INDIAN INSTITUTE OF TECHNOLOGY INDORE
2021 Spring Semester
AA 674N/474N: Radio Astronomy
End-Semester Examination

Number of Questions: **Date: March 10, 2021**
Section A: 10, Section B: 4 **Time: 10:00-13:00 hours**

Number of pages: 3 **Maximum Marks: 60**

Section A

Select only one option for each question. In case of numerical answers, choose the nearest value in the options. 10 questions. Answer ALL. **[20 marks]**

1. Which of the following correctly describes a relationship between the sky and your location on Earth?
   a) If you are in the Northern Hemisphere, the altitude of the celestial equator equals your latitude.
   b) If you are in the Northern Hemisphere, the altitude of the north celestial pole equals your longitude.
   c) If you are in the Northern Hemisphere, the altitude of the north celestial pole equals your latitude.
   d) If you are in the Northern Hemisphere, the longitude of the north celestial pole is circumpolar, and therefore crosses your zenith at the meridian.

2. An astronomer observes that Polaris is 40 degrees above her northern horizon. What can she say about her longitude from this?
   a) nothing b) that it is 40 degrees north c) that it is 50 degrees south
   d) that it is 40 degrees east e) that it is 50 degrees west

3. A X magnitude star is 100 times as bright as an 8th magnitude star, where X is
   a) 3rd b) 7th c) 13th d) 108th

4. What is a disadvantage of using a single, large lens in a telescope?
   a) Large lenses are expensive to fabricate.
   b) A lens has to be supported only at its edges, so the lens can sag in the middle.
   c) Different colors of white light on passing through a lens focus at different points and result in a blurred image.
   d) Some lens materials completely absorb short wavelengths.
   e) All of the above.

5. An X-ray photon of 100 keV is impinging on a scintillation detector. What is the dominant physical process by which it interacts with detector?
   a) Pair-production b) Compton scattering
   c) Thompson scattering d) Photo-electric effect

6. Electromagnetic radiation is emitted from a distant object with a frequency of 300 MHz. Suppose a radio telescope of diameter 45 m is constructed to detect this signal.

What will be the resolution of such a telescope?
a) 10 arcmin b) 30 arcmin c) 15 arcmin d) 1 arcmin

7. The effective area (in m^2) of the telescope in the previous problem is:
   a) 450 b) 420 c) 490 d) 500

8. We are still discussing about the previous telescope. The size of the radio source emitting the signal is found to be elliptical with a major axis of 0.3^o and a minor axis of 0.1^o. What is the solid angle of the source in 10^{-6} sr?
   a) 4.3 b) 7.2 c)8.2 d) 5.2

9. The diffraction limited field-of-view (FWHM) for a single VLA antenna in arcminutes at 330 MHz is:
   a) 2.12^o b) 0.5^o c) 4^o d) 0.001^o

10. A radio observation at a wavelength of 6 cm yields the determination that a particular radio source has a solid angle of 7.18×10^{-6} sr and has a flux density of 350 Jy. What is the temperature of the radio source?

    a) 64 K b) 100 K c) 770 K d) 32 K

Section B

4 questions. Answer ALL. **[40 marks]**

1. (a) The **synodic** period of Mars is 780 days. Find its orbital distance from sun in AU. **[2]**

   (b) The Terrestrial Planet Finder (TPF) is a proposed space telescope that would be able to image an Earth-like planets orbiting solar type. One concept for TPF is an optical interferometer consisting of four diffraction-limited telescopes operating in the 3-30 μm wavelength range with separations between telescopes in the range 25-1000 m. Estimate the maximum resolution that could be achieved by TPF. How does this compare with the angular size of the Earth seen at a distance of 10 pc? How does it compare with the angular separation between the Earth and Sun as seen from the same distance? **[3]**

   (c) A source is observed in the infrared as follows: First, a small area of sky is observed which contains the object of interest. Then, an equal area of sky, in nearly the same direction but not containing the object (or any other), is observed for an equal length of time. The signals from these two observations are then subtracted to determine the flux from the source alone. If n_1 photons are detected in the first field and n_2 in the second, estimate the signal-to-noise ratio that will be obtained for the flux. **[3]**

   (d) Find x_{av} , the average distance traversed by photons in a beam passing through a detector being attenuated as $N(x) = N_i exp(-\sigma n x)$ where n is the number of target atoms in the detector interacting with the impinging photons. Carry out the integration required by the formal definition of an average taking into account all path lengths from 0 to ∞. **[2]**

2. If the calibrated response of the two element multiplicative interferometer is given by : $R = F_\nu cos\,(\pi b/\lambda sin(\omega_E t_{HA})$, where flux density of the source $F_\nu = 3$ Jy, $\omega_E = 7.29 \times 10^{-5}$ radians/s = angular rotation rate of the Earth,

   (a) What calibrated value is measured by the two antennas acting as a multiplicative interferometer? **[2]**

   (b) What are the amplitude and phase of the detected fringe? **[3]**

   (c) How long must we wait to measure one full oscillation of the fringes? **[2]**

   (d) The radio galaxy Cygnus A contains two especially bright points of radio emission separated by about 0.71 arcmin. Imagine you set out to build your own interferometer to observe at a wavelength of 1 m and decided to use this bright radio galaxy to test it out. Over what range of baselines should you make observations of Cygnus A to be able to measure the angular separation between these two points? **[3]**

3. The WMAP satellite has determined that the temperature of the cosmic microwave background (CMB) is 2.73 K.

   (a) Use Planck's function to determine the brightness of the CMB at a wavelength of 1 mm. **[2]**

   (b) Use the value of part (a) at 1 mm and the Rayleigh-Jeans approximation to the Planck function. What temperature do you derive for the microwave background? **[2]**

   (c) Redo (a) and (b) at 90 cm to find the temperature you would obtain if you measured the CMB at 90 cm? **[4]**

   (d) Suppose you had an emitting molecular cloud at T=100 K. Redo part (b) using 1 mm wavelength to see how good the Rayleigh-Jeans approximation is at this temperature. **[2]**

4. A typical cell phone transmits 200 mW of power at 900 MHz with a bandwidth of 30 kHz.

   (a) What is the flux (in mW/cm^2) from the antenna at a distance of 5cm? **[2]**

   (b) Compare that to the "harmful" threshold set by the FCC of 10 mW/cm^2. Are you in danger from your cell phone? **[2]**

   (c) What is the flux density from your cell phone (in Jy) that a 45 m radio antenna 10 km away would see? **[2]**

   (d) If signals larger than 10^9 Jy cause gain compression in the receiver, is the antenna safe? **[2]**

   (e) How many photons would this 45 m antenna intercept each second? **[2]**

——— **QUESTION PAPER ENDS** ———