BOARD OF STUDIES
NEW SOUTH WALES

HIGHER SCHOOL CERTIFICATE EXAMINATION

2000
COSMOLOGY
DISTINCTION COURSE
MODULES 4, 5, 6 AND 7

(120 Marks)

Time allowed—Two hours
(Plus 5 minutes reading time)

DIRECTIONS TO CANDIDATES

- A data sheet is attached to this paper.
- Board-approved calculators may be used.
- Answer the questions in the Writing Booklet provided.
- You may ask for extra Writing Booklets if you need them.

SECTION I (20 marks)

- Attempt FIVE questions.
- Each question is worth 4 marks.
- Allow about 20 minutes for this Section.

SECTION II (40 marks)

- Attempt FOUR questions.
- Each question is worth 10 marks.
- Allow about 40 minutes for this Section.

SECTION III (60 marks)

- Attempt BOTH questions.
- Each question is worth 30 marks.
- Allow about 60 minutes for this Section.

SECTION I

(20 Marks)

Attempt FIVE questions.

Each question is worth 4 marks.

QUESTION 1

Why did Einstein introduce an arbitrary *cosmological constant* (the *lambda constant*) into his description of the static Einstein universe?

QUESTION 2

Explain briefly what is meant by the term *big bang universes*.

QUESTION 3

Where in the Universe can we observe such extreme physical conditions that we may test predictions of the General Theory of Relativity?

QUESTION 4

Distinguish between the *reception distance* and the *emission distance* to a quasar. What is the relationship of these distances to the redshift z of the quasar?

QUESTION 5

Describe the propagation of gravitational waves, and explain how we might detect their presence near the Earth.

QUESTION 6

The development of life on Earth depends (amongst other elements) on carbon, hydrogen, iodine and nitrogen. Discuss the origin of each of these four elements.

QUESTION 7

Outline an experiment on Earth that shows the effect of gravity on the wavelength of emitted light.

SECTION II

(40 Marks)

Attempt FOUR questions.

Each question is worth 10 marks.

QUESTION 8

Space within the Universe is filled with radiation, and yet the night sky is dark. Discuss the cosmological significance of this observation.

QUESTION 9

Draw and label a space/time diagram to display graphically the propagation of radiation from a distant galaxy to Earth in an expanding universe.

QUESTION 10

When considering distant parts of the Universe, Harrison wrote 'The observable universe is usually only a portion of the whole universe'. However, when we consider our local region, parts of this may not be observable. Identify these parts and explain why they may not be observable.

QUESTION 11

In the Big Bang cosmology, the temperature fell to 3000 K during the period about redshift 1500. Describe the major changes that occurred in the universe during this period.

QUESTION 12

Explain the relationship between the age of the Big Bang universe and its expansion rate. Calculate the present age of our Universe on this model, using our present value for the expansion rate.

QUESTION 13

The jets ejected from a quasar nucleus emit radiation that, much later, is observed on Earth. Describe the processes or phenomena that produce a shift in the frequency of this radiation (either blue or red), giving typical numerical values for the shifts caused by each process.

Please turn over

SECTION III

(60 Marks)

Attempt BOTH questions.

Each question is worth 30 marks.

QUESTION 14

The edge of the Universe became a scientific concept only in the mid-twentieth century. Discuss this concept, comparing and contrasting the edge represented by the particle horizon and the event horizon.

QUESTION 15

The standard Big Bang model is accepted as our best description of the origin of the Universe. Discuss how observations of the cosmic microwave background radiation, and its variations with angular scale, support or raise doubts about this theory.

End of paper

Cosmology Distinction Course 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	$2{\cdot}997\,924\,58 \times 10^{8}$ m s^{-1} (exact)
permeability of a vacuum	μ_0	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of a vacuum, $[\mu_0 c^2]^{-1}$	ϵ_0	$8{\cdot}854\,187\,817\ldots \times 10^{-12}$ F m^{-1}
elementary charge (of proton)	e	$1{\cdot}602\,177\,33(49) \times 10^{-19}$ C
gravitational constant	G	$6{\cdot}672\,59(85) \times 10^{-11}$ N m^{2} kg^{-2}
Planck constant	h	$6{\cdot}626\,0755(40) \times 10^{-34}$ J s
Avogadro constant	N_A	$6{\cdot}022\,1367(36) \times 10^{23}$ mol^{-1}
molar gas constant	R	$8{\cdot}314\,510(70)$ J K^{-1} mol^{-1}
Boltzmann constant	k	$1{\cdot}380\,658(12) \times 10^{-23}$ J K^{-1}
unified atomic mass constant	m_u	$1{\cdot}660\,5402(10) \times 10^{-27}$ kg
rest mass of electron	m_e	$9{\cdot}109\,3897(54) \times 10^{-31}$ kg

SI secondary units

astronomical unit	AU	$1{\cdot}495\,978 \times 10^{11}$ m
parsec	pc	$3{\cdot}0856 \times 10^{16}$ 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	$5{\cdot}977 \times 10^{24}$ kg
solar mass, $M_\odot$	$1{\cdot}989 \times 10^{30}$ 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	$9{\cdot}460 \times 10^{15}$ m = 63 240 AU
energy (erg)	erg	10^{-7} J
magnetic field (gauss)	G	10^{-4} T
wavelength (angstrom)	Å	10^{-10} m