THIS IS A LEGACY SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

PHYSICS A

Cosmology

2825/01

Candidates answer on the Question Paper

OCR Supplied Materials:
None

Other Materials Required:
- Electronic calculator

Thursday 28 January 2010
Afternoon

Duration: 1 hour 30 minutes

* 2 8 2 5 0 1 *

* O C E / 1 6 4 3 8 *

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use 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, however additional paper may be used if necessary.

INFORMATION FOR CANDIDATES

- The number of marks 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 six questions concern Cosmology. The last question concerns general physics.
- This document consists of **20** pages. Any blank pages are indicated.

Examiner's Use Only:			
1			
2			
3			
4			
5			
6			
7			
Total			

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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, $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$

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

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Answer **all** the questions.

1 **(a)** State Kepler's three laws of planetary motion.

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..... **[4]**

(b) State **two** ways in which the Copernican model of the Solar System differs from that proposed later by Kepler.

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

(c) When observed from Earth the planet Mars shows retrograde motion.

(i) What is meant by *retrograde motion*?

.....

.....

(ii) How did Copernicus explain the retrograde motion of Mars?

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.....

..... **[4]**

[Total: 10]

2 **(a)** **(i)** Define the *parsec*.

.....

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

(ii) State the value of 1 parsec in metres.

1 parsec = ... m **[1]**

(b) The apparent magnitude m of the star Sirius is –1.46. For Barnard's star m = 9.5.

The value of m for a star is related to the intensity I of the light received on Earth from the star by the expression

$$m = -2.5 \lg I + \text{constant}.$$

Calculate the ratio $\dfrac{I \text{ for Sirius}}{I \text{ for Barnard's star}}$.

ratio = ... **[3]**

(c) **(i)** State the relation between apparent magnitude m, absolute magnitude M and distance d from Earth.

..... **[1]**

(ii) For Sirius, M = + 1.4. Calculate the distance of Sirius from Earth.

distance = ... pc **[2]**

[Total: 9]

3 Fig. 3.1 is an outline of the Hertzsprung-Russell (H-R) diagram.

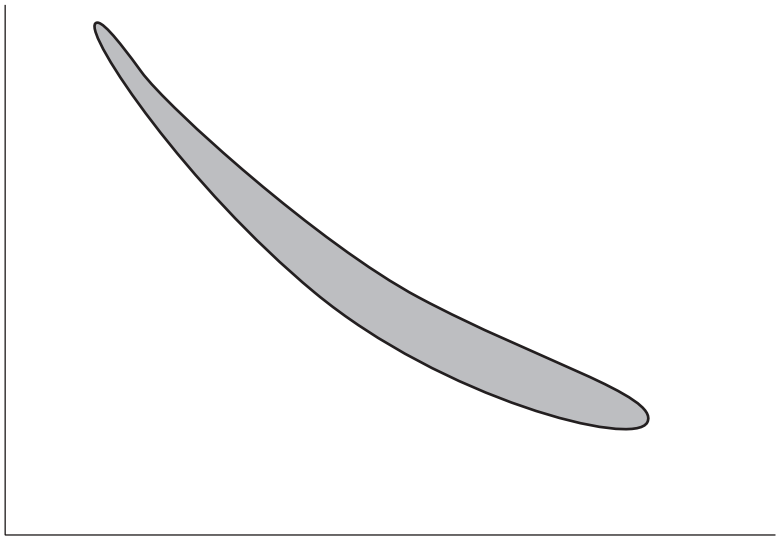

Fig. 3.1

(a) On Fig. 3.1

(i) label the axes with indication of increasing values **[2]**

(ii) name the region which is shaded **[1]**

(iii) mark the approximate position that currently represents the Sun. Label this point **S**. **[2]**

(b) Also on Fig. 3.1

(i) mark and name positions in two other regions that the Sun is expected to occupy in the future **[4]**

(ii) draw a line showing the path that the Sun is expected to take over the next 5×10^9 years. **[2]**

(c) Explain what is likely to be the final fate of the Sun (assuming that the Universe is open).

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

[Total: 13]

4 **(a)** Explain what is meant by the *Doppler effect*.

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

(b) A line in the spectrum of calcium has a wavelength of 397.0 nm when measured from a stationary laboratory source. The same spectral line is observed in five galaxies, resulting in the data shown in Fig. 4.1.

galaxy	distance / Mpc	wavelength / nm	velocity of recession / $\times 10^3$ km s^{-1}
A	50	400.3	2.5
B	300	416.9	15.0
C	620	438.0	31.0
D	980	461.8	49.0
E	1300	483.0	65.0

Fig. 4.1

(i) State the equation for the change in wavelength produced by the Doppler effect and use it to explain why the light from galaxy E undergoes a much greater change in wavelength than the light received from galaxy A.

.....

.....

.....

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

(ii) Plot a graph on the grid in Fig. 4.2 of recession velocity against distance. **[2]**

(iii) Use the graph to find a value for the Hubble constant, giving a unit with your answer.

Hubble constant = ... unit ..... **[3]**

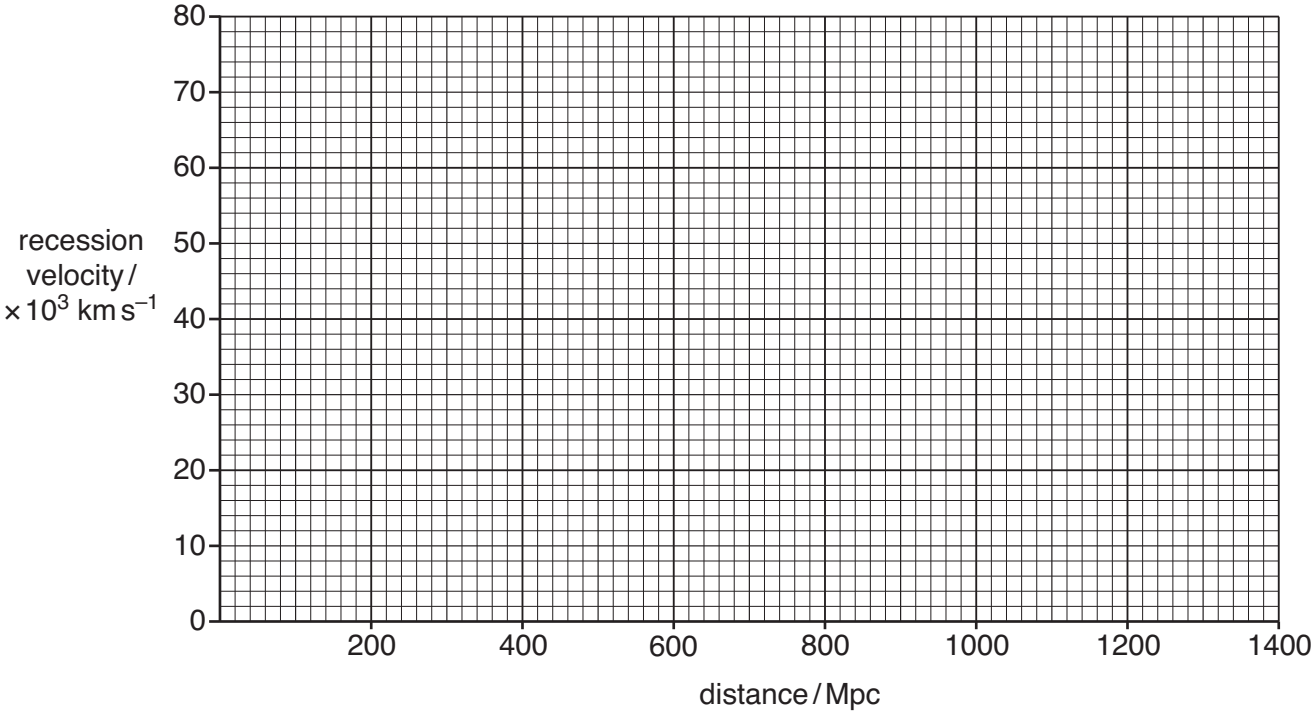

Fig. 4.2

(c) Explain why Hubble's constant may not be a constant at all.

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

(d) The graph in Fig. 4.2 has been used to support the Big Bang model of the Universe. Describe and explain one other piece of evidence which supports this model.

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..... **[3]**

[Total: 14]

5 **(a)** The transparency of the Earth's atmosphere affects the locations at which astronomical observations in different regions of the electromagnetic spectrum are possible.

Put ticks (✓) in the relevant boxes to indicate at which locations observations may be made.

[4]

	γ-radiation	X-rays	microwave	radio
at sea level				
aboard a spacecraft				

Fig. 5.1

(b) Other than the range of wavelengths which may be detected, give **one** advantage and **one** disadvantage of using ground-based telescopes compared to those mounted on satellites.

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

[Total: 6]

6 **(a)** What **two** assumptions are necessary to establish the Special Theory of Relativity?

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

(b) Describe a **thought** experiment to illustrate time dilation.

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..... **[5]**

(c) The time dilation equation may be written as

$$t = \frac{t_0}{\sqrt{(1 - v^2/c^2)}} .$$

(i) Explain what the symbols t and t_0 in this equation represent.

.....

.....

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

(ii) Muons are sub-atomic particles having, when at rest, a half-life of 1.52 μs. Such particles, created in the upper atmosphere, travel towards the Earth's surface at a speed approximately equal to that of light.

A muon detector, suspended from a balloon at an altitude of 2750 m, detects 6210 muons in 5 minutes. A similar detector at sea level, vertically below the balloon, detects 1280 muons in the same time interval.

1 Assuming that the muons travel at the speed of light, calculate the time of travel between the two detectors, as measured by a person on Earth.

time = ... μs **[2]**

2 Use your answer to **1**, and assume that fast-moving muons also have a half-life of 1.52 μs. Calculate the number of muons which would be expected at the sea level detector in the five minute period.

number = ... **[3]**

3 Comment on your answer to **2** by comparing it with the **actual** number detected.

.....

.....

..... **[1]**

(d) The path of light can be affected by gravitational forces. Explain how a stellar object may therefore produce two visible images at the same time.

.....

.....

.....

..... **[3]**

[Total: 18]

7 A householder wants to reduce the amount of mains energy used in his home, in order to combat global warming. He plans to install a device which is powered by a renewable energy source.

He considers three options:

A an array of photoelectric cells mounted on his house roof

B a solar panel mounted on the house roof for heating water by solar radiation

C an aerogenerator attached by a short pole to the house chimney.

Option A: Photoelectric cells

Photoelectric cells consist of two layers of different semiconductor materials in contact with each other. When a cell is exposed to solar radiation an e.m.f. is created. See Fig. 7.1. The cells are arranged in an array as shown in Fig. 7.2.

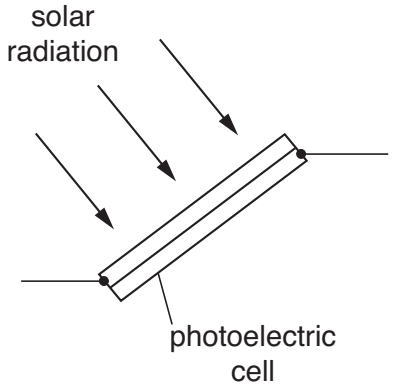

Fig. 7.1

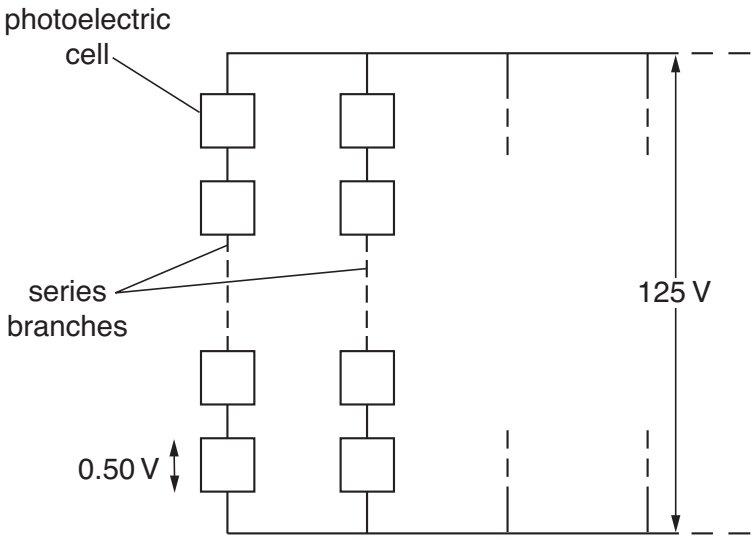

Fig. 7.2

intensity of solar radiation falling on the house	=	800 W m^{-2}
voltage output of each cell for this intensity	=	0.50 V
efficiency of each photoelectric cell	=	10 %
surface area of each photoelectric cell	=	5.0 cm^2
required output from photoelectric cell array	=	125 V

(a) (i) Calculate the total area of photoelectric cells needed to generate 1000 W of electrical power.

area = ... m^2 **[2]**

(ii) Show that the number of photoelectric cells needed is 25 000.

[1]

(iii) The photoelectric cells are arranged as in Fig. 7.2.

1 State the number of cells in **one** series branch. .....

2 State the number of branches in parallel. ..... **[2]**

(iv) Calculate the current through each photoelectric cell.

current = ... A **[2]**

Option B: Solar Panel

Solar radiation passes through a layer of glass and is absorbed by tubes of water. Cool water flows into the tubes and is heated. Hot water flows out and is led to an insulated storage tank.

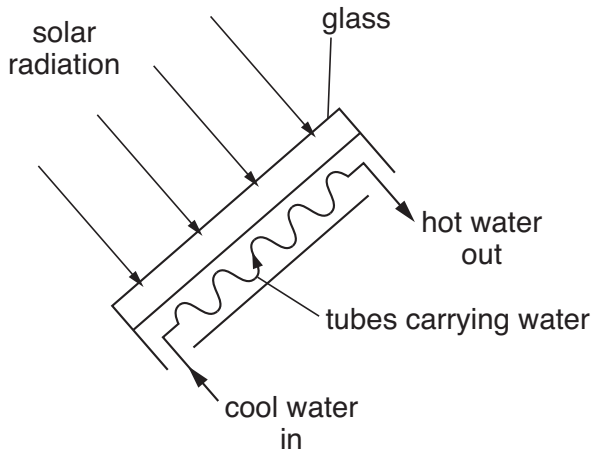

Fig. 7.3

intensity of solar radiation falling on the house	=	800 W m^{-2}
efficiency of solar panel	=	70 %
incoming water temperature	=	20 °C
outgoing water temperature	=	75 °C
specific heat capacity of water	=	4200 J kg^{-1} K^{-1}

(b) (i) Calculate the area of the solar panel needed for the water to gain 1000 J of heat energy per second.

area = ... m^2 **[2]**

(ii) Calculate the rate in kg s^{-1} at which water must flow through the tubes in order to emerge at 75 °C.

rate = ... kg s^{-1} **[3]**

Option C: Aerogenerator

This consists of a fan that rotates in the wind, and an electrical generator.

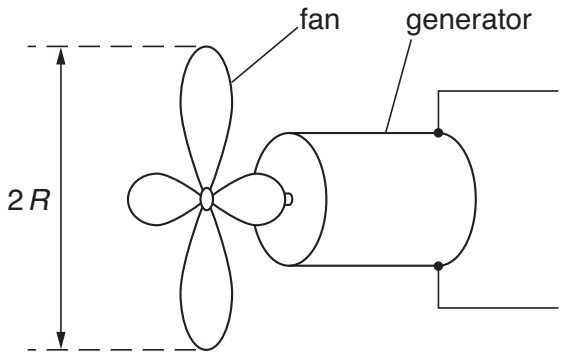

Fig. 7.4

efficiency of aerogenerator = 40 %
wind speed = 5.0 m s^{-1}
density of air = 1.3 kg m^{-3}

(c) The air flowing through the fan in 1 second is a body of air having a cylindrical shape, of diameter 2*R* and length *v* where *v* is the speed of the air. See Fig. 7.5.

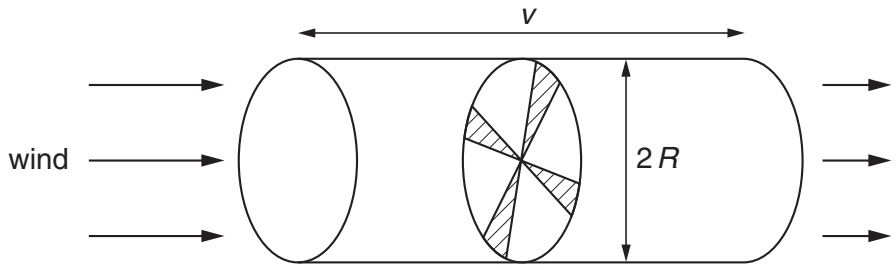

Fig. 7.5

The aerogenerator supplies 1000 J of electrical energy from this air in 1.0 second. This is 40 % of the initial kinetic energy of the air.

(i) Show that the initial kinetic energy of the cylinder of air is 2500 J.

[1]

(ii) Calculate the mass of this cylinder of air.

mass = ... kg **[2]**

(iii) Calculate the radius R of the aerogenerator fan.

R = ... m **[2]**

(d) The householder needs to make a choice.
Comment on the appropriateness or otherwise of **one** of these energy-generating processes for the house.

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..... **[3]**

[Total: 20]

END OF QUESTION PAPER

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