U.G. 4th Semester Examination - 2020

PHYSICS

[PROGRAMME]

Course Code : PHYG-CC-T-4(A),(B),(C)&(D)

SET-2

Full Marks : 40 Time : $2\frac{1}{2}$ Hours

The figures in the right-hand margin indicate marks.

Candidates are required to give their answers in their own words as far as practicable.

Answer all the questions from selected Option.

OPTION-A

PHYG-CC-T-4A

(Quantum Mechanics)

1. Answer any **five** questions : 2×5=10

   a) What is zero-point energy?

   b) Show that the eigen values of a Harmitian operator are real.

   c) What is Gyromagnetic ratio?

   d) What do you mean by expectation value?

   e) What is quantum mechanical operator?

   f) Write down the ground state wave function and ground state energy expression for Hydrogen atom.

   g) Show that Scrödinger equation is a normal consequence of conservation of energy principle.

   h) What is zero-point energy?

2. Answer any **two** questions : 5×2=10

   a) What is box normalization? Normalize the wave function $\psi(x) = Ne^{ikx}$. 2+3

   b) What is a stationary state? Prove that if a wave function is normalized in coordinate space it is normalized in momentum space also. 1+4

   c) Explain Anomalous Zeeman effect showing a net diagram of transition between the split energy levels with required selection rules. Why spin is important in this case? 3+2

   d) Why simultaneous measurement of position and momentum of a quantum particle is not possible? Calculate the uncertainty in the angle of emergence of 1 Mev electron passing through a hole of diameter 20 micron. 2+3

3. Answer any **two** questions : 10×2=20

   a) Write down the expression of Scrödinger equation for Hydrogen atom in spherical polar coordinate. Using separation of variable solve the azimuthal angle (ϕ) dependent solution. What

is the outcome of Stern-Gerlach experiment? Write the form of energy eigen values and ground state energy eigen function of such oscillator. 2+3+3+2

b) What is space quantization? What is Bohr magneton? What is its value? What is J-J and L-S coupling interaction? Sketch the normal Zeeman transition of sodium D_2 line $3\,^2P_{\frac{3}{2}} \rightarrow 3\,^2S_{\frac{1}{2}}$. 2+1+1+3+3

c) A free particle is moving in X-direction within a confined region $0 \le x \le a$, write the Scrödinger equation for the system. Determine the energy eigen value and eigen function of the system. Show that the energy eigen values are discrete. What will be the energy eigen values if the particle is free in three dimension? 2+3+3+2

d) Discuss briefly the result of Stern-Gerlach experiment. Why silver atom is chosen for Stern-Gerlach experiment? What is term symbol of alkali spectra? Derive the expression of components of angular momentum operator. Show that the components follows the commutation relation $\left[L_i, L_j\right] = \frac{h}{2\pi} L_k$ (i,j,k are x,y,z in cyclic order). 3+1+1+2+3

OPTION-B

PHYG-CC-T-4B

(Solid State Physics)

1. Answer any **five** questions : 2×5=10

   a) What is reciprocal vector in a crystal system?

   b) What is the unit cell of a crystal system?

   c) Draw the (130) plane for a simple cubic system.

   d) What is optical Phonon?

   e) State the limitations of Dulong-Petit's Law of specific heat of solids.

   f) What is anti-Ferromagnetism?

   g) What is isotope effect in superconductivity?

   h) Explain how can you identify the type of semiconductor by Hall effect experiment.

2. Answer any **two** questions : 5×2=10

   a) Explain the effective mass of an electron in presence of electric field in Brillouin Zone. What is the Type-I and Type-II Superconductivity? 3+2

   b) What is the origin of Paramagnetism? Calculate the average value of magnetic moment vector for a paramagnetic system subjected to external

field H. 2+3

c) Calculate the number of atoms per cell for a face centered cubic crystal system. Define Tetargonal crystal system. 3+2

d) Calculate the intercepts on three axes of a plane having Miller Indices (220). Draw the (220) plane for a simple cubic system. 3+2

3. Answer any **two** questions : 10×2=20

a) Write down the expression of force equation for a monatomic lattice chain along x-direction. Derive the relation between angular frequency and wave-vector for such system. Draw the dispersion curve for such system. How does the dispersion curve differ in diatomic one dimensional system? What happens in the curve if both atoms in that diatomic system have same mass? 2+3+2+2+1

b) Explain the Bloch theorem. Explain the concept of forbidden energy bands. Why Hysteresis Loss happens for a magnetic system? Write the Clausius Mossotti equation for dielectric. What is Plasma oscillation? 2+2+2+2+2

c) State Dulong-Petit's Law. What is the drawback of the law? How Einstein has solved the problem

explain with mathematical deductions. State the how Debye propose the solution of Einstein equation for deduction of specific heat of solids. 2+2+5+1

d) What are the Millar indices of a crystal plane? What are the differences between amorphous and crystalline materials? Explain how the Basis and Lattice generate crystal structure. Does the choice of unit cell is unique? Explain how does a quartz crystal used as piezoelectric material. What is electrostrictive effect? 1+1+2+2+2+2

OPTION-C

PHYG-CC-T-4C

(Electromagnetic Theory)

1. Answer any **five** questions : 2×5=10

   a) What do you mean by Gauge Transformation in electromagnetic theory?

   b) State the Poynting theorem.

   c) Using the Maxwell's equation derive the expression of wave equation in a dielectric medium.

   d) What is E-ray and O-ray?

   e) What is retarded plate?

   f) State Biot's Law of rotatory polarization.

   g) What is relaxation time in case of electromagnetic wave propagation?

   h) What is Plasma frequency?

2. Answer any **two** questions : 5×2=10

   a) What is Poynting vector? Show that average energy density in a harmonic electromagnetic field is $\langle u \rangle = \frac{1}{4} \mathrm{Re}\left[\vec{E}\vec{D}^{*} + \vec{H}\vec{B}^{*}\right]$. 2+3

   b) What is the origin of displacement current? State how the Ampere's Law of magnetomotive force is corrected by the concept of displacement current. 2+3

   c) State the Brewster's law. Using Fresnel's formula of refraction of an electromagnetic wave, establish the Brewster's Law. Draw a neat diagram how a plane polarised light can be generated using this law. 2+2+1

   d) What is Babinet compensator? What is TE and TM mode of wave guide? 1+2+2

3. Answer any **two** questions : 10×2=20

   a) What is a wave-guide? Show that in TE-mode of wave-guide magnetic vector satisfied the equation $\left(\nabla^2 + \frac{\omega^2}{c^2}\right)\vec{H} = 0$. Derive the expression of cut-off frequency and cut off wavelength in TE-mode wave-guide. Deduce the expression of phase velocity for such case. 2+2+4+2

   b) What is optic axis? Using the concept of resolution of a linear optical vibration into two circularly polarised vibration derive the expression of phase difference in terms of difference of refractive indices of left and right

circularly polarised light. Explain the basic principle of a Laurent half-shade polarimeter. A 20 cm long tube containing sugar solution gives a rotation of 11^0 of the plane of vibration of a plane polarised light. If the specific rotation of sugar be 66^0 $dm^{-1}.g^{-1}.cm^{-3}$, calculate the strength of the solution. 2+4+2+2

c) Write the expression of four Maxwell's equation stating the significance of each of them. Derive the wave equation from it in a conducting medium. Show that the electric field amplitude is spatially attenuated. What is skin depth? 2+3+3+2

d) Discuss the action of a Nicole prism as an analyzer. Calculate the thickness of a quarter wave plate for sodium light of wavelength 5893 Å. Given refractive index of ordinary and extraordinary waves are 1.5442 and 1.5533, respectively. A plane polarised electromagnetic wave is incident in the interface of a two dielectric medium having refractive index μ_1 and μ_2, find the relation between angle of incident and angle of refraction. 2+3+5

OPTION-D

PHYG-CC-T-4D

(Statistical Mechanics)

1. Answer any **five** questions : 2×5=10

   a) State and explain the basic postulate of equal a priory theory.

   b) What is entropy of a statistical system under thermal equilibrium?

   c) State the limitations of Wines displacement law.

   d) What is the difference between macroscopic and microscopic states?

   e) Define Micro-canonical and Grand-canonical ensemble.

   f) What is Fermi level?

   g) Write the expression of BE distribution function.

   h) What is super-fluidity?

2. Answer any **two** questions : 5×2=10

   a) Show that the value of Fermi energy is $E_F = \frac{h^2}{2m}\left(\frac{3N}{8\pi}\right)^{\frac{2}{3}}$. The molar mass of Li is 0.00694 and its density 0.53×10^3. Calculate the

Fermi energy and Fermi temperature of electron. 3+2

b) State equipartition of energy theorem. Using MB distribution function show that the mean energy per degrees of freedom of a molecular assembly at absolute temperature T is KT. 1+4

c) What is ideal gas? Assuming the free particle concept of an ideal gas derive the expression of equation of state of such gas using MB distribution function. 1+4

d) Why the electron in a white dwarf star is considered as degenerate? Using First law of thermodynamics show that the product of wavelength of emitted radiation varies inversely to the absolute temperature. 2+3

3. Answer any **two** questions : 10×2=20

a) A particle of unit mass is falling freely under gravity. Sketch and explain the trajectory of the particle in phase space. Explain how μ-space is defined and what is the minimum dimension of each phase cell in that space? What is partition function? Derive the expression of partition function for a Grand-canonical system. 3+3+1+3

b) Calculate the probability that a small system be in energy state E having number of particle N resides in a big micro-canonical ensemble having energy E_0 and number of particle N_0 under equilibrium, established by energy and particle exchange. Assuming the partition function (Z) of a canonical ensemble as a function of β and energy E, show that the entropy of the system becomes $S = k\left(\ln Z + \beta\langle E\rangle\right)$. T=equilibrium absolute temperature and $\beta = \frac{1}{KT}$. Express the Helmoltz free energy of a canonical system in terms of partition function and temperature. 4+3+3

c) Derive the expression of number of fermion (using grand canonical ensemble concept) present in a particular energy state E_s. What conclusion can you draw about the minimum energy of a boson from the expression of BE-distribution function? Show that for an ideal Bose gas the product of its pressure (P) and volume (V) related to mean energy (E) by PV=$\frac{3}{2}$ E. Explain qualitatively the phenomena of B-E condensation. 3+1+4+2

d) Show that the amount of radiation emitted from a black body at absolute temperature T_1 surrounded by another black body at absolute temperature T_2 is $Q = \sigma\left(T_1^4 - T_2^4\right)$. σ is a constant. Show that if T_1 and T_2 are nearly equal the above law reduced to simple calorimetric heat exchange rule. Using First law of thermodynamics show that the product of wavelength of emitted radiation varies inversely to the absolute temperature of the body. State the limitations of Rayleigh-Jeans Law. What is Chandrasekhar limit? 3+1+2+2+2

———————