

M.Sc. PHYSICS
FOURTH SEMESTER
LASER & NONLINEAR OPTICS
MSP-403 D
[USE OMR FOR OBJECTIVE PART]

2023/06

**SET
A**

Duration: 3 hrs.

Full Marks: 70

Time: 30 min.

(Objective)

Marks: 20

Choose the correct answer from the following:

1X20=20

- For a pure state with density operator ' ρ ', which of the following condition is true?
a. $\text{Tr}(\rho)=1$
b. $\text{Tr}(\rho^2)=1$
c. both (a) and (b) are true
d. none of the above
- The completeness equation related to a two-state system having states $|a\rangle$ and $|b\rangle$ is
a. $|a\rangle\langle a| + |b\rangle\langle b| = 0$
b. $|a\rangle\langle b| + |b\rangle\langle a| = 1$
c. $|a\rangle\langle a| + |b\rangle\langle b| = 1$
d. $\langle a|a\rangle + \langle b|b\rangle = 1$
- The Rabi-oscillation associated with a two-level system and an external field E is given by
a. $\Omega_R = \frac{\hbar}{i} |\mu_{ab}| E$
b. $\Omega_R = \frac{\hbar |\mu_{ab}|}{E}$
c. $\Omega_R = \frac{|\mu_{ab}| E}{\hbar}$
d. $\Omega_R = \frac{\hbar E}{|\mu_{ab}|}$
- The dipole matrix approximation for a light-matter interaction suggests the following relation to be true
a. $\mathbf{K} \cdot \mathbf{r} = 0$
b. $\mathbf{K} \cdot \mathbf{r} = 1$
c. $\mathbf{K} \cdot \mathbf{r} \ll 1$
d. $\mathbf{K} \cdot \mathbf{r} \gg 1$
- Which among the following conditions indicates slow light?
a. $V_g > c$
b. $V_g < c$
c. $V_g = c$
d. $V_g \times c = 0$
- In Z scan technique the sign of the nonlinear phase shift $\Delta\phi > 0$ indicates____
a. Self-focusing
b. Self-defocusing
c. parametric generation
d. Self-modulation
- The Z scan technique measures which two among the following quantities?
a. Imaginary $\chi^{(1)}$, Real $\chi^{(1)}$
b. Imaginary $\chi^{(3)}$, Real $\chi^{(3)}$
c. Imaginary $\chi^{(2)}$, Real $\chi^{(2)}$
d. Imaginary $\chi^{(4)}$, Real $\chi^{(4)}$
- Select the true relation between n_2 and $\chi^{(3)}$, (n_0 being linear index of refraction)
a. $n_2 = \frac{3}{8n_0} \chi^{(3)}$
b. $n_2 = \frac{8}{3n_0} \chi^{(3)}$

c. $n_2 = \frac{\chi^{(3)}}{n_0}$

d. $n_2 = n_0 \chi^{(3)}$

9. Which among the following is not determined by Z-scan technique
 a. Nonlinear absorption b. Raman Effect
 c. Nonlinear refractive index d. Two photon absorption
10. In close aperture Z-Scan method, the phase shift for the case of $\Delta\phi > 0$,
 a. peak trails the valley b. valley trails the peak
 c. no peak and valley appear d. none of the above.
11. The pump-probe method is successful in study _____ phenomena.
 a. ultraslow b. ultrafast
 c. stopped light d. none of these
12. Sodium lamp used for Laser trapping are operated in _____ wavelength.
 a. 5890 nm b. 5890 Å
 c. 5890 μm d. 5890 fm
13. The widely used laser in astronomy is
 a. argon laser b. dye laser
 c. Ruby laser d. CO₂ laser
14. For liver and Lung treatment _____ and _____ lasers are widely used.
 a. Argon ion, He-Ne b. dye, Ruby
 c. Ruby, diod d. Argon ion, CO₂
15. For cutting different types of materials, _____ lasers can be very useful.
 a. argon laser b. dye laser
 c. Ruby laser d. CO₂ laser
16. A step index fiber supports single mode propagation if the V parameter is
 a. V=0 b. V<0
 c. V<2.405 d. 2.405<V
17. Silica fiber made by MCVD method possesses a communication window.
 a. 340-750 nm b. 1.0-1.3 μm
 c. 1.5-1.6 μm d. 4.0 μm -1.0 mm
18. For anomalous dispersion, the group velocity dispersion 20/7
 a. $\beta_2 < 0$ b. $\beta_2 > 0$
 c. $\beta_2 = 0$ d. $\beta_2 = \infty$
19. At which wavelength the optical fibers possess minimum loss about 0.2 dB/km?
 a. 850 nm b. 1.06 μm
 c. 1.55 μm d. 10.06 μm
20. Which among the following is described by the concept of numerical aperture in an optical fibre?
 a. Light collection b. Light scattering
 c. Light dispersion d. Light polarisation

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(Descriptive)

Time : 2 hrs. 30 mins.

Marks : 50

[Answer question no.1 & any four (4) from the rest]

If a single mode field \vec{E} interacts with a two-level atom, having states $|a\rangle$ (upper) and $|b\rangle$ (lower), with energy eigenvalues $\hbar\omega_a$ and $\hbar\omega_b$ associated with the states, respectively, then using completeness equation and dipole matrix element write the expressions for the following

4+6=10

Unperturbed Hamiltonian (H_0)

Interaction Hamiltonian (H_I)

- a. What you mean by nonlinear optical susceptibility of a medium? Discuss the three-fold motivation towards obtaining nonlinear susceptibilities 5+5=10
- b. What you mean by statistical mixture of states? Discuss the three step process, how density operator enable us to obtain all physical predictions be calculated from state vector $|\psi\rangle$
3. What you understand by electromagnetically induced transparency (EIT)? Discuss briefly about the three basic schemes of EIT. 4+6=10
4. Describe the operation of Z-scan technique. Discuss briefly the observations through Open and Close apertures 4+6=10
5. a. Discuss briefly the experimental technique of pump-probe spectroscopy. 5+5=10
- b. Discuss why third-order nonlinear materials are important? Give examples of atomic vapour, dye solution and liquid that offer large nonlinearity

$$d_{ba} = \frac{2\hbar}{\lambda} \left[\dots \right] \quad |1\rangle = \frac{a_0}{\sqrt{2}} \left(\dots \right)$$

6. a. How can laser cooling be employed to trap neutral atoms? 5+5=10
b. Discuss two techniques how a laser can be used for communication.
7. Write briefly about the application of lasers in Plasma as well as for Thermonuclear fusion. 4+6=10
8. Describe the method of fabrication of optical fibers 10

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$$n_2 = 1 - \frac{v_2}{c} \left(\frac{v_1}{\omega} \right)^2$$