Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
June 2003
Advanced Subsidiary Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

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

Friday 6 June 2003 Afternoon Session

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

Time allowed: 1 hour 30 minutes

For Examiner's Use			
Number	Mark	Number	Mark
A			
6			
7			
8			
9			
10			
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 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**.

SECTION A

Answer **all** questions in this section.

There are **26** marks in this section.

1 The table below includes some of the parts of the electromagnetic spectrum in order of increasing wavelength.

	gamma radiation		ultraviolet radiation		microwaves		medium wave radio waves	

(a) (i) Indicate with a letter **L** the correct position in the sequence for *visible light*. *(1 mark)*

(ii) Indicate with a letter **U** the correct position for the waves used in *UHF TV transmissions*. *(1 mark)*

(b) State which of the regions in the table has the highest photon energy.

....
(1 mark)

2 A student has access to a radioactive source that decays by emitting alpha, beta and gamma radiation. The student wishes to investigate whether the count rate due to the gamma radiation varies with distance from the source according to an inverse square law and sets up the source and detector as shown in **Figure 1**.

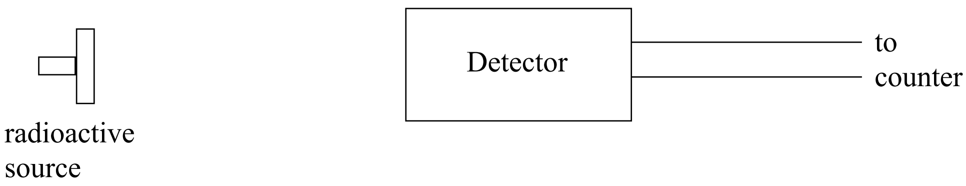


Figure 1

(a) State and explain how the student can ensure that only gamma radiation is detected during the investigation.

....

....

....

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

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

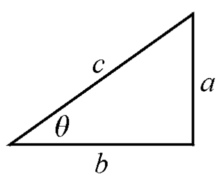
Geometrical and Trigonometrical Relationships

circumference of circle $= 2\pi r$

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

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

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



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

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

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

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

Turn over ▶

(b) The corrected count rate due to gamma radiation is 64 counts per second at a distance of 50 mm from the source. Assuming that an inverse square law is obeyed calculate the expected corrected count rate at a distance of 80 mm from the source.

Count rate at 80 mm ....

(2 marks)

(c) Using the data from part (b) sketch, on the axes in **Figure 2**, the graph the student would expect if an inverse square law were obeyed. The corrected count rate at 50 mm has been plotted already.

(2 marks)

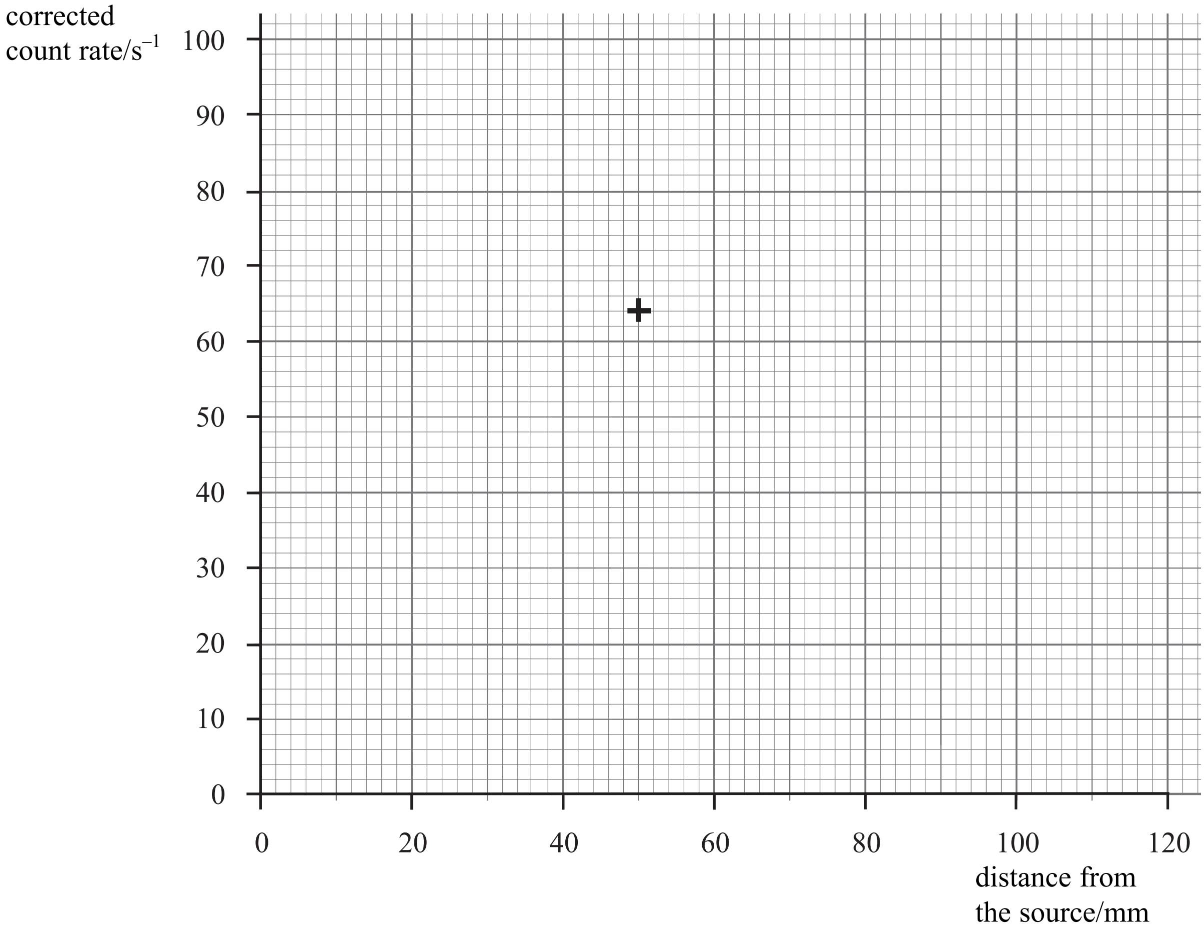


Figure 2

3 **Figure 3** shows a small red dot being viewed by an eye that has a pupil diameter of 3.5 mm. **Figure 4** shows how the intensity of the image on the retina varies with angle from the straight through position.

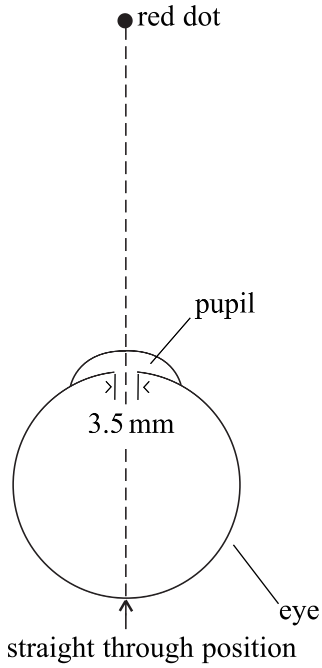


Figure 3

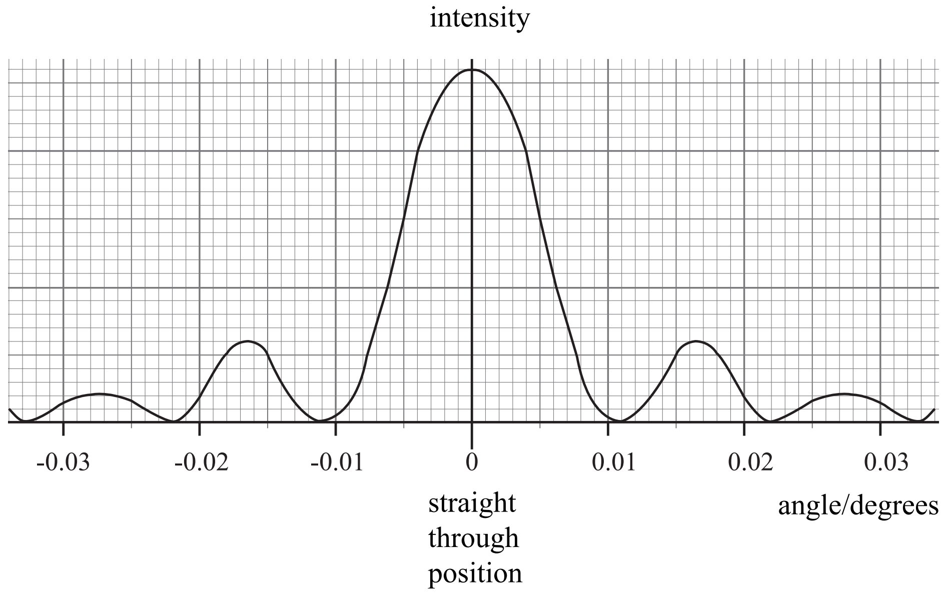


Figure 4

(a) (i) State the name of the phenomenon that gives rise to this variation in intensity.

....

(1 mark)

(ii) Calculate the wavelength of red light.

Wavelength of red light ....

(3 marks)

(b) Two small red dots are just seen as separate when viewed by the eye at a distance of 0.35 m.

Calculate the separation of the two red dots.

Separation ....

(2 marks)

LEAVE MARGIN BLANK

4 (a) A particle is made up from an anti-up quark and a down quark.

(i) Name the classification of particles that has this type of structure.

....

(1 mark)

(ii) Find the charge on the particle.

(1 mark)

(iii) State the baryon number of the particle.

(1 mark)

(b) A suggested decay for the positive muon (μ^+) is

$$\mu^+ \longrightarrow e^+ + \nu_e$$

Showing your reasoning clearly, deduce whether this decay satisfies the conservation rules that relate to baryon number, lepton number and charge.

Baryon number ....

Lepton number..

Charge...

(3 marks)

5 (a) (i) One possible value for the Hubble constant is $65\,\text{km}\,\text{s}^{-1}\,\text{Mpc}^{-1}$. Calculate, in Mpc, the distance from the Earth for a galaxy travelling at the speed of light, $3.0 \times 10^8\,\text{m}\,\text{s}^{-1}$.

Distance from Earth ....Mpc

(2 marks)

(ii) State what this distance represents.

....

(1 mark)

(b) Calculate the time taken, in years, for light to travel from the galaxy in part (a) to Earth.
1 parsec = 3.3 light years.

Time taken ....years

(2 marks)

26

Turn over

SECTION B

Answer **all** questions in this section.

Total for this question: *8 marks*

6 (a) **Figure 5** shows how the displacement *s* of the particles in a medium carrying a pulse of ultrasound varies with distance *d* along the medium at one instant.

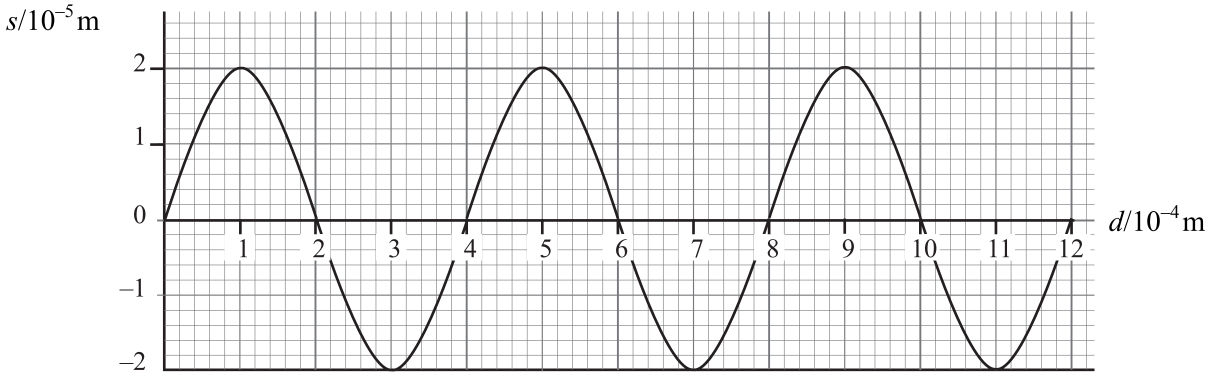


Figure 5

(i) State the amplitude of the wave.

....

(1 mark)

(ii) The speed of the wave is $1200\,\mathrm{m\,s^{-1}}$. Calculate the frequency of oscillation of the particles of the medium when the ultrasound wave is travelling through it.

Frequency of oscillation ....

(3 marks)

(b) An ultrasound transmitter is placed directly on the skin of a patient. **Figure 6** shows the amplitudes of the transmitted pulse and the pulse received after reflection by an organ in the body.

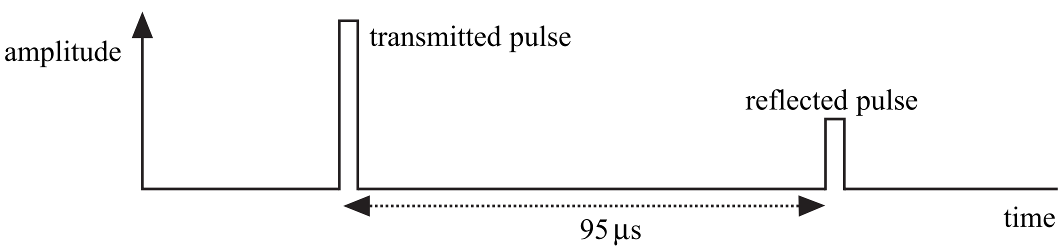


Figure 6

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(i) Give **two** possible reasons why the amplitude of the received pulse is lower than that which is transmitted.

Reason 1...

....

Reason 2...

....

(2 marks)

(ii) The speed of ultrasound in body tissue is $1200\,\mathrm{m\,s^{-1}}$. Calculate the depth of the reflecting surface below the skin.

Depth of reflecting surface ....

(2 marks)

$\overline{8}$

TURN OVER FOR THE NEXT QUESTION

Turn over ▶

Total for question: *8 marks*

7 The range of frequencies in the note emitted when a guitar string is plucked is shown in the sound frequency spectrum in **Figure 7**.

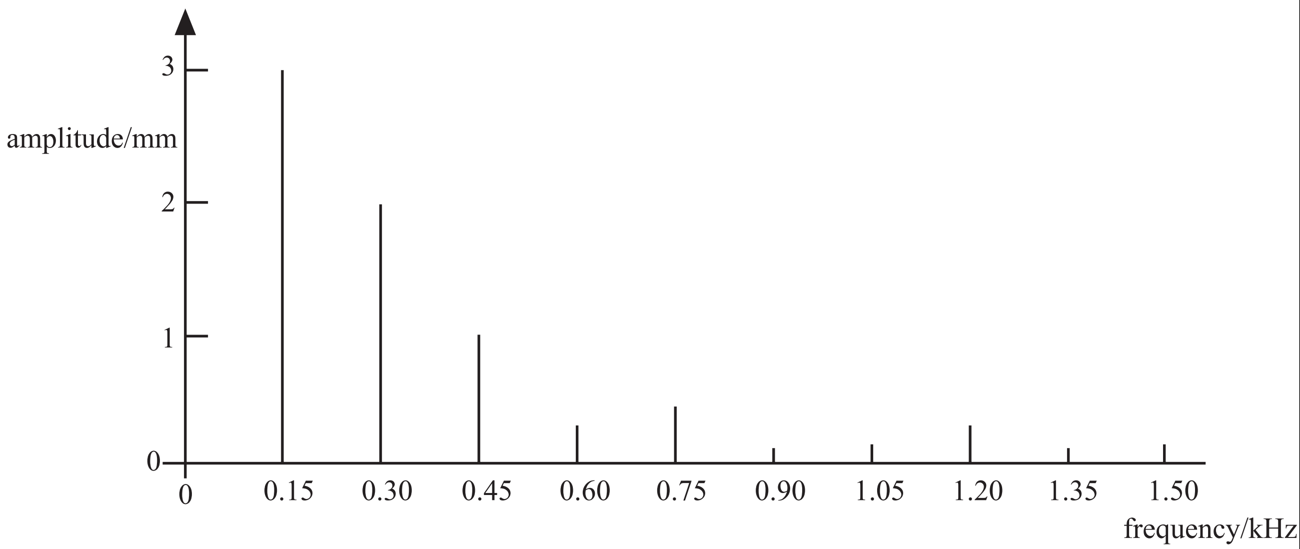

Figure 7

The lengths of the vertical lines represent the relative amplitudes of the frequencies present. The frequency with the highest amplitude is the fundamental frequency of the string.

(a) (i) Calculate the period of the fundamental frequency.

Period...

(1 mark)

(ii) Show, on the axes below, how the displacement of the centre of the string would vary with time if the string were emitting only the fundamental frequency. Give appropriate scales for the axes.

(2 marks)

(b) Draw below the mode of vibration of the string if it were emitting only the third harmonic (second overtone) with the amplitude shown in the frequency spectrum. Use a suitable scale that shows the magnitude of the amplitude clearly.

(2 marks)

(c) The length of the string affects the frequency of the emitted note. State **two** other factors that determine the frequency of the emitted note and, in each case, explain its effect.

Factor 1 ....

Effect ....

Factor 2 ....

Effect ....

(2 marks)

(d) State **one** effect of transmitting this note using a base bandwidth of 100 Hz to 1000 Hz.

....

....

(1 mark)

—
8

Turn over

Total for this question: *9 marks*

8 (a) Sodium-21 ($^{21}_{11}Na$) decays to neon-21 ($^{21}_{10}Ne$). A nucleus of neon-21 is stable.

(i) State the names of the particles emitted when a sodium-21 nucleus decays.

....

....

(2 marks)

(ii) How many neutrons are there in a nucleus of neon-21?

....

(1 mark)

(b) **Figure 8** shows how the activity *A* of a freshly prepared sample of sodium-21 varies as it decays. **Figure 9** shows how *N*, the number of sodium-21 nuclei, varies with time *t* during the same time interval.

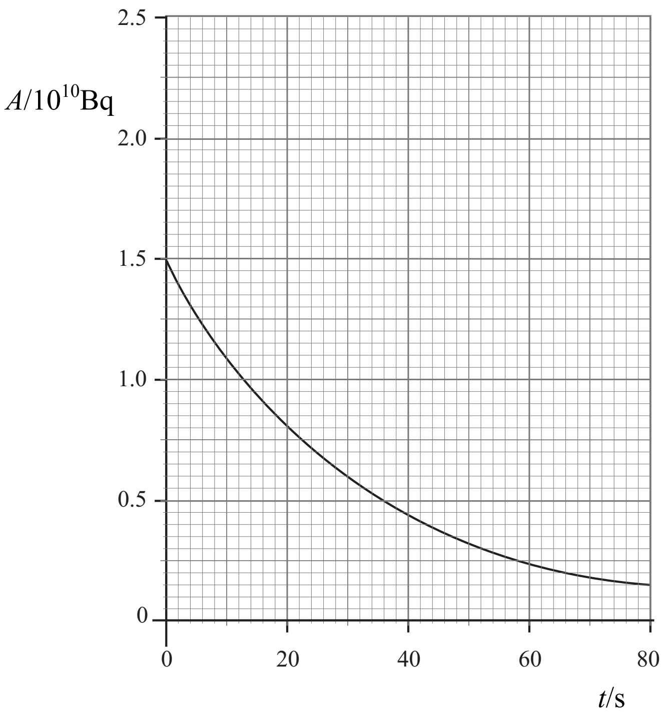

Figure 8

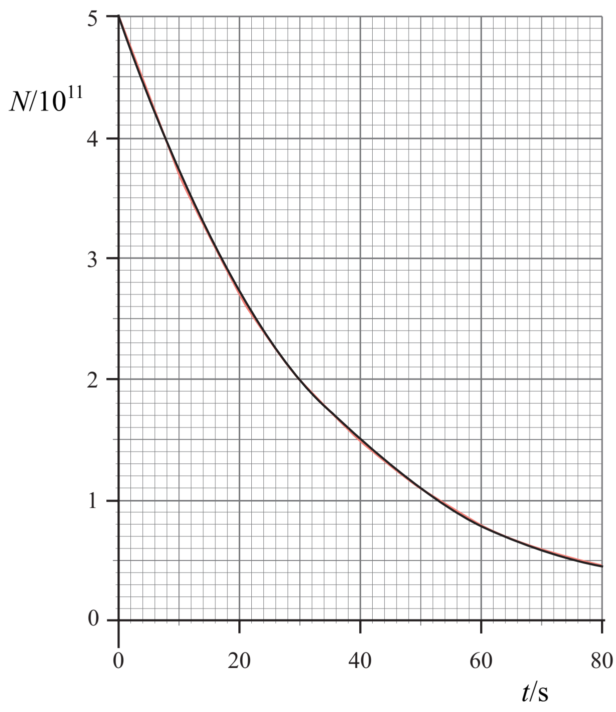

Figure 9

(i) Use the graphs to find the number of active sodium nuclei and the corresponding activity one half-life after $t = 0$. Hence find the probability of decay of a sodium-21 nucleus.

Probability of decay ....

(3 marks)

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(ii) The total energy produced when a sodium-21 nucleus decays is 5.7×10^{-13} J. Calculate the number of radioactive atoms in a sample that is producing 2.6 mJ of energy each second.

Number of radioactive atoms ....

(3 marks)

9

TURN OVER FOR THE NEXT QUESTION

Total for this question: *14 marks*

9 One spectral line emitted by a helium-filled discharge tube has a wavelength of 590 nm when measured using a source in a laboratory on Earth. The same spectral line measured using light from a distant galaxy has a wavelength 650 nm.

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

(a) (i) State the name of the effect that gives rise to this change in wavelength.

....

(1 mark)

(ii) What do these measurements of wavelength suggest about the nature of the universe?

....

(1 mark)

(b) Calculate the velocity of the galaxy relative to Earth. (hint: $\frac{\Delta\lambda}{\lambda} = \frac{\Delta f}{f}$)

Velocity of galaxy ....

(2 marks)

(c) The spectral lines are analysed using a diffraction grating with 4.5×10^5 lines per m.

(i) Calculate the angle at which the spectral line of wavelength 590 nm produces a maximum in the second order spectrum.

Angle ....

(3 marks)

LEAVE MARGIN BLANK

(ii) Explain how the diffraction grating produces the bright spectral lines for a particular wavelength.

You may wish to draw a diagram to help you explain.

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

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(7 marks)

14

Turn over

LEAVE MARGIN BLANK

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

10 **Figure 10** shows four radio stations **A**, **B**, **C** and **D** that are producing analogue signals with frequencies up to a maximum of 20 kHz. After sampling, the signals are being transmitted as digital signals down a single optical fibre.

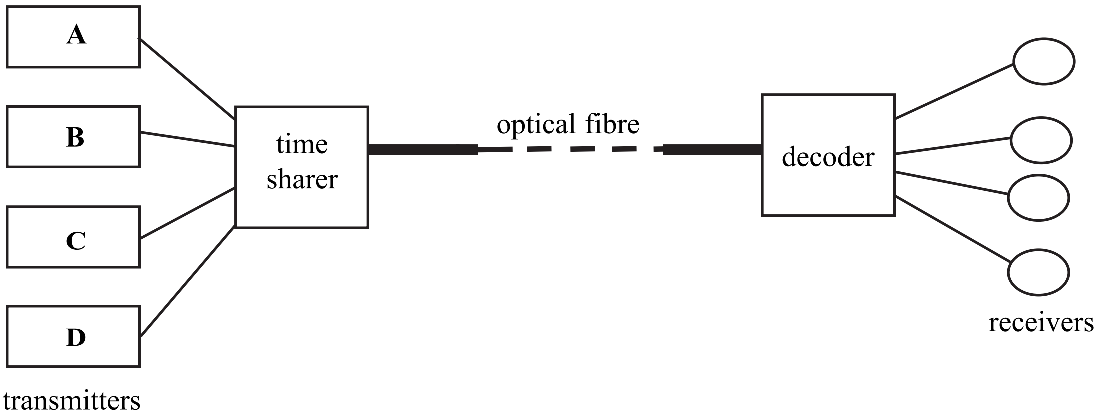

Figure 10

(a) Calculate the minimum frequency at which the signal from each station must be sampled for high quality transmission of data from the transmitters.

(1 mark)

(b) Explain why the use of a sampling frequency that is lower than the minimum sampling frequency could reduce the quality of the data received.

....

(1 mark)

(c) A single optical fibre can transmit 1.5×10^8 bits per second. Calculate the number of radio stations transmitting signals up to 20 kHz that could be transmitted using the single fibre. Each time a signal is sampled 8 bits have to be sent down the fibre.

Number of radio stations..

(2 marks)

(d) Explain how the digital signals from stations **A**, **B**, **C** and **D** are simultaneously transmitted down the optical fibre and why an optical fibre is preferred to a coaxial cable made from copper wire. You may draw a diagram to support your explanation if you wish.

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

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(6 marks)

10

END OF QUESTIONS