Ref. No.: Ex/SC/PHY/UG/DSE/TH/03/A3/2023(s)

B. Sc. (Physics) 3rd Year 2nd Sem. Supplementary Examination - 2023(S)

Sub : Astrophysics **Time : 3 Hours** **Full Marks : 75**

Paper: DSE - 3A

Some useful constants: Solar mass ($M_\odot$) = 1.98×10^{30} Kg; Solar luminosity ($L_\odot$) = 3.83×10^{26} W; Solar radius ($R_\odot$) = 6.98×10^8 m; Earth mass ($M_\oplus$) = 5.97×10^{24} Kg; Earth radius ($R_\oplus$) = 6.37×10^6; AU= 1.49×10^{11} m; Persec = 3.08×10^{16} m; G= 6.67×10^{-11} N $m^2\ kg^{-2}$; $m_e = 9.109 \times 10^{-31}$ Kg; $m_p = 1.672 \times 10^{-27}$ Kg; $m_n = 1.674 \times 10^{-27}$ Kg; $m_H = 1.673 \times 10^{-27}$ Kg; Stefan-Boltzmann constant (σ) = 5.67×10^{-8} $Wm^{-2}\ K^{-4}$.

Answer **anyone** from questions (1 and 2), **question 3**, **anyone** from questions (4 and 5), any **two** from questions (6, 7 and 8) (Total 5 questions need to be answered)

1. [CO-1] (a) A ray passes through matter, energy may be added or subtracted from it by emission or absorption. Define emission coefficient and absorption coefficient. Derive the formal solution of the radiative transfer equation where both the mechanism (absorption and emission) are present. In this derivation you assume that the source function is constant.
   (b) Explain the brightness temperature and the effective temperature of a source.
   (c) At a distance of 1 AU from the Earth, the Sun has apparent magnitude $m = -26.8$. What is the Sun's absolute magnitude? [(2+2+4)+(2+2)+3]

2. [CO-1] (a) Discuss advantages and disadvantages of the "Trigonometric Parallax" method in determining distances. Calculate the maximum distance that can be measured using this method if the measuring device can measure angular separation as small as $0.0001''$. (b) Discuss, briefly, the basic idea that Kapteyn and his team used to find the shape and size of the Milky Way. What are the major drawbacks of the method? How did Shapley measure the shape and size and why his estimate was better than Kapteyn? [(3+3)+(3+2+4)]

3. [CO-2] (a) Discuss properties of elliptical and disk galaxies. Give examples of galaxies which do not fit into the Hubble tuning fork diagram. (b) Discuss the Faber-Jackson relation. How the relation can be used to measure distances to far galaxies? (c) If the rotational velocity of a star around a supermassive blackhole is 10,000 km/s, calculate the mass (in unit of the solar mass) of the blackhole and the corresponding Schwarzschild radius. The star is at a distance of 10 from the blackhole. [(3+2)+(2.5+2.5)+5]

4. [CO-3] (a) Assume a star has a radius of $R = 5R_\odot$ and a quadratic density profile: $\rho(r) = \rho_c[1 - (\frac{r}{R})^2]$. Here, $\rho_c = 25$ g/cm^3 is the central density. What is the solution of $P(r)$ using hydrostatic equilibrium? What is the central pressure of the star ?
   (b) What is the Solar Corona ? Give some properties of the Solar Corona. What is the connection of Solar wind to the Corona. [(6+2)+(2+3+2)]

[Turn Over

5. [CO-3] (a) Write down and explain the four fundamental equations (hydrostatic equilibrium, mass distribution, luminosity distribution and radiation transport) for stellar structure and evolution.

   (b) The opacity of the Sun at an average density of $1.4 gm/cm^3$ and an average temperature of 4.5×10^6 K implies a "mean free path" l for a photon of about 17.0 mm before it interacts with matter. Consider the 1-D random work of N steps where the photon starts off at the origin (the center of the Sun) and it has equal probability of going left or right. Calculate the total photon flight time to walk a distance $R_\odot$. Compare this value with the hypothetical free-flight time $R_\odot/c$ if only the photon could fly in a straight line from the center out to the surface. [(2.5+2.5+2.5+2.5)+(4+1)]

6. [CO-4], (a) What is Eddington luminosity ? Consider a spherical star has mass M. Assume that the photospheric gases are a plasma of ionized hydrogen consisting solely of electrons and protons (ideal, spherically symmetric situation). Calculate the outward radiation force, on the plasma, which is applied primarily to the electrons because the cross section is much greater than that of protons. Also calculate the gravitational inward force on a proton by the star. Using the condition of Eddington limit, obtain the Eddington luminosity for the star. Show that the Eddington luminosity for a 1 -$M_\odot$ star is 33,000 times greater than the actual solar luminosity.
   (b) Derive the expression of time for a spherical cloud of gas to collapse under free fall if there is no pressure support. [(2+6+2)+5]

7. [CO-4], (a) Write short notes on (i) Red giant phase and (ii) Tripple alpha process. (b) Calculate the de-Broglie wavelength of electrons inside a main sequence star with core temperature 1.5×10^7 K. Calculate the lower limit of ionized hydrogen density at the above temperature in which the corresponding electron gas starts behaving as quantum gas. When electrons inside a white dwarf become relativistic?

   [(4+4)+(3+2+2)]

8. [CO-4], (a) Calculate the degenerate electron pressure for ionized Helium gas at density $\rho \sim 10^6\,\mathrm{g/cm^3}$, temperature $T \sim 10^7$ K. (b) Discuss how major elements up to iron form inside a massive star with mass $M > 8M_\odot$. (c) How does the core collapse take place in supernovae? How neutrinos are produced during a core collapse supernovae?

   [5+3+(3+4)]