B. Sc. Physics (Hons.) Examination, 2023

(3rd Year, 2nd Semester)

Astrophysics

Paper – DSE - 3A

Time : 3 hours Full Marks : 75

Some useful constants: Solar mass $(M_\odot) = 1.98\times10^{30}$ Kg; Solar luminosity $(L_\odot) = 3.83\times10^{26}$ W; Solar radius $(R_\odot) = 6.98\times10^{8}$ m; Earth mass $(M_\oplus) = 5.97\times10^{24}$; Earth radius $(R_\oplus) = 6.37\times10^{6}$; AU=$1.49\times10^{11}$ m; Persec = 3.08×10^{16} m; G=6.67×10^{-11} N m^2kg^{-2}; m_e=9.109×10^{-31} Kg; m_p = 1.672×10^{-27} Kg; m_n = 1.674×10^{-27} Kg; m_H=1.673×10^{-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) 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) 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.

   (c) What is color index? Explain temperature of two stars for having one (i) $U - V > 0$ and another (ii) $U - V < 0$.

(d) 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+3+1)+3+(2+2)+2

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

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 $\rho \sim 10^6$ 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)

4. [CO-3] Assume a star has a radius of $R = 3R_{\odot}$ and a quadratic density profile: $\rho(r) = \rho_c\left[1-\left(\frac{r}{R}\right)^2\right]$. Here, $\rho_c = 20$ g/cm^3 is the central density.

   (a) What is the solution of $P(r)$ using hydrostatic equilibrium? What is the central pressure of the star?

   (b) Calculate the mass profile $m(r)$ as function of r and average density $\bar{\rho}$ of the star. What is the mass of this star in terms of solar mass $(M_{\odot})$. (6+2)+(2+2+3)

5. [CO-3] (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 galaxies), 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. Show $\bar{K} = \bar{U}$ for simple harmonic oscillator. Use the viral theorem to the Keplerian situation (self-gravitationally bound system) for circular orbit.

   (c) Calculate the viral temperature of Sun using viral theorem where we will assume that the Sun is made of ideal gas of hydrogen. (2+2)+(5+2)+4

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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) Calculate the maximum mass of hydrogn-burning star without exceeding the Eddington luminosity. For this calculation use only the p-p process. Further, calculate the corresponding Eddington luminosity in terms of solar luminosity. (2+6+2)+(3+2)

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 hydrogn density at the above temperature in which the corresponding electron gas starts behaving as quantum