Roll No.:	Name:

INDIAN INSTITUTE OF TECHNOLOGY INDORE

2021 Spring Semester

AA 674N/474N: Radio Astronomy

Mid-Semester Examination

Number of Questions: 11 **Date: 28 January, 2021**
Number of pages: 2 **Time: 10:00 – 12:00 Hrs.**

Maximum Marks: 40

Instructions: (1) Do not use **Unfair Means**; (2) **Answer all the questions** (3) Students are **not allowed** to consult their fellow classmates during the examination.

1. What is the flux (in Jy) of a blackbody with temperature $T = 10,000$ K, with the size of the sun ($R \approx 7\times10^8$m), at the distance of the nearest star, about 3.3 parsec ($\approx 10^{17}$m)? What should be the Noise Temperature (T_N) of a single-dish radio telescope, so that it is able to detect this star at 5σ within one hour of observation? [2 + 2]

2. Given that the temperature of the CMB is 2.7 K, estimate the observing frequency range in which the Rayleigh-Jeans law is a safe approximation. [2]

3. A radio telescope with a collecting area of 1.2 m^2 observes a radio source at a frequency of 1500 MHz with a bandwidth 2 MHz. The power measured is 1.2×10^{-19}W. What is the flux density F_ν of the source in Jansky, at the observed frequency? [3]

4. Pluto is 38.5 AU from the earth at closest approach. The radius is thought to be $\sim$ 1500 km. At wavelength of 1.3 mm, the measured flux density of Pluto is 50 mJy. Calculate the disk temperature. For a 30m radio telescope, with geometric area 1000 m^2, beam efficiency $\eta = 0.5$ and FWHP beam size 12", calculate the antenna temperature. [2 + 2]

5. A spherical radio source has a temperature of T = 2400 K and an angular diameter 18 arcsec. An observation is made at $\lambda = 15$ cm with a bandwidth of $\Delta\nu = 2$ MHz, using a radio telescope that has a diameter of 10 metres and aperture efficiency $\eta_A = 0.6$. The system temperature is $T_{\rm sys}$ =100 K.

   (a) What is the brightness temperature of the radiation? [2]

   (b) What is the flux density of the radiation in Jy? [2]

   (c) What is the observed antenna temperature? [3]

   (d) What is the minimum integration time required in order to detect the radiation at a level five times the noise? [2]

6. Find the Fourier transform of the function

$$f(x) = \begin{cases} 1 & |x| < a \\ 0 & |x| > a. \end{cases}$$

   This should remind you of a physical phenomenon − name it. [2 + 1]

7. The latitude of Indore is 22.7196° N and 75.8577° E. The LST at Indore on January 27, 2021 at 10 PM (IST, local time) is 5.98 Hrs. The star Betelgeuse is a bright supergiant star which will explode following a supernova in the (near) future. Recently it generated a lot of interest as it has been consistently dimming since December indicating significant implication about its fate. This dimming in intensity of the star is more deeper, faster and longer than any previous behaviour observed from this variable star. Calculate the altitude and azimuth of Betelgeuse (RA= 05h 55m 10.3s, Dec = $+07°24'25''$) as measured from Indore at that time. [*Hint:* $\sin h = \sin\phi \sin\delta + \cos\phi \cos\delta \cos H$; $\sin A = -\cos\delta \sin H / \cos h$ where h and A are the altitude and azimuth respectively and ϕ is the latitude of the observer.] [4]

8. Let us say there is an optical observatory in Indore. The atmospheric conditions affect the image formed by the telescope and due to this, the minimum angular size observable is found to be 2 arcsecs. What is the maximum distance of stars observable that the telescope can measure? [2]

9. The famous Chandra X-ray telescope has a focal length of 10 m. The High resolution imaging camera (HRC-I) placed at the focal plane of the telescope consists of a CCD of 90 mm × 90 mm size. Calculate the field of view (closest rounded off value) of the telescope. [3]

10. A 2048 × 2048 CCD array with 15 μm pixels is placed at the f/8 focus of a 4-meter telescope. What is the image scale in arcsec/pixel and what are the angular dimensions of the region of sky covered by the CCD? [3]

11. Suppose that during an observation, n photons are incident on a detector that has quantum efficiency Q. Suppose also that the detector adds noise which has an RMS (σ) value equal to the signal produced by r photons. Derive an expression for the Detective Quantum Effieciency $D[= ((s/n)_{out}/(s/n)_{in})^2]$ of this observation, in terms of the above quantities. Show that in the limit when the detector noise can be neglected that $D = Q$. [3]