RAMAKRISHNA MISSION VIDYAMANDIRA

(Residential Autonomous College affiliated to University of Calcutta)

B.A./B.Sc. SIXTH SEMESTER EXAMINATION, JULY 2021

THIRD YEAR [BATCH 2018-21]

Date : 10/07/2021 **PHYSICS (HONOURS)**

Time : 11.00 am - 3.00 pm **Paper : VIII** Full Marks : 100

Group - A

Answer **any five** questions of the following : [5×10]

1) a) Explain how Maxwell arrived at the expression for the displacement current.
   b) Derive Maxwell's equations in a material medium at rest(in terms of D, H, etc)
   c) Deduce the wave equation for a non-conducting charge free medium with dielectric constant ε (4+3+3)

2) a) Show that free charge density inside a conducting medium decays exponentially with time.
   b) In an imperfect dielectric medium of conductivity σ the electromagnetic wave is damped. Find out the refractive index in such a medium. Explain the significance of the real and imaginary parts. Define skin depth in this context.
   c) What type of wave (plane, spherical, etc) would you expect for a point source radiating e.m. wave. (2+4+2+1+1)

3) a) Establish the principle of the conservation of energy for an e.m. wave propagating in a medium.
   b) Find out the values of E, H on the surface of a straight current carrying wire of length l and radius r respectively. Compute Poynting's vector and show that it represents a flow of energy into the wire. (5+5)

4) a) A plane e.m. wave polarized in the plane of incidence is incident obliquely at the interface of two isotropic dielectric media. Assuming boundary conditions derive Fresnel's formula. Find out the angle of incidence for which there is no reflected wave.
   b) A charged parallel plate capacitor is immersed in a medium of permittivity ε. Charge on the plate varies sinusoidally with time. Compare the conduction and the displacement currents. (7+3)

5) a) Calculate the total scattering cross section by
      i) A free electron,
      ii) A bound electron
      for a polarized e.m. wave.
   b) Compute the energy absorbed by an electron from an incident e.m. field in the neighbourhood of resonance. (4+3+3)

6) a) An e.m. wave is propagating in the z-direction in a rectangular waveguide with perfectly conducting boundary being the xy-plane with x extending from 0 to a and y from 0 to b. Find out the lower cut-off frequency for such a wave. Compute the phase velocity and the group velocity for this wave. Does the magnitude of the phase velocity being greater than c violate the special theory of relativity? Explain.
   b) What difference would you expect if the boundary be a dielectric instead of a perfect conductor? (Only qualitative explanation is needed) (5+2+1+2)

7) a) Using Fresnel's formula prove that two possible directions of displacement vector $\vec{D}$ for a given wave vector in anisotropic media are orthogonal.
   b) What will happen when s-polarisation and p-polarisation wave is incident on a refracting surface at Brewster's angle?

c) Write the polarisation state of the following wave.

$\vec{E}x = E_0 \ sin(kz - wt + \frac{\pi}{3})$

$\vec{E}x = E_0 \ sin(kz - wt - \frac{\pi}{6})$ (5+2+3)

8) a) What are Biot's law for optical rotation?

b) How do you distinguish unpolarised light and circularly polarised light?

c) A left circularly polarised beam $(\lambda_0 = 5893A^0)$ is incident normally on a calcite crystat (optic axis will parallel to the surface) of thickness $0.010282mm$ what will be the state of polarisation of emarquent beam? ($n_o - n_e = 0.17195$ where n_o and n_e are refractive index of o and e - ray)

Group - B

Answer **any five** questions of the following : [5×10]

9) a) Is it possible to split the ${}^4D_{\frac{1}{2}}$ term in a magnetic field, explain this in terms of the vector model.

b) Which of the following molecules will show rotational, vibrational, rotational-vibrational spectra. Explain your answer, $CO, CO_2, N_2, O_2, HCl, C_2H_6, CH_4, BCl_3, H_2O.$

c) The fundamental model of *HCl* occurs at $2886cm^{-1}$. Predict the frequency of the corresponding mode of *DCl*. [(2+3)+3+2]

10) a) The spectral lines corresponding to the $3p \rightarrow 3s$ transition in sodium have the wavelength $\lambda_2 = 589.6nm$ and $\lambda_1 = 589.0nm$. Calculate the magnetic field strength at which the lowest Zeeman level of the ${}^2P_{\frac{3}{2}}$ term would coincide with highest level of the ${}^2P_{\frac{1}{2}}$ term, if the conditions for the anomalous Zeeman effect were still fulfilled.

b) A laser beam of wavelength $660nm$ has coherence time $6\times10^{-5}s$. Calculate the order of magnitude of its coherence length and spectral width.

c) Determine the intensity ratio of the anti-stokes and stokes Raman lines for a molecular quanta with wave number $50cm^{-1}$, observed at temperature 27^oC. (5+2+3)

11) a) Calculate the spin-orbit splitting of the states of hydrogen atom with $n = 30$ for the largest $(l = 1)$ and the smallest $(l = 29)$ splitting?

b) The $J = 0 \rightarrow J = 1$ rotational absorption line occurs at 1.153×10^{11} cycle / s in ${}^{12}C^{16}O$ and at 1.102×10^{11} cycle / s in ${}^{x}C^{16}O$. Calculate the mass number of the unknown carbon isotope.

c) Find the amplitude of vibration of *HCl* molecule in the first excited vibrational level. The force constant of the vibrating *HCl* molecule in $480N/m$ and its reduced mass is $1.62\times10^{-27}kg$. (5+3+2)

12) a) An electron generated a spectral line between the orbitals $3s$ and $3p$ in a hydrogen atom. Accounting the spin-orbit interaction, calculate the shifts in the wave number of the lines generated.

b) Explain the basic working principle of solid state LASER with necessary diagram.

c) What do you mean by optical resonator. (5+3+2)

13) a) Consider a two-electron system with a $2p$ and $3d$ electron for the case of jj coupling, show that the number of possible states and their total angular momentum j_{an} are the same as in $L-S$ coupling.

b) How Bohr-Sommerfeld model can explain the 'fine structure' of atomic spectra.

c) What is the main characteristics of the spectra of alkali atoms? How do this originate? (5+3+2)

14) a) The spin-orbit interaction splitting of $3p$ level of sodium atom is $16.228cm^{-1}$. Find the screening effect of $3p$ electron.

b) The double splitting of the first excited state ${}^2P_{\frac{3}{2}} - {}^2P_{\frac{1}{2}}$ of H atom is $0.362cm^{-1}$. Calculate the corresponding separation for Li^{++}.

c) State Pauli's principle and principle and hence show that the helium atom in its ground state can exist only in single state. [5+2+(1+2)]

15) a) Explain theoretically how one can have the concept of spin magnetic moment from Stern-Gerlach experiment.

b) The copper $(Z=29)$ target in an x-ray tube has some impurity. In the spectrum of x-rays emitted from the tube, there appear a line of wavelength $0.054nm$ in addition to the copper K_α line of wavelength $0.154nm$. Use Moseley's law to detect the impurity.

c) What element has a K_α x-ray line of wavelength $0.1785nm$. (5+3+2)

16) a) A positronium atom is a system consisting of a positron and an electron revolving about their common centre of mass, which lies half-way between them. Compare the emission spectrum with those of the hydrogen atom (with infinitely heavy nucleus).

b) A beam of electrons enters in a uniform magnetic magnetic field of flux density 1.2 *testa*. Calculate the energy difference between electrons whose spins are parallel and anti parallel to the field.

c) Compute the possible terms and energy levels for a configuration with three optically active electrons $2p3p4d$. (3+2+5)

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