OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced GCE

PHYSICS A

2825/01

Cosmology

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	6	
2	4	
3	10	
4	4	
5	13	
6	3	
7	11	
8	10	
9	9	
10	20	
TOTAL	90	

This question paper consists of 19 printed pages and 1 blank page.

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 Galileo is credited with the first application of the telescope to astronomy.

(a) On January 7 1610, Galileo observed the planet Jupiter and saw tiny spots of light either side of it. On subsequent days the pattern of spots changed, as shown in Fig. 1.1.

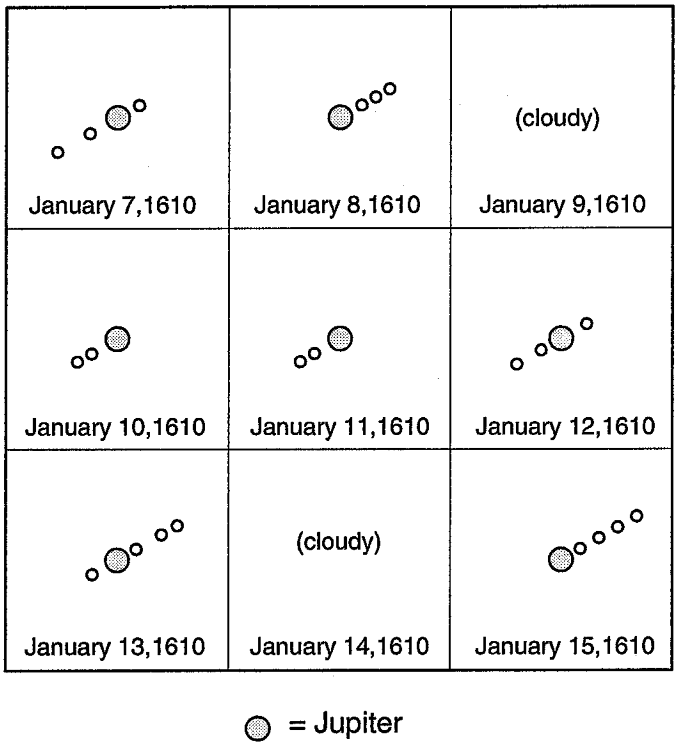

Fig. 1.1

(i) Explain the existence of the spots of light near Jupiter.

....

....

(ii) Explain why there are two spots in some sketches and three or four in others.

....

....

[2]

For Examiner's Use

(b) State **two** other astronomical discoveries made by Galileo. For each one explain how the observation conflicts with previous models of the Universe.

1. ....

....

....

2. ....

....

.... [4]

[Total : 6]

2 **(a)** Spectroscopic analysis of starlight reveals the presence of dark lines in the spectrum. Explain how these absorption lines occur.

....

....

....

....

....

....[2]

(b) Outline how the composition of stellar atmospheres may be obtained from stellar spectra.

....

....

....[2]

[Total : 4]

For Examiner's Use

3 The Sun produces its energy mainly by a series of nuclear fusion reactions in which hydrogen is converted to helium. For each 1.000 kg of hydrogen consumed in the fusion reactions, the rest mass of the products is only 0.993 kg. This change in mass is associated with the production of energy.

(a) Calculate the energy produced from 1.000 kg of hydrogen.

energy = ... J [4]

(b) The Sun's power output is 3.9×10^{26} W. Calculate the rate at which the Sun is using up its hydrogen.

rate of consumption of hydrogen = ... kg s^{-1} [2]

(c) The mass of the Sun is 2.0×10^{30} kg and it is expected to leave the Main Sequence when approximately 10% of its hydrogen has been used up.

(i) Estimate the Main Sequence lifetime of the Sun. Give a suitable unit for your answer.

lifetime = ...

(ii) State **one** assumption you have made in carrying out this calculation.

....

....

[4]

[Total : 10]

For Examiner's Use

4 The Sun is one of many stars within our Galaxy.

Sketch a plan view and a side view of our Galaxy. Label important features and indicate the approximate position of the Sun.

Plan view

Side view

[4]

[Total : 4]

[Turn over

For Examiner's Use

5 In a binary star system, two stars orbit each other, held together by their mutual gravitational attraction. A line in the spectrum of calcium has wavelength 393.40 nm when measured from a source at rest in the laboratory.

The wavelength of the same line from one of the stars of a binary star system was measured over a period of time and the results are recorded in Fig. 5.1.

time/hour	wavelength/nm
0	393.40
10	393.63
20	393.69
30	393.53
40	393.27
50	393.11
60	393.17
70	393.40
80	393.63
90	393.69
100	393.53

Fig. 5.1

(a) On Fig. 5.2 plot a graph of wavelength against time. [3]

(b) Suggest why the wavelength varies.

....

....

....[2]

(c) Calculate the orbital speed of the star.

speed = ... m s^{-1} [3]

For Examiner's Use

(d) **(i)** Use your graph to show that the orbital period of the star is 2.5×10^5 s. [2]

(ii) Calculate the radius of the orbit, assuming that it is circular.
Give a suitable unit for your answer.

radius = ...
[3]

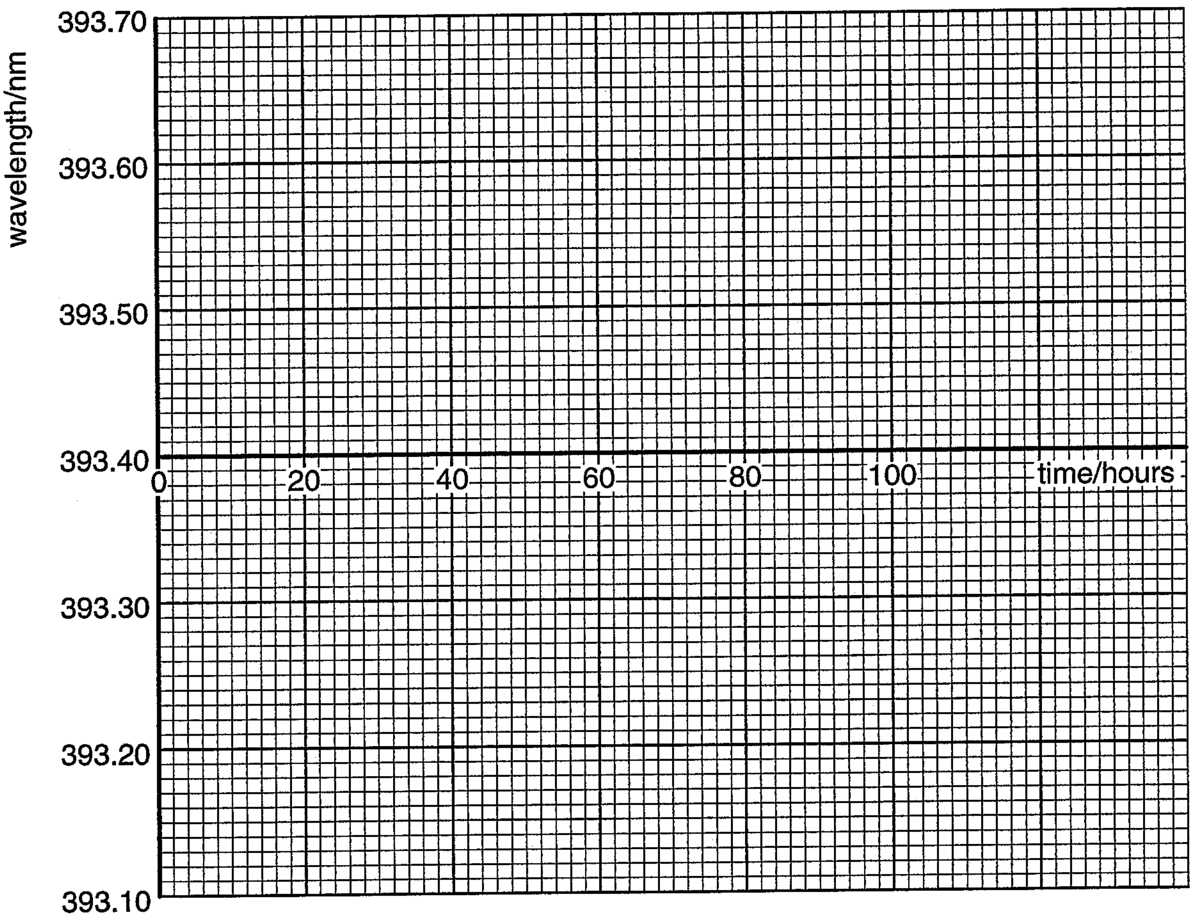

Fig. 5.2

[Total : 13]

For Examiner's Use

6 Fig. 6.1 shows how the transparency of the Earth's atmosphere to electromagnetic radiation of different wavelengths varies with the altitude above sea level. The top of the shaded region shows the altitude above which the atmosphere is transparent.

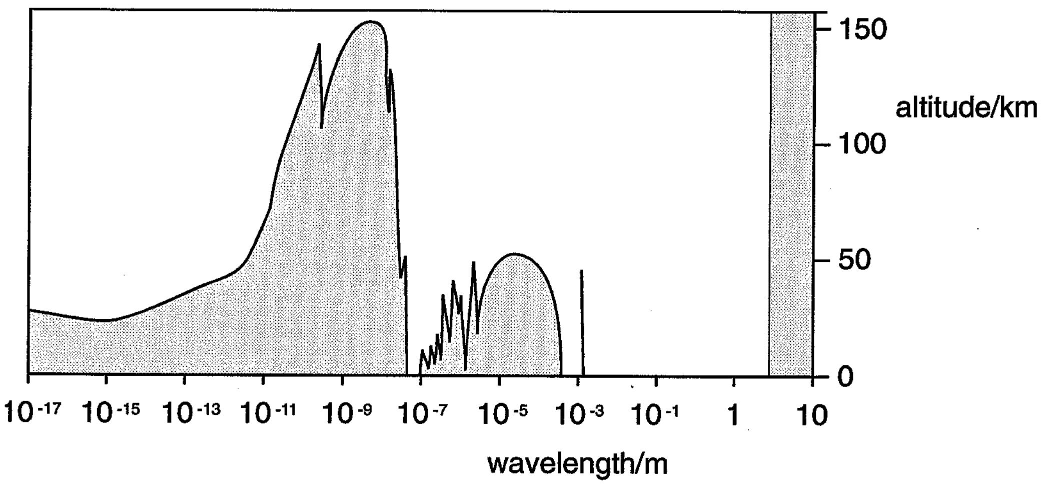

Fig. 6.1

(a) Name **two** regions of the electromagnetic spectrum which *cannot* be observed from the Earth's surface.

1. ....

2. .... [2]

(b) Name a region of the electromagnetic spectrum other than visible light to which the Earth's atmosphere is transparent.

....

....[1]

[Total : 3]

For Examiner's Use

7 **(a)** State **three** properties of the cosmic microwave background radiation.

1. ....

2. ....

3. ....
[3]

(b) Describe how the microwave background radiation is thought to have arisen in standard Big Bang cosmology.

....

....

....

....

....

....

....

....

....

....[5]

(c) The Cosmological Principle states that 'on a sufficiently large scale, the Universe is *homogeneous* and *isotropic*'.

(i) Explain the meaning of the terms *homogeneous* and *isotropic.*

homogeneous..

....

isotropic..

....
[2]

(ii) State how the microwave background radiation supports the Cosmological Principle.

....

....[1]

[Total : 11]

For Examiner's Use

8 (a) Describe, with the aid of a diagram, a thought experiment to illustrate time dilation.

....

....

....

....

....

....

....

....

....

....[4]

For Examiner's Use

(b) Pions are subatomic particles produced in high-energy collisions between particles and nuclei, for example when a cosmic ray collides with a nucleus in the atmosphere. Pions have a mean lifetime of 26 ns when at rest. If they have a speed of $0.80c$ relative to the laboratory, calculate

(i) the mean lifetime of the high-speed pions as measured by stationary observers in the laboratory,

lifetime = ... ns [3]

(ii) the mean distance travelled by the high-speed pions according to stationary observers in the laboratory,

distance = ... m [2]

(iii) the mean distance travelled by the pions in the laboratory if their lifetime did not depend on their velocity.

distance = ... m [1]

[Total : 10]

For Examiner's Use

9 **(a)** What is the *equivalence principle*?

....

....

....

....[2]

(b) Fig. 9.1 is an image showing *gravitational lensing* caused by the galaxy Abell 2218 taken by the Hubble space telescope.

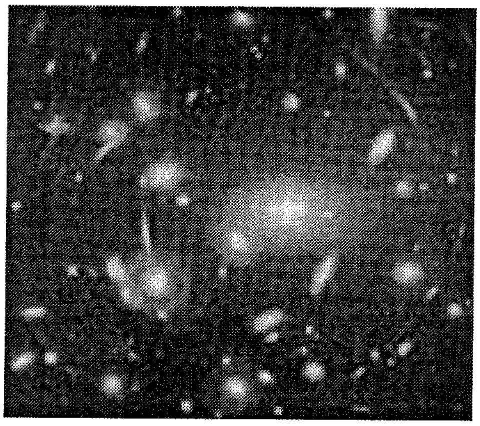

Fig. 9.1

(i) Photons have zero rest mass. With reference to General Relativity, explain how the path taken by light can be affected by gravitational fields.

....

....

....[2]

(ii) Suggest what is meant by the term *gravitational lens*.

....

....

....

....

....[2]

For Examiner's Use

(iii) Sketch a labelled diagram to show gravitational lensing.

[3]

[Total : 9]

For Examiner's Use

10 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. 10.1 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.

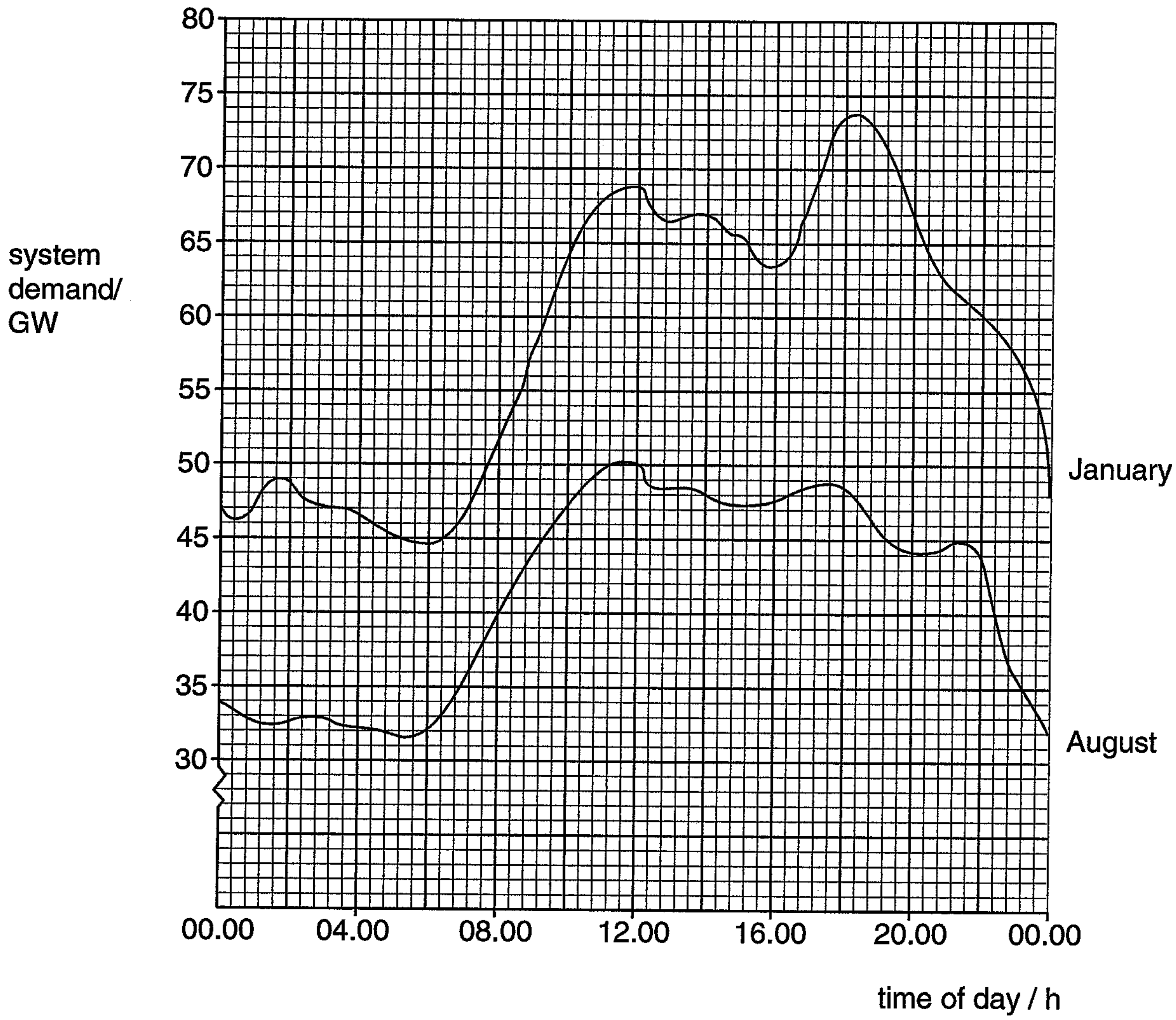

Fig. 10.1

Fig. 10.1 shows the average variation in electricity demand from the electricity companies in the UK with time of day for January and August.

For Examiner's Use

Answer the following questions about this passage.

(a) State **four** major features of the graphs of Fig. 10.1 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. 10.1 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. 10.1.

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

power = ... GW
[2]

(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]

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Copyright Acknowledgements:

Question 10. 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.