OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE **2825/01**

PHYSICS A

Cosmology

TUESDAY 17 JUNE 2008 Afternoon

Time: 1 hour 30 minutes

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

CUP/T50113

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.
- 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 paper is **90**.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- The first seven questions concern Cosmology. The last question concerns general physics.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	**8**	
2	**9**	
3	**11**	
4	**9**	
5	**14**	
6	**6**	
7	**13**	
8	**20**	
TOTAL	**90**	

This document consists of **18** printed pages and **2** blank pages.

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,	$= \surd\,(1 - \dfrac{v^2}{c^2})$
current,	$I = nAve$
nuclear radius,	$r = r_0 A^{1/3}$
sound intensity level,	$= 10\,\lg\left(\dfrac{I}{I_0}\right)$

Answer **all** the questions.

1 **(a)** **(i)** What did Copernicus mean by the *heliocentric* model of the Universe?

.... [1]

(ii) Describe and explain *retrograde motion* in relation to planetary orbits.

....

....

....

.... [2]

(b) **(i)** By completing the table of Fig. 1.1, state the full name and meaning of the units ly and AU.

unit	full name of unit	meaning of unit
ly		....
AU		....

Fig. 1.1

[4]

(ii) Place the units AU, ly, km, pc in order of **decreasing** size.

largest smallest

……………… ……………… ……………… ……………… [1]

[Total: 8]

2 **(a)** State Newton's law of gravitation, explaining any symbols used.

....

....

....

.... [1]

(b) **(i)** Sketch in the space below the shape of our Galaxy when it is viewed edge-on.

[2]

(ii) On your diagram mark the approximate position of the Sun with an **X.**

Add an arrow to indicate the direction of the resultant gravitational force acting on the Sun. [2]

(c) The average orbital velocity of the Sun within the Galaxy is 230 km s^{-1}. Assuming the orbit is circular with radius of 2.6×10^{17} km calculate the mass of that part of the Galaxy which is bounded by the Sun's orbit.

Treat the Sun and inner part of the Galaxy as point masses.

mass = ... kg [4]

[Total: 9]

3 **(a)** Describe and explain the Sun's principal energy-generating process.

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.... [3]

(b) Describe the important features of the spectrum of visible light emitted by the Sun.

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.... [2]

(c) The Sun emits radiation across the full electromagnetic spectrum. The variation in intensity of this radiation at the Earth's surface is shown by the sketch in Fig. 3.1.

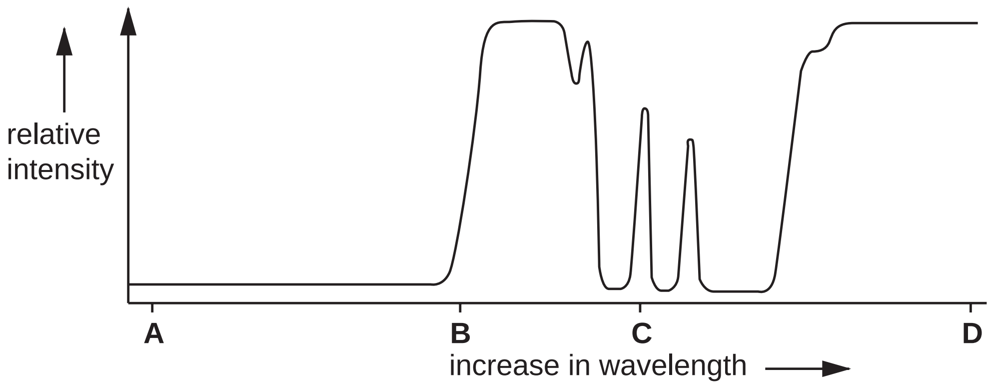

Fig. 3.1

Point **A** is in the gamma-ray region of the spectrum. State the name of the radiation corresponding to points **B**, **C** and **D**.

region **B** ....

region **C** ....

region **D** .... [3]

(d) It has been estimated that a photon of light may take up to 200 000 years to travel from the centre of the Sun to its surface.

(i) Calculate the average radial velocity of this photon. Take the Sun's radius to be 7×10^8 m.

average radial velocity = ... m s^{-1} [2]

(ii) Explain why your answer differs from c.

....

....

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.... [1]

[Total: 11]

4 **(a)** Stars are thought to evolve into *red giants***.** Explain where this state fits into the life history of a star and the reasons why the name is appropriate.

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.... [3]

(b) The magnitude of some stars varies periodically with time. The graph in Fig. 4.1 shows how the maximum absolute magnitude of some of these stars depends upon the period.

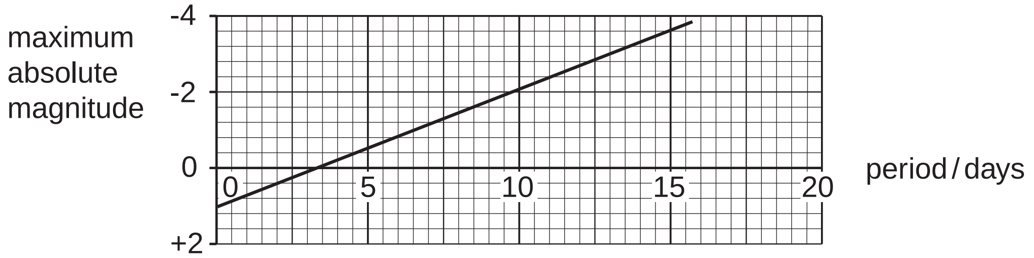

Fig. 4.1

(i) Use the graph to find the maximum absolute magnitude of a star which varies in brightness with a period of 6.5 days.

maximum absolute magnitude = ... [1]

(ii) Calculate the distance of this star from Earth if its maximum **apparent** magnitude is +7.

distance from Earth = ... pc [3]

(iii) Suggest why for these same stars there is no simple linear relationship between period and **apparent** magnitude.

....

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.... [2]

[Total: 9]

5 **(a)** Describe the events which occurred in the earliest moments of the Universe prior to the formation of atoms.

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.... [5]

[Turn over

(b) The relative intensity of the cosmic microwave background radiation has been measured for different frequencies. The results are given in Fig. 5.1.

frequency / GHz	relative intensity
190	1.0
210	1.5
230	1.8
250	1.9
290	1.9
340	1.6
380	1.3
420	1.0

Fig. 5.1

(i) Plot a graph of relative intensity versus frequency using the axes in Fig. 5.2. [1]

(ii) Draw a smooth curve through the points and determine the frequency for which the intensity is greatest.

frequency giving greatest intensity = ... GHz [3]

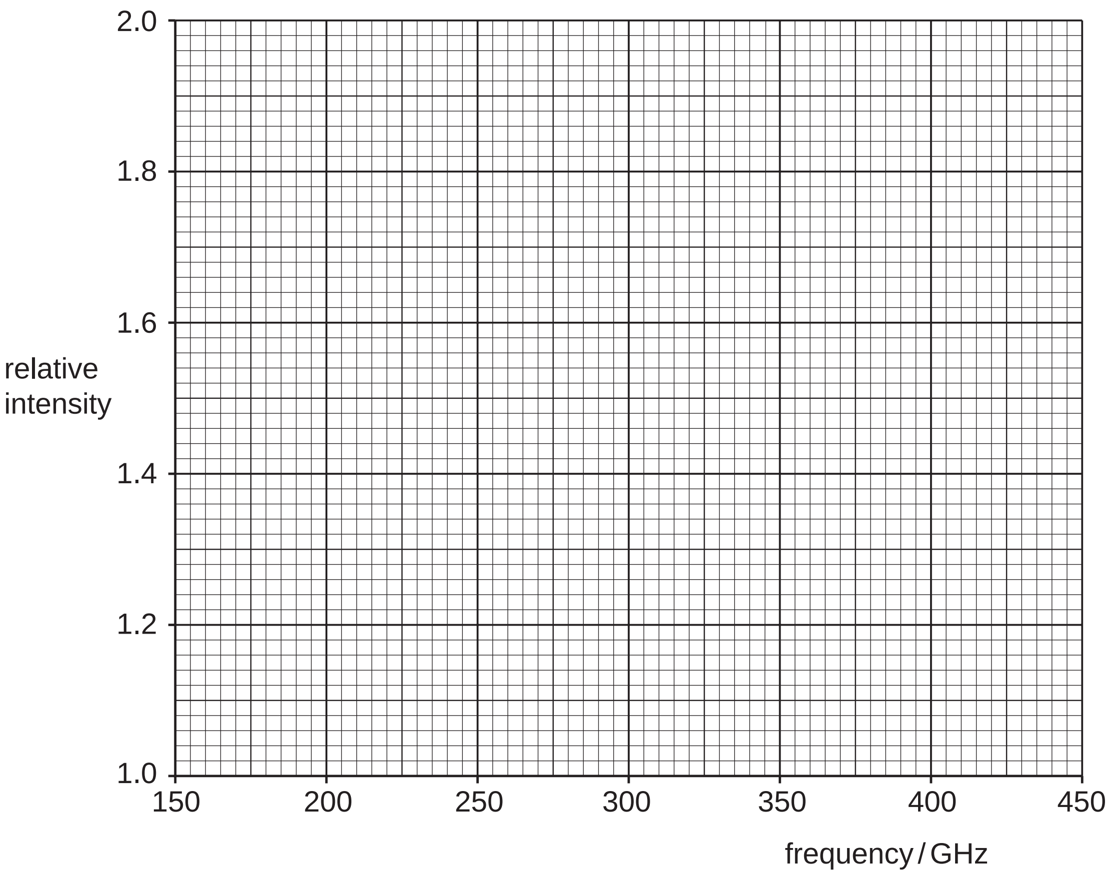

Fig. 5.2

(iii) Calculate the wavelength λ_m of the microwaves which have the maximum intensity.

λ_m = ... m [2]

(iv) The temperature T in Kelvin which corresponds to this maximum intensity is given by the relationship

$$\lambda_m = \frac{2.9 \times 10^{-3}}{T}.$$

Calculate a value for *T.*

T = ... K [1]

(c) What was the significance of these measurements and calculations when they were first performed in 1964?

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.... [2]

[Total: 14]

6 **(a)** Explain how the work of Edwin Hubble changed our understanding of the origin of the Universe.

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.... [3]

(b) Discuss how the Universe may evolve.

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.... [3]

[Total: 6]

7 **(a)** Within the Special Theory of Relativity, what is meant by

(i) an inertial frame of reference

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....

.... [1]

(ii) time dilation?

....

....

.... [2]

(b) **(i)** An electron is accelerated from rest to a speed close to the speed of light, *c.* Using the axes in Fig 7.1, sketch a graph to illustrate how the mass of the electron varies during this time. The rest mass of the electron is 9.11×10^{-31} kg.

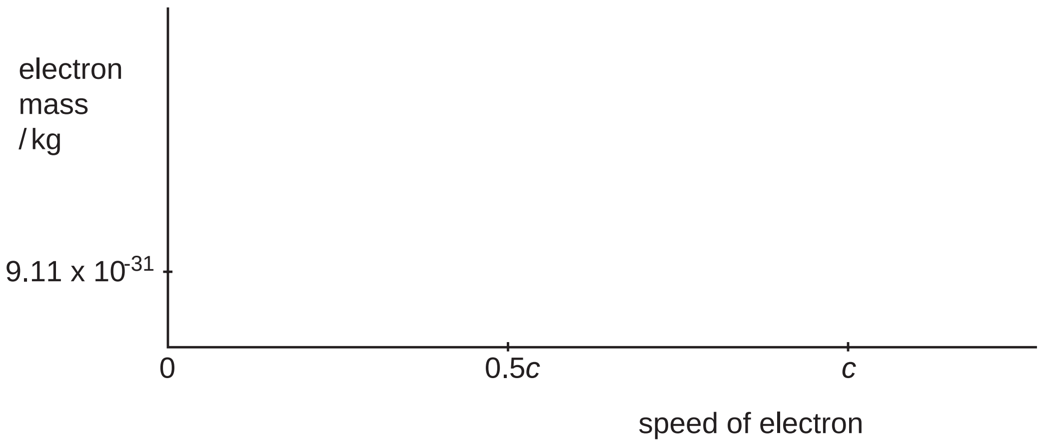

Fig. 7.1 [3]

(ii) The particle accelerators which provide energy for electrons are becoming increasingly powerful. Explain how your graph relates the speed and mass of the electrons to their energy as their energy increases.

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.... [2]

(c) Describe a **thought** experiment which demonstrates the effect of a gravitational field upon the frequency of light.

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.... [5]

[Total: 13]

8 A photo-voltaic cell is an electrical component which can generate a current proportional to the intensity of light incident on its light-sensitive surface. One type of solar panel uses a number of photo-voltaic cells in series to provide a sufficient voltage to power a practical device.

(a) The measured intensity of the solar radiation received on the upper atmosphere of the Earth is $1400\,\mathrm{W\,m^{-2}}$. The mean radius of the Earth's orbit round the Sun is $1.5 \times 10^{11}\,\mathrm{m}$.

(i) Show that

1 the surface area of a sphere of radius $1.5 \times 10^{11}\,\mathrm{m}$ is about $3 \times 10^{23}\,\mathrm{m^2}$

[1]

2 the Sun emits radiation with a total power of about $4 \times 10^{26}\,\mathrm{W}$ into the surrounding space.

[1]

(ii) Calculate the rate of conversion of mass to energy in the Sun.

rate of conversion = ... $\mathrm{kg\,s^{-1}}$ [2]

(b) Explain why, when the Sun is directly overhead at the equator

(i) the maximum intensity received on the surface of the Earth is less than $1000\,\mathrm{W\,m^{-2}}$

....

.... [1]

(ii) the maximum intensity decreases with distance North and South of the equator.

....

.... [1]

(c) An ornamental water fountain is driven by a pump powered by the electrical output of a solar panel. The following data is relevant to the operation of the system, which is arranged to give maximum solar power input.

area of light-sensitive surface of panel:	$0.080\,m^2$
solar intensity at the location of the panel:	$750\,W\,m^{-2}$
voltage output of panel:	17 V
current delivered to the pump:	270 mA
delivery rate of the fountain:	$0.50\,m^3$ per hour
efficiency of pump:	35%
density of water:	$1000\,kg\,m^{-3}$

Calculate

(i) the solar power input to the panel

power input = ... W [1]

(ii) the electric power generated by the panel

power generated = ... W [1]

(iii) the efficiency of the panel in converting solar power to electrical power

efficiency = ... [2]

(iv) the height of the fountain of water.

maximum height = ... m [5]

(d) A solar panel of greater area than the one in **(c)** supplies 80 W of electrical power to a heating coil immersed in water.

(i) Calculate the time required to heat 0.50 kg of water from 25 °C to 100 °C, assuming no loss of heat to the surroundings. The specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

time = ... s [3]

(ii) Suggest **two** reasons why this type of solar panel is unlikely to replace conventional mains-powered electric kettles as a means of boiling water, even when the solar power is a maximum.

1. ....

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2. ....

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.... [2]

[Total: 20]

END OF QUESTION PAPER

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