PHY305A
End Sem Exam

time: 3 hours max. marks 120

Instructions:
I. Calculators and mobiles are not allowed. You may leave your final answer in the form of a numerical expression. However all numerical substitutions must be done and you are required to simplify the final result as much as possible.
II. Please answer all parts of a question adjacent to one another. We will grade an answer only at the first place where it appears in the answer sheet.

1a. Write down the first nuclear reaction that contributes to the PP1 chain. What interactions contribute to this reaction. Why is the rate of this reaction relatively slow?

1b. Assuming that the Sun's Luminosity is constant in time, how long will it last assuming that its source of energy is (a) nuclear fusion (b) gravitational potential energy. No calculation is needed.

1c. What is the observational evidence that nuclear fusion is the source of energy of the Sun? List all evidences that were discussed in class.

1d. The equation for radiative transport inside a star can be expressed as

$$\frac{\cos\theta}{\kappa(r)}\frac{dI}{dr} = -\rho I + J(r)\,.$$

where the symbols have their usual meaning. Starting from this equation obtain the equation for dT/dr assuming that radiative transport dominates. You may use $B = \sigma T^4/\pi$.

(marks 5+2+3+5)

2. Consider the Hydrogen atoms and ions in a stellar atmosphere.

a. Let N_1 and N_2 be the number of Hydrogen atoms in the ground state and first excited state respectively. Determine N_2/N_1.

b. Let N_I and N_{II} be the number of Hydrogen atoms and Hydrogen ions respectively. We can determine N_{II}/N_I by using the Saha's equation, which involves the partition functions Z_I and Z_{II}. For the case of Hydrogen determine Z_I and Z_{II}. For Z_I write down the complete formula without any approximations.

c. Express N_2/N_{total} in terms of N_2/N_1 and N_{II}/N_I making suitable approximations. Here N_{total} is the total number of Hydrogen particles, including both atoms and ions. What approximation has to be made in getting the final answer?

d. Make a rough sketch of N_2/N_{total} as a function of temperature.

e. Briefly explain the reason for why Calcium spectral lines dominate in Sun type stars in comparison to Hydrogen.

(marks 2+3+4+2+4)

3a. The Harvard sequence of stars is O B A F G K M. Approximately what is the temperature of the hottest star in each of these categories? Make a rough sketch to show the variation of the strength of the Balmer spectral lines of H over these different classes?

3b. Explain how we can use the HR diagram in order to obtain the age of an open cluster of stars. Using the fact that on the main sequence $L \propto M^{3.5}$, where L is the luminosity and M the mass of a star, determine the formula for the age of the cluster. You may use the fact that the total energy available to a star on the main sequence is a proportional to Mc^2 where c is the speed of light.

3c. In the process of star formation a cloud of gas and dust undergoes fragmentation. Briefly explain why this process happens and why the fragmentation eventually ends.

(marks 5 + 6 + 4)

4a. Briefly explain what are supernovae Type 1a. Why are they useful for cosmological parameter estimation?

4b. The peak absolute visual magnitude of a supernova Type 1a is $M_V \approx -19.3$. The limiting apparent magnitude that the Hubble space telescope can detect is $V = 31$. (a) Ignoring interstellar extinction, find the maximum distance over which it can observe such a supernova. (b) How does this result change if we include extinction in V band due to the Milky Way. Assume that light propagates a distance of 6 Kpc within the Milky Way.

4c. Starting with the equation for intensity in the presence of extinction:

$$I_\lambda(r) = I_\lambda(R)e^{-\tau_\lambda}$$

where $I_\lambda(r)$ and $I_\lambda(R)$ are the specific intensities at Earth and the surface of the star respectively and τ_λ is the total optical thickness of the medium, obtain the equation for the flux density at Earth in terms of the flux density at the surface of the star.

(marks 5+5+5)

5a. Obtain the equation for the age of the Universe within the framework of the LCDM model. You may leave the final answer in the form of an integral.

5b. The equation for number density of particles in equilibrium is given by

$$n = g_{int}\left(\frac{mkT}{2\pi\hbar^2}\right)^{3/2} e^{(\mu - mc^2)/kT}$$

where the symbols have their standard meaning. Using this obtain the formula for equilibrium distribution of Deuteron (D) in the early Universe. Express your answer in terms of μ_D, m_b and T.

location

5.

5c. Explain why the current temperature of primordial neutrino gas is different from that of the cosmic microwave background radiation.

5d. Approximately at what value of kT does recombination take place. How does this value compare with the binding energy of Hydrogen atom. Explain the reason for the difference between the two.

(marks 4+3+4+4)

6a. Neutrinos decouple from the cosmic plasma at some early time. Briefly explain why do they decouple. (Write random shit)

6b. Briefly explain the term Baryogenesis.

6c. Write down the symbols for the three charged leptons and all the quarks.

6d. What are the sites of active star formation in the Milky Way. Briefly explain why these are the appropriate sites.

(marks 4+4+3+4)

7a. Briefly explain the difference between a solar day and a sidereal day. Write down the relationship between the two. A derivation is not needed.

7b. What procedure did Eratosthenes use in order to measure the radius of the Earth?

7c. What is meant by the term VLBI? Give a brief description.

7d. Consider a star located at an angle θ with respect to the ecliptic pole. The Earth appears to move in an ellipse with respect to the star. Determine the eccentricity of this ellipse.

7e. Give a brief description of a gamma ray burst.

(marks 3+3+3+3+3)

8a. In the transformation from the equatorial to galactic coordinates describe the first step. About which axis would you rotate. How would you determine the angle of rotation?

8b. State the virial theorem which applies to a system of particles which interact with one another through the gravitational force. Under what conditions does it apply.

8c. Make a rough sketch of the Mass Fraction of H and He as a function of r/R_S for the Sun as given by the Standard Solar Model. Here r is the distance from the center and R_S the solar radius.

8d. Briefly explain the concept of reionization in the cosmic history of the Universe. When does it occur and why?

(marks 4+4+4+3)