Ref. No.: Ex/SC/PHY/UG/DSE/TH/01/3B/2022(S)

B. Sc. (Physics) 3rd Year 2nd Sem. Supplementary Exam. - 2022

Sub : Astrophysics **Time : 3 Hours** **Full Marks : 80**

Paper: DSE - 3B

Use separate Answer Script for both Groups A and B

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} $Wm^{-2}\ K^{-4}$.

Group: A

Answer any ***Four*** questions

1. A star is a sphere of gas that is held together by its self gravity, and is balanced against collapse by pressure gradients through hydrostatic equilibrium. What is the solution of $P(r)$ assuming constant density? What is the central pressure of a constant density star? Why is this a lower limit on the true central pressure of a real star? [5+3+1+1]

2. (a) In a binary system, the apparent magnitude of the primary star is 1.0 and that of the secondary star is 2.0 Find the maximum combined magnitude of this system.
(b) The distance of a star is $r = 100$ pc and its apparent magnitude $m = 6$. What is its absolute magnitude? [6+4]

3. (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) Calculate the total luminosity of a star whose surface temperature is 7500 K, and whose radius is 2.5 times that of our Sun. Give your answer in units of the solar luminosity, assuming the surface temperature of the Sun is 5800 K. [(1+1+4)+4]

4. (a) What is virial theorem ? What does it mean when a system " virialized"?
(b) A system, contains N number of objects or particles (may be stars or galalxies), which is influenced by a potential $U \propto x_a^n$ (some polynomial of x_a), where x_a s' are the location of the objects from an origin. Show $2\bar{K} - n\bar{U} = 0$ for a bound system (virialized), where $\bar{K}$ and $\bar{U}$ are the average kinetic energy and potential energy respectively. Use the virial theorem to the Keplerian situation (self-gravitating bound system) for circular orbit to show $\bar{K} = -\frac{1}{2}\bar{U}$. [(2+1)+(2+3+2)]

5. (a) What is the absolute magnitude ? How is the absolute magnitude defined in terms of distance and apparent magnitude? What is the distance modulus of a star?
(b) What is a color index? Explain for two stars (i) $U - V > 0$ (ii) $U - V < 0$. How is color related to blackbody temperature? [(1+3+1)+(2+3)]

[Turn over

Group: B

Answer any ***Four*** questions

6. (a)The rotational velocity of a star, which is 10 Kpc from the centre of a spiral galaxy, is 200 km/s. The total amount of luminous matter (baryonic matter) inside the radius 10 Kpc is measured to be $1.046 \times 10^{10} M_{\odot}$. Calculate the fraction of the dark matter the galaxy has inside the above radius.
(b) Assume that a Cepheid variable has a mean apparent magnitude of 18 and period of 10 days. Calculate its distance. The absolute magnitude (M) varies with the period P as $M = -2.78 log_{10}(P) - 1.35$. [6+4]

7. (a) Discuss, briefly, the major stages that a star with initial mass in the range $8M_{\odot} < M < 30M_{\odot}$ go through and corresponding physical processes occur during those major stages.
(b) Show that the electron degeneracy pressure inside a white dwarf scales as $P_e \propto \rho^{5/3}$ in the non-relativistic case, where ρ is the matter density inside the white dwarf. [5+5]

8. (a) Show that the age of a pulsar can be written as $t_{\rm pulsar} = \frac{\omega_0^3}{2\dot{\omega}_0}\left(\frac{1}{\omega_0^2} - \frac{1}{\omega_i^2}\right)$, where ω_0 and ω_i are the present and initial angular (during formation) frequencies of the pulsar respectively. $\dot{\omega}_0$ is the present value of $d\omega/dt$. (b) The supernovae associated with the Crab pulsar occured in the year 1054. The present angular frequency and the rate of change of the angular frequency are found to be $190\,{\rm s}^{-1}$ and $-2.4 \times 10^{-9}\,s^2$. Calculate the time period of the Crab pulsar during the time it was formed. [5+5]

9. (a) How the Tully-Fisher relation relation can be used to estimate distances to distant spiral galaxies? (b) Our galaxy hosts a supermassive black of mass $\sim 4 \times 10^6 M_{\odot}$ in its centre. Estimate the size of the Schwarzschild radius corresponding to the blackhole and its angular size observed from the earth. Will a telescope similar in size to the diameter of the earth be able to resolve the angular size at wavelength 1.3 m? [2.5+7.5]

10. Write a short note on (i) Hubble tuning fork diagram (ii) Chandrasekhar limit (iii) Pulsar. [3+4+3].