SIR ARTHUR LEWIS COMMUNITY COLLEGE

SCIENCE, TECHNOLOGY, INNOVATION AND SUSTAINABILITY

2024 – 2025 ACADEMIC YEAR - SEMESTER II

END OF SEMESTER EXAMINATION

COURSE TITLE	**:**	**ASTROPHYSICS & COSMOLOGY**
COURST CODE	**:**	**PHY216**
LECTURER	**:**	**OZZY KING**
DATE	:	**Monday 9th December 2024**
TIME	**:**	**1.00 – 3.00 PM**
DURATION	**:**	**2 HRS**
STUDENT ID#	**:**	**…….**

READ THE FOLLOWING INSTRUCTIONS CAREFULLY.

1. Write your student's ID number on all the work you hand in.
2. This paper consists of SIX (6) questions
3. Answer ***all*** the questions.
4. A data and formula sheet is included.
5. The use of a silent, non-programmable, scientific calculator is permitted.
6. No graphing calculators are allowed.
7. Show all calculations and working.
8. Do not use correction fluid.

DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO DO SO

List of Physical Constants

- Speed of light, $c = 3.00 \times 10^{8}$ m s^{-1}
- Stefan-Boltzmann constant, $\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}
- Wien's displacement constant, $b = 2.90 \times 10^{-3}$ m K
- Hubble's constant, $H_0 = 2.27 \times 10^{-18}$ s^{-1}

1. a. In 2016 the Breakthrough Starshot initiative was announced. This project intends to send a fleet of small probes to Proxima Centauri, the nearest star to the Sun. With the probes traveling at 20% the speed of light, this journey would take about twenty years.

   i. Describe how the distance to nearby stars like Proxima Centauri is determined. [3]

   ii. Calculate, in meters, an estimate of the distance of Proxima Centauri [2]

   b. Define the parsec (pc) and show from this definition that it is equal to 2.06×10^{5} astronomical units (au) [3]

   c. Using an appropriately labelled diagram, describe the structure of the Milky Way. [5]

TOTAL 13 marks

2. a. State:

   i. the Stefan-Boltzmann Law [1]

   ii. Wien's Displacement Law [1]

   b. Betelgeuse is our nearest red giant star. It has a radiant power (luminosity) of 4.49×10^{31} W and emits radiation with a peak wavelength of 850 nm. Determine:

   i. the surface temperature of Betelgeuse [2]

   ii. the radius of Betelgeuse [3]

   c. Show that the Schwarzschild radius R_S of a black hole is given by: $R_S = \frac{2GM}{C^2}$ where *G* is the universal gravitational constant, *M* is the mass of the black hole and *c* is the speed of light [2]

TOTAL 09 marks

3. a. Explain why:

   i. regions on the sun's surface (known as sunspots) appear darker than the surrounding area [2]

   ii. the sun's corona (outer atmosphere) is several orders of magnitude hotter than its photosphere (surface) [2]

   b. The core of the sun is a nuclear fusion reactor in which energy is produced by two primary mechanisms, one of which is the proton-proton (PP) chain. Using an appropriately labelled diagram, describe the mechanism of the PP chain. [5]

TOTAL 09 marks

4. a. Identify, briefly, three (3) contributions of either *Aristarchus of Samos* OR *Eratosthenes* to the development of Astronomy [3]

   b. State Kepler's Third Law [1]

   c. Show that the equation representing Kepler's Third Law can be derived by applying Newton's Law of Gravitation to a circular orbit [3]

   d. The Earth can be considered a uniform sphere of radius *R*. *R* is assumed to be 6.4 x 10^6 m. A satellite of angular velocity ω is orbiting the Earth. Show that the radius r of the satellite's orbit is given by the equation:

$$r = \sqrt[3]{\frac{gR^2}{\omega^2}}$$

   where *g* is the gravitational field strength at the surface of Earth. [3]

TOTAL 10 marks

5. a. State Hubble's Law [1]

   b. Describe, briefly, how cosmological redshift can be used to determine the distance from Earth of a very distant galaxy [2]

   c. The observed wavelength of a particular spectral line from a distant galaxy is 680 nm, while the rest wavelength is 570 nm. Calculate its recessional velocity and determine its distance from Earth [3]

   d. Provide a brief description of the timeline of the Big Bang model of the origin and evolution of the universe [4]

TOTAL 10 marks

6. a. Describe:
      i. the cosmological principle [1]
      ii. Olbers' paradox [2]

   b. Describe two (2) resolutions of Olbers' paradox (one of which must be the standard resolution) [3]

   c. What is the consequence to the geometry and ultimate fate of the universe if the matter density parameter, Ω_M is less than 1? [2]

   d. How would the fate of the universe, expressed in part d., alter if we factor in the effect of dark matter? [1]

TOTAL 09 marks

END OF EXAMINATION