BOARD OF STUDIES
NEW SOUTH WALES

HIGHER SCHOOL CERTIFICATE EXAMINATION

1998
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 provided on page 8 of this paper.
- Board-approved calculators may be used.

Section I (20 marks)

- Attempt FIVE questions.
- Answer this Section in a SEPARATE Writing Booklet.
- Each question is worth 4 marks.
- Allow about 20 minutes for this Section.

Section II (40 marks)

- Attempt FOUR questions.
- Answer this Section in a SEPARATE Writing Booklet.
- Each question is worth 10 marks.
- Allow about 40 minutes for this Section.

Section III (60 marks)

- Attempt BOTH questions.
- Answer this Section in a SEPARATE Writing Booklet.
- 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

Explain the difference between the future of an open and of a closed universe. What is the time scale on which the difference would appear?

QUESTION 2

What is meant by the term *lookback time* for different cosmological models?

QUESTION 3

What are the main differences in the concepts of space and time held by Newton and Einstein?

QUESTION 4

Sketch a typical ‘rotation curve’ for a galaxy and mark clearly which feature indicates the presence of dark matter.

Add a dashed curve to show the rotation curve that would be expected in the absence of dark matter.

QUESTION 5

What is meant by *peculiar motions* of stars and galaxies? Give typical numerical values for such motions.

QUESTION 6

Select the appropriate description for our Universe from the following pairs of opposing concepts: disobeys . . . — obeys the perfect cosmological principle; bounded — unbounded; finite — infinite; static — evolving.

QUESTION 7

Why are MACHOs and WIMPs important in cosmology?

SECTION II

(40 Marks)

Attempt FOUR questions.

Each question is worth 10 marks.

Answer this Section in a SEPARATE Writing Booklet.

QUESTION 8

Give a brief description of the nature of gamma ray bursts. Why do we now believe they are emitted from distant parts of the Universe?

QUESTION 9

Discuss the basic physical assumptions that are made in deriving the Friedmann universe. Describe the relationship between gravity and expansion that leads to the Friedmann equations.

QUESTION 10

The 2 dF facility on the Anglo-Australian Telescope is probing the large-scale structure of our local Universe out to redshift 0·3. To what distance does this reach?

Sketch the type of structure indicated by the initial observations, giving its scale size.

QUESTION 11

Draw a graph of a universe’s *Scaling Factor* against time, and discuss, in simple terms, how the expansion of that universe is related to the Scaling Factor, the Hubble Constant and the age of the universe.

QUESTION 12

Jets from the nucleus of a quasar are thought to be blobs of highly relativistic plasma. Explain why, from our viewpoint, some quasars show blobs separating at speeds greater than the speed of light.

Please turn over

QUESTION 13

The spectrum of light from a distant quasar, given in Figure 1, shows the main peak emitted as Lyman alpha radiation, with wavelength 121·6 nm, from hydrogen.

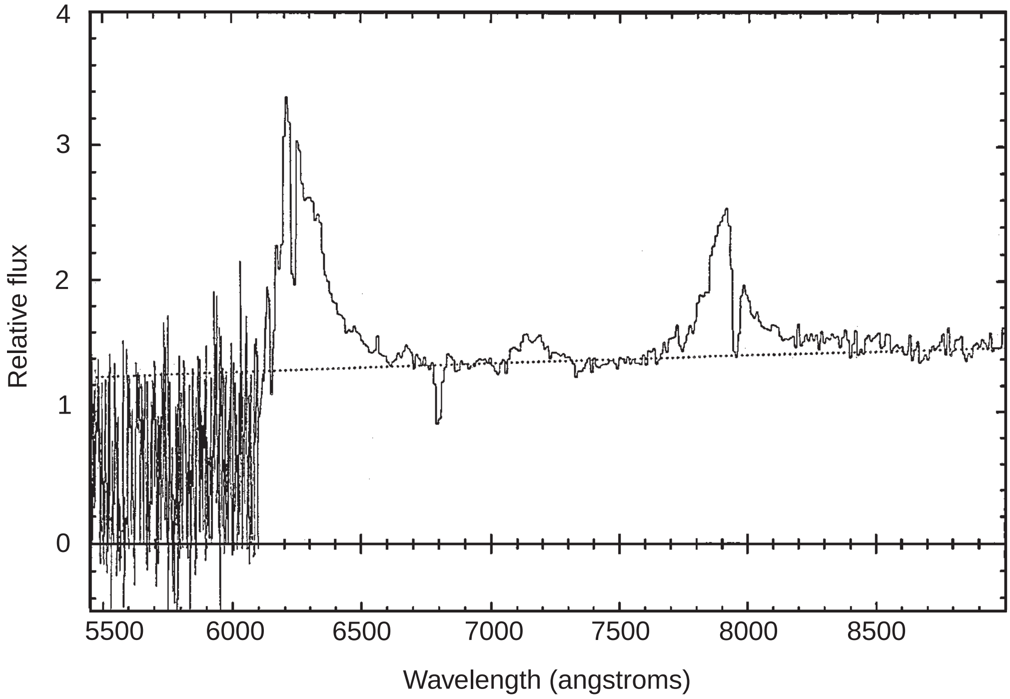

FIG. 1

(a) Calculate the redshift for this quasar.

(b) Explain the change in appearance of the spectrum near wavelength 615 nm.

SECTION III

(60 Marks)

Attempt BOTH questions.

Each question is worth 30 marks.

Answer this Section in a SEPARATE Writing Booklet.

QUESTION 14

The most rigorous observational tests of the Theory of General Relativity have been made by astronomers. Describe the objects and systems that were observed. How did the results differ from the predictions of Newtonian physics?

QUESTION 15

The Hubble Space Telescope examined five square arcminutes of the sky for ten days to obtain spectacular images of the *Hubble Deep Field*. How would you justify such an extravagant examination of a tiny region of sky? What characteristics would you consider in choosing a suitable target field in the sky? Discuss the information obtained and its relevance to current cosmological problems.

End of paper

BLANK PAGE

BLANK PAGE

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 = $3{\cdot}262$ ly
Gregorian calendar year	y	$365{\cdot}2425$ 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 $0{\cdot}5$)

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