THIS IS A LEGACY SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

PHYSICS A

2825/01

Cosmology

Candidates answer on the Question Paper

OCR Supplied Materials:
None

Other Materials Required:
- Electronic calculator

Tuesday 29 June 2010
Afternoon

Duration: 1 hour 30 minutes

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

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	10	
2	7	
3	8	
4	8	
5	13	
6	14	
7	10	
8	20	
TOTAL	90	

Turn over

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,	$\rho_0 = \dfrac{3{H_0}^2}{8\pi G}$
relativity factor,	$= \sqrt{(1 - \dfrac{v^2}{c^2})}$
current,	$I = nAve$
nuclear radius,	$r = r_0 A^{1/3}$
sound intensity level,	$= 10 \lg \left(\dfrac{I}{I_0}\right)$

Answer **all** the questions.

1 **(a)** **(i)** State the important observations made by Galileo of

1 Jupiter ....

....

2 the Earth's moon. ....

.... **[2]**

(ii) How did these observations help develop the understanding of the Universe?

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.... **[2]**

(b) Explain how a close study of the motion of Uranus further improved the knowledge of the Solar System.

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.... **[3]**

(c) Complete the table shown in Fig. 1.1 by entering estimates, to the nearest order of magnitude, for the mass of a galaxy, planet and moon expressed as a fraction of the Sun's mass.

object	$\frac{\text{mass of object}}{\text{mass of Sun}}$
Galaxy similar to 'Milky Way'	
Sun	1
Planet	
Moon	

[3]

Fig. 1.1

[Total: 10]

2 **(a)** **(i)** State the equation that represents Newton's law of gravitation, defining all symbols.

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.... **[1]**

(ii) Why did Newton believe that the Universe must be infinitely large?

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.... **[1]**

(b) The period T and average orbital radius R of two Earth-orbiting research satellites are given in Fig. 2.1.

satellite	T / h	R / km
X	2.15	8430
Y	9.00	21900

Fig. 2.1

(i) Satellite Y has the larger orbital radius. Use one of Kepler's laws of gravitation to explain why the satellites have such different periods.

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.... **[3]**

(ii) Using data from Fig. 2.1 calculate the average orbital radius for a satellite with a period of 48.1 hours.

radius = ... km **[2]**

[Total: 7]

3 **(a)** The cosmic microwave background radiation is evidence for the way in which the Universe began. State a feature of the intensity of this background radiation.

.... [1]

(b) The first stars are thought to have formed many years after the Universe came into being. What are the similarities and differences between the **composition** of the Sun and that of the very first stars?

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.... [3]

(c) The chemical composition of a star can be found from the light that it emits. Explain how some of the elements present in a star can be detected from a study of the spectrum of the star.

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.... [4]

[Total: 8]

4 **(a)** State Hubble's Law.

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.... **[1]**

(b) **(i)** Describe Olbers' paradox.

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.... **[4]**

(ii) Using Hubble's Law or otherwise explain how Olbers' paradox can be resolved.

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.... **[3]**

[Total: 8]

5 **(a)** Explain the terms *apparent magnitude* and *absolute magnitude*.

apparent magnitude ....

....

absolute magnitude ....

.... **[2]**

(b) The total energy emitted each second by a star is called its luminosity. The Sun has a luminosity *L*(Sun) of approximately 3.90×10^{26} W.

The absolute magnitude *M* and their luminosities *L*(star) of 5 stars are given in the table.

star	M	Luminosity / W	$\frac{L(\text{star})}{L(\text{Sun})}$	$\lg \frac{L(\text{star})}{L(\text{Sun})}$
A	4.1	7.96×10^{26}	2.04	0.31
B	2.2	4.10×10^{27}	10.6	
C	-1.6	1.26×10^{29}	323	
D	-4.1	1.38×10^{30}		
E	-7.1	2.36×10^{31}		

(i) Using the value for the Sun's luminosity given above, complete the last two columns of the table. **[2]**

(ii) Plot a graph of *M* against $\lg \frac{L(\text{star})}{L(\text{Sun})}$ using the axes provided in Fig.5.1. **[2]**

(iii) Draw the best straight line through the points on the graph. **[1]**

(iv) The absolute magnitude *M* and ratio of luminosities *L*(star) / *L*(Sun) is predicted to follow a relationship of the form

$$M = a \lg[L(\text{star}) / L(\text{Sun})] + b$$

where *a* and *b* are constants.

Use the graph to find the values of *a* and *b*.

a = ...

b = ... **[3]**

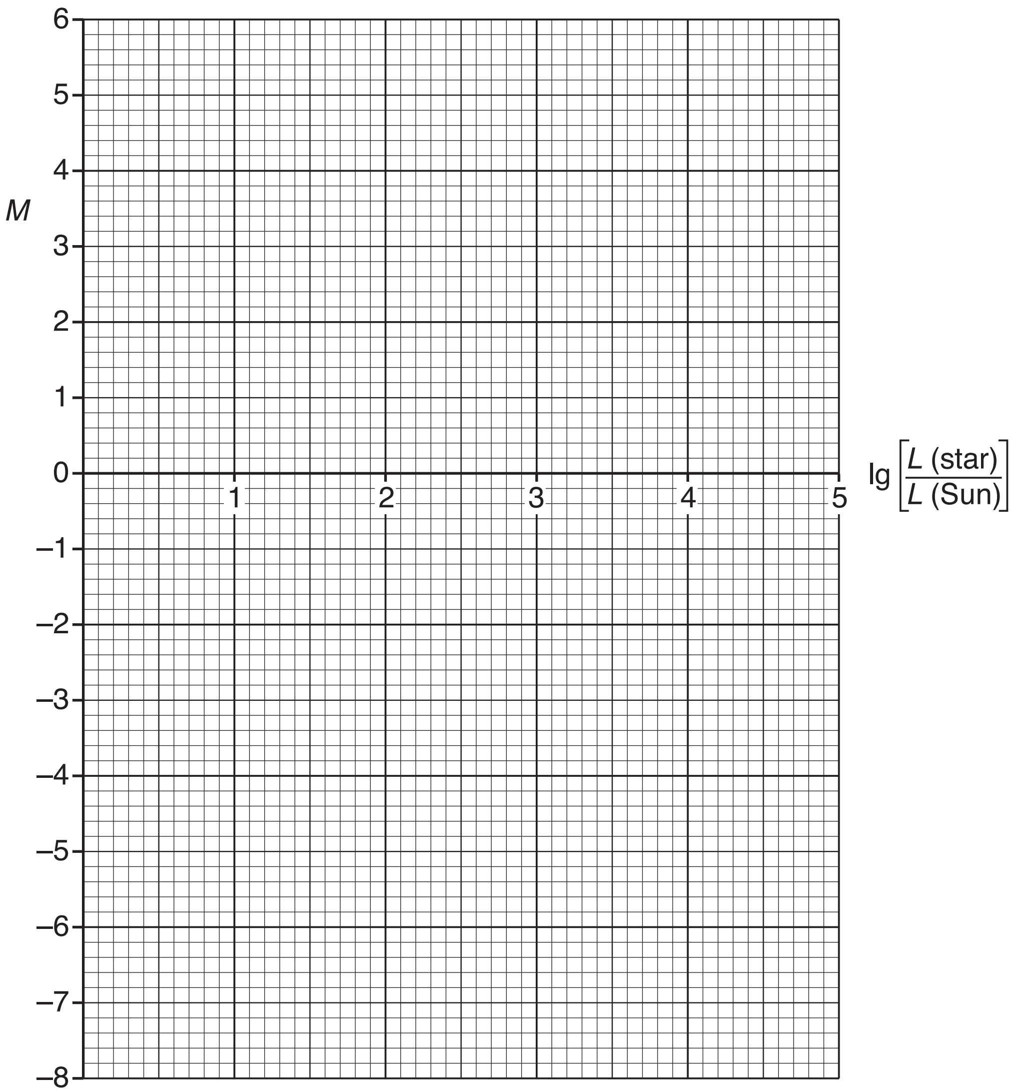

Fig. 5.1

(c) Explain how the Sun's absolute magnitude will change in the next stage of its development, when it ceases to be a main sequence star.

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.... **[3]**

[Total: 13]

6 **(a)** Describe the events which occurred after the Big Bang up to the formation of the first atoms.

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.... **[5]**

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

isotropic ....

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homogenous ....

.... **[2]**

(c) One possible value for the critical density of the Universe is 3.8×10^{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) Describe and explain how the Universe may evolve.

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.... **[5]**

[Total: 14]

7 **(a)** What is meant by the *principle of equivalence*?

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.... **[2]**

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

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.... **[5]**

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

(i) Explain what is meant by *orbital precession*.

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.... **[2]**

(ii) State one reason why the rate of precession of Mercury's orbit is greater than that of any other planet within the Solar System.

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.... **[1]**

[Total: 10]

8 This question is about a cliff railway that is entirely powered by water. The rail line links a town at the top of a hill with another town at the bottom of the hill. The railway has two carriages running on parallel tracks. They are connected by a continuous cable running around two pulley wheels mounted at the top and bottom of the track bed (see Fig. 8.1). Brakes can be applied to the lower pulley wheel to control the speed of the carriages.

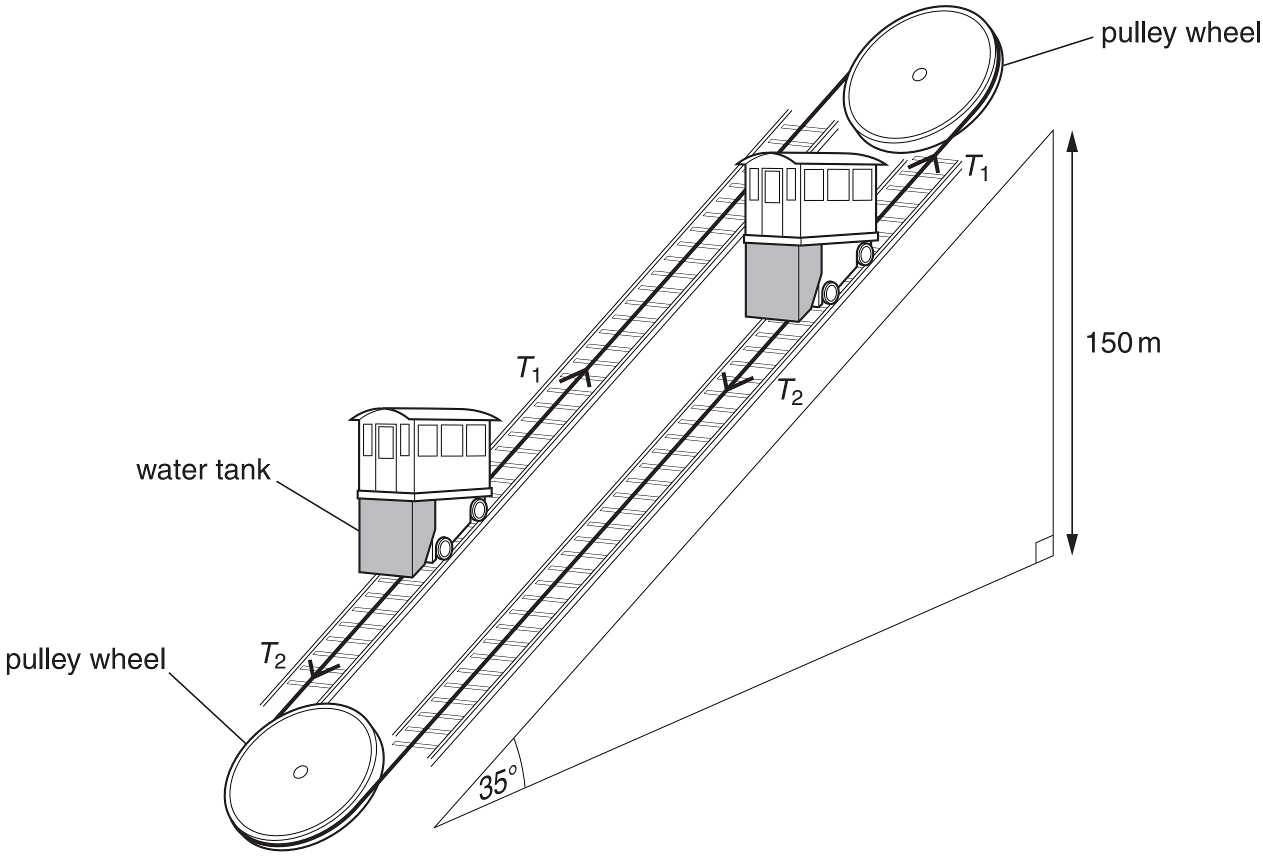

Fig. 8.1

Each carriage has a tank beneath the passenger compartment which can hold $5.0\,m^3$ of water. Before the start of each journey both tanks are full of water. When the passengers are aboard, water is released from the lower carriage until the weight of the lower carriage is less than that of the upper carriage. The brakes on the pulley wheel are released and the carriages accelerate toward the other station. When the speed of the carriages reaches $6.6\,m\,s^{-1}$, the brakes are partially applied to maintain a constant speed.

When the carriages reach the stations the brakes are fully applied and the carriages slow down and stop. While the passengers leave, the water tank beneath the carriage at the top station is refilled with water from a river. Passengers board both lower and upper carriages and the whole process is repeated.

Data: mass of each carriage fully loaded (including a full tank of water) = 10 000 kg
volume of water tank = $5.0\,m^3$
length of rails = 260 m
vertical height from lower station to the top station = 150 m
angle of inclination of rails = 35°
density of water = $1000\,kg\,m^{-3}$
mass of each brake block = 25 kg

(a) Describe the energy changes that occur when the lower carriage is lifted to the upper station while the upper carriage moves to the lower station.

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.... **[3]**

(b) Just before the water tank in the lower carriage begins to drain, both carriages are carrying their full load and the tension T_2 in the lower cable is small enough to be ignored.

Show that the tension T_1 in the upper cable is about 5.5×10^4 N when both carriages are fully loaded.

[2]

(c) When the brakes are released, the acceleration of both cars is $1.5\,\mathrm{m\,s^{-2}}$ and there is a resultant force of 8.7×10^3 N parallel to the track acting on the lower carriage.

(i) Calculate the volume of water which has been released from the lower carriage.

volume = ... $\mathrm{m^3}$ **[4]**

(ii) Calculate the time taken from the moment the lower carriage leaves the station to the point when it reaches its maximum speed of $6.6\,m\,s^{-1}$. Assume the acceleration remains constant.

time = ... s **[2]**

(iii) Calculate the distance travelled during this time.

distance = ... m **[2]**

(d) At the start of one particular journey both carriages are fully loaded. 3800 kg of water is released from the lower carriage.

(i) Show that the net change in potential energy of the system is about 5.5 MJ.

[2]

Six iron brake blocks, each of mass 25 kg, apply a force against the lower pulley wheel. This maintains the constant speed during the journey and then, following an increase in this force, brings the carriages to a halt.

(ii) Calculate the rise in temperature of the brake blocks in this journey if the brake blocks absorb all of the potential energy change calculated in **(i)**.

The specific heat capacity of iron is $4.7 \times 10^2\,\mathrm{J\,kg^{-1}\,K^{-1}}$.

rise in temperature = ... K **[3]**

(iii) In practice the rise in temperature of the brake blocks is much less than the value calculated in **(ii)**. Discuss reasons why.

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.... **[2]**

[Total: 20]

END OF QUESTION PAPER

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