The Open University of Sri Lanka
B.Sc. Degree Programme - Level 05
Final Examination – 2024/2025
PHU5311/PHE5311- Astronomy
Duration: Two (02) Hours

Index No.

Date: 29.04.2025 **Time: 1.30 p.m. – 3.30 p.m.**

Electronic calculators are allowed.

All symbols have their usual meaning.

(Useful information: Mass of the Sun $M_\odot = 1.9891 \times 10^{30}$ kg, Radius of the Sun $R_\odot = 6.960 \times 10^8$ m, Speed of Light $c = 2.9979 \times 10^8$ m s^{-1}, Universal gravitational constant $G = 6.6726 \times 10^{-11}$ m^3 kg^{-1} s^{-2}, 1 AU = 1.5×10^{11} m)

Answer FOUR (04) questions only.

1. (A). Answer the following parts.

(a). What is mean by the "Escape Velocity"? **(2 Marks)**

(b). State the Kepler's 3rd law of planetary motion. **(2 Marks)**

(c). Suppose that mass of the Earth is M_e and an object of mass m ($M_e \gg m$) rotates around the Earth, with a constant speed v_c and the radius of the orbit is R.

i) Write an expression for period P as a function of radius R and orbital velocity v_c. **(2 Marks)**

ii) The exact form of Keplar's third law as derived from Newton's laws can be written as $P^2 = \frac{4\pi^2}{G(M_e+m)} a^3$. Show that $v_c = \sqrt{\frac{GM_e}{R}}$. [Hint: $(M_e + m) \sim M_e$] **(3 Marks)**

iii) If mass m leaves from orbit R, with an initial speed of v_0, show that escape velocity can be written as $v_e = \sqrt{\frac{2\,GM_e}{R}}$. **(3 Marks)**

iv) Show that $v_e = \sqrt{2}\, v_c$. **(2 Marks)**

B). An optical telescope has an objective lens with a focal length of 80 cm and this telescope is used to observe a binary star. The distance between the components of the binary star is $1.38''$.

a) What is an optical telescope? **(2 Marks)**

b) Write three major tasks of the optical telescope in astronomical observations. **(2 Marks)**

c) If two objects are seen as separate, the angular distance between two objects is $\theta \geq {}^{\lambda}/_{D}$, $[\theta] = red$. What should be the diameter of the telescope (D) to be resolved the binary? (In optical region, $\lambda \sim 550\ nm$) **(2 Marks)**

d) If the resolution of eye is $2''$, calculate the required magnification. **(2 Marks)**

e) What should be the focal length of the eyepiece to be resolved with the components? **(3 Marks)**

2. A). Seasons are four distinct periods of the year: Spring, Summer, Autumn (Fall), and Winter. Different regions experience varying weather conditions during each season due to changes in sunlight and temperature.

a) How does Earth's axial tilt contribute to seasonal variations? **(3 Marks)**

b) Explain how the length of daylight hours during different seasons affects the amount of solar radiation received at a particular location. **(4 Marks)**

c) The intensity of solar radiation (insolation) received by Earth's surface can be estimated using the formula:

$$I = S \cos\theta$$

where: I - Solar radiation received per unit area (W/m²)

S - Solar constant (1361 W/m²)

θ - Solar zenith angle (angle between the Sun's rays and vertical direction)

i) On the Spring, equinox (March 21st) is at latitude 30°N. Find the Sun's altitude at solar noon. (Hint: $altitude\ (h) = 90^{\circ} - latitude$.) **(2 Marks)**

ii) Find the zenith angle on the Spring Equinox (March 21st) at latitude 30°N. **(2 Marks)**

iii) Find the solar radiation (I), received at noon. **(3 Marks)**

B). Astronomical coordinates help astronomers to locate celestial objects in the sky using reference systems like the Equatorial Coordinate System (Right Ascension and Declination) and the Horizon System (Altitude and Azimuth).

a) Briefly explain about

i) Equatorial Coordinate System and

ii) Horizon System.

(4 Marks)

b) A star is located at Right Ascension (RA) = 6h 15m, Declination (Dec) = +25°.

i) Convert Right Ascension (RA) into degrees. (hint: 1 hour = 15°) **(2 Marks)**

ii) What does the Declination (+25°) indicate? **(2 Marks)**

iii) Explain, will this star be visible from latitude 35°S? **(3 Marks)**

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3. A) The Nebular Hypothesis is the most widely accepted theory explaining the formation of the solar system.

   a) Briefly explain the formation of nebular. **(3 Marks)**
   b) What evidence from meteorites and planetary compositions supports the Nebular Hypothesis? **(3 Marks)**
   c) How does the conservation of angular momentum influence the collapse and rotation of the solar nebula? **(4 Marks)**

   B) Comets are icy celestial bodies that orbit the Sun in elongated, elliptical orbits.

   a) Briefly explain the composition and the structure of comets. **(3 Marks)**

   b) A comet follows an elliptical orbit around the Sun with perihelion of 0.5 AU and an aphelion of 30 AU.
      i) Calculate the semi major axis in AU. **(3 Marks)**
      ii) Determine the orbital period of the comet (T) in Earth years. **(3 Marks)**
      iii) Velocity of a comet at perihelion and aphelion can be written as:

$$V_{p/a} = \sqrt{\mu\left(\frac{2}{r_{p/a}} - \frac{1}{a}\right)}.$$

      Hence show that perihelion velocity $V_p \gg V_a$ aphelion velocity. ($\mu = 1.327\times10^{20}$ m^3/s^2, a - semi major axis, $r_p =$ perihelion distance, $r_a =$ aphelion distance) **(6 Marks)**

4. A) The Hertzsprung-Russell (H-R) diagram is a graph that plots stars based on their luminosity (brightness) and temperature. It helps classifying stars and understand their life cycles.
   a) What are the two main axes of the H-R diagram? **(2 Marks)**
   b) Draw the H-R diagram by indicating the position of the main sequence, Sun, red giants, blue giants, white dwarfs and red dwarfs. **(6 Marks)**
   c) How does the position of a star change as it evolves? **(3 Marks)**
   d) How does a star's luminosity relate to its temperature on the H-R diagram? **(3 Marks)**

   B) Binary stars are systems of two stars orbiting a common center of mass.

   a) What are the different types of binary stars based on their method of detection? **(3 Marks)**

   b) Why are binary star systems important in astronomy? **(3 Marks)**

   c) Show that the relationship between stellar masses m_1 masses m_2, radial distances from common center of gravity r_1 and r_2 and period can be given as

$$\frac{4\pi^2(r_1+r_2)^3}{G} = (m_1 + m_2)p^2$$

   for a binary system. **(5 Marks)**

5. A). The Sun, which is the star at the center of our solar system and is the primary source of energy for life on Earth. The Sun is divided into multiple layers. Solar interior consists of three layers (A, B, and C). State and explain the conditions necessary for fusion to occur in a star. The solar atmosphere is composed of three layers (D, E and F).

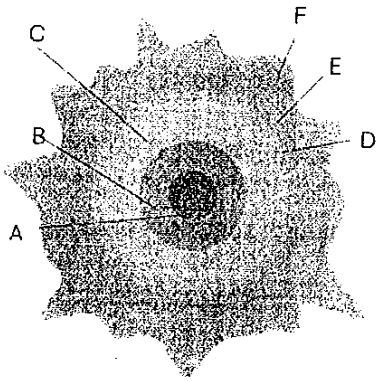

Figure 01

a) Name the layers from A to F listed in Figure 01. **(3 Marks)**

b) What are sunspots, and why do they appear darker than their surroundings? **(3 Marks)**

c) In stars, with masses of about the of the Sun or smaller, energy is produced by the Proton-Proton (PP) chain.

$$4 \times {}_1^1H \rightarrow {}_2^4He + 2\,e + 2\nu + 2\gamma + Energy$$

i) Calculate the energy released in MeV. **(4 Marks)**

(Atomic mass of H and He are 1.0078 amu and 4.0026 amu, respectively. $1\ amu = 1.66 \times 10^{-27} kg$)

ii) How many pp reactions take place in the Sun every second? (The luminosity of the Sun is $3.9 \times 10^{26}\ W$) **(3 Marks)**

B). The magnitude of a star is a measure of its brightness, with lower numbers representing brighter objects.

a) Briefly explain the following terms. **(3 Marks)**
i) Apparent Magnitude

ii) Absolute Magnitude

b) The relationship between apparent magnitudes m_1 and m_2 of two stars and corresponding flux densities (amount of energy received per unit area per unit time from the star at a given distance) F_1 and F_2 can be written as:

$$m_1 - m_2 = -2.5\ lg \frac{F_1}{F_2}$$

i) Show that, $\frac{F(r)}{F_{(10)}} = \left(\frac{10\,pc}{r}\right)^2$, where $\frac{F(r)}{F_{(10)}}$ is the ratio of flux density at a distance r, to the flux density at a distance of 10 parsecs (pc). **(3 Marks)**

ii) Hence show that $m - M = 5\log r - 5$. (where M is absolute magnitude of the star) **(3 Marks)**

iii) The distance of a star is 100 pc and its apparent magnitude $m = 6$. What is its absolute magnitude? **(3 Marks)**

6. A) Answer the following parts.

a) Describe briefly the Big Bang theory on universe and provide two key pieces of observational evidence supporting it, **(3 Marks)**

b) Briefly explain about Hubble's Law. **(3 Marks)**

c) How does the density parameter (Ω) determine the fate of the universe? **(3 Marks)**

d) The redshift "z" is given by the formula:

$$1 + z = \frac{\lambda_{observed}}{\lambda_{emited}}$$

i) If a distant galaxy emits light at 400 nm, but we observe it at 600 nm, calculate its redshift z. **(3 Marks)**

ii) The velocity, (v) of a receding galaxy (for small z) is approximately given by:

$v \sim zc$ where $c = 3.0 \times 10^5\ km\ s^{-1}$(speed of light)

Using the values obtained from part (i), calculate the velocity of the galaxy. **(3 Marks)**

B) Write short notes on any **TWO (02)** of the following topics. **(10 Marks)**

a) Sideral and Synodic Time
b) Dark Matter and Dark Energy
c) Nova
d) Neutron Star

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