
(2 marks)

(b) Calculate the number of positions of maximum light intensity that are produced when the laser light is incident on the grating.
Show your reasoning clearly.

number of positions……
(3 marks)

5 Neutrons were discovered when beryllium, ${}^{9}_{4}\text{Be}$, was bombarded with alpha particles.
An alpha particle knocked a neutron out of a beryllium nucleus producing a carbon nucleus, C.

(a) Write down the equation that describes this reaction.

.....
(2 marks)

(b) (i) Describe the quark substructure of a neutron.

.....

.....
(1 mark)

(ii) Describe how the quark substructure of a meson differs from that of a baryon such as a neutron.

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(1 mark)

6 The graph in **Figure 3** shows the results of an investigation of how the visible light intensity I varies with distance d from a filament lamp. The lamp can be assumed to behave as a point source of light.

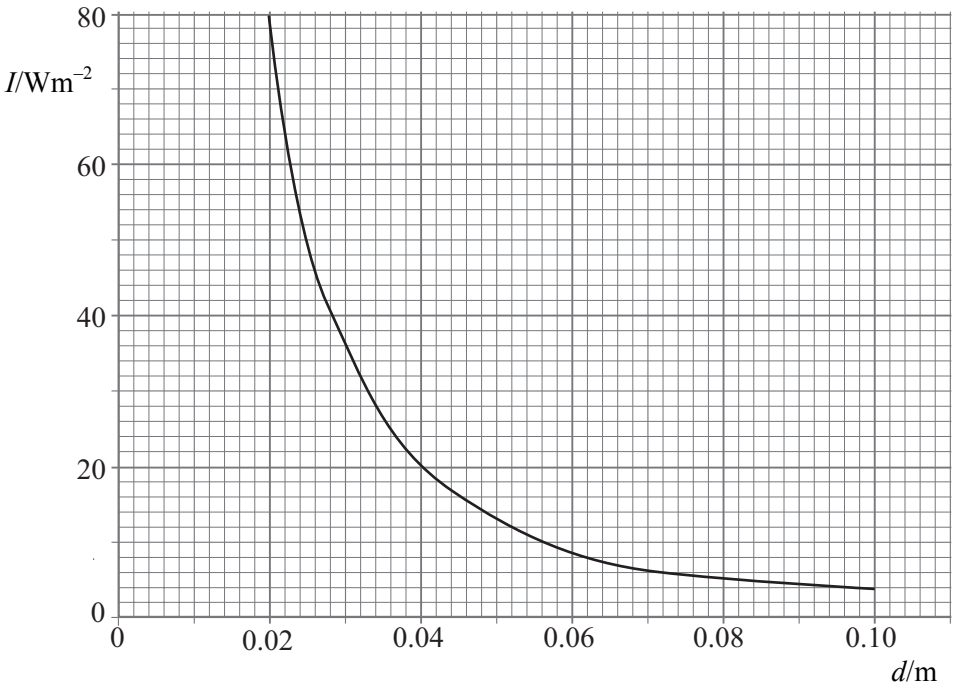

Figure 3

(a) Use data from the graph to show that the visible light intensity varies with distance according to an inverse square law.

(3 marks)

(b) Find the power of the visible light emitted by the filament lamp.

power.....

(2 marks)

25

SECTION B

Answer **all** questions in this section.

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

Total for this question: *13 marks*

7 **Figure 4** shows an arrangement to investigate the interference between microwaves that meet after being reflected from two parallel surfaces.

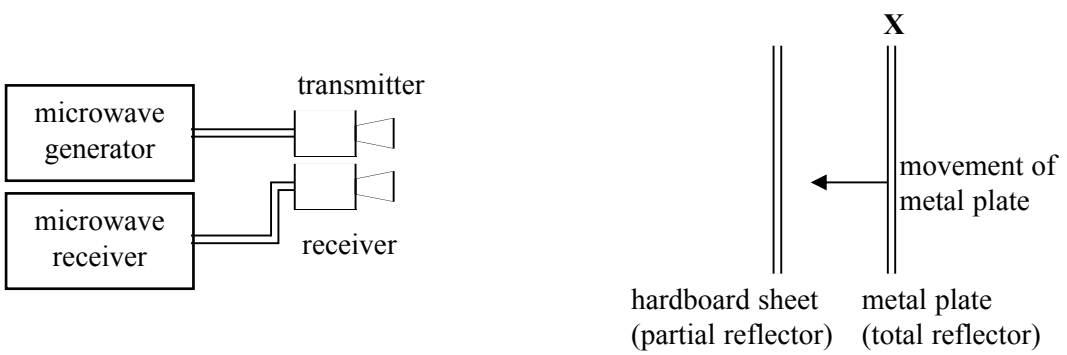

Figure 4

The hardboard sheet reflects some energy while allowing some to pass through it and the metal plate reflects all the energy that falls on it.
As the metal plate is moved toward the hardboard sheet the received signal strength goes through a series of maximum and minimum values.

(a) Explain why the received signal strength is a minimum for certain positions of the metal plate.

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

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(6 marks)

(b) The wavelength of the microwaves used in the experiment is 28 mm. A maximum signal is observed when the metal plate is in position **X**.

(i) Calculate the least distance that the metal plate will have to be moved so that another maximum is observed. Show your reasoning clearly.

least distance……..
(2 marks)

(ii) When the metal plate moves at a constant velocity the received signal strength varies at a constant frequency. Calculate this frequency when the metal plate is moved at 0.50 m s^{-1}.

frequency……
(1 mark)

(c) The apparatus is now arranged as shown in **Figure 5** to investigate diffraction at the transmitter aperture. A maximum is observed at **P** and the signal strength first falls to a minimum at **Q**.

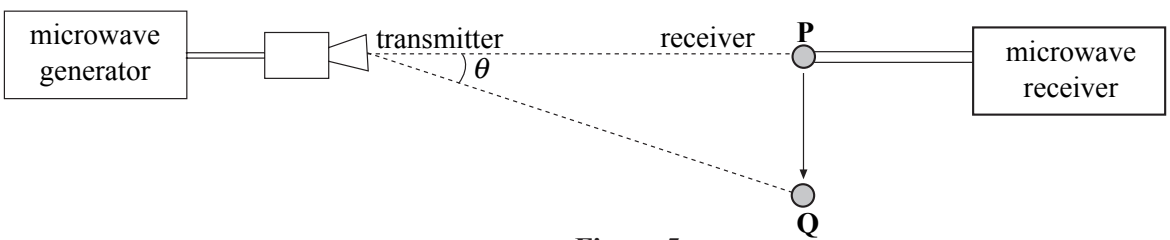

Figure 5

(i) Explain briefly what is meant by *diffraction*.

.....

.....

.....

.....
(2 marks)

(ii) The width of the aperture of the transmitter is 60 mm. Calculate the angle θ at which the intensity of the received signal falls to a minimum.

angle θ .....
(2 marks)

8 **Total for this question: *10 marks***

(a) (i) State what is meant by the Doppler effect.

.....

.....

(2 marks)

(ii) Describe briefly a practical situation other than the 'red shift' in which the Doppler effect occurs.

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(2 marks)

(b) A scientist measures the frequency of a spectral line of the radiation from a galaxy to be 4.531×10^{14} Hz. The same spectral line from a laboratory source has a measured frequency of 4.600×10^{14} Hz.

speed of electromagnetic radiation in free space = $3.0 \times 10^{8}\,\text{m s}^{-1}$
Hubble constant = $65\ \text{km s}^{-1}\ \text{Mpc}^{-1}$

Calculate

(i) the velocity of the galaxy with respect to the Earth,

velocity .....

(2 marks)

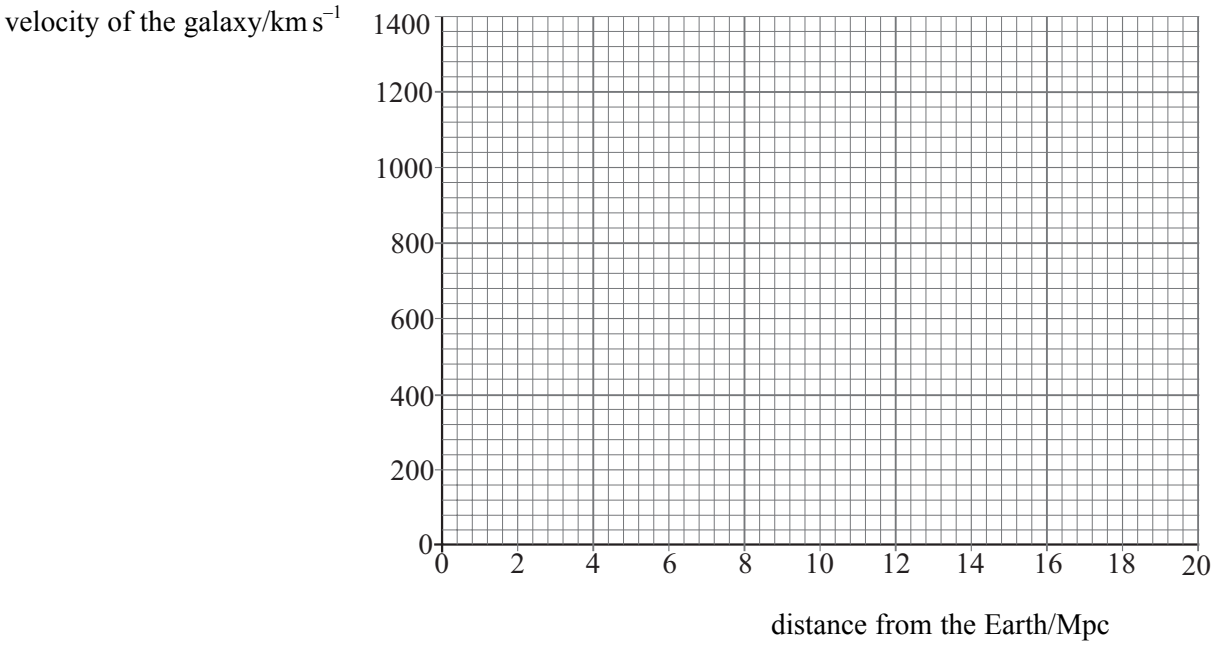
(ii) the distance of the galaxy from Earth.

distance from Earth.....

(2 marks)

(c) Draw on the axes below a graph to show how the velocities of the galaxies vary with their distances from the Earth assuming the Hubble law to be correct.

(2 marks)



10

TURN OVER FOR THE NEXT QUESTION

9 **Total for this question: *12 marks***

A freshly prepared radioactive source that emits negatively charged beta particles (β^-) has an activity of 120 Bq and a half-life of 12 h.

(a) (i) State the effect on the proton number Z and the nucleon number A when a β^- particle is emitted.

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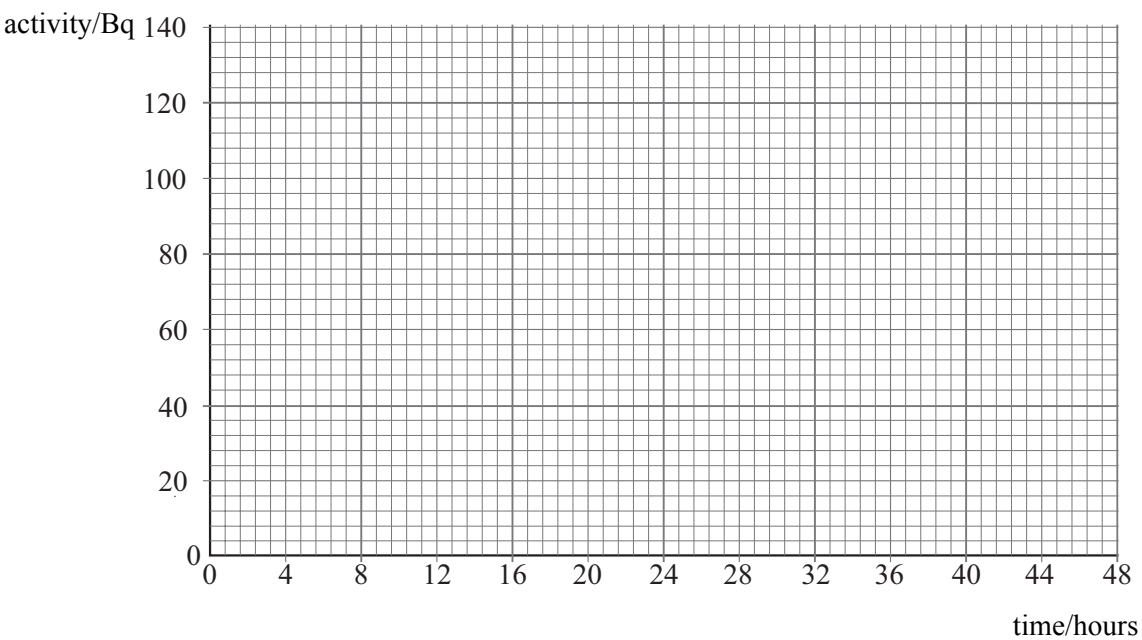
(2 marks)

(ii) Sketch, on the axes below, a graph that shows how the activity varies during the two days after the source was prepared.



(3 marks)

(b) (i) The total energy released in each decay is 5.5×10^{-13} J.
Calculate the initial energy produced each second by the source.

initial energy.....J
(1 mark)

(ii) **Figure 6** shows the energy spectrum for the beta particles emitted in the decay. It shows that different energy beta particles are possible.

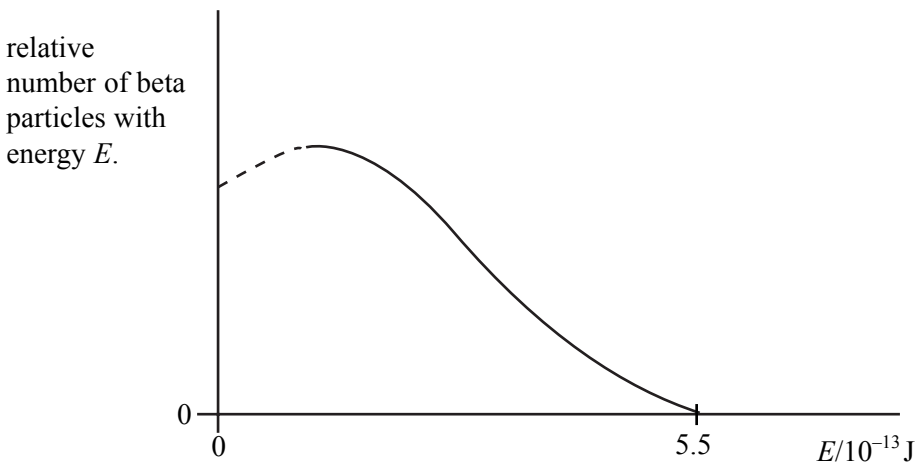


Figure 6

Explain why all the beta particles that are emitted do not have 5.5 x 10^{-13} J of energy.

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(3 marks)

(c) The probability of one of the radioactive atoms decaying each second is 1.6×10^{-5}. How many radioactive atoms are present when the activity is 120 Bq?

number of radioactive atoms.....
(1 mark)

(d) A scientist undertaking an investigation places the freshly prepared source close to a Geiger-Müller tube as shown in **Figure 7** and records a count rate of 50 counts per second.

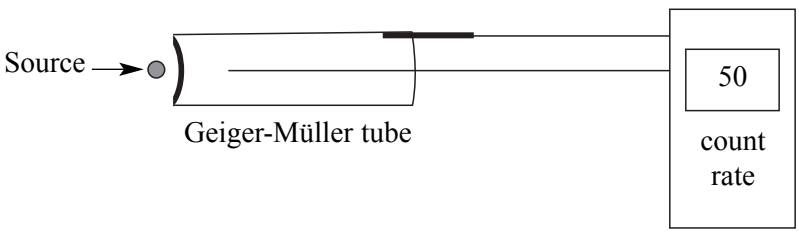

Figure 7

State and explain **two** reasons why the measured count rate is lower than the activity of the source.

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(2 marks)

12

TURN OVER FOR THE NEXT QUESTION

10 **Total for this question: *15 marks***

Figure 8 shows the block diagram of a communication system.

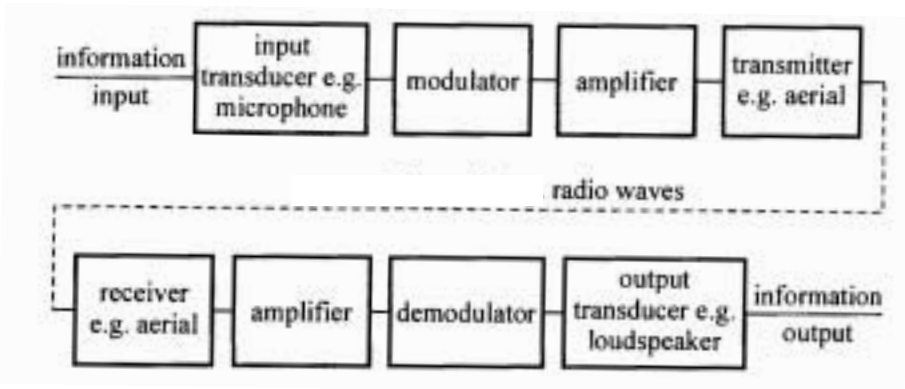

Figure 8

(a) State

(i) the useful energy transfer that occurs at the receiver aerial,

.....

.....

(1 mark)

(ii) the purpose of the demodulator.

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(2 marks)

(b) Two points on the Earth's surface are separated by a distance of several hundred kilometres.

Describe **two** transmission paths other than cable or fibre optics that would enable communication between these two points. In each case name a suitable region of the electromagnetic spectrum for the transmission.

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

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(6 marks)

QUESTION 10 CONTINUES ON THE NEXT PAGE

(c) **Figure 9** shows the analogue signal from a transducer.

analogue voltage/mV

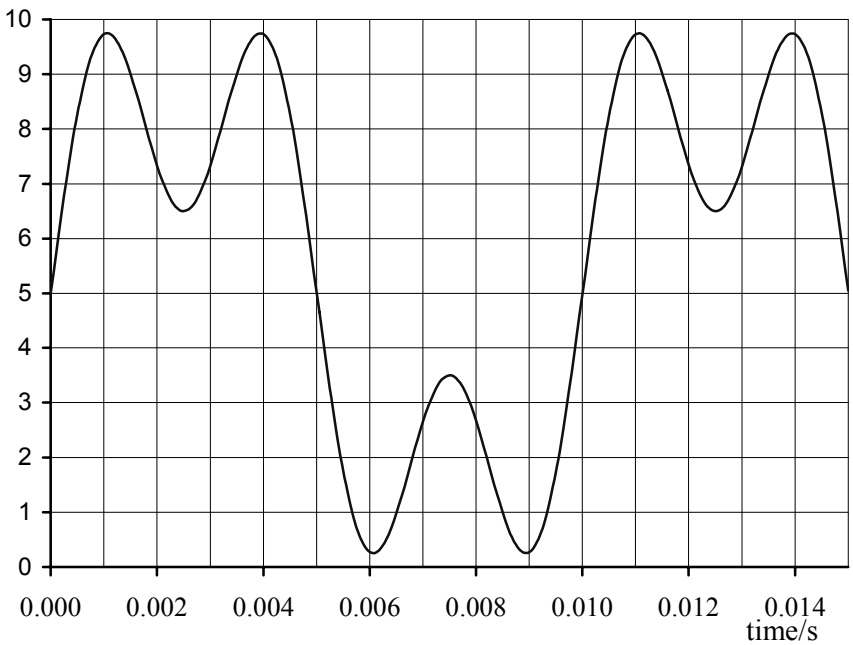


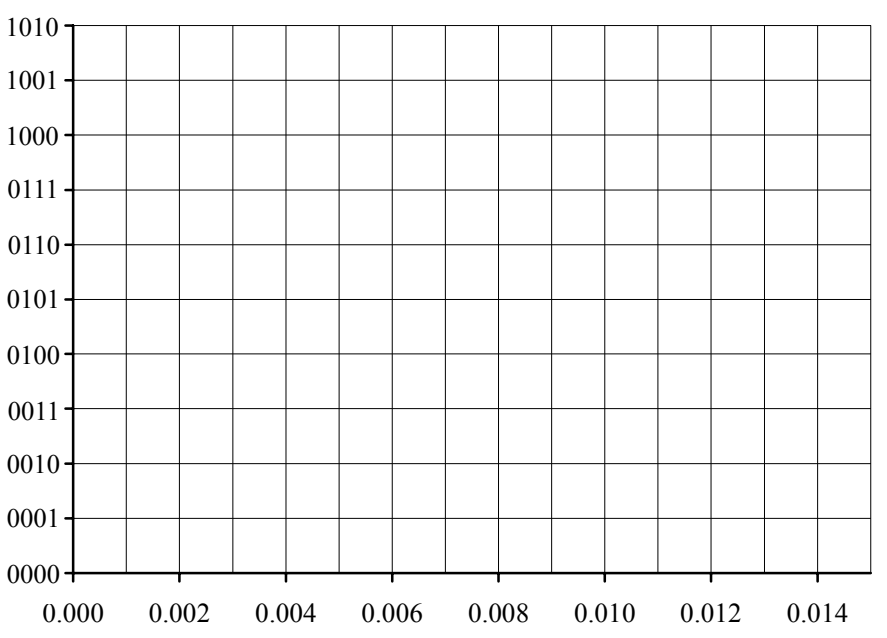
Figure 9

(i) For transmission the signal is digitally sampled at 0.002 s intervals starting at 0 s. In the analogue to digital, A to D, converter

0 to 1 mV produces a digital output 0000
+10 mV produces a digital output 1010

The bits for each sample are transmitted down four parallel wires.
Show on the axes below how the output of the A to D converter varies with time.

output of A to D converter



(3 marks)

(ii) Calculate the fundamental frequency of the sound that produces this waveform.

fundamental frequency.....
(2 marks)

(iii) The third harmonic (second overtone) is also present in the waveform. State the period of this harmonic.

period.....
(1 mark)

15

END OF QUESTIONS