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BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
SECOND SEMESTER 2022-2023

Mid-Semester Exam 2023 Part –I (Closed Book)

Course Title: **Introduction to Astronomy & Astrophysics (PHY F215)** Date: 13.3.2023

Max. Time: 30 min. Total Marks: 40

Name: ID:

Use the table provided on the last page to write your answer choices. Make sure to mention the set A or B in the table heading. Each question carries a credit of 2 Marks. For questions with multiple right options, full marks will be awarded for choosing all the right options. For a wrong answer -0.5 marks will be deducted. Overwriting is not allowed.

Q1. How did the Ptolemaic model explain the apparent retrograde motion of the planets?
(A) It varied the motion of the celestial sphere so that it sometimes moved backward.
(B) It held that the planets moved along small circles that moved on larger circles around the Sun.
(C) It held that the planets moved along small circles that moved on larger circles around the earth.
(D) It held that sometimes the planets moved backward along their circular orbits.

Q2. What is an artificial star?
(A) A meteor
(B) The unseen member of a binary star system
(C) A satellite orbiting the earth
(D) A point of light in the earth's atmosphere created by a laser for the purpose of monitoring atmospheric fluctuations

Q3. If a material is transparent, it means it
(A) scatters light well
(B) emits light well
(C) transmits light well
(D) Reflects light well

Q4. Why do we expect the cosmic background radiation to be almost, but not quite, the same in all directions?
(A) The overall structure of the universe is very uniform, but the universe must have contained some regions of higher density in order for galaxies to form.
(B) The temperature of the universe can be found by taking an average over the entire sky, but individual stars will create peaks in the spectrum over small angles.
(C) The overall structure of the universe is very uniform, but the synthesis of different elements produces varying signatures within the background spectrum.
(D) The overall structure of the universe is very uniform, but intervening gas between us and the era of nuclei absorbs wavelengths depending on the composition and redshift of the gas.

Q5. The spectral sequence sorts stars according to
(A) Apparent brightness (B) Luminosity (C) Surface temperature (D) Core temperature

Q6. In the spectrum of a spectral type A star, you would expect to find strong lines caused by
(A) Ionized Hydrogen (B) Ionized helium (C) Neutral Hydrogen (D) Neutral Helium

Q7. Which of the following statements best describes the two principal advantages of telescopes over eyes?
(A) Telescopes have greater magnification and better angular resolution.
(B) Telescopes can collect far more light with far better angular resolution.
(C) Telescopes can collect far more light with far greater magnification.
(D) Telescopes collect more light and are unaffected by twinkling.

Q8. A 2-m telescope can collect a given amount of light in 1 hour. Under the same observation conditions, how much time would be required for a 4-m telescope to collect the same amount of light?
(A) 15 minutes (B) 30 minutes (C) 2 hours (D) 8 hours

Q9. Which of the following statements about the telescopes is CORRECT?
(A) Longer focal length increases the illumination but reduces the resolution.
(B) Longer focal length improves the resolution but reduces the illumination.
(C) Bigger aperture increases the illumination but reduces the resolution.
(D) Bigger aperture improves the resolution but decreases the illumination.

Q10. What can we say about a star with negative color indices, U-B and B-V?
(A) This star has to be of spectral type A0.
(B) This star has to be of some spectral type later than A0.
(C) This star has to be of some spectral type earlier than A0.
(D) None of the above.

Q11. What kinds of spectral lines occur in the photosphere of main-sequence stars?
(A) Emission lines
(B) Absorption lines
(C) Both emission and absorption lines
(D) No spectral lines occur in the photosphere

Q12. Which of the following statements relating different terms in the radiation field is/are INCORRECT?
(A) Radiative flux is basically specific intensity integrated over all directions.
(B) Specific energy density is basically specific intensity integrated over all directions divided by c, where c is the speed of light.
(C) In the case of the isotropic radiation field, radiative flux is just the mean specific intensity.
(D) In the case of the isotropic radiation field, radiative pressure is non-zero.

Q13. Which of the following statements about local thermodynamic equilibrium (LTE) inside stars is/are CORRECT?
(A) Atoms are in LTE in the photosphere but photons are not.
(B) Photons are in LTE in the photosphere but atoms are not.
(C) Photons as well as atoms are in LTE in the interiors of stars.
(D) Atoms are in LTE in the interiors of stars but photons are not.

Q14. A beam of radiation with specific intensity I is normally incident on an absorbing slab with optical thickness τ. What is the specific intensity of the radiation coming out of the slab?
(A) $Iexp(-\tau)$ (B) $Iexp(\tau)$ (C) I/τ (D) I

Q15. Consider three stars: Star A of spectral class F3V, Star B of spectral class F0V and Star C of spectral class A7V. Which of these three stars is reddest in color?
(A) Star A (B) Star B (C) Star C (D) There is no correlation between spectral class and the color of the star.

Q16. The parallax of a star is 10 mili-arcseconds, and its apparent visual magnitude is 3.5. What is its absolute visual magnitude?
(A) -3.5 (B) 3.5 (C) 1.5 (D) -1.5

Q17. Which of the equations given below has an error?
(A) $\frac{F_2}{F_1} = 100^{\frac{(m_1-m_2)}{5}}$ (B)$m_1 - m_2 = -2.5\log\left(\frac{F_1}{F2}\right)$ (C)$m_1 - m_2 = 2.5\log(\frac{F_2}{F1})$ (D) $d = 10^{\frac{(m-M+5)}{5}} meter$

Q18. If Earth receives a flux of 1365 W m^{-2} from the Sun, what is the flux due to Sun at the Neptune? It is approximately at AU from the Sun.
(A) 45 W m^{-2} (B) 1.51 W m^{-2} (C) 1365 W m^{-2} (D) 1228500 W m^{-2}

Q19. From what you have studied, which of the following statements is/are a CORRECT explanation of stars showing the presence of different spectral lines in their spectra despite the fact that they are all composed of mostly Hydrogen gas?
(A) Because the presence of spectral lines as well as their strengths not only depend on the total abundance of various elements in stars but also on their populations in specific excitation levels of those atoms (or ions).
(B) Though stars are mostly Hydrogen gas, they have different surface temperatures which lead to the differences in the presence of spectral lines.
(C) Although stars are mostly Hydrogen gas, depending upon their core temperatures, they fuse different elements even when they are on the main-sequence. This fact leads to changes in the spectral lines of different stars.
(D) The presence of different spectral lines comes about because of the different lines-of-sights to different stars. This fact implies the absorption of specific wavelengths should occur depending upon the abundance of elements in interstellar media in those specific directions thus different absorption lines.

Q20. Which of the following statements about the optical depth is INCORRECT?
(A) Optical depth is defined to express the combined effect of opacity, density, and distance on the reduction of intensity in a medium.
(B) The radiation from the Sun (or stars) does not leave from a fixed radius of the photosphere, but at different physical depths where $\tau_\lambda = 2/3$ for that particular wavelength.
(C) $\tau_\lambda = \int \kappa_\lambda \rho ds$. In this expression τ_λ is the optical depth of the final layer of the media.
(D) τ_λ is dependent on the wavelength.

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Max. Time: 60 min. Total Marks: 50

Q1. HD93343 is one of the brightest stars of the Carina Nebula. Its spectral type is O7, and has an apparent magnitude V = 9.60 mag, and a parallax of 0.00044". It has a surface temperature of 38,500 K, and it shows a weak Hα line at 656.5 nm. **[2x6]**

(A) What is the distance to HD93343?

(B) What is the absolute visual magnitude of HD93343?

(C) We know that the faintest star visible to the naked eye has a magnitude of V=6 mag. At what distance, HD93343 would become barely visible to the naked eye?

(D) What is the apparent angular extent (diameter) of HD93343 as viewed from Earth?

(E) At what wavelength, does the blackbody continuum peak for HD93343?

(F) Why do you think it shows a rather weak Hα line?

Q2. At a certain wavelength, stellar radiation originally having a specific intensity of 6.0 X 10^{-5} W m^{-2} sr^{-1} $Å^{-1}$ is observed to reduce to 2.0 X 10^{-5} W m^{-2} sr^{-1} $Å^{-1}$ while passing through the layers in the photosphere. **[3+7]**

(1) What is the optical depth of the medium at this wavelength?

(2) Assuming that the density of the medium is 2.1x 10^{-4} kg m^{-3}, and the opacity at this wavelength is 0.03 m^2 kg^{-1}, determine the physical depth from which the radiation is originating.

Q3. According to the polytropic model of stars, the central density of hot stars can be as high as 2.0X10^6 kg m^{-3}. The mean opacity at 5500 Å is 0.5 m^2 kg^{-1} and the radius of the star is 1.4 X10^{10} m. Assume that the star is fully composed of Hydrogen gas. [**4+2+7]**

(1) Calculate the mean free path of photons in the centers of these stars.

(2) Consider a hypothetical scenario in which a photon can travel unimpeded all the way from the center of this star to the "surface" and escape. How long would it take this photon to escape?

(3) Using the mean free path determined in part (1), estimate the average time a photon would take to escape from this star if this mean free path remained constant for the photon's journey to the surface.

Q4. He II lines are only visible till early-B stars. For an O star (40000) and a B5 star (15000),

(A) Determine the ratio of singly-ionized Helium to neutral Helium at these two temperatures. The ionization potential for losing the first electron is 24.5 eV, whereas Z_I=1, Z_{II} =2, and P_e=30 N m^{-2}.

(B) Pickering series is a spectral series due to transitions to/from n=4 to levels to higher n, of singly ionized Helium. By using the Boltzmann equation, find the ratio of the number of He II in n=4 and the He II in n=1 at these two temperatures. Note that the singly-ionized Helium is a Hydrogen-like atom. Therefore, you may take the energies corresponding to n=1 and n=4 levels as well as the degeneracies same as those of Hydrogen.

(C) What do you conclude from the first two parts? **[7+7+1]**

Constants: k = 1.38 x 10^{-23} Joule K^{-1}, k = 8.6 x 10^{-5} eV K^{-1}, h = 6.6 x 10^{-34} Joule s, m_e = 9.1 x 10^{-31} kg, 1 pc = 3.08 x 10^{16} m, $L_\odot$ = 3.8 x 10^{26} Watt, M_V (sun) = 4.83, m_V (sun) = -26.74