BOARD OF STUDIES
NEW SOUTH WALES

HIGHER SCHOOL CERTIFICATE EXAMINATION

1999
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 each section in a SEPARATE Answer Booklet.

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.

Answer this Section in a SEPARATE Writing Booklet.

QUESTION 1

What is a *universal scaling factor*? Define *redshift* z in terms of the scaling factor.

QUESTION 2

What characteristic of our Universe would determine whether we live in spherical or hyperbolic space?

QUESTION 3

Describe the main features of a Friedmann model universe.

QUESTION 4

Oscillation of the Sun (and some stars) can be detected with velocities as small as 2 m s^{-1}. Calculate the change in wavelength that is measured.

QUESTION 5

What experimental evidence is there for the presence of dark matter in the Universe?

QUESTION 6

Describe briefly TWO of the major observational tests that indicate that the General Theory of Relativity is valid in our Universe.

QUESTION 7

What is the *Principle of Equivalence* that is used in deriving current cosmological models?

SECTION II

(40 Marks)

Attempt FOUR questions.

Each question is worth 10 marks.

Answer this Section in a SEPARATE Writing Booklet.

QUESTION 8

Explain clearly the relationship between the Hubble constant, the Hubble length and the Hubble period.

QUESTION 9

Sketch the typical features in the optical spectrum observed from a distant quasar. Label those features that depend on a distant quasar. Label those features that depend on:

- the redshift you choose for the quasar
- the nature of the emitting region in the quasar
- the nature of the path between the quasar and the Earth.

QUESTION 10

Describe the significance of the irregularities observed in the Cosmic Microwave Background radiation.

QUESTION 11

Discuss the effect of gravity on electromagnetic radiation propagating near a black hole in the nucleus of a galaxy.

QUESTION 12

Discuss the TWO main effects that cause a redshift in the light from a galaxy. Give typical magnitudes for the observed redshifts caused by the two processes.

QUESTION 13

Sketch the typical features in the distribution of visible matter found in surveys of galaxies.

On what scale does the observed universe become homogeneous?

Please turn over

SECTION III
(60 Marks)

Attempt BOTH questions.

Each question is worth 30 marks.

Answer this Section in a SEPARATE Writing Booklet.

QUESTION 14

Compare and contrast the observational predictions for two of the major cosmological models. Discuss reasons why our current observational evidence does not allow us to say which model, if any, is a valid description of our Universe.

QUESTION 15

Elements may be transmuted from one atomic number to another. Discuss the creation of our present elemental abundances. How do we make abundance measurements in the local and distant parts of our Universe?

End of paper

Cosmology Distinction Course

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