Anubhav

AA 474/674 End Semester Exam

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Section - A

Q.1 :-

Ans → c

Q.2 :-

Ans → a

Q.3 :-

Ans → a

Q.4 :-

Ans → e

Q.5 :-

Ans → b

Q.6 :→ d

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Q : 9 →

Ans → a (2.12°)

Q : 10 →

Ans → a (64K)

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Section - B

Problem : 1 :-

(a) given in questions -

Synodic period of mars = 780 days = 2.137 yrs

~~for superior planet~~ (for two planet) →

$$\frac{1}{S} = \frac{1}{P_i} - \frac{1}{P_o}$$

where P_i → sidereal period of inner planet.

P_o → sidereal period of outer planet.

for superior planet ∃

$$\frac{1}{S} = 1 - \frac{1}{P}$$

$$\frac{1}{2.137} = 1 - \frac{1}{P_o}$$

$$P_o = \frac{2.137}{1.137} = 1.55 \text{ yrs}$$

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using Kepler's 3rd law

$$\left(\frac{p}{1\,yr}\right)^2 = \left(\frac{a}{1\,AU}\right)^3$$

where a = distance of mars from sun.

$$\Rightarrow a = (p)^{2/3}\ AU$$

$$a = (1.55)^{2/3}\ AU$$

$$a = 1.33\ AU$$

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1 (b)

So Angular resolution of an interferometer type array → $\theta = 1.02 \frac{\lambda}{d_{max}}$

~~θ ...~~

the maximum resolution will be achieved by shortest wavelength

$$\theta = \frac{1.44 \times 10^{11}}{3.086 \times 10^{16}} = 4.89 \times 10^{-6} \text{ radian}$$

$$\boxed{\theta = 1.01''}$$

So This distance can be resolved by the TPIC

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I(c)

given in question,

$S+B$ count is $\Rightarrow S+B = n_1$

B counts is $B = n_2$

Signal count can be -

$S = (S+B) - B$

$$\boxed{S = n_1 - n_2} \text{ --- (A)}$$

Now considering two observation to be independent

So $\sigma_S^2 = \sigma_{S+B}^2 + \sigma_B^2$

then $(S+B)$ and B observation are poisson -

$\sigma_{S+B} = \sqrt{S+B}$

$\sigma_{S+B} = \sqrt{n_1}$

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and $\sigma_B = \sqrt{B} = \sqrt{n_2}$

then $\sigma_s^2 = n_1 + n_2$ —— (B)

Signal ~~to~~ ratio $\frac{S}{\sigma_s}$ ⇒ from eqn (A) & (B) -

$$\boxed{\frac{S}{\sigma_s} = \frac{n_1 - n_2}{\sqrt{n_1 + n_2}}}$$

1(d) given $N(x) = N_i \exp(-\sigma n x)$

taking integration → 0 to ∞

$$\int_0^\infty N(x) = \frac{\int_0^\infty x N_i \exp(-\sigma n x)\, dx}{\int_0^\infty N_i \exp(-\sigma n x)\, dx}$$

$$= \frac{\int_0^\infty x \exp(-\sigma n x)\, dx}{\int_0^\infty \exp(-\sigma n x)\, dx}$$

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$$\int_0^\infty N(n) = \frac{\frac{-1}{\sigma^2 n^2}\left[\exp(-\sigma n n)\right]_0^\infty}{\frac{1}{-\sigma n}\left[\exp(-\sigma n n)\right]_0^\infty}$$

$$\int_0^\infty N(n) = \frac{\frac{1}{\sigma^2 n^2}}{\frac{1}{\sigma n}} = \frac{1}{\sigma n}$$

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Problem: 2 →

given.

The two element multiplicative interferometer is given by -

2(a)

$$R = F_v \cos(\pi b / \lambda \sin(\omega_E t\, HA)$$

So where flux density of the source.

$F_v = 3\ Jy$, $\omega_E = 7.29 \times 10^{-5}$ radians/s = angular rotation rate of the earth

As a single measured value. The information we can get from this interferometer does not come with a single measurement we need to measure the output for a range of times to detect the oscillations of the fringes.

2(b)

So the answer to this question from this single measurement from the setup of the ~~example and our calculations~~ question, we know that amplitude is 3.00 Jy and the phase difference can be measured by $\Delta\phi = \frac{2\pi b}{d} \sin wt$

where b = baseline

2(c)

For the completion of the full cycle we need to find to for the phase difference is 2π

we know - $\Delta\phi = 2\pi$

$$\therefore \Delta\phi = \frac{2\pi b}{d} \sin wt$$

$$2\pi = \frac{2\pi b}{d} \sin wt$$

$$\frac{d}{b} = \sin wt$$

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$$\Rightarrow \quad t = \frac{1}{\omega} \sin^{-1}\left(\frac{d}{b}\right)$$

$\therefore \omega = 7.29 \times 10^{-5}$ rad/s (given)

$$\boxed{t = 1.372 \times 10^{4} \sin^{-1}\left(\frac{d}{b}\right) \text{ rad}}$$

Q (d)

given in question -

$\Rightarrow \quad \theta = 0.71'$ arcmin $= 2.0653 \times 10^{-4}$ radians

$\Rightarrow$ wavelength $= 1$ m

So the angular resolution of interferometer system

is - $\quad \theta = \dfrac{1.02\ \lambda}{D_{max}}$

the system to be able to resolve the radio feature, $\theta < 0.71'$

$$2.0653 \times 10^{-4} > \frac{1.02 \times 1}{D_{max}}$$

$$b_{max} > \frac{1.02 \times 1}{2.0653 \times 10^{-4}}$$

$$b_{max} > 4938.75\,m$$

$$\boxed{b_{max} > 4.94\,km}$$

The baseline of interferometer is bigger than 4.94 km to observation of cygnus A at this given curvature.

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Problem: 3 →

given in questions →

CMB temperature = 2.73 K

3(a) at wavelength (λ) = 1 mm

Brightness of CMB = ?

using planck's function ⇒

$$I_\lambda = \frac{2hc^2}{\lambda^5} \frac{1}{\left(e^{hc/\lambda k_B T} - 1\right)}$$

then put values -

$$I_\lambda = \frac{2 \times 6.626 \times 10^{-34} \times (3 \times 10^8)^2}{(10^{-3})^5 \times \left[e^{\left(\frac{6.626 \times 10^{-23} \times 3 \times 10^8}{10^{-3} \times 1.38 \times 10^{-23} \times 2.73}\right)} - 1\right]}$$

$$\boxed{I_\lambda = 6.13 \times 10^{-4} \; W\, m^{-3}\, sr^{-1}}$$

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3 (b)

Using 3(a) part →

$$I_d = \frac{2c}{d^4} k_B T$$

$$\boxed{T = \frac{I_d\, d^4}{2 c k_B}}$$

Put values -

$$T = \frac{6.13 \times 10^{-4} \times (10^{-3})^4}{2 \times 3 \times 10^{8} \times 1.38 \times 10^{-23}}$$

$$\boxed{T = 0.074\ K}$$

So this is very much less than them $(Temp)_{CMB} = 2.73$ So Rayleigh Jeans approximation donot give good results for CMB at this wavelength.

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3(c)

at $d = 90\,cm$

$$I_d = \frac{2hc^2}{d^5} \times \frac{1}{e^{(hc/d k_B T)} - 1}$$

$$I_d = \frac{2 \times 6.626 \times 10^{-34} \times (3 \times 10^8)^2}{(90 \times 10^{-2})^5 \times \left[e^{\left(\frac{6.626 \times 10^{-34} \times 3 \times 10^8}{90 \times 10^{-3} \times 1.38 \times 10^{-23} \times 2.73}\right)} - 1 \right]}$$

$$\boxed{I_d = 3.435 \times 10^{-14}\ W m^{-3} sr^{-1}}$$

then calculating temp. considering Rayleigh Jeans approximation we get→

$$T = \frac{I_d\, d^4}{2 c k_B}$$

$$T = \frac{3.435 \times 10^{-14} \times (90 \times 10^{-2})^4}{2 \times 3 \times 10^8 \times 1.38 \times 10^{-23}}$$

$$\boxed{T = 2.722\,K}$$

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So this ~~equation~~ Rayleigh Jeans approximation yield good results at d = 90cm

3(d) given -

$T = 100K$

$d = 1mm = 10^{-3} m$

then -

$$I_d = \frac{2hc^2}{d^5}\left[\frac{1}{\left(e^{hc/d k_B T} - 1\right)}\right]$$

$$I_d = \frac{2 \times 6.626 \times 10^{-34} \times (3 \times 10^8)^2}{(10^{-3})^5 \left[e^{\left(\frac{6.26 \times 10^{-3} \times 3 \times 10^8}{10^{-3} \times 1.38 \times 10^{-23} \times 100}\right)} - 1\right]}$$

$$I_d = 0.77 \ W m^{-3} sr^{-1}$$

considering Rayleigh Jeans approximation

$$T = \frac{I_d d^4}{2cK} = \frac{0.77 \times (10^{-3})^4}{2 \times 3 \times 10^8 \times 1.38 \times 10^{-23}}$$

$$\boxed{T = 92.97K}$$

Rayleigh Jeans approximation holds good in this case

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(17)

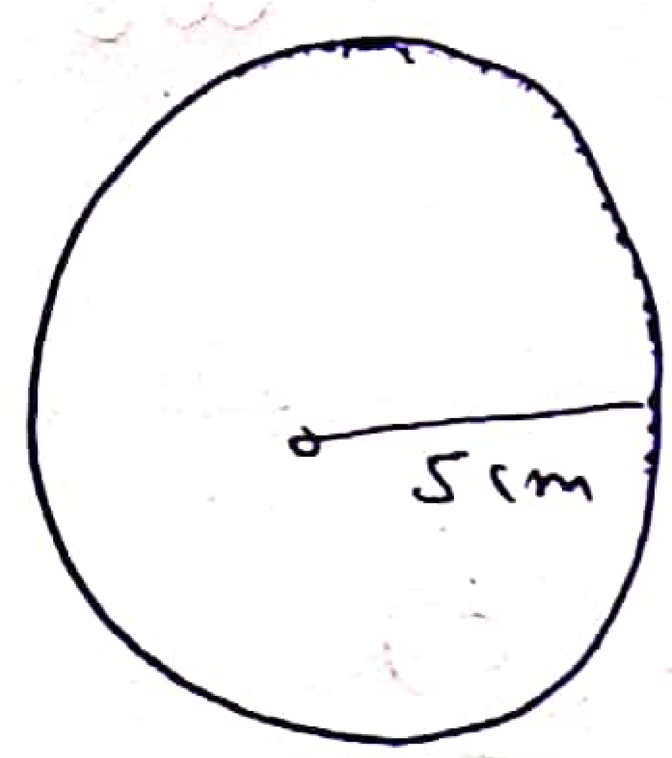
Problem: 4 8-

Cell phone transmits power = 200 mW
at frequency $\nu = 900\,MHz$
with $\Delta\nu = 30\,KHz$.

4(a)

$$\text{flux}\left(\frac{mW}{cm^2}\right) = ?$$

distance = 5 cm



$$\text{flux} = \frac{\text{Power}}{\text{Area}}$$

$$= \frac{200\,(mW)}{4\pi \times (5)^2\,cm^2}$$

$$= \frac{200\,mW}{4\pi \times 25\,cm^2}$$

$$\boxed{\text{flux} = 0.6369\,mW\,cm^{-2}}$$

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4(b)

So flux at distance of 5 cm ≈ 0.63 < 10 mW/cm^2

So cellphone is not harmful

we are not in danger

4(c)

distance of radio antenna = 10 km
(45 m)

then

flux density at 10 km $f_v = \dfrac{\text{Power}}{4\pi d^2 \times \Delta v}$

$$f_v = \frac{200 \times 10^{-3}}{4 \times \pi \times (10 \times 10^3)^2 \times (30 \times 10^3)}$$

$$f_v = 5.3 \times 10^{-15}\ W m^{-2} Hz^{-1}$$

$$\boxed{f_v = 5.3 \times 10^{11}\ Jy}$$

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4(d)

so the flux density (5.3×10^{11} Jy) captured by 45m radio antena 10km away from cellphone $> 10^9$ Jy. which causes the gain compression in receiver. The ANTENA is not safe.

4(e)

power recieved by radio Antenna over disk are of dimeter 45m.

$= F_\nu \times \text{Area} \times \Delta\nu$

$= 5.3 \times 10^{11} \times \pi \times \left(\frac{45}{2}\right)^2 \times 30 \times 10^3$

$= 5.3 \times 10^{11} \times \pi \times (22.5)^2 \times 30 \times 10^3$

$= 2.52 \times 10^{19}$

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Number of photon emitted per second

$$(n) = \frac{\text{Energy emitted by } n \text{ photons in } 1 \text{ sec}}{\text{Energy of } 1 \text{ photon}}$$

$$= \frac{2.52 \times 10^{19}}{(6.626 \times 10^{-34} \times 900 \times 10^{6})}$$

$$= 4.22 \times 10^{43} \text{ photons}$$