

**ADVANCED GCE****PHYSICS A**

Cosmology

2825/01

Candidates answer on the question paper

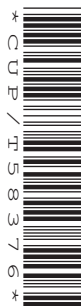
OCR Supplied Materials:

None

Other Materials Required:

- Electronic calculator

Tuesday 27 January 2009
Morning

Duration: 1 hour 30 minutes

Candidate Forename		Candidate Surname	
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Centre Number						Candidate Number				
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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 **16** pages. Any blank pages are indicated.

FOR EXAMINER'S USE

Qu.	Max.	Mark
1	10	
2	11	
3	14	
4	12	
5	15	
6	8	
7	20	
TOTAL	90	

Data

speed of light in free space,	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
elementary charge,	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant,	$h = 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27} \text{ kg}$
molar gas constant,	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
gravitational constant,	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall,	$g = 9.81 \text{ m s}^{-2}$

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,

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$$

capacitors in parallel,

$$C = C_1 + C_2 + \dots$$

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,

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

Answer **all** the questions.

- 1 (a) Writing your answers in the table of Fig 1.1 give approximate values for 1 parsec in metres and the mass of the Sun in kilograms.

quantity	magnitude
1 parsec /m	
mass of Sun /kg	

[2]

Fig. 1.1

- (b) Planets in the Solar System were once thought to move in epicycles.

- (i) Explain what is meant by an epicycle. Why were epicycles necessary?

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..... [3]

- (ii) Explain why the Copernican model of the Solar System removed one reason for epicycles.

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..... [3]

- (c) Explain **one** astronomical observation made by Galileo which lent scientific support to the Copernican model of the Solar System.

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..... [2]

[Total: 10]

- 2 During the evolution of a star there is a corresponding change in the processes that take place within the star. Hydrogen burning occurs in a star when the core temperature exceeds about 10^7 K.

In Hydrogen burning four protons combine to form a ${}^4_2\text{He}$ nucleus. Energy is released in this process.

- (a) (i) Calculate the energy released, in joules, when a single helium nucleus is formed in this way.

mass of proton = 1.00728 u

mass of ${}^4_2\text{He}$ = 4.00153 u

energy released = J [3]

- (ii) Explain the meaning of the numbers 4 and 2 in ${}^4_2\text{He}$.

..... [1]

- (b) Helium burning occurs in red giants at temperatures above 10^8 K. Suggest why helium burning requires a higher temperature than hydrogen burning.

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..... [1]

- (c) Describe and explain how the Sun will change when it evolves into a red giant.

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- (d) Explain the term *white dwarf* when applied to the evolution of a star.

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..... [3]

[Total: 11]

Turn over

- 3 (a) What is meant by the *Doppler Effect*?

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..... [2]

- (b) Fig. 3.1 shows part of a *continuous spectrum* obtained from a light source in a laboratory. The spectrum is crossed by a single *absorption line* of wavelength 410 nm.



Fig. 3.1

- (i) State what is meant by a *continuous spectrum*.

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..... [1]

- (ii) Explain how an *absorption line* occurs.

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..... [2]

Fig. 3.2 shows another four continuous spectra received from four different galaxies. The spectra are crossed by the same dark line as in Fig. 3.1 but each one has become red shifted. The resulting wavelength is given beside the spectrum.

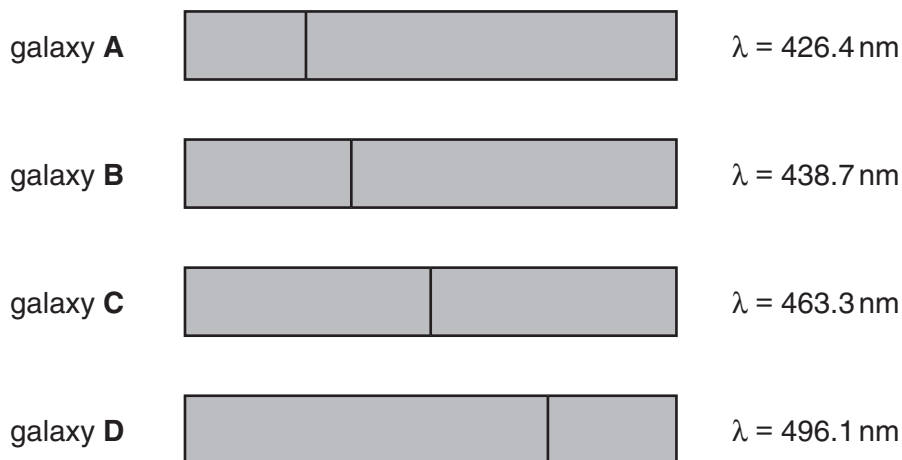


Fig. 3.2

- (iii) What can be deduced about the galaxies from the fact that the lines are red shifted?

..... [1]

- (iv) Calculate the change in wavelength $\Delta\lambda$ of the absorption line in galaxy **D**. Write your answer in the second column of the table in Fig 3.3.

[1]

- (v) Use the value of $\Delta\lambda$ to calculate the velocity of galaxy **D** relative to the observer. Write your answer in the third column of the table in Fig. 3.3.

[2]

galaxy	change in wavelength $\Delta\lambda/\text{nm}$	velocity of galaxy $/10^7 \text{ m s}^{-1}$	distance to galaxy $/10^{24} \text{ m}$
A	16.4	1.2	4.65
B	28.7	2.2	8.50
C	53.3	3.9	15.1
D			24.4

Fig. 3.3

- (c) Plot a graph of galaxy velocity against distance on Fig. 3.4. Draw the best straight line through the points. [2]

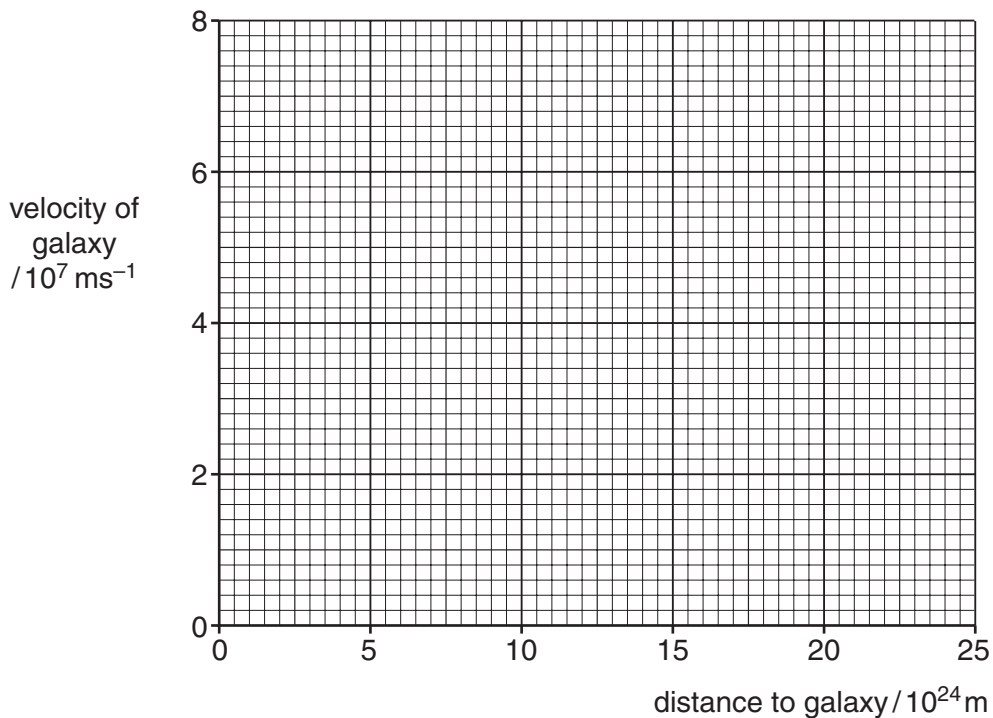


Fig. 3.4

- (d) Use your graph to estimate the age of the Universe. Give a unit for your answer.

age of Universe = unit [3]

[Total: 14]

Turn over

- 4 (a) What is meant by the *Cosmological Principle*?

.....
 [2]

- (b) Fig. 4.1 represents a cluster of galaxies. Two galaxies, labelled **X** and **Y**, have a distance of 4×10^{22} m between their centres.



Fig. 4.1

- (i) Calculate the force on galaxy **X** due to galaxy **Y** alone.

mass of galaxy **X** = 2×10^{41} kg mass of galaxy **Y** = 5×10^{40} kg

force = N [3]

- (ii) Draw an arrow on the diagram to represent this force vector. [1]
 (iii) Explain why Newton believed the Universe to be infinite in size.

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 [1]

- (c) Discuss Olbers' paradox and show how an expanding Universe provides a solution.

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[Total: 12]

- 5 (a) Outline the main events which occurred in the Universe after the Big Bang up to the moment of recombination when atoms were formed.

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..... [5]

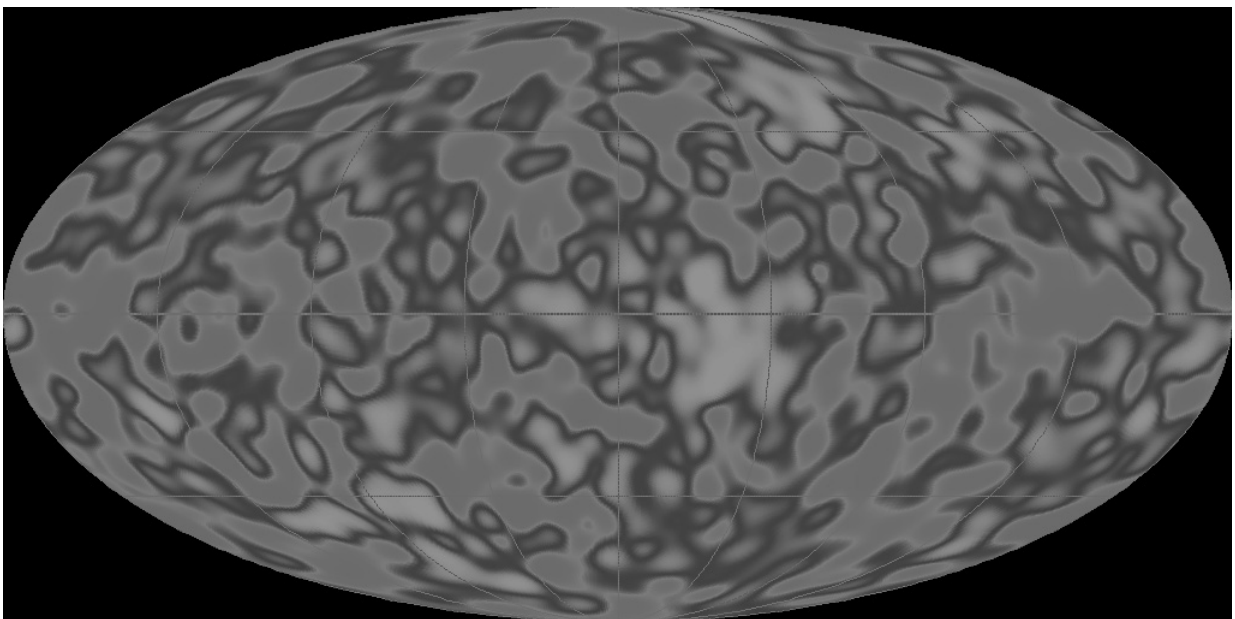
- (b) Explain why there is very little experimental evidence for events in the first 1 ms after the Big Bang.

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..... [2]



Credit: DMR, COBE, NASA, Two-Year Sky Map

Fig. 5.1

(c) Fig. 5.1 is a temperature map of the Universe taken by the cosmic background explorer (COBE) satellite. It represents the distribution of microwave energy across the sky.

- (i) How do measurements of cosmic background microwave radiation provide evidence that the Universe began with a Big Bang?

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 [2]

- (ii) What is the significance of the very small temperature fluctuations detected by the satellite?

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 [1]

- (d) A galaxy of mass M is a distance r from the Earth and is moving at a speed v directly away from the Earth. Show that it has a kinetic energy given by $\frac{1}{2}MH_0^2r^2$ where H_0 is the Hubble constant.

[2]

- (e) Explain how the future evolution of the Universe will be determined by its density in comparison with its critical density.

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 [3]

[Total: 15]

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

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..... [2]

- (b) What is meant by *time dilation* within the Special Theory of Relativity?

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- (c) Outline a **thought** experiment which shows time dilation within the Special Theory of Relativity.

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..... [5]

[Total: 8]

- 7 The speed with which a bullet emerges from the barrel of a gun can be measured by a number of different techniques. This question relates to **two** experiments performed using the same rifle and bullets.

Data:

- mass of rifle 4.3 kg
- mass of bullet 28 g
- length of rifle barrel 72 cm

- (a) Fig. 7.1 shows the first experiment where the rifle fires the bullet into a measured distance D between two fast optical sensors each of which is connected to a timer.

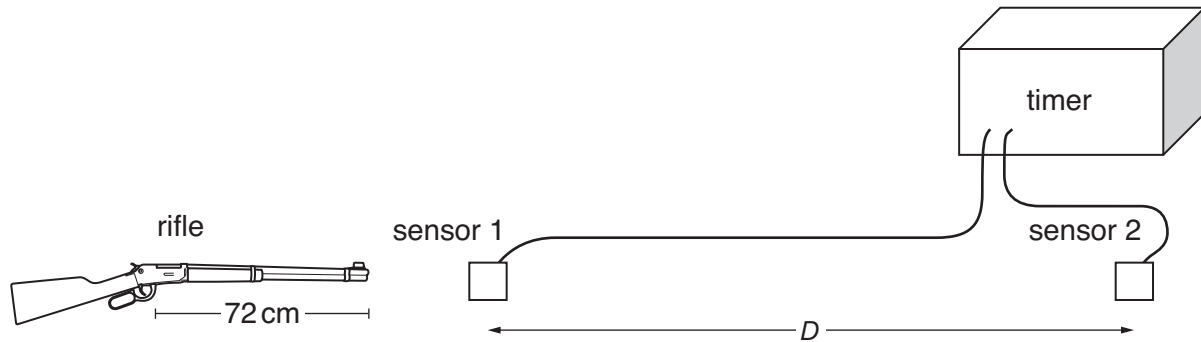


Fig. 7.1

When the bullet reaches sensor 1 the timer starts and when the bullet passes sensor 2 the timer stops.

distance D = 1.28 m
time t = 1.50 ms

- (i) Show that the speed of the bullet is about 850 m s^{-1} .

[1]

- (ii) The bullet accelerates as it travels along the rifle barrel. Show that the average acceleration in the barrel is about $5 \times 10^5 \text{ m s}^{-2}$.

[2]

- (iii) Calculate the average force on the bullet in the barrel.

average force on bullet = N [2]

- (iv) Discuss the effect this force has on the rifle.

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..... [2]

- (b) Fig. 7.2 shows the second experiment where the same rifle fires the bullet horizontally into the middle of a block of lead resting on top of a vertical support.

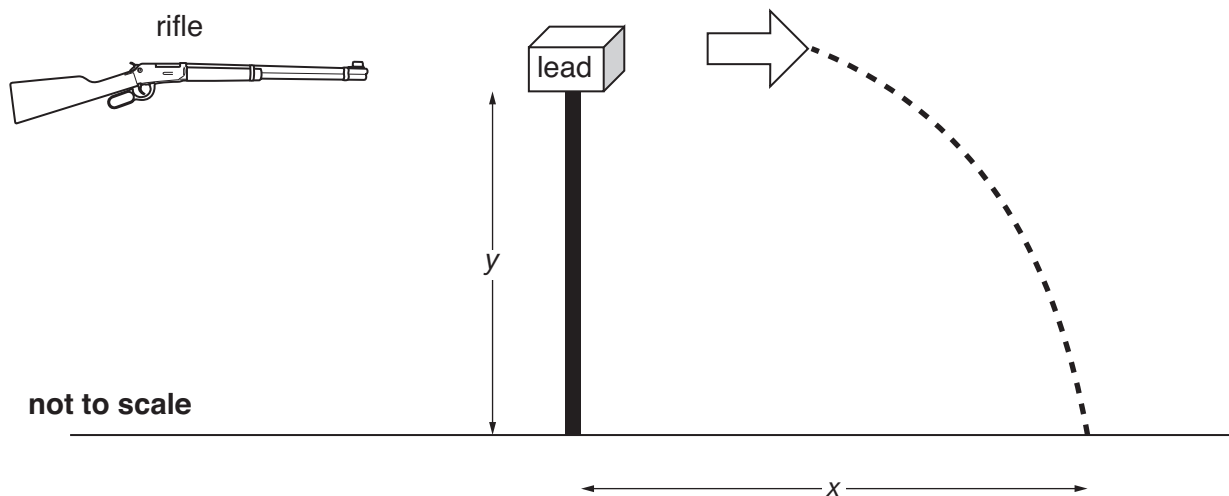


Fig. 7.2

When the bullet reaches the block it becomes embedded in the lead and the block is projected a horizontal distance x and falls a vertical distance y as shown. The following measurements are made;

mass of bullet	28 g
mass of lead block	3.60 kg
vertical distance y	2.41 m
horizontal distance x	4.60 m

- (i) Show that the time taken for the block to fall through the vertical distance y is about 0.70 s.

[2]

- (ii) Show that the horizontal projection speed of the block from the support is about 6.6 m s^{-1} .

[1]

- (iii) Show that the speed of the bullet given by this collision experiment is also about 850 m s^{-1} .

[3]

- (c) The initial kinetic energy of the bullet is transferred to the block as kinetic energy and thermal energy.

- (i) Estimate the rise in temperature of the lead block. The specific heat capacity of lead is $126 \text{ J kg}^{-1} \text{ K}^{-1}$.

rise in temperature = K [5]

- (ii) Explain **two** assumptions you made in this calculation.

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..... [2]

[Total: 20]

END OF QUESTION PAPER

PLEASE DO NOT WRITE ON THIS PAGE



Copyright Acknowledgements:

Fig 5.1 © NASA Credit: DMR, COBE, NASA, Two-Year Sky Map , www.nasa.gov

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