ADVANCED GCE

PHYSICS A

Cosmology

FRIDAY 25 JANUARY 2008

2825/01

Morning

Time: 1 hour 30 minutes

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

Candidate Forename | Candidate Surname

Centre Number | Candidate Number

INSTRUCTIONS TO CANDIDATES

- Write your name in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use blue or black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Do **not** write outside the box bordering each page.
- Write your answer to each question in the space provided.

INFORMATION FOR CANDIDATES

- The number of marks for each question is given in brackets [ ] at the end of each question or part question.
- The total number of marks for this question paper is **90**.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- The first six questions concern Cosmology. The last question concerns general physics.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	**8**	
2	**13**	
3	**14**	
4	**8**	
5	**13**	
6	**14**	
7	**20**	
TOTAL	**90**	

This document consists of **15** 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, $n = \frac{1}{\sin C}$

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

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

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

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

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

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

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

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

current, $I = nAve$

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

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

Answer **all** the questions.

1 **(a)** When viewed from Earth over several months the appearance of Venus changes. This was first observed by Galileo.
Describe and explain this variation in appearance. A space is provided for a diagram, if required.

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....[4]

(b) State **two** other observations made by Galileo which helped change our understanding of the Solar System. Outline the significance of each one.

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....[4]

[Total: 8]

2 **(a)** Explain why Newton believed the Universe to have an infinite size.

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.... [3]

(b) Fig. 2.1 shows a plan view of the elliptical orbit of a planet around a star.

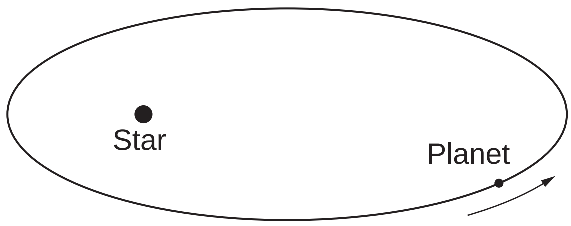

Fig. 2.1

Describe and explain how the speed of the planet varies as it orbits the star once.

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.... [3]

(c) Two planets **A** and **B** orbit a star with near circular orbits. The planets and part of their orbital paths are shown in Fig. 2.2

Fig. 2.2

(i) Explain why the orbital speed of planet **A** is greater than the speed of **B**.

....

....

.... [2]

(ii) Draw arrows on Fig. 2.2 to represent the gravitational force that each planet exerts on the other. [2]

(iii) Explain the effects of these forces on the motion of planets **A** and **B**. State how this led to the discovery of Neptune.

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....[3]

[Total: 13]

3 **(a)** What is meant by the *apparent magnitude* of a star?

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....[2]

(b) The table in Fig. 3.1 shows the intensity I of radiation received and the distance d of four stars from Earth. The value of $1/d^2$ is given for two of the stars.

Star	$I / 10^{-4}\ W\ m^{-2}$	d / pc	$\frac{1}{d^2} / pc^{-2}$
W	16.1	2.1	0.23
X	7.9	3.0	0.11
Y	4.9	3.8	
Z	3.4	4.6	

Fig. 3.1

(i) Complete the last column of the table. [1]

(ii) Plot a graph of I versus $1/d^2$ using the axes in Fig. 3.2 and draw the best straight line through the points. [2]

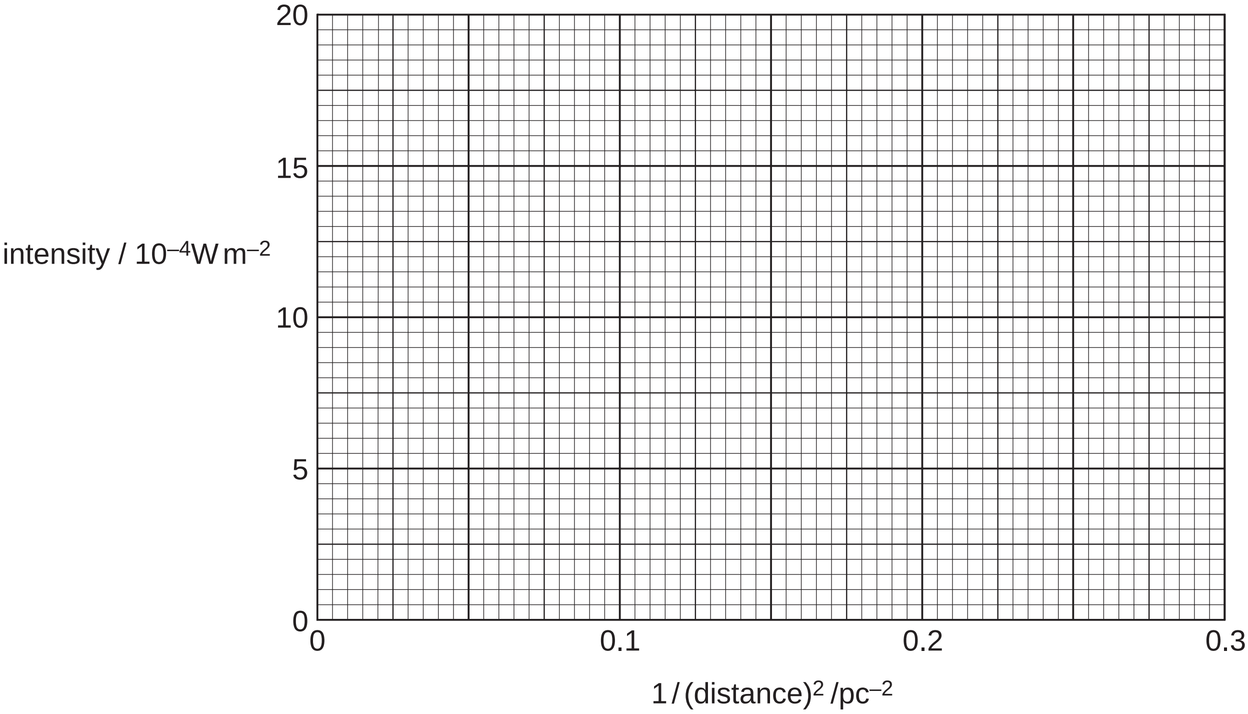

Fig. 3.2

(iii) Assuming a relationship of $I = k/d^2$, use your graph to calculate a value for the constant k. Give a suitable unit with your answer.

constant k = ... unit .... [3]

(c) **(i)** Use the equation for intensity in **(b)(iii)** and your value for k to write down an expression for lg (I) in terms of d.

[2]

(ii) The apparent magnitude m is given by the expression $m = -2.5 \lg(I) + a$ where a is a constant. Show by substitution of $\lg(I)$ that the apparent magnitude may be expressed as $m = 5 \lg(d) + b$ where b is another constant.

[2]

(d) Calculate the absolute magnitude of star W if its apparent magnitude is 3.0.

absolute magnitude of star W = ... [2]

[Total: 14]

4 **(a)** Sketch a Hertzprung-Russell (H-R) diagram. Show how the diagram may be used to represent the evolution of a main sequence star such as the Sun.

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....[5]

(b) The Sun releases energy at the rate of 3.9×10^{26} W through the fusion of protons into helium.

(i) Why does the fusion of protons produce energy?

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....[1]

(ii) Calculate the number of fusion reactions in one second if each one releases 26 MeV of energy.

number per second = ... [2]

[Total: 8]

5 **(a)** State and explain **two** pieces of evidence which suggest that the Universe began with a 'big bang'.

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....[6]

(b) The oldest rocks discovered on Earth were formed about 4.5×10^9 years ago.

(i) Use this to find a limiting value for the Hubble constant, expressing your answer in $\mathrm{km\,s^{-1}\,Mpc^{-1}}$.

H = ... $\mathrm{km\,s^{-1}\,Mpc^{-1}}$ [3]

(ii) Explain whether your answer is a maximum or minimum.

....[1]

(iii) Explain why the value of the Hubble constant is not known to a high degree of accuracy and suggest why it may not be a constant at all.

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....[3]

[Total: 13]

6 **(a)** The speed of light is sometimes referred to as being invariant. With reference to the Special Theory of Relativity explain what is meant by this.

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....[2]

(b) A neutron star of diameter 30 km spins on its axis as shown in Fig. 6.1.

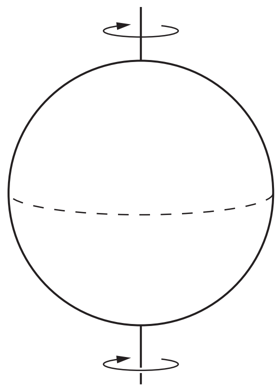

Fig. 6.1

(i) State the maximum possible speed of the star's surface.

....[1]

(ii) Calculate the maximum possible number of revolutions per second.

maximum number of revolutions per second = ... [2]

(iii) Suggest why this frequency could not be reached.

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....[2]

(c) Describe a thought experiment which demonstrates the bending of light by a gravitational field.

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(d) What was the particular significance of the observations made during the solar eclipse of 1919?

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[Total: 14]

7 The normal temperature of a healthy human body is 37 °C. When an adult person at this temperature is at rest, energy from food is required to maintain normal internal body activity (the basal metabolic rate). On average this energy is supplied to the body at the rate of 75 W. When involved in physical activity, extra energy from food is used. 20% of this extra energy is needed to do mechanical work; the remaining 80% heats the body and has to be dissipated. The energy available from 1 g of food in the form of carbohydrate is about 1.7×10^4 J.

(a) A meal provides a person with 250 g of carbohydrate.

(i) Estimate the period of rest in hours which is provided for by this intake of food.

period of rest = ... hour [2]

(ii) Suggest why the temperature of the person's body remains steady during this period.

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....[2]

(b) A mountaineer of mass 70 kg climbs a mountain to a vertical height of 800 m above the starting point in 1.5 hours. Calculate

(i) the gain in potential energy of the mountaineer

potential energy gain = ... J [2]

(ii) the mass of carbohydrate used to provide this gain in potential energy

mass = ... g [1]

(iii) the minimum total mass of carbohydrate used by the mountaineer.

mass = ... g [3]

(c) A marathon runner, of mass 65 kg, competes on a day when the temperature of the environment is 40 °C. The rate of heating of the runner's body is 900 W.

(i) Calculate the rate of temperature rise of the runner's body. Assume that the body has a specific heat capacity of $4200\,J\,kg^{-1}\,K^{-1}$.

rate of temperature rise = ... $K\,s^{-1}$ [2]

(ii) Explain why the runner's body cannot lose heat to the surrounding air by the processes of conduction, convection and radiation.

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....[2]

(iii) The runner maintains normal body temperature by using heat from the body to evaporate water (sweat) from the surface of the skin. The heat required to vaporise 1 kg of water is 2.4×10^6 J. Calculate the mass of water evaporated from the skin in 2.5 hours of running.

mass = ... kg [2]

(iv) To minimise harm to the body **during the race**, state and explain **two** precautions the runner should take.

1. ....

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2. ....

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....[4]

[Total: 20]

END OF QUESTION PAPER

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