NATIONAL UNIVERSITY of SCIENCE AND TECHNOLOGY

FACULTY of APPLIED SCIENCES

DEPARTMENT of APPLIED PHYSICS

B.Sc. (Hons) PART IV

ASTROPHYSICS (II)

SPH 4290

Second Semester Examination Paper

April 2025

This examination paper consists of 4 printed pages

Time Allowed : **3 Hours**

Total Marks : **100**

Special Requirements : **None**

Examiner : **PROF. G. G. NYAMBUYA**

INSTRUCTIONS

ANSWER ALL PARTS OF QUESTION 1 IN SECTION A AND ANY THREE QUESTIONS FROM SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS.

MARK ALLOCATION

QUESTION	MARKS
1.	**40**
2.	**20**
3.	**20**
4.	**20**
5.	**20**
6.	**20**
Maximum possible mark	**100**

Permittivity of Free Space	ε_o	$= 8.85 \times 10^{-12}$ F m^{-1}
Permeability of Free space	μ_o	$= 4\pi \times 10^{-7}$ Hm^{-1}
Mass of an Electron	m	$= 9.1 \times 10^{-31}$ kg
Charge on an Electron	e	$= 1.6 \times 10^{-19}$ C
Mass of proton	m_p	$= 1.67 \times 10^{-27}$ kg
Planck's constant	$\hbar$	$= 1.05 \times 10^{-35} Js$
Avogadro's number	N_A	$= 6.03 \times 10^{23}$/mole
Speed of light in vacuum	c	$= 3 \times 10^{8}$ ms^{-1}

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SECTION A (40 MARKS)

Answer **ALL** Questions in this Section.

Question 1

(a) Explain what you understand by the term *Standard Candle* in cosmology. Give examples and explain their importance. **[5]**

(b) What are *Cosmic Distance Ladders* in cosmology? Give three examples and explain their importance in Cosmology as a field of human endeavour. **[5]**

(c) What role does the *Cosmological Principle* play in the construction of a *Cosmological Model*. In your answer, state (i) the the principle, and (ii) explain the motivation leading to its introduction. **[5]**

(d) Briefly compare and contrast the *Cosmological Principle* and the *Perfect Cosmological Principle* (PCP). In your answer, state clearly the PCP. **[5]**

(e) List the three main features of the *Cosmic Microwave Background* (CMB) radiation and their physical origin. **[5]**

(f) In a five-point format presentation, briefly discuss the motivation leading to the *Steady State Cosmology Model*. **[5]**

(g) In short, explain why — *according to the Big Bang Theory* — there is more matter than antimatter in the *Universe*? Give your answer in a 5-point format. **[5]**

(h) Briefly explain the role played by *Darkmatter* in *Structure Formation* in the *Early Universe*. Give your answer in a 5-point format. **[5]**

SECTION B (60 MARKS)

Answer **ANY THREE** Questions in this Section.

Question 2

In the questions paused below, the symbols used have their usual meaning as ordinarily understood in ΛCDM cosmology.

(a) **(i)** Stating clearly all your assumptions, use arguments from *Newtonian Gravitational Theory* to derive the *Friedman equation*:

$$\left(\frac{\dot{R}}{R}\right)^2 = \frac{8\pi G\varrho}{3} - \frac{kc_0^2}{R^2}.$$

In your derivation, define all the symbols in this equation. **[8]**

(ii) Stating clearly all your assumptions, use the *First Law of Thermodynamics* to derive the *Fluid equation*:

$$\dot{\varrho} + 3\left(\varrho + \frac{P}{c_0^2}\right)\frac{\dot{R}}{R} = 0.$$

In your derivation, define the symbol P in this equation. **[8]**

(b) From the two equations presented in Question 2(a) above, derive the *acceleration equation*: **[4]**

$$\frac{\ddot{R}}{R} = -\frac{4\pi G}{3}\left(\varrho + \frac{3P}{c_0^2}\right).$$

Question 3

(a) **(i)** State *Olber's Paradox.* **[2]**

(ii) In your own opinion and making reference to *Olber's Paradox*, is the Universe infinite in its temporal and/or spatial extent? Discuss. Your discussion must be presented in an 8-point format. **[8]**

(b) **(i)** State *Hubble's Law.* **[2]**

(ii) From the view point of the ΛCDM cosmology, discuss the *Big Bang Cosmology Model* and in your discussion make clear its *salient features.* Your discussion must be presented in an 8-point format. **[8]**

Question 4

Give an exposition of the *Darkmatter phenomenon.* In your exposition, make clear the following:

(i) What the *Darkmatter Problem* really is, *i.e.*, how it manifested in the first place. Give your answer in a 10-point format. **[10]**

(ii) The type of galaxies this problem has manifested itself in. Give your answer in a 5-point format. **[5]**

(iii) What are the alternative approaches to resolving this problem — that is, approaches that do not evoke the existence of darkmatter. Give your answer in a 5-point format. **[5]**

Question 5

Give an exposition of the *Darkenergy phenomenon*. In your exposition, make clear the following:

(i) What the *Darkenergy Problem* really is, *i.e.*, how it manifested in the first place. Give your answer in a 10-point format. **[10]**

(ii) Differentiate between *Darkmatter* and *Darkenergy*. Give your answer in a 5-point format. **[5]**

(iii) Apart from the original evidence that lead to the postulation of possibility of the existence of Darkenergy — *if any* — what other evidence exists that supports this hypothesis? Give your answer in a 5-point format. **[5]**

Question 6

(a) **(i)** State the *Anthropic Principle*. **[2]**

(ii) In your own opinion does the *Anthropic Principle* have a val'd basis in *Science*? Support your answer. **[3]**

(b) **(i)** What do you understand by the term *Multiverse*. **[2]**

(ii) Explain how the *Anthropic Principle* is an answer the the *Multiverse concept*? **[3]**

(c) **(i)** In a 5-point format, give a brief exposition of the *Steady State Cosmology*. **[5]**

(ii) In a 5-point format, give a brief exposition of why the *Steady State Cosmology* fell out of favour with mainstream Cosmology. **[5]**

END OF EXAMINATION