BOARD OF STUDIES
NEW SOUTH WALES

2006

HIGHER SCHOOL CERTIFICATE EXAMINATION

Cosmology

Distinction Course

Modules 1, 2 and 3 (including Residential 1)

General Instructions

- Reading time – 5 minutes
- Working time – 1 hour
- Write using black or blue pen
- Board-approved calculators may be used
- A data sheet is provided at the back of this paper

Total marks – 60

Section I Page 2

8 marks

- Attempt FOUR questions from Questions 1–6
- Allow about 8 minutes for this section

Section II Page 3

12 marks

- Attempt Questions 7–8
- Allow about 12 minutes for this section

Section III Page 4

40 marks

- Attempt Questions 9–10
- Allow about 40 minutes for this section

Section I

8 marks
Attempt FOUR questions from Questions 1–6
Allow about 8 minutes for this section

Answer all questions in the writing booklet provided. Extra writing booklets are available.

Question 1 (2 marks)

Distinguish between the terms *homogeneous* and *isotropic* in cosmology when applied to the universe.

Question 2 (2 marks)

Rank the following astronomical objects in order of increasing mean density:

- neutron star
- red giant
- white dwarf
- the Sun.

Question 3 (2 marks)

Contrast the design of equatorial and alt-az telescopes.

Question 4 (2 marks)

The star Alpha Crucis is observed at apparent magnitude 0.76.

Calculate its distance from Earth, given that its Absolute Magnitude is –4.6.

Question 5 (2 marks)

Identify the four fundamental forces in nature.

Which force is weakest at the atomic or nuclear scale?

Question 6 (2 marks)

Define the parallax of a star. State briefly why parallax is important in our understanding of the universe.

Section II

12 marks
Attempt Questions 7–8
Allow about 12 minutes for this section

Answer each question in the writing booklet provided. Extra writing booklets are available.

Question 7 (6 marks)

Discuss the value of instruments such as 6dF, 2dF and AA-Omega in improving the efficiency of telescopes such as the UK Schmidt and the Anglo-Australian Telescope.

Question 8 (6 marks)

(a) Compare what is meant by the *anthropic* and *theistic* principles in cosmology.

(b) In anthropic and theistic terms, what would be the cosmological significance of the discovery of oxygen in the spectrum of an extrasolar planet?

Please turn over

Section III

40 marks
Attempt Questions 9–10
Allow about 40 minutes for this section

Answer each question in the writing booklet provided. Extra writing booklets are available.

Question 9 (20 marks)

Identify and describe two techniques currently used to detect extrasolar planets.

Contrast the observational difficulties as well as the success of the two chosen techniques.

Question 10 (20 marks)

The acceptance of a heliocentric model of the solar system required both observational evidence and theoretical developments.

Discuss the key observations and developments and explain how they helped supplant the former Ptolemaic and Aristotelian models.

End of paper

Cosmology

Data Sheet

Physical Constants and Conversion Factors

Recommended values

Abstracted from the consistent set of constants in CODATA Bull. No. 63 (1986) by the Royal Society, the Institute of Physics, and the Royal Society of Chemistry.

The number in parenthesis after each value is the estimated uncertainty (standard deviation) of the last digit quoted.

speed of light in a vacuum	c	$2.997\,924\,58 \times 10^{8}$ m s^{-1} (exact)
permeability of a vacuum	μ_0	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of a vacuum, $\left[\mu_0 c^2\right]^{-1}$	ϵ_0	$8.854\,187\,817\ldots \times 10^{-12}$ F m^{-1}
elementary charge (of proton)	e	$1.602\,177\,33(49) \times 10^{-19}$ C
gravitational constant	G	$6.672\,59(85) \times 10^{-11}$ N m^2 kg^{-2}
Planck constant	h	$6.626\,0755(40) \times 10^{-34}$ J s
Avogadro constant	N_A	$6.022\,1367(36) \times 10^{23}$ mol^{-1}
molar gas constant	R	$8.314\,510(70)$ J K^{-1} mol^{-1}
Boltzmann constant	k	$1.380\,658(12) \times 10^{-23}$ J K^{-1}
unified atomic mass constant	m_u	$1.660\,5402(10) \times 10^{-27}$ kg
rest mass of electron	m_e	$9.109\,3897(54) \times 10^{-31}$ kg

SI secondary units

astronomical unit	AU	$1.495\,978 \times 10^{11}$ m
parsec	pc	3.0856×10^{16} m = 3.262 ly
Gregorian calendar year	y	365.2425 days = 31 556 952 s
jansky	Jy	10^{-26} W m^{-2} Hz^{-1}

Indicative values

earth mass	5.977×10^{24} kg
solar mass, $M_\odot$	1.989×10^{30} kg
galaxy mass	$10^{11}\ M_\odot$
Hubble constant, H_0	$100\ h$ km s^{-1} Mpc^{-1} (typically h ranges from 1 to 0.5)

Conversion factors

distance (light-year)	ly	9.460×10^{15} m = 63 240 AU
energy (erg)	erg	10^{-7} J
magnetic field (gauss)	G	10^{-4} T
wavelength (angstrom)	Å	10^{-10} m

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BOARD OF STUDIES
NEW SOUTH WALES

2006

HIGHER SCHOOL CERTIFICATE EXAMINATION

Cosmology

Distinction Course

Modules 4, 5, 6 and 7 (including Residential 2)

General Instructions

- Reading time – 5 minutes
- Working time – 2 hours
- Write using black or blue pen
- Board-approved calculators may be used
- A data sheet is provided at the back of this paper

Total marks – 120

Section I Page 3

20 marks

- Attempt FIVE questions from Questions 1–7
- Allow about 20 minutes for this section

Section II Pages 4–5

40 marks

- Attempt FOUR questions from Questions 8–13
- Allow about 40 minutes for this section

Section III Page 6

60 marks

- Attempt Questions 14–15
- Allow about 60 minutes for this section

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Section I

20 marks
Attempt FIVE questions from Questions 1–7
Allow about 20 minutes for this section

Answer each question in the writing booklet provided. Extra writing booklets are available.

Question 1 (4 marks)

Explain briefly what is meant by the term *emission distance* of a galaxy.

Question 2 (4 marks)

Describe the concept of *hyperbolic space*. What is the curvature within a hyperbolic universe?

Question 3 (4 marks)

What is the *universal scaling factor*? How has the value of the universal scaling factor changed between redshift 4 and the present time?

Question 4 (4 marks)

Discuss the function of the deceleration term that occurs in most cosmological models.

Question 5 (4 marks)

What is meant by *peculiar motions* of stars and galaxies? Give a typical numerical value for the peculiar motion of a galaxy.

Question 6 (4 marks)

What are the main features of a Friedmann model universe?

Question 7 (4 marks)

Explain how the value of the cosmological constant Lambda (Λ) affects the predicted future of the Universe.

Section II

40 marks
Attempt FOUR questions from Questions 8–13
Allow about 40 minutes for this section

Answer each question in the writing booklet provided. Extra writing booklets are available.

Question 8 (10 marks)

The detection and mapping of the cosmic microwave background (CMB) has been a triumph of 20th century technology.

Explain the significance of the CMB data for the development of cosmological ideas.

Question 9 (10 marks)

State clearly the difference between dark matter and dark energy. Describe the key observations that reveal the location and amount of dark matter.

Question 10 (10 marks)

Describe the observable effect that a gravitational lens produces on radiation from galaxies in a distant cluster. Explain how General Relativity predicts these effects.

Question 11 (10 marks)

Using the most likely Hubble constant $H_0 = 75$ km s^{-1} Mpc^{-1} and the Data Sheet provided, calculate

(a) the size of the Universe c/H_0

and

(b) the critical density of the Universe $3H_0^2/(8\pi G)$.

Question 12 (10 marks)

Discuss the origin of the confusion between Doppler redshifts and expansion redshifts. Distinguish between the causes of these two types of redshift.

Question 13 (10 marks)

The most rigorous tests of Einstein's Theory of General Relativity have been made by recent observations of a binary pulsar system.

Describe the system that was observed and the crucial results that support the theory.

Please turn over

Section III

60 marks
Attempt Questions 14–15
Allow about 60 minutes for this section

Answer each question in the writing booklet provided. Extra writing booklets are available.

Question 14 (30 marks)

In the Big Bang model of the Universe, the initial furnace created nuclei of hydrogen, helium and a trace of lithium only. All other elements were created during the evolution of the Universe up to today.

Discuss the processes that formed these other elements and the molecules that we find existing within our galaxy.

Question 15 (30 marks)

The Big Bang theory postulates that the early Universe was hot and homogeneous before its expansion to the present size.

(a) On what scale does the present observed Universe become homogeneous?

(b) Describe the largest structures found in the Universe.

(c) Discuss the experimental methods used for observing the large-scale structure of the Universe.

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Cosmology

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