OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A

2825/04

Nuclear and Particle Physics

Thursday **27 JUNE 2002** Morning 1 hour 30 minutes

Candidates answer on the question paper.
Additional materials:
Electronic calculator

Candidate Name	Centre Number	Candidate Number

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers in the spaces on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	12	
2	12	
3	12	
4	12	
5	12	
6	10	
7	20	
TOTAL	90	

This question paper consists of 20 printed pages.

[Turn over

Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion, $s = ut + \frac{1}{2}at^2$

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

refractive index, $n = \dfrac{1}{\sin C}$

capacitors in series, $\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \ldots$

capacitors in parallel, $C = C_1 + C_2 + \ldots$

capacitor discharge, $x = x_0 e^{-t/CR}$

pressure of an ideal gas, $p = \frac{1}{3}\dfrac{Nm}{V}<c^2>$

radioactive decay, $x = x_0 e^{-\lambda t}$

$t_{\frac{1}{2}} = \dfrac{0.693}{\lambda}$

critical density of matter in the Universe, $\rho_0 = \dfrac{3H_0^2}{8\pi G}$

relativity factor, $= \sqrt{(1 - \dfrac{v^2}{c^2})}$

current, $I = nAve$

nuclear radius, $r = r_0 A^{1/3}$

sound intensity level, $= 10 \lg\left(\dfrac{I}{I_0}\right)$

For Examiner's Use

Answer **all** the questions.

1 Two adjacent protons, situated inside a certain nucleus, are acted upon by three forces. These are electrostatic, gravitational and strong interaction (i.e. strong force).

(a) State whether each of these forces is attractive or repulsive.

1 electrostatic ....

2 gravitational ....

3 strong interaction ....
[1]

(b) The average separation of the nucleons in this nucleus is 0.80×10^{-15} m.
Calculate, giving an appropriate unit in each case, the magnitude of

(i) the electrostatic force

force = ...

(ii) the gravitational force.

force = ...
[6]

(c) Use your answers to **(b)** to comment on the relative importance of electrostatic and gravitational forces inside the nucleus.

....

....

....[2]

For Examiner's Use

(d) Fig. 1.1 shows the variation with nucleon-nucleon separation of the strong interaction between two nucleons.

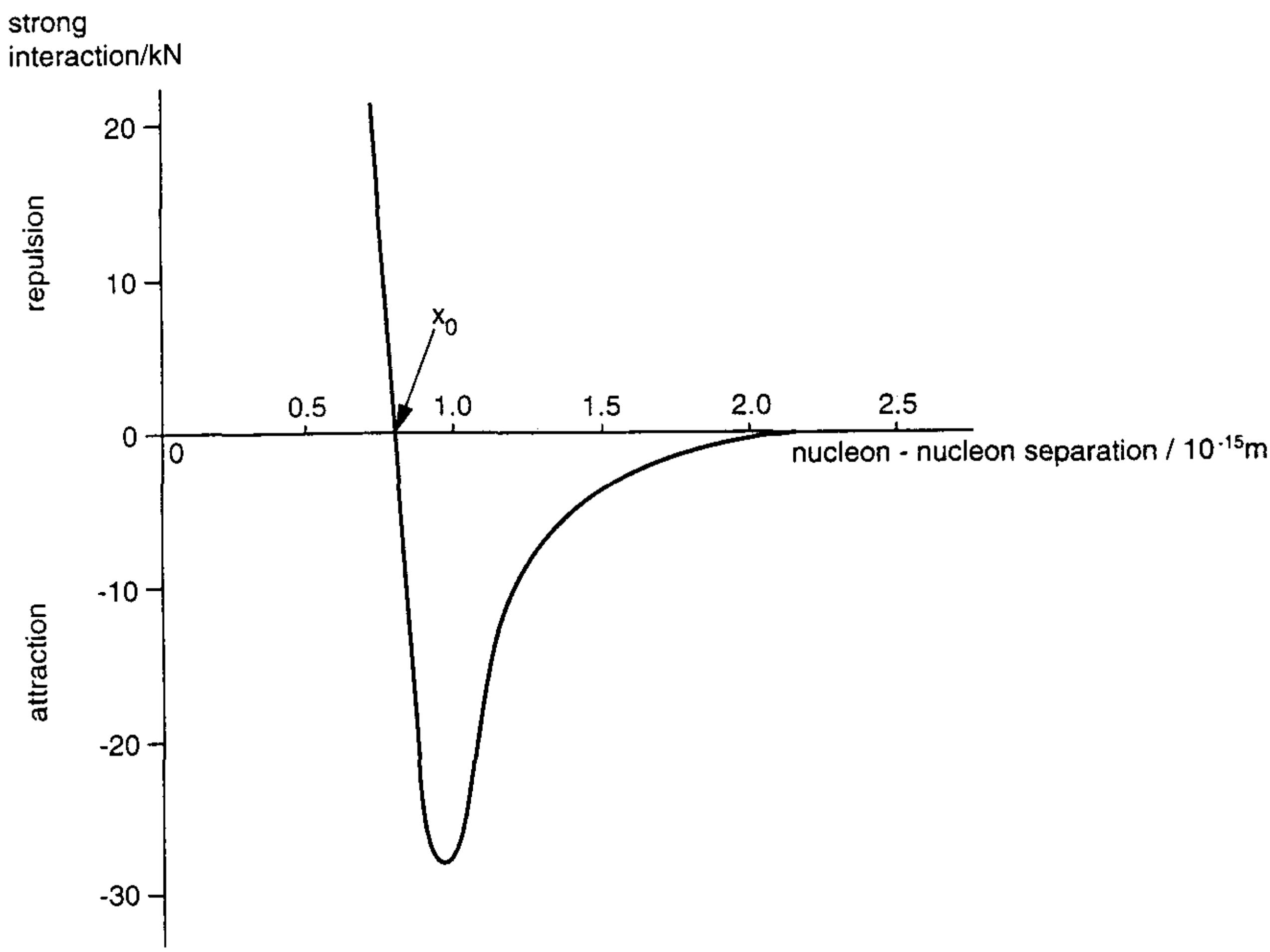

Fig. 1.1

When both nucleons are *neutrons*, the equilibrium separation is x_0. Explain whether the equilibrium separation between two *protons* will be greater, less than or equal to x_0.

....

....

....

....[3]

[Total : 12]

[Turn over

For Examiner's Use

2 Fig. 2.1 shows the variation with nucleon number (mass number) of the binding energy per nucleon for various nuclides.

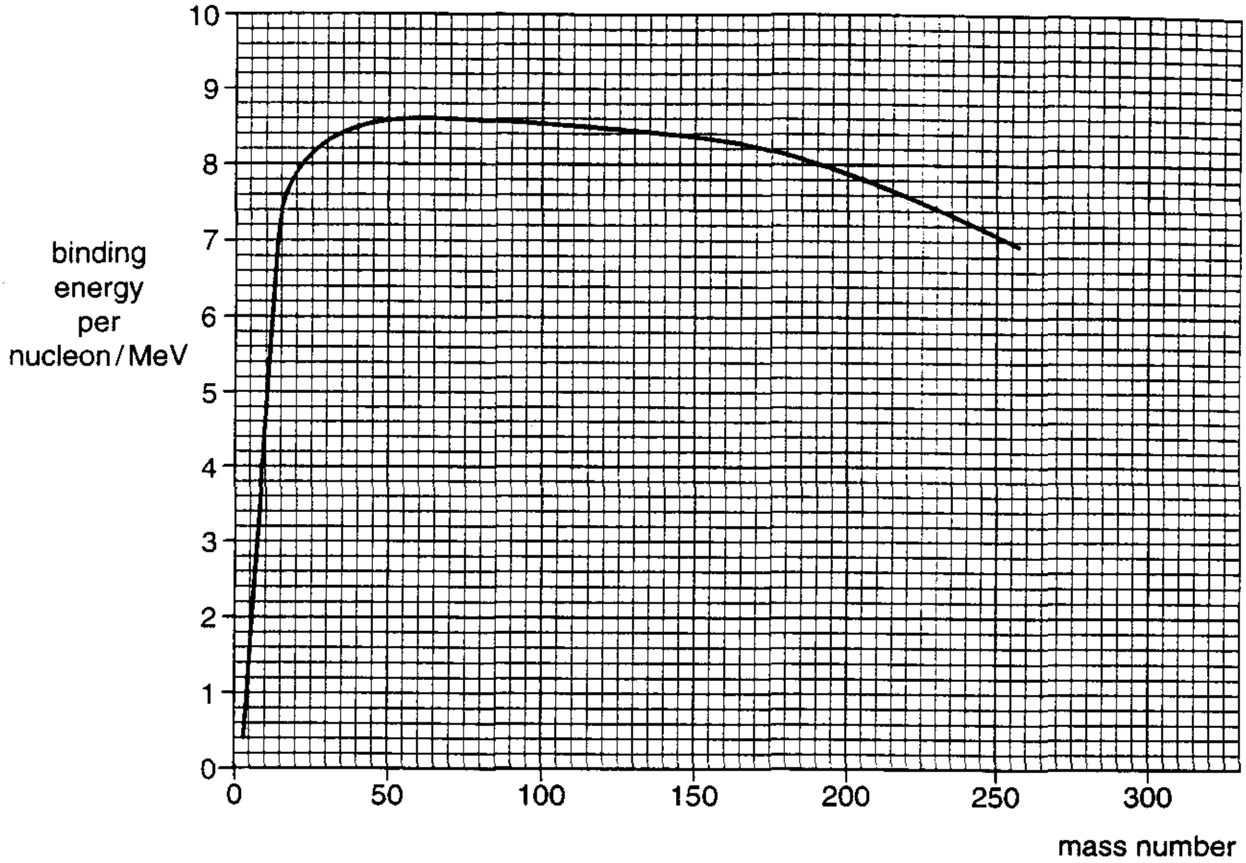

Fig. 2.1

(a) State the number of nucleons in the nucleus of

$^{94}_{37}Rb$ ....

$^{142}_{55}Cs$ ....

$^{235}_{92}U$ ....

[2]

For Examiner's Use

(b) Use Fig. 2.1 to calculate the energy released when a $^{235}_{92}U$ nucleus undergoes fission, producing nuclei of $^{94}_{37}Rb$ and $^{142}_{55}Cs$.

energy = ... MeV [6]

(c) **(i)** On Fig. 2.2, sketch a graph which shows the variation with nucleon number of the *relative yield of fission products for a fissile material such as Uranium-235.* [2]

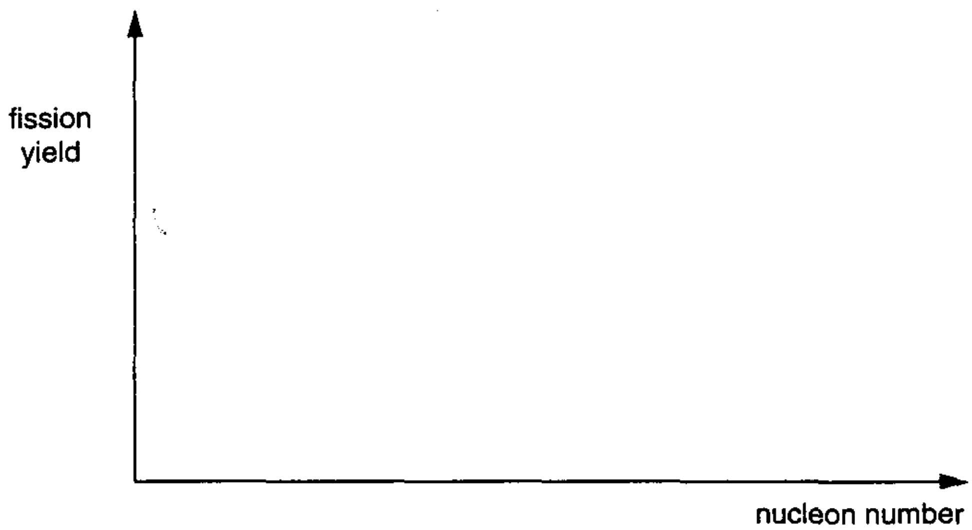

Fig. 2.2

(ii) Mark possible positions for $^{94}_{37}Rb$ and $^{142}_{55}Cs$ on your graph and label them. [2]

[Total : 12]

For Examiner's Use

3 (a) (i) Explain what is meant by a *plasma*.

....

....

..........[2]

(ii) Explain why the material in the interior of the Sun is in the form of a plasma.

....

....

..........[2]

(b) (i) Explain how the high temperature inside the Sun aids the process of nuclear fusion.

....

....

(ii) State **one** other condition inside the Sun which increases the likelihood of fusion.

....

....

[2]

For Examiner's Use

(c) Fig. 3.1 is a flow diagram illustrating the stages in the carbon cycle, which occurs inside the Sun.

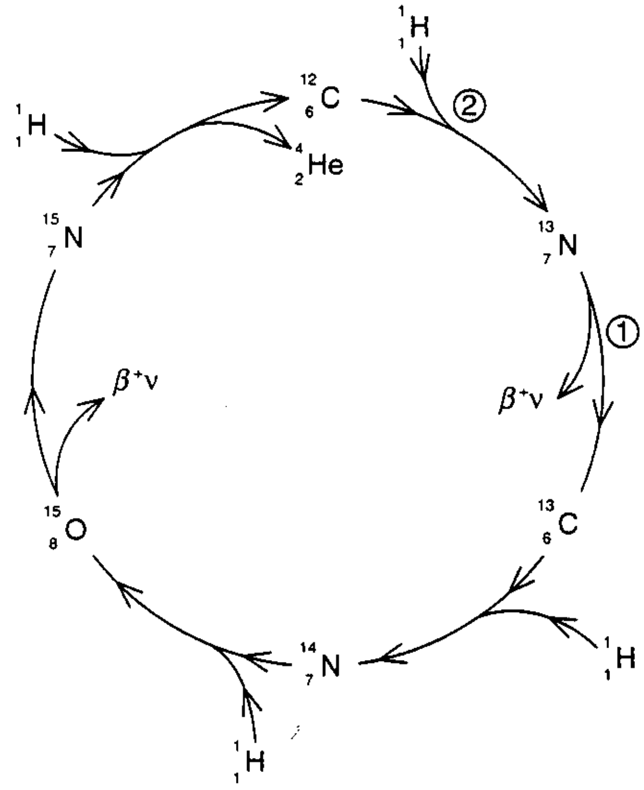

Fig. 3.1

(i) For the stages labelled '1' and '2', write a nuclear equation for the reaction and state in words what change is taking place.

1 ....

....

....

2 ....

....

....

[4]

(ii) Write an equation which summarises the overall reaction of the carbon cycle. Describe in words the process which this equation represents.

....

....

....[2]

[Total : 12]

[Turn over

4 This question is about particle accelerators.

(a) Explain why particle accelerators are used for research in physics.

....

....

....[2]

(b) A cyclotron has two hollow dees A and B, and a source of protons, P. Fig. 4.1 is a simplified diagram showing the path of a proton.

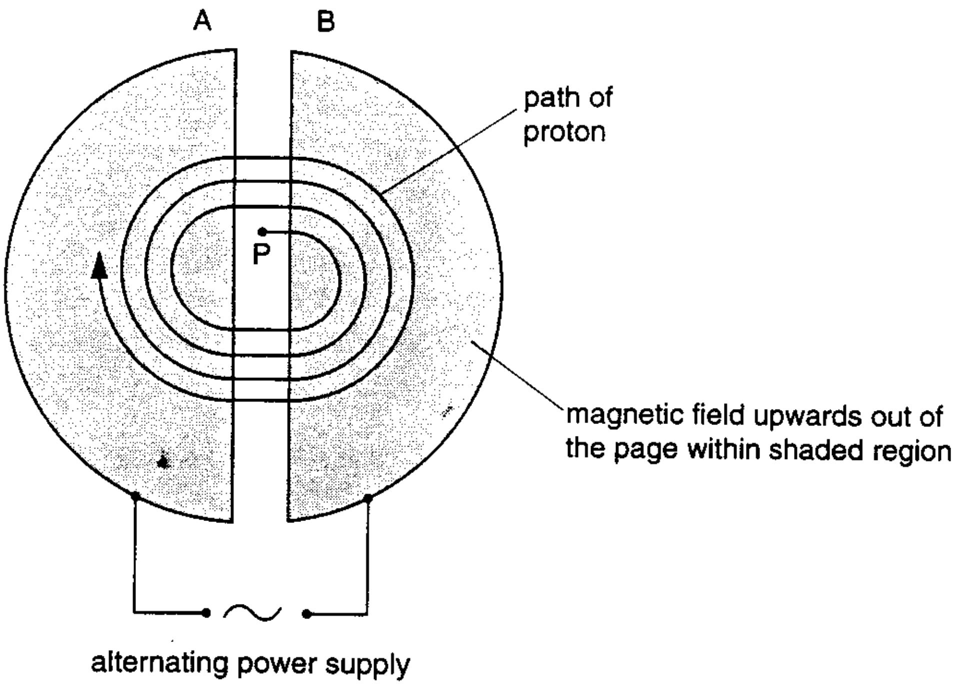

Fig. 4.1

For Examiner's Use

Explain why

(i) this proton, when released, enters dee B rather than dee A

....

....[1]

(ii) the proton inside each dee follows a circular path with constant speed

....

....

....

....

....[4]

(iii) the frequency of the potential difference between A and B must be constant.

....

....[1]

(c) (i) Explain why the cyclotron is not suitable for obtaining very high energy protons.

....

....

....[2]

(ii) Explain how the synchrotron overcomes this problem.

....

....

....[2]

[Total : 12]

[Turn over

For Examiner's Use

5 **(a)** State the names of the classes of particles (one in each case) which include

(i) positrons and neutrinos ....

(ii) protons and neutrons. ....

[2]

(b) An unstable nucleus may decay by emitting a positron and a neutrino. This can be due to a proton decaying to a neutron. Write an equation to represent this proton decay.

[2]

(c) **(i)** State the composition of the proton and neutron in terms of their constituent quarks.

proton ....

neutron ....

[2]

(ii) Hence write an equation for the process described in **(b)**, in terms of changes in quark composition.

[1]

(iii) State the baryon number and charge of each particle in the equation of **(c)(ii)**. Hence show that baryon number and charge are conserved.

....

....

....

....

....

....

....

....

....

....[5]

[Total : 12]

For Examiner's Use

6 Strontium-90 is one of the radioactive by-products of the fission of uranium. Values of the activity of a sample of Strontium-90 at various times after its formation are recorded in Fig. 6.1.

Activity / 10^6 Bq	79.5	62.1	48.5	37.8	29.5	23.1	18.0
Time / year	5.0	15.0	25.0	35.0	45.0	55.0	65.0

Fig. 6.1

For Examiner's Use

(a) On Fig. 6.2 below, plot a graph to show the variation with time of the activity of this sample. [3]

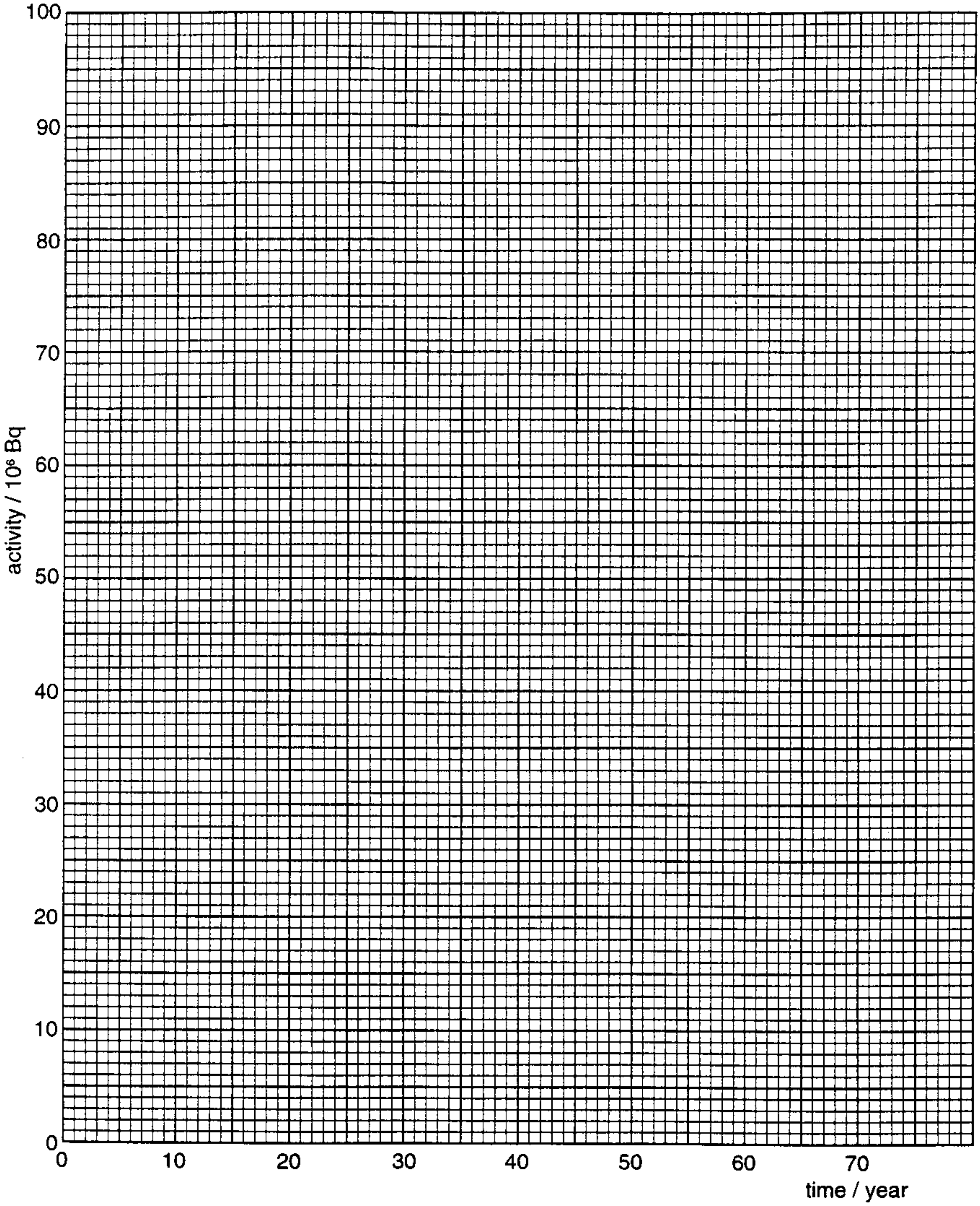

Fig. 6.2

[Turn over

For Examiner's Use

(b) Activity A is related to time t by the equation

$$A = A_0 e^{-\lambda t}.$$

Use your graph to find values of

(i) A_0 (give an appropriate unit for your answer)

A_0 = ...

(ii) the half-life, $t_{½}$, of the isotope.

half-life = ... year [3]

(c) Use your answer to **(b)(ii)** to show that the value of λ for this material is 2.5×10^{-2} $year^{-1}$.

[1]

(d) This sample, in a suitable containment, is considered safe when its activity has fallen to 1% of its initial value. Calculate the time t when this occurs.

time = ... years [3]

[Total : 10]

For Examiner's Use

7 The following passage is based on a scientific article.

Power stations are normally most efficient when running under full load. The variation in demand over a day means that there must be capacity to meet peak demand, but much of this will be out of use for most of the day. This is wasteful of capital equipment when it is standing idle and of the fuel needed to run the station up to full demand and down at times of minimum demand.

The demand shown for January in Fig. 7.1 below is met for most of the day by power stations which are called *base load* stations. It has been suggested that during periods of peak demand, hydroelectric stations may be used to top-up the supply. The water for the hydroelectric stations is pumped into reservoirs at times when the *base load* stations' output is greater than demand. This is called a 'pumped storage' system.

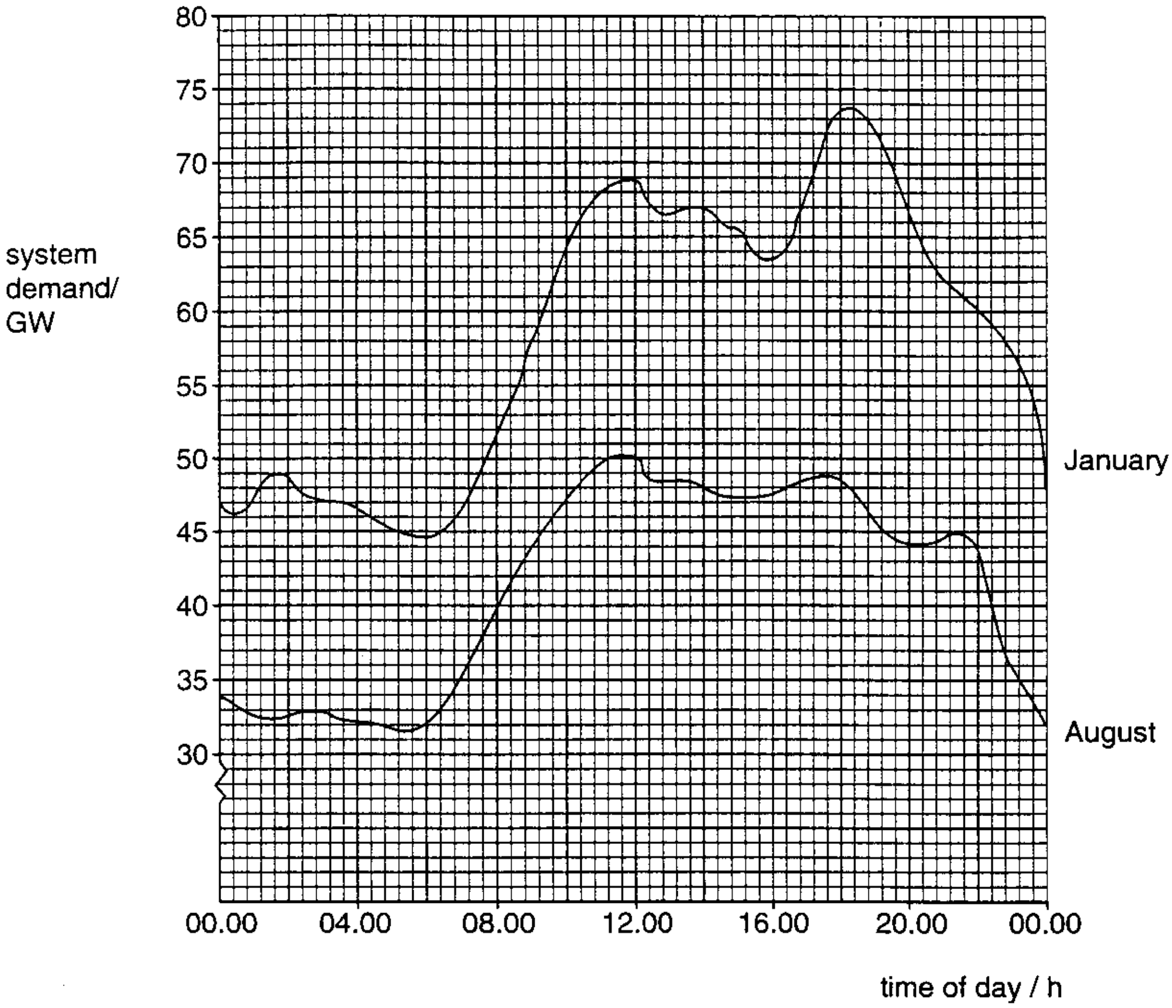

Fig. 7.1

Fig. 7.1 shows the average variation in demand for electrical energy from the electricity companies in the UK with time of day for January and August.

[Turn over

For Examiner's Use

Answer the following questions about this passage.

(a) State **four** major features of the graphs of Fig. 7.1 for January and August and suggest reasons for these features.

1. ....

....

2. ....

....

3. ....

....

4. ....

....

[4]

(b) Suggest **two** reasons why a *base load* coal-fired power station cannot simply be switched on or off when the demand suddenly changes.

....

....

....[2]

(c) **(i)** Use Fig. 7.1 to estimate the *base load* power for January, that would allow the system to meet the demand for 18 hours out of a 24 hour period.
Show this as a horizontal line labelled BL on Fig. 7.1. [1]

(ii) Estimate the maximum power output of the hydroelectric power stations needed to meet the extra demand.

power = ... GW
[1]

For Examiner's Use

(d) Water in one of the hydroelectric power stations falls through a vertical distance of 100 m.

(i) Show that the minimum volume of water required per second to flow through the turbines to produce an output of 1.0 GW from the generator is about $1 \times 10^3\,m^3$. (The density of water = $1000\,kg\,m^{-3}$.)

[4]

(ii) Calculate the length of one side of a square reservoir of depth 35 m which would just supply water at a rate of $1.0 \times 10^3\,m^3\,s^{-1}$ for a continuous period of 4 hours.

length = ... m [4]

(iii) Comment on the feasibility of a number of such power stations to meet the extra requirements during periods of peak demand.

....

....[2]

(iv) Give **two** reasons why the actual volume of water required per second to produce an output of 1.0 GW is greater than that calculated in **(d)(i)**.

....

....

....[2]

[Total : 20]

Copyright Acknowledgements:

Question 3. Fig. 3.1 Reproduced with the permission of Nelson Thomes Ltd from Nuclear and Particle Physics, by David Sang, (ISBN 0-333-46658-6), first published in 1995.

Question 7. Passage based on Question 24, page 441, Nuffield Students' Guide, published by Addison Wesley and Longman.
Graph data based on pages 7 and 8, SATIS No.601 Students' Guide, published by ASE, Hatfield, Herts.