M.Sc. PHYSICS
SECOND SEMESTER
ATOMIC, MOLECULAR &LASER PHYSICS
MSP - 204
(Use Separate Answer Scripts for Objective & Descriptive)

Duration: 3 hrs.

Full Marks: 70

[PART-A: Objective]

Time: 20 min.

Marks: 20

Choose the correct answer from the following: *1X20=20*

1. The time during which the number of atoms in a given excited state diminishes to -------
   - times of its initial value is a called the life time of the excited state.
   a. $1/e$ b. $1/e^3$ c. $1/e^2$ d. $1/e^4$

2. The longitudinal modes of resonator are also known as ------------ .
   a. TEM modes   b. TE modes
   c. Parallel   d. axial modes

3. The degree of non-monochromacity is related to the -------------
   a. Rayleigh length   b. coherence length
   c. bandwidth   d. coherence time

4. In a He-Ne laser the ratio of He to Ne is -------.
   a. 1:10   b. 10: 1   c. 10:2   d. 2:10

5. The correlation between field at a point and field at the same point certain time later is
   called ------------.
   a. spatial coherence   b. temporal coherence
   c. non coherent   d. partially coherent

6. The major drawback of conventional holographic process is the requirement of coherent
   --------- in the image reconstruction.
   a. absorption   b. distribution
   c. variation   d. illumination

7. During amplification of beam, -----------.
   a. stimulated emission must   b. spontaneous emission must
      predominate over spontaneous   predominate over stimulated emission.
      emission.
   c. stimulated emission does not occur.   d. spontaneous emission does not occur.

8. The real image obtained in holography is called --------- image.
   a. inverted   b. lateral
   c. pseudoscopic   d. None of the above

9. For a typical laser, the beam divergence is ----------- 0.01 milliradian.
   a. equal to   b. more than
   c. less than   d. none of these

10. Single-mode fiber is used for -----------distance transmission.

a. Short   b. very short   c. long   d. very long

11. Multiplicity of states involved in normal Zeeman effect is:
     a. One   b. Two   c. Three   d. Four

12. Doppler broadening of spectral lines from a source can be minimized by:
     a. Decreasing both T and M   b. Decreasing T and increasing M
     c. Increasing both T and M   d. Increasing T and decreasing M
     [T=absolute temperature, M=mass of the atom emitting radiation]

13. The ground state of helium (He) atom is:
     a. $^3P_2$ b. $^3S_1$
     c. $^1S_0$ d. $^1P_1$

14. The ratio of the frequencies of first spectral line of Lyman series and that of Balmer series of hydrogen atom is:
     a. $\dfrac{4}{27}$ b. $\dfrac{8}{27}$
     c. $\dfrac{27}{8}$ d. $\dfrac{27}{5}$

15. Considering the relativity correction only the number of spectral lines for the transition from n=3 to n=2 of hydrogen atom is:
     a. 3   b. 4   c. 5   d. 6

16. The eccentricity of Sommerfeld elliptic orbit is:
     a. $1-k^2/n^2$ b. $\sqrt{1-k^2/n^2}$
     c. $\dfrac{k^2}{n^2}$ d. $\dfrac{1}{\sqrt{1-k^2/n^2}}$
     [K=Azimuthal Quantum number,   n= Principal Quantum number]

17. Rotational spectrum is not shown by the molecule:
     a. HCl   b. OCS   c. CH_4 d. HCN

18. For a diatomic molecule the relation among D, B and fundamental vibrational frequency $\bar{v}$ (cm^{-1}) is such that D is equal to:
     a. $\dfrac{2B^3}{\bar{v}^3}$ cm^{-1} b. $\dfrac{4B^2}{\bar{v}^2}$ cm^{-1}
     c. $\dfrac{B^3}{\bar{v}}$ cm^{-1} d. $\dfrac{4B^3}{\bar{v}^2}$ cm^{-1}

19. The selection rule for R and P branches of rotational spectral lines in rotation vibration spectra are respectively:
     a. $\Delta J = +1 \, \& -1$ b. $\Delta J = -1 \, \& +1$
     c. $\Delta J = 0 \, \& +1$ d. $\Delta J = 0 \, \& -1$

20. The intensity distribution of vibrational bands in the electronic transition of O_2 molecule shows that:
     a. $r_e^{'} < r_e^{''}$ b. $r_e^{'} \approx r_e^{''}$
     c. $r_e^{'} > r_e^{''}$ d. $r_e^{'} \ll r_e^{''}$
     [$r_e^{'}$=Internuclear distance in upper electronic state,
     $r_e^{''}$ = Internuclear distance in lower electronic state]

Time : 2 hrs. 40 min.   Marks : 50

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

1. a. Derive the relationship between various Einstein's coefficients.   5+5=10

    b. Explain the concept of population inversion. Prove that population inversion is necessary condition for light amplification.

2. a. What is diffraction loss? How can it be minimized in an optical resonator?   5+5=10

    b. Draw the energy level diagram of Helium Neon laser. Explain the operation principle of He-Ne laser.

3. a. What are the different types of optical fiber? Discuss about Step index multimode fiber and graded index multimode fiber and support with diagram.   6+4=10

    b. Give qualitative idea of formation and reconstruction of a hologram.

4. a. Elucidate the Quantum theory of Raman effect. What are the discrepancies of classical theory of Raman spectroscopy?   7+3=10

    b. Discuss the rotational Raman spectrum.

5. a. What do you mean by orthohelium and parahelium? Discuss the emission spectra of helium atom. State the ground state of the said atom.   2+2+1=10

    b. Define the breadth of the spectral line. Explain the contribution of Doppler effect towards it.   1+4=5

6. a. Distinguish between normal and anomalous Zeeman effect. What do you mean by Lorentz unit and give the expression of it? Calculate the g value for $^2P_{3/2}$ level and give the selection rule used in anomalous Zeeman pattern.   2+1+1+1=5

    b. Show the Zeeman pattern of sodium D_2 line with π (pi) and σ (sigma) components.   5

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7. a. State Lande interval rule and prove it. Apply this rule in case of ^3D state of atom. 5

    b. Explain what do you mean by L-S and j-j coupling scheme. Draw the vector diagram of both the couplings. 5

8. a. Write down the term value of an anharmonic vibrating rotator. Find the frequency of fundamental, first overtone and second overtone mode of vibration. What do you mean by hot bands? Calculate the frequency of first hot band along with the selection rule to be applied. 1+1+1+1 +1=5

    b. Starting from term value of rotation vibration spectra, calculate the frequencies of $\underline{P}$ and R branches of spectral lines and show the position of zero line diagrammatically. 2+2+1=5

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