BOARD OF STUDIES
NEW SOUTH WALES

2007

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)

Define the Astronomical Unit.

Where in the universe is it an appropriate unit for scale?

Question 2 (2 marks)

The star Sirius has a measured parallax of 0.375 arcseconds.

Calculate the distance (in metres) that this parallax represents.

Question 3 (2 marks)

Describe the characteristics of a neutron star.

Question 4 (2 marks)

Contrast the design of a prime-focus telescope with that of a Cassegrain telescope.

Question 5 (2 marks)

Describe what is meant by the concept of the Perfect Cosmological Principle.

Question 6 (2 marks)

Describe the key observational evidence that led to the development of the Big Bang theory 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)

(a) Astronomers always seem to want larger telescopes!

Distinguish between the desire for larger size and the desire for larger area.

(b) Outline some observations that could be undertaken with a large-area telescope.

Question 8 (6 marks)

What are the advantages in using several telescopes as an interferometer?

Briefly outline the technical problems in linking the telescopes.

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)

Australian observatories have been productive and efficient for many years.

Discuss, using examples, how the development of technically advanced instrumentation has achieved efficiency.

Question 10 (20 marks)

In the 17th century some key observations led to the heliocentric model of the universe supplanting the geocentric model.

Discuss some of the technological and sociological developments that affected these observations.

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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NEW SOUTH WALES

2007

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 Pages 2–3

20 marks

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

Section II Page 4

40 marks

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

Section III Page 5

60 marks

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

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)

Contrast the Newtonian and Einsteinian understanding of the concept of *simultaneous events*.

Question 2 (4 marks)

The Andromeda Nebula (M31) is known to be moving towards our Milky Way.

How do we determine the motion of galaxies, such as M31, within our Local Group?

Question 3 (4 marks)

Give a brief outline of the history of star formation in the Universe.

Question 4 (4 marks)

The density of the Universe is thought to be close to the critical value described by omega (Ω) = 1.

Describe the major constituents of the Universe that contribute to this density.

Question 5 (4 marks)

Explain the essential differences between spherical space and Euclidean space.

Question 6 (4 marks)

Describe the simplifying assumptions that Friedmann made in developing the equations he used to describe a model universe compatible with General Relativity.

Question 7 (4 marks)

A telescope fixed to Earth moves.

List the various motions that are taken into account in considering the absolute velocity of the telescope with respect to the whole Universe.

Please turn over

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)

What is meant by the term *Hubble Period* in cosmology?

Calculate the Hubble Period for a Hubble constant $H_0 = 70$ km s^{-1} Mpc^{-1}

Question 9 (10 marks)

Explain the significance of observations of the *surface of last scattering* to understanding the structure in the distant Universe.

Question 10 (10 marks)

The *principle of equivalence* forms one of the corner stones of General Relativity.

State the principle and explain briefly how it is used in General Relativity.

Question 11 (10 marks)

Describe the essential features of a cosmological model based on the Steady State Theory.

Explain how the Steady State Theory conforms to the Perfect Cosmological Principle.

Question 12 (10 marks)

Using the relative scaling factors for the Universe at redshift 6 and redshift 1, calculate how long it took for the Universe to expand from redshift 6 to redshift 1.

Assume that the present age of the Universe is 14 Gy.

Question 13 (10 marks)

Describe ONE source that generates a gravitational wave in space, and outline an observing program that might detect gravitational waves.

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)

Describe the experimental methods used for measuring the *Distance Scale of the Universe*.

Consider BOTH primary and secondary distance indicators, and outline the accuracy of the distance estimates obtained by each method.

Question 15 (30 marks)

A fundamental question in cosmology is "How did galaxies form?".

What are the physical processes involved in the formation and evolution of galaxies?

In your answer refer to some of the questions about galaxy formation that are at present unanswered.

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Cosmology

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