Register Number:
DATE:

ST. JOSEPH'S COLLEGE (AUTONOMOUS), BANGALORE-27

M.Sc. PHYSICS - IV SEMESTER

SEMESTER EXAMINATION- APRIL 2017

PH 0416: ASTROPHYSICS

Time: 2.5 hrs. **Maximum Marks: 70**

This question paper has 4 printed pages and 2 parts

PART A **MAX. MARKS 5x10=50**

Answer any FIVE full questions.

1. Brightness of an object is defined as the amount of energy passing through unit area normal to the direction of radiation per unit time per unit solid angle. Consider an extended object having brightness B_1 with a surface area σ_1 at a distance d_1 from an optical system of collecting area A. Assuming that the object is imaged at a distance d_2 with an image area of σ_2 show that the brightness of the image is equal to the brightness of the object.

(**10 Marks**)

2. Consider a charge at rest. At time $t=0$, the charge is accelerated for a time Δt to a speed v (after which time, the acceleration is stopped and the charge moves with a constant velocity $v \ll c$ the speed of light). The electric field from the charge is measured after time $t \gg \Delta t$. Using an appropriate figure show that the power radiated is proportional to E_θ^2 (the square of the electric field in the angular direction) and is given by $P=\frac{2}{3}\frac{e^2 a^2}{c^3}$ where a is the magnitude of the acceleration, e is the charge all in Gaussian units.

(**10 Marks**)

3. The radiative transfer equation is given as: $\frac{dI_\nu}{ds} = -\alpha_\nu I_\nu + j_\nu$ where I_ν is the specific intensity.
   a) Define specific intensity of a source (**2 Marks**)
   b) Describe the various terms in the radiative transfer equation (**2 Marks**)
   c) Define optical depth (**2 Marks**)
   d) Using an appropriate integrating factor, obtain a general solution to the radiative transfer equation. (**4 Marks**)

4. Consider a star in radiative equilibrium. Assume that the star can be described by a constant density and temperature (the average density and temperature of a real star).
   a) If l is the mean free path of the photons, argue that the number of scatterings by the photon $N = \frac{R^2}{l^2}$. (**2 Marks**)
   b) From this, express the time of diffusion for the photons. (**2 Marks**)
   c) Using Stefan-Boltzmann law, express the energy density in terms of the temperature of the star. (**2 Marks**)
   d) What will the expression for luminosity of the star be from (b) and (c) above? (**2 Marks**)
   e) Using the hydrostatic equilibrium equation $\frac{dP}{dr} = -\rho g$ and assuming the photon gas in the star (in radiative equilibrium) to obey ideal gas law equation, obtain the mass-luminosity relationship for such "Eddington" stars. (**2 Marks**)

5. How is neutral hydrogen detected in the interstellar medium. Describe the phenomenon that causes neutral hydrogen to "radiate". (**10 Marks**)

6. In a short paragraph (not more than one page) and with a HR diagram describe stellar evolution:
   a) Touch on the aspects that distinguish low mass stars, intermediate ones and high mass stars. (**3 Marks**)
   b) What are the key stages of the stellar evolution (how do they differ for the three mass brackets described in (a))? (**4 Marks**)
   c) What are the end states for these three types? (**3 Marks**)

7. What is Cosmic Microwave Background Radiation? Write a short note touching the following aspects (only):
   a) What do these represent? (**3 Marks**)
   b) What is the cosmological importance of this radiation? (**3 Marks**)
   c) Is this radiation isotropic? What does isotropy and anisotropy of CMBR imply? (**4 Marks**)

PART B **MAX. MARKS 4x5=20**

Answer any FOUR full questions.

[Constants: $h=6.6x10^{-34}$ J s (Planck's constant), 1eV = $1.6x10^{-19}$ J (electron volt to Joules), $c=2.99x10^{8}$ m/s (speed of light), 1Å = $1x10^{-10}$m (Angstrom to meters), e = $1.6x10^{-19}$ C (electronic charge), $m_{proton}=1.673x10^{-27}$kg (mass of proton), $m_{electron}=9.109x10^{-31}$kg (mass of electron), $G=6.674x10^{-11}m^{3}kg^{-1}s^{-2}$ (Gravitational constant), $M_{\odot}=1.9891x10^{30}$ kg (Solar mass), $R_{\odot}=6.9x10^{8}$ m, $\sigma = 5.67x10^{-8}$ W m^{-2} K^{-4} (Stefan-Boltzmann constant), $M_{Earth}=5.97x10^{27}$kg (Mass of Earth), $D_{earth-sun}=1.49x10^{11}$m (Earth-Sun distance), 1 inch = 2.54 cm]

8. A stellar field was observed using a CCD detector twice, once in a red (R) filter and once through a blue (B) filter. The exposure time for the R filter was 20s and for the B filter 60s. One star was of Solar Type and known to have an apparent R magnitude of 12.1. A second star was also measured in the same field. The total photon counts from each star through each filter were as follows:

	Solar-type star	Other star
R filter 20s	23456	58919
B filter 60s	20954	49405

Obtain the B and R magnitudes of the other star (B-R for the Sun is 1.17). Is this star redder or bluer than the Sun? (**5 Marks**)

9. The Sun rotates once (the rotation is differential, however, for our purpose here we assume rigid rotation) in 24.47 days. If we conserve the angular momentum of the sun and if the Sun becomes a white dwarf of radius 1000 km, how fast would the white dwarf rotate? (**5 Marks**)

10. Assuming equipartition of thermal energy and that this energy is equal to the potential energy of a proton due to the entire mass and radius of sun, estimate the central temperature of sun.

11. An amateur astronomer has a dark adapted pupil diameter of 8 mm. She uses a 10 inch telescope. What are the allowed focal length of eyepieces she can use? (**5 Marks**)

12.

a) Calculate the specific intensity of Cosmic Microwave Background Radiation at a frequency of 1 GHz (hint: $B_\nu = \frac{2\nu^3/c^2}{e^{h\nu/kT}-1}$). (**2 Marks**)

b) Where is the maximum of this flux? (**3 Marks**)

13. A super-massive black hole at the center of a galaxy accretes stars at the rate of $\frac{dM}{dt}$. The accretion has a conversion (to luminosity) efficiency of $\nu \approx 0.1$. For every mass m accreted by the black hole, therefore, an energy of $\nu m c^2$ is released. Estimate $\frac{dM}{dt}$ required to produce a luminosity of $L = 10^{40}$ ergs/s. Convert this rate to solar masses per year. (**5 Marks**)