OCR RECOGNISING ACHIEVEMENT

ADVANCED GCE UNIT **2825/01**

PHYSICS A

Cosmology

THURSDAY 21 JUNE 2007 Afternoon

Time: 1 hour 30 minutes

Additional materials: Electronic calculator

CUP/T27965

Candidate Name

Centre Number

Candidate Number

INSTRUCTIONS TO CANDIDATES

- Write your name, Centre Number and Candidate Number in the boxes above.
- Answer **all** the questions.
- Use blue or black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Do **not** write in the bar code.
- Do **not** write outside the box bordering each page.
- WRITE YOUR ANSWER TO EACH QUESTION IN THE SPACE PROVIDED. ANSWERS WRITTEN ELSEWHERE WILL NOT BE MARKED.

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	**14**	
3	**14**	
4	**9**	
5	**7**	
6	**9**	
7	**9**	
8	**20**	
TOTAL	**90**	

This document consists of **20** printed 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,	$n = \frac{1}{\sin C}$
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)** What is meant by the *retrograde motion* of a planet?

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....

....

....[2]

(b) Explain how the Copernican system accounts for this retrograde motion.

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....[2]

(c) At the time of Copernicus the Earth-Sun distance had been measured as approximately 1100 × the Earth's radius.

(i) Using this relationship and taking the Earth's radius to be 6400 km calculate the average orbital speed of the Earth.

speed = ... $m\ s^{-1}$ [2]

(ii) Other than ideas of religion, give **two** reasons why Copernicus' ideas were not immediately accepted.

....

....

....

....[2]

[Total: 8]

2 The star Vega has been used to define the zero point of the scale of apparent magnitude.

(a) **(i)** What is meant by *apparent magnitude*?

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....

....[1]

(ii) State and explain the change in the value of the apparent magnitude of Vega if it were to move closer to the Earth.

....

....

....[2]

(iii) Vega has an absolute magnitude of 0.58. Calculate the distance of Vega from the Earth.

distance = ... pc [3]

(b) Vega is a Main Sequence star. Describe and explain how energy is generated within Vega.

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....[3]

(c) A comparison can be made between the power radiated by Vega and the power generated by a human being, by finding the power per unit mass for each.

(i) Vega has a mass of 5.2×10^{30} kg and radiates a power of 2.0×10^{28} W. Calculate the power radiated per unit mass by Vega.

power radiated per unit mass = ... W kg^{-1} [1]

(ii) A person of mass 60 kg ascends a vertical height of 2.5 m in a time of 10 s. What is the average power per unit mass required during this movement?

power per unit mass = ... W kg^{-1} [2]

(iii) Calculate the ratio

$$\frac{\text{average human power per unit mass}}{\text{power radiated per unit mass by Vega}}.$$

ratio = ... [1]

(iv) Suggest why the radiated power per unit mass of Vega is relatively small compared to the average human power per unit mass.

....

....

....[1]

[Total: 14]

3 **(a)** What is meant by *stellar parallax*?

....

....

....[2]

(b) The first recorded stellar parallax had a value of 0.314 arc seconds.

(i) Calculate the distance of the star from Earth, giving your answer in parsecs.

distance = ... pc [2]

(ii) What is this distance in metres?

distance = ... m [1]

(c) The distances d of some galaxies, together with their recessional velocities v are given in Fig. 3.1.

distance of galaxy d / 10^{24} m	velocity of galaxy v / 10^7 m s^{-1}
5.3	1.1
6.6	1.4
7.3	1.5
10.7	2.2

Fig. 3.1

(i) Plot a graph of recessional velocity v against distance d on Fig. 3.2. [1]

(ii) Draw the best straight line through the points. [1]

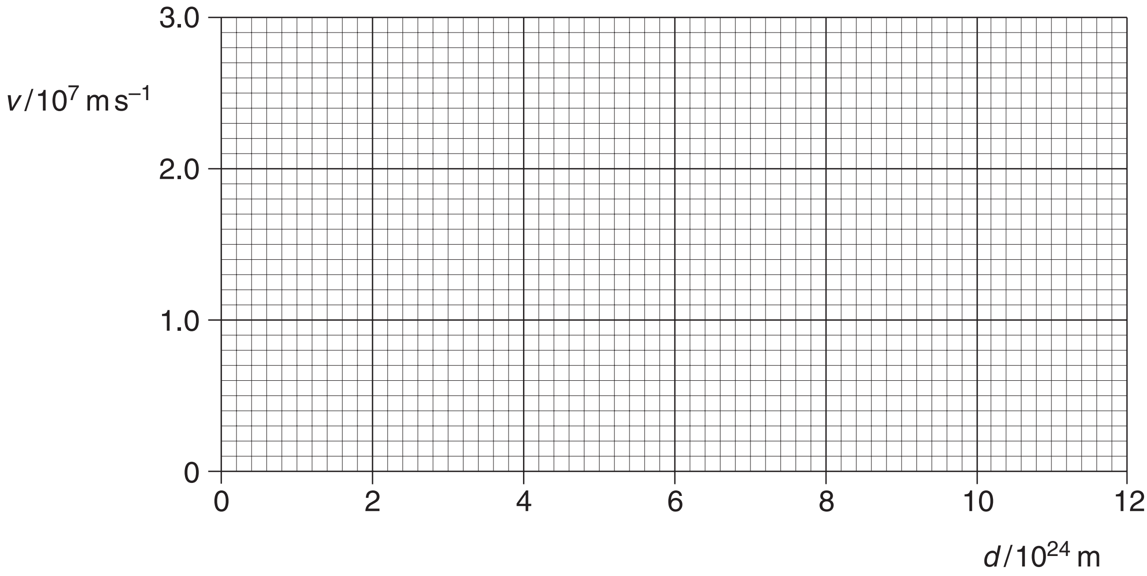

Fig. 3.2

(iii) The relationship between v and d is

$$v = kd$$

where k is a constant.
From your graph find, stating the unit in each case, the values of

1 k

k = ... unit .... [2]

2 $\frac{1}{k}$

$\frac{1}{k}$ = ... unit .... [1]

(iv) Explain the significance of your answers to **(iii)**.

....

....

....[2]

(d) Suggest why the method of stellar parallax was **not** used to obtain the distance data in Fig. 3.1.

....

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....[2]

[Total: 14]

4 **(a)** Galaxies were first classified by Edwin Hubble. Fig. 4.1 shows two particular galaxies, **A** and **B**.

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galaxy **A** galaxy **B**

Fig. 4.1

(i) **A** is a spiral galaxy, similar to our own. Sketch the shape of galaxy **A** when viewed side-on.

[2]

(ii) What general name is given to galaxies such as that shown in **B**?

....[1]

(b) (i) Using the axes in Fig. 4.2 sketch a Hertzprung-Russell (HR) diagram showing where Main Sequence stars appear. Label the axes.

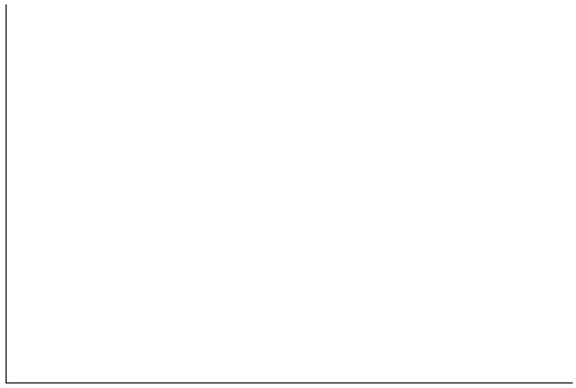

Fig. 4.2

[3]

(ii) Galaxy **A** contains some Main Sequence, low mass, red stars. Use a cross (**x**) on Fig. 4.2 to show the region where these stars would appear. [1]

(c) Explain why the mass of a star determines the time for which it will remain on the Main Sequence.

....

....

....

....[2]

[Total: 9]

5 **(a)** The Universe is assumed to be *isotropic* and *homogenous*. Explain the meaning of these two terms.

isotropic ....

....

homogenous ....

....[2]

(b) One possible value for the critical density of the Universe is 3.3×10^{23} kg pc^{-3}.

(i) Assuming this density, what average volume of space would be required to contain a mass of 2×10^{30} kg, the mass of the Sun?

volume = ... pc^3 [2]

(ii) Explain how the Universe would evolve if measurements showed that the volume required to contain 1 solar mass was significantly greater than that found in **(i)**.

....

....

....

....

....[3]

[Total: 7]

6 All the information that we have about stars and galaxies comes from electromagnetic radiation.

(a) Describe the essential features of **stellar** spectra.
Explain how these are used to find the chemical composition of stars.

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....[5]

(b) Describe the relative transmission through the Earth's atmosphere of each of the following radiation:

- X-rays
- short wavelength ultra-violet rays
- visible light
- short-wavelength radio waves

You may sketch a labelled diagram to support your answer.

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[4]

[Total: 9]

7 **(a)** Describe a thought experiment which illustrates the effect of gravity upon time.

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....[5]

(b) Measurements show that the orbit of Mercury precesses about the Sun at the rate of about 570 arc seconds per century.

(i) By adding to the diagram in Fig. 7.1 explain what is meant by *orbital precession*.

....

....

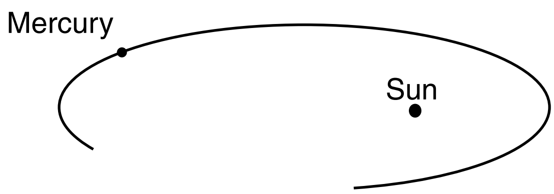

Fig. 7.1

[2]

(ii) Why is the rate of precession of Mercury's orbit greater than that of any other planet within the Solar System?

....

....[1]

(iii) The rate of precession is about 40 arc seconds per century larger than that predicted by Newton's law of gravitation. What is the significance of this?

....

....[1]

[Total: 9]

8 The suspension system for road vehicles can be modelled using springs and masses. The natural frequency of oscillation *f* for a mass *m* supported by a spring is given by

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

where *k* is the spring constant.

(a) **(i)** A spring is found to compress by 40 mm when loaded with a mass of 5000 kg. Show that the spring constant *k* is $1.2 \times 10^6\,\mathrm{N\,m^{-1}}$.

[2]

(ii) A 5000 kg mass is supported by four such springs as shown in Fig. 8.1.

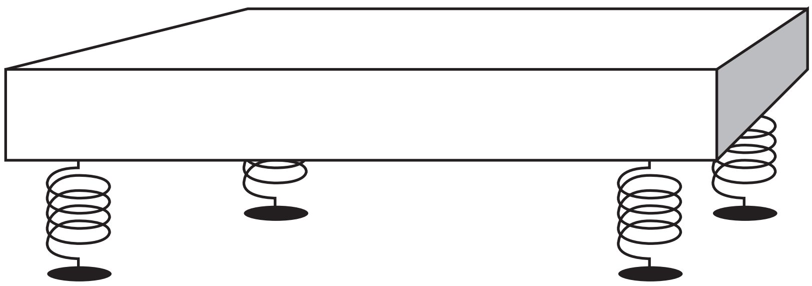

Fig. 8.1

Calculate the natural frequency of oscillation of the mass.

natural frequency = ... Hz [2]

(b) The suspension systems of large lorries require springs made from rods which may be several centimetres thick. Steel rod of this diameter would snap if bent into shape at room temperature. To prevent this the rod is 'hot-coiled': it is heated from 20 °C to 1000 °C before being wound into a spring.

The method of heating is electrical, using a supply of 50 V, which passes a current of 12 000 A through the steel rod. Large contacts at each end of the rod are necessary and these are water-cooled (see Fig. 8.2).

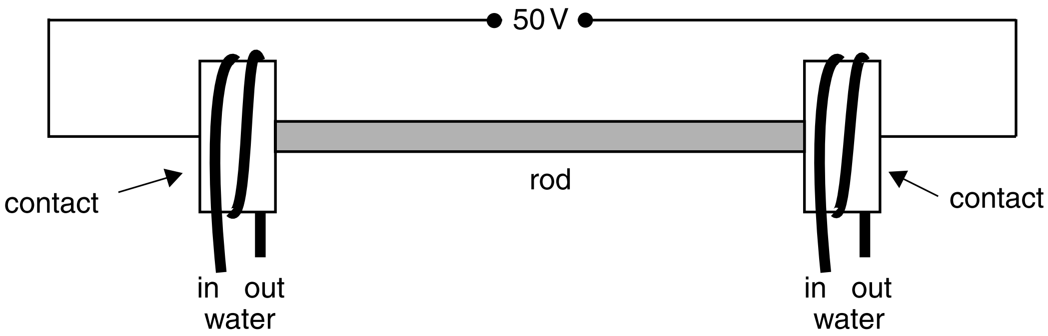

Fig. 8.2

(i) Calculate the resistance of the rod, assuming that the voltage across it is 50 V.

resistance = ... Ω [1]

(ii) Show that the electrical power generated in the rod is 600 kW.

[1]

The mass of the rod is 15 kg.

The specific heat capacity of steel is 420 $J\,kg^{-1}\,K^{-1}$.

(iii) Calculate the energy required to heat the rod from 20 °C to 1000 °C.

energy = ... J [2]

(iv) Calculate the minimum time required to heat the rod to 1000 °C.

minimum time = ... s [2]

(c) In practice the time taken to reach 1000 °C is greater than the value found in **(b)(iv)**. Consequently, the total energy supplied is found to vary according to the time taken for the heating process. The relationship between the energy supplied and time taken is shown in Fig. 8.3.

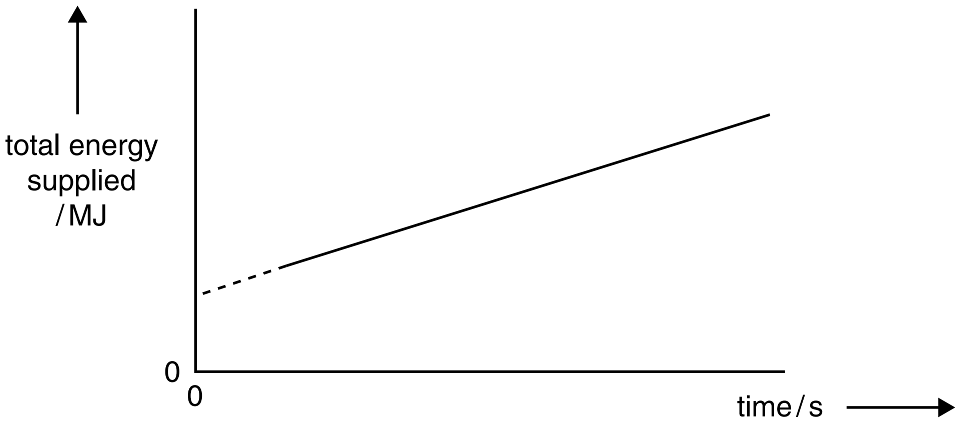

Fig. 8.3

Discuss **two** ways in which energy is lost from the rod during heating and explain the trend shown by the graph in Fig. 8.3.

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....[3]

(d) A spring is made from a steel rod of the same length but with **twice** the radius.

Suggest, **with reasons**, how the following will change.

(i) The resistance of the rod.

....

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....

....[2]

(ii) The time taken to heat the rod from 20 °C to 1000 °C, using the same voltage across the rod.

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....[3]

(iii) The natural frequency of the mass-spring system in **(a)**.

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....[2]

[Total: 20]

END OF QUESTION PAPER

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Copyright Acknowledgements:

Fig. 4.1 galaxy A source: University of Cambridge, Department of Applied Mathematics and Theoretical Physics (DAMTP), www.damtp.cam.ac.uk
Fig. 4.1 galaxy B source: Students for the Exploration and Development of Space, www.seds.org