**63/2 (SEM–4) PHY 402**

**2024**

**PHYSICS**

Paper : PHY 402

***(Atomic and Molecular Physics)***

*Full Marks : 80*

*Pass Marks : 32*

Time : Three hours

***The figures in the margin indicate full marks for the questions.***

1. Answer all of the following questions : 1×5=5

*(a)* Polarization rules for Zeeman lines says, when viewed perpendicular to the field, $\Delta m_j = \pm 1$ provides

*(i)* plane polarized, σ components

*(ii)* plane polarized, π components

*(iii)* circularly polarized, σ components

*(iv)* forbidden components

(b) For a beam of light, if $D_b$ is the linear spread of the beam at a distance $l$ from the source and $\Delta\theta$ is the angular spread, then

(i) $D_b = 2l\Delta\theta$

(ii) $D_b = l\Delta\theta$

(iii) $2D_b = l\Delta\theta$

(iv) $D_b = 4l\Delta\theta$

(c) In a laser cavity, the permitted modes have to satisfy the condition ($L$ = length of cavity, $m$ = mode)

(i) $m\lambda = L$

(ii) $m\lambda = 2L$

(iii) $m\lambda = \frac{L}{2}$

(iv) $m = L\lambda$

(d) In case of skew ray, if $\theta_{as}$ is the acceptance angle, $\gamma$ is the angle between projection of the ray and the radius of fibre core at the point of reflection, $NA$ is numerical aperture, then

(i) $\sin\theta_{as}\cos\gamma = NA$



(ii) $\cos\theta_{as}\sin\gamma = NA$

(iii) $\sin\theta_{as}\cos\gamma = \frac{1}{NA}$

(iv) $\cos\theta_{as}\sin\gamma = \frac{1}{NA}$

(e) Which of the following is observed both in emission and absorption ?

(i) Electronic spectra

(ii) Vibrational-rotational spectra

(iii) Rotational spectra

(iv) All of the above

2. Answer ***all*** of the following questions : 2×5=10

(a) Outline the advantages of 4 level system laser over 3 level system laser.

(b) Give a brief explanation of hyperfine structure on the basis of isotope effect.

(c) Discuss hyperfine structure of fine structure line due to transition $^2P_{3/2} \rightarrow {}^2S_{1/2}$ (Given I = 3/2).

(d) Distinguish between the vibrational-rotational bands and pure rotational bands.

(e) Show that the absorption spectrum of a rigid rotator consists of a series of equidistant lines with constant separation $2B$ where $B = \frac{h^2}{8\pi^2 lc}$ [Use rotational energy, $E = \frac{h^2}{8\pi^2 l} J(J+1)$].

3. Answer the following questions : ***(any five)*** 5×5=25

(a) Write about various types of Stark effect. Describe experimental arrangement for studying Stark effect. 2+3=5

(b) Discuss Zeeman pattern of line due to transitions : 2½+2½=5

(i) $^3D_2 \rightarrow {}^3P_1$

(ii) $^2D_{5/2} \rightarrow {}^2P_{3/2}$

(c) Show that smaller the line width, higher is the quality factor of laser. Write about the electrical pumping. 3+2=5



(d) Explain how a semiconductor junction diode can be used as a laser. Compare it with other radiation pumped lasers. 3+2=5

(e) Write about graded index fibre and mention some advantages of optical fibre transmission. 3+2=5

(f) In the near infra-red spectrum of $HCl$ molecule, there is an intense band at 2886 $cm^{-1}$. Find the energies of the lowest and the first excited vibrational levels of the molecule. Also find the force constant. Given : mass of hydrogen atom, $M_H = 1.67 \times 10^{-27}$ $kg$, $h = 6.63 \times 10^{-34}$ J s, $c = 3.0 \times 10^8$ $m$ $s^{-1}$. 3+2=5

4. Answer the following questions : ***(any four)*** 10×4=40

(a) Outline the differences between anomalous Zeeman effect and Paschen-Back effect. Find the expression of shift in wave number in case of Paschen-Back effect. Discuss Paschen-Back effect for the transition $^2P_{3/2} \rightarrow {}^2S_{1/2}$ and $^2P_{1/2} \rightarrow {}^2S_{1/2}$. 2+4+4=10

(b) Write the laser rate equation related to photon density and carrier density. Discuss in detail about the carrier density and photon density below the threshold, at the threshold and above the threshold. Find the expression for photon density. At threshold how the medium will behave for incoming signal? 2+4+3+1=10

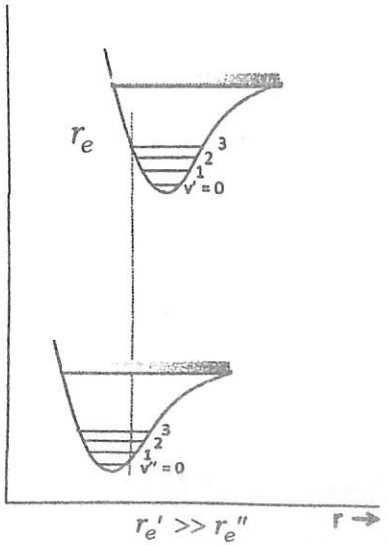
(c) Define acceptance angle in optical fibre and deduce expression for it. What are fibre optic connectors? Discuss about various types of dispersion in a fibre. 4+2+4=10

(d) With proper theory describe the rotational structure of Raman spectrum of a diatomic molecule. Give comparison between Raman spectra and Infrared spectra. The exciting line in an experiment is 5460 Å and Stokes line is at 5520 Å. Find the wavelength of anti-Stokes line. 4+3+3=10

(e) (i) The far infra-red spectrum of $H^1Br^{79}$ consists of a series of lines spaced 17 $cm^{-1}$ apart. Find the internuclear distance of $H^1Br^{79}$. ($h = 6.63 \times 10^{-34}$ J s, $c = 3.0 \times 10^8$ $m$ $s^{-1}$, $N_A = 6.023 \times 10^{23}$ per mol). 5



(ii) State Franck-Condon principle. In the following diagram, identify the most probable vibrational transition when $r_e' >> r_e''$ ($r_e''$ is the equilibrium internuclear distance of the molecule in lower electronic state and $r_e'$ is that of the same molecule in upper electronic state) by drawing the absorption transition arrow between the two electronic states :




Give the reason. Draw the expected spectrum for such a molecule. 2+1+1+1=5