M.Sc. 2nd Semester Examination, 2021

PHYSICS

(Mathematical Methods II & Advanced Optics)

Paper: 201C

Course ID: 22451

Time: 2 Hours **Full Marks: 40**

Candidates are required to give their answers in their own words as far as practicable.
The questions are of values indicated in the margin.

Unit-I

1. Answer *any three* of the following questions: **2x3=6**

a) Find the Laplace transforms of $e^{2t}\cos^2 t$.

b) Define a mixed tensor of rank two.

c) If $P_n(x)$ is a Legendre polynomial of degree n and α is such that $P_n(\alpha) = 0$. Show that $P_{n-1}(\alpha)$ and $P_{n+1}(\alpha)$ are of opposite sign.

d) What do you mean by equal tensors?

e) Show that the trace of an anti-symmetric tensor is zero.

2. Answer *any two* of the following questions: **4x2=8**

a) Find the inverse Laplace transform of $f(s) = \frac{s}{(s^2+a^2)^2}$ by the use of the convolution theorem.

b) State and prove Parseval's relation.

c) What do you mean by special function? Does it really correspond to the solution of a differential equation? Explain briefly. Give an example. 1+1+1+1=4

d) Prove that symmetric tensor of rank 2 has almost N(N+1)/2 different components in N-dimensions.

3. Answer *any one* of the following questions: **6x1=6**

a) Consider the following differential equation

$\frac{d^2y}{dx^2} = R(x)$ with $y(0) = 0$ and $y'(1) = 0$

Find the Green's function required to solve the given differential equation. Solve the equation for $R(x) = Cos\ x$. 4+2=6

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b) Two function ψ(x) and ϕ(p) are Fourier transforms of each other:

$$\psi(x) = \frac{1}{\sqrt{2\pi\hbar}} \int_{-\infty}^{\infty} \phi(p) e^{\frac{ipx}{\hbar}} dp$$

$$\phi(p) = \frac{1}{\sqrt{2\pi\hbar}} \int_{-\infty}^{\infty} \psi(x) e^{-\frac{ipx}{\hbar}} dx$$

Show that $\int_{-\infty}^{\infty} |\psi(x)|^2 \, dx = \int_{-\infty}^{\infty} |\phi(p)|^2 \, dp$.

The symbols have their usual significance as in Physics.

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Unit-II

4. Answer *any three* of the following questions: 2x3=6

a) Calculate the ratio of the Einstein coefficients of spontaneous and stimulated emission, A and B for transitions involving 580 nm visible light.

b) Why flash lamp is used as a pump in solid-state laser but electric discharge is used as pump in gas laser system?

c) Give a schematic diagram of a double hetero-junction strip-contact AlGaAs laser diode indicating its different parts and emitting edge.

d) Define phase matching.

e) What is the difference between p-i-n photodiode and Avalanche Photo Diode?

5. Answer *any two* of the following questions: 4x2=8

a) (i) Find the ratio of the probability of spontaneous emission to the stimulated emission at 300 K for (a) microwave photons and (b) optical photons.

(ii) A He-Ne laser has a gas discharge temperature of 400 K. The atomic masses of Ne is 3.35×10^{-26} kg. If the lasing wavelength is 630 nm, calculate the line shape broadening due to Doppler effect. 2+2 = 4

b) What do you mean by responsivity of a photodetector and its quantum efficiency? A photodiode has a responsivity of 0.5 A/W at 850 nm. Find the quantum efficiency of the detector. 2+2=4

c) Explain how the population inversion is achieved in Dye laser. Show that it is a tunable four level laser. 2+2=4

d) Why in Nd:YAG laser crystal, the doping of Nd ion is restricted? Explain with a near energy level diagram all the possible transitions of Nd ion in YAG host.

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6. Answer *any one* of the following questions: 6x1=6

(a) Sketch the energy level diagram for a four level laser system with an example. Obtain the threshold population inversion requirements in a four-level laser starting from rate equations. 1+5=6

(b) Discuss briefly the working principle, construction and applications of a Bolometer and Pyro-electric detector. 6
