BOARD OF STUDIES
NEW SOUTH WALES

2003

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 2

20 marks

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

Section II Pages 3–4

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)

How does an active galaxy differ from a normal galaxy?

Question 2 (4 marks)

What is the Hubble period and how is it related to the Hubble constant?

Question 3 (4 marks)

Describe the difference between a whimper-bang universe and a bang-whimper universe.

Question 4 (4 marks)

Discuss briefly the way that expansion of the universe is described mathematically.

Question 5 (4 marks)

Describe a method by which we detect molecules in the galaxy.

Question 6 (4 marks)

State what is meant by critical density in the Einstein-De Sitter model (the simplest of the Friedmann universes). How does the deceleration term q vary with density above and below this critical value?

Question 7 (4 marks)

How do we measure the primordial elemental abundances in the distant 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)

Explain the essential differences between gravitational redshift, Doppler shift and cosmological redshift.

Question 9 (10 marks)

The critical density of the universe is thought to be close to the value described by $\Omega = 1$. Describe the constituents that make up this value, and outline briefly how their proportions may change over the life of the universe.

Question 10 (10 marks)

Explain the difference between primary and secondary distance indicators on the cosmological distance ladder. Describe one recent method that can be used to extend the distance at which objects can be measured.

Question 11 (10 marks)

A distant QSO at redshift of 3 radiates an optical continuum as well as a broad emission line from hydrogen at a wavelength of 121.6 nm. The radiation passes through hydrogen in a galaxy at redshift 2 on its way to Earth, where a spectrum is observed.

(a) Calculate the wavelength at which the line emission is received on Earth.

(b) What is the wavelength at which hydrogen affects the radiation in the intervening galaxy?

(c) What is the wavelength at which this intervening effect is received?

(d) Sketch the shape of the received spectrum, marking the features associated with the QSO, and the effects of the intervening galaxy.

Question 12 (10 marks)

The De Sitter universe and the static Einstein universe are both models that are called static.

(a) Explain the difference between these two models.

(b) How does a static model differ from a steady state model?

Question 13 (10 marks)

In an expanding universe, we observe a galaxy at a great distance as it was when the universe was smaller than at present.

(a) Explain the difference between the emission distance and reception distance to the galaxy.

(b) How do these distances relate to the universal scaling factor and redshift?

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)

Some galaxies are thought to contain a supermassive black hole. Discuss the processes operating near such a black hole. Describe what is observed when looking towards the galaxy from Earth.

Question 15 (30 marks)

After Einstein gave the mathematical description of a static universe model in 1917, many different model universes were devised. Over the same decades, optical and then radio astronomers probed in and beyond our galaxy to make key observations that had far-reaching consequences for the models.

Discuss some of these key observations. Describe their critical importance for various cosmological models.

End of Paper

BLANK PAGE

BLANK PAGE

BLANK PAGE

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

BLANK PAGE