CENTRAL UNIVERSITY OF HARYANA

Second Semester Term End Examinations September 2022

Programme: M.Sc. Physics | **Session: 2021-22**

Semester: Second | **Max. Time: 3 Hours**

Course Title: Statistical Mechanics | **Max. Marks: 70**

Course Code: SBS PHY 01 201 CC 3104

Instructions:

1. Question no. 1 has seven parts and students are required to answer any four. Each part carries three and half Marks.

2. Question no. 2 to 5 have three parts and students are required to answer any two parts of each question. Each part carries seven marks.

Q 1. (4X3.5=14)

a) Write the relation for canonical partition function for: (i) non-degenerate energy states, (ii) energy states with degeneracy, and (iii) energy states in thermodynamical limit.

b) Explain the difference between intensive and extensive properties? What do you mean by thermodynamic limit?

c) Write the units and dimensions of Boltzmann's factor. Define fugacity for a grand-canonical ensemble.

d) State and prove Liouville's theorem.

e) What is the entropy change of water when 1000 g of water is heated from 20°C to 80°C? Given that specific heat of water has a constant value of 4.2 J/g-°C.

f) State equipartition and virial theorems.

g) Write the difference between Fermions and Bosons. Draw the distribution function for an ideal Fermi gas.

Q 2. (2X7=14)

a) What do you mean by Brownian motion? Discuss in detail Einstein-Samulchowski theory of Brownian motion.

b) A mass m, of water at temperature, T_1, is isobarically and adiabatically mixed with an equal mass of water at temperature T_2. Show that the entropy change of the universe is found to be $2mC_p*\log_e\left(\frac{T_1+T_2}{2(T_1T_2)^{1/2}}\right)$.

c) State and prove Central limit theorem.

Q3. (2X7=14)

a) Discuss Gibbs paradox. How is it resolved?

b) Derive the expression for temperature, pressure, chemical potential, Helmholtz free energy, Gibbs free energy and thermal capacities using Sackur-Tetrode equation for entropy of the system.

c) Discuss the thermodynamics for a micro-canonical ensemble.

Q 4. (2X7=14)

a) Discuss in detail about number density fluctuations and energy fluctuations in a grand-canonical ensemble.

b) For given canonical ensemble, show that $C_v = k\beta^2\left[\frac{\partial^2}{\partial\beta^2}\left(ln\ Q_N(V,\ \beta)\right)\right]_{N,V}$

c) Discuss a system of harmonic oscillators in terms of canonical ensemble and find the Helmholtz energy for the same system.

Q5. (2X7=14)

a) Write the relation for mean occupation number for different ideal gases. Prove that mean energy is always larger than chemical potential for an ideal Bose gas.

b) Define macrocanonical partition function. Show that A= G-PV = -kT*ln$\left(\frac{Q(z,V,T)}{z^{\langle N \rangle}}\right)$.

c) Discuss the phenomenon of diffusion and state Fick's first law of diffusion and second law of diffusion. Derive the relation between coefficient of diffusion and viscosity.

CENTRAL UNIVERSITY OF HARYANA

Second Semester Term End Examinations August-September 2022

Programme: M.Sc. Physics | **Session:** 2021-22

Semester: II | **Max. Time:** 3 Hours

Course Title: Solar Energy and Physics of Photovoltaics | **Max. Marks:** 70

Course Code: SBS PHY 03 806 DS 4004

Instructions:

- Question no. 1 has seven parts and students are required to answer any four. Each part carries three and half Marks.
- Question no. 2 to 5 have three parts and student are required to answer any two parts of each question. Each part carries seven marks.

Q 1. **(4x3.5=14)**

a) Define and explain the following with neat diagrams:-
i) Solar azimuth angle ii) Declination angle

b) What do you mean by Direct and Indirect Band gap semiconductors. Give examples.

c) Define solar constant, Air Mass and Zenith.

d) State the limitation of Solar Cell efficiency.

e) Explain solar air heating.

f) Explain the working of a Zener diode. How is it used for voltage stabilization?

Q 2. **(2x7=14)**

a) Explain the construction and working of solar flat plate collectors. Discuss the thermal analysis of flat plate collector?

b) Explain the principle of solar collector tracking system with neat diagram. Give the merits and demerits of collector tracking system.

c) Classify the different solar energy measuring equipments. What is the difference between a Pyrheliometer and a pyranometer.

Q3. **(2x7=14)**

a) Explain the construction and working of a solar pond with neat sketch. What are its advantages and disadvantages?

b) Explain the need for energy storage solar systems? Describe mechanisms of sensible heat energy storage.

c) Explain the working principle, construction and elements of combined solar heating and cooling systems by giving their applications.

Q 4. **(2x7=14)**

a) What is p-n junction ? Discuss the function of p-n junction and explain its working in forward and reverse bias. Calculate the density of electron at 300 K if band gap energy for semiconductor is 0.7 eV. $k = 1.38 \times 10^{-23}$ J/K and $m = 9.1 \times 10^{-31}$ kg.

b) What are the steps involved in Si wafer fabrication? Explain Czochralski and Float zone techniques in detail.

c) What is Fermi distribution function? Show that fermi level for an intrinsic semiconductor lies exactly in the middle of valence band and conduction band. There are 2.54×10^{22} free electrons per cm^3 in sodium. Calculate its Fermi energy, Fermi velocity and Fermi temperature. ($h = 6.63 \times 10^{-34}$ Js, $k = 1.38 \times 10^{-23}$ J/K and $m = 9.1 \times 10^{-31}$ kg and $1\ eV = 1.6 \times 10^{-19}$ J).

Q 5. **(2x7=14)**

a) What is Photovoltaic Effect? Draw the typical current-voltage and power- voltage characteristics of a solar cell and explain its salient points. A solar cell is made from single crystal silicon and the array consists of 24 modules, each model consists of 36 cells with 10.4x 10.4 cm size. It is given that the inverter efficiency is 85 %. calculate power output in watts.

b) Define fill factor of solar PV system. A solar cell ($0.9\ cm^2$) receives solar radiation with photons of 1.8 eV energy having an intensity of $0.9\ mW/cm^2$. Open circuit voltage is $0.6\ V/cm^2$, short circuit current is $10\ mA/cm^2$ and the maximum current is 50% of the short circuit current. The efficiency of the cell is 25%. Find the maximum voltage that the cell can give and the fill factor.

c) Explain the working mechanism of a perovskite and tandem solar cell giving a neat sketch. Is it more efficient than single junction solar cell? Justify.

CENTRAL UNIVERSITY OF HARYANA

Jant-Pali, Mahendergarh, Haryana

Term End Examination August-September-2022

Name of Programme : M.Sc. Physics

Year & Semester : September 2022, Second Semester

Course Name : Introduction to Astronomy and Astrophysics

Course Code : SBS PHY 01 204 DCEC 3104

Maximum Marks : 70 Duration : 3 Hrs

Note:

Attempt any Four parts in Question No. 1, each part carries 3.5 marks.

Attempt any Two parts from each of the remaining questions. Each part carries 7 marks.

Q1.

a. The luminosity of Betelguese is 27500 times the luminosity of the sun. If thetemperature of Betelguese is 3400 K. Determine the size of Betelguese compared to the sun. Given that temperature of sun is 5500 K.

b. Apparent magnitude of a star is -26.74. This value changes to 4.83 if the staris placed at 10 parsec from the observer. Find the actual distance of the star from observer.

c. Using the rules of spherical trigonometry prove that the celestial equator cuts the horizon at an angle of $90-\varphi$ where φ is the lattitude of the observer.

d. Define sidereal time, apparent solar time and mean solar time.

e. How do stellar motions and atmospheric extinction affect the distance measurement of stars?

f. What do you understand by Photosphere? What is the cause of granulation on photosphere of the sun?

g. Define and classify different types of intrinsic variable stars.

Q 2.

a. Illustrate with diagrams, the Horizon, Equatorial, Ecliptic and galactic system of coordinates.

b. The star Aldebaran has Right Ascension 4h36m, declination +16°31'. What are its ecliptic coordinates?

c. Describe the evolution of a star from H-R diagram

Q 3.

a. Define apparent magnitude and absolute magnitude of a star. If the absolute magnitude of a star is larger than the absolute magnitude of the Sun by 5, what is the luminosity of that star, expressed in solar luminosity

b. What do you understand by black body spectrum? How is this used to calculate the temperature of stellar objects?

c. A star in nearby star cluster has been photographed 10 years apart and found to have moved by 3" during this period. If the radial velocity (Doppler Shift) of the star is 2 AU per year, find the distance of the star.

Q 4.

a. What do you understand by binary stars? Define visual and spectroscopic binaries.

b. The α Centauri system is 1.338 pc distant with a period of 79.92 years. The A and B components have a mean separation of 23.7 AU (although the orbits are highly elliptical). What is the total mass of the system?

c. Write a short note on Supernovae.

Q 5.

a. Describe the babcock model for formation of sunspots.

b. What do you understand by Corona of the sun? Describe Parker Model of Solar wind.

c. Describe the cause of solar rotation and solar magnetic field.

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Second Semester Term End Examinations August-September 2022

Programme: M.Sc. Physics | **Session: 2021-22**

Semester: II | **Max. Time: 3 Hours**

Course Title: Classical Electrodynamics | **Max. Marks: 70**

Course Code: SBS PHY 01 202 CC 3104

Instructions:

1. Question no. 1 has seven parts and students are required to answer any four. Each part carries three and half Marks.

2. Question no. 2 to 5 have three parts and student are required to answer any two parts of each question. Each part carries seven marks.

Q 1. (4X3.5=14)

a) How far are we justified in assuming $\rho = 0$ for conducting medium like metals?

b) Bring out the difference between Dirichlet and Neumann boundary condition.

c) Using Stoke's theorem, find line integral of a vector field $-y\hat{i} + x\hat{j}$ over a circle of radius a with centre at the origin in the x-y plane.

d) How does the Lorentz condition lead to the concept of displacement current?

e) What are Stoke's parameters?

f) What is the significance of Hertz potential?

g) A uniform wave propagating in a medium has $E = 2e^{-\alpha z}\sin(10^8 t - 5z)a_y$. If medium is characterized by $\varepsilon_r = 1$, $\mu_r = 20$ and $\sigma = 3$ mho/m, find α, β and H.

Q 2. (2X7=14)

a) Derive an expression for energy of a charge distribution in Dielectric Media.

b) Obtain boundary conditions for all the field vectors D, E B and H.

c) Consider a point charge q at a distance d from the center of a grounded conducting sphere of radius a using method of images. Calculate the surface density of induced charge and the force between the sphere and the charge q.

Q3. (2X7=14)

a) Derive law of conservation of energy for em field and hence define the Poynting vector.

b) In an unbounded homogeneous medium, show that a plane monochromatic wave travels with a phase velocity $c/\sqrt{\mu\varepsilon}$.

c) Derive an expression for skin Depth in conductors. What is the ratio of skin depth in Cu at 10^{14} Hz to that at 10^{10} Hz. Given that $\sigma = 5\times10^{17} s^{-1}$.

Q 4. (2X7=14)

a) Derive Dispersion Relation and hence differentiate between Normal and Anomalous Dispersion.

b) Bring out the difference between induced polarization and orientational polarization. What is the effect of temperature on them?

c) Derive TE and TM modes of electromagnetic waves in a Waveguide.

Q 5. (2X7=14)

a) In the long wavelength approximation, calculate the radiation field produced by a system of harmonically oscillating source.

b) Show that there will be no emission of radiation in dipole approximation for systems consisting of particles having same e/m ratio.

c) What are retarded potentials? Obtain limiting conditions on these potentials.

CENTRAL UNIVERSITY OF HARYANA
Jant-Pali, Mahendergarh, Haryana

Name of Programme	: M.Sc. Physics
Year & Semester	: August-September 2022, Second Semester
Course Name	: Mathematical Methods in Physics - II
Course Code	: SBS PHY 01 203 CC 3104
Maximum Marks	: 70 Duration : 3 Hrs

Note:

All Questions are compulsory. Use of basic calculator is allowed.

Attempt any Four parts in Question No. 1, each part carries 3.5 marks.

Attempt any two parts from each remaining question. Each part carries 7 marks.

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1. (a) Find the regular-singular points of the differential equation

$$(x+2)^2(x-1)y^{00} + 3(x-1)y^0 + 2y = 0$$

(b) Using the power series solution of Laguerre differentialequation

$$xy^{00} + (1-x)y^0 + ny = 0$$

as $y = \sum_{k=0}^{\infty} a_k x^k$, find the relation between a_p and a_0 where p is a positive integer.

(c) Convert the Chebishev equation,

$$(1-x^2)y^{00} - xy^0 + n^2y = 0$$

for $x \in [-1,1]$ into a Sturm Liouville form.

(d) If y_1 and y_2 are two solutions of

$$y^{00} + p(x)y^0 + qy = 0$$

then prove that the Wronskian $W(x) = y_1(x)y_2'(x) - y_1'(x)y_2(x)$ of y_1 and y_2 satisfies

$$\frac{d}{dx}W(x) + p(x)W(x) = 0$$

(e) A 2π-periodic odd function f is given in $t \in [0,\pi]$ as

$$f(t) = t(\pi - t)$$

. Find the fourier series for f.

(f) Find the Fourier transform of $f(x)$ such that $f(x) = 1$ when $|x| < a$ and is zero otherwise. What physical process does this represent.

(g) Describe, using Laplace transformation, the motion of aparticle of mass m that receives an impulse P at time $t = t_0$.

2. (a) Using the Rodrigues' formula, prove that the generating function for Legendre Polynomial is $g(x,t) = (1 - 2xt + t^2)^{-1/2}$

(b) The Bessel function $J_n(x)$ satisfies the equation

$$x^2\frac{d^2J_n}{dx^2} + x\frac{dJ_n}{dx} + (x^2 - n^2)J_n = 0$$

. Prove that $\int_0^1 tJ_n(at)J_n(bt)dt = 0$ where a and b are zeros of J_n, i.e. $J_n(a) = 0 = J_n(b)$

(c) Set up the recurrence relation

$$H_n''(x) - 2xH_n'(x) + 2nH_n(x) = 0$$

3. (a) The Associated Legendre polynomial is related to Legendre polynomial via

$$P_l^m(x) = (-1)^m(1 - x^2)^{m/2}\frac{d^m}{dx^m}P_l(x)$$

. Starting from the Legendre differential equation, set up the Associated Legendre differential equation.

(b) Show that for non zero value of the Associated legendrepolynomial $P_l^m(x)$, we require $-l \leq m \leq l$.

(c) **Prove that**

$$P_l^{-m}(x) = (-1)^m \frac{(l-m)!}{(l+m)!} P_l^m(x)$$

4. **(a) Starting from the Fourier integral formula**

$$f(t) = \frac{1}{\pi}\int_0^{\infty} d\omega \int_{-\infty}^{\infty} f(t')\cos(\omega(t-t'))dt'$$

Derive the expression for direct and inverse Fourier Transforms.

(b) State and prove the Convolution theorem of Fourier Transforms.

(c) Find the convolution of $f(t) = e^{-t}$ **and** $g(t) = sin(t)$.

5. **(a) (i) Let** $a \geq 0$ **and Laplace Transformation** $L(f(t)) = F(s)$.
Prove that

$$L(f(t-a)U(t-a)) = e^{-as}F(s)$$

where $U(t-a)$ **is the unit step function such that** $U(t-a) = 1$ **when** $t \geq a$ **and** $U(t-a) = 0$ **when** $0 \leq t < a$. **(2 Marks)**

(ii) Determine $\mathcal{L}(\sin(\frac{\pi}{2}t)U(t-3))$.

(b) Solve the following Initial Value problem using Laplacetransformation $xy^{00} - xy^{0} + y = 2$

with the initial condition $y(0) = 2$ **and** $y^{0}(0) = -4$.

(c) Solve the following partial differential equation using LaplaceTransformation

$$\frac{dy}{dt} = -\alpha\frac{dy}{dx}$$

with side condition $y(0,t) = C$ **and** $y(x,o) = 0$

CENTRAL UNIVERSITY OF HARYANA

Second Semester Term End Examinations August-September 2022

Programme: M.Sc. Physics
Semester: II
Course Title: Quantum Mechanics-II
Course Code: SBS PHY 01 202 CC 3104

Session: 2021-22
Max. Time: 3 Hours
Max. Marks: 70

Instructions:

1. Question number 1 has seven sub parts and students need to answer any four. Each sub part carries three and half marks.
2. Question number 2 to 5 have three sub parts and students need to answer any two sub parts of each question. Each sub part carries seven marks.

Question Number 1. (4X3.5=14)

a) Prove that the parity operator is Hermitian and unitary.

b) "Matrix elements of the dipole moment operator vanish between states with the same parity". Prove this statement.

c) A constant perturbation H' is applied to a system for time Δt (where $H'\Delta t \ll \hbar$) leading to a transition from a state with energy E_i to another with energy E_f. If the time of application is doubled, then how will the probability of transition be affected?

d) Consider a system in the unperturbed state described by the Hamiltonian, $H_0 = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$. The system is subjected to a perturbation of the form $H' = \begin{pmatrix} \delta & \delta \\ \delta & \delta \end{pmatrix}$, where $\delta \ll 1$. Determine the energy eigenvalues of the perturbed system using the first order perturbation approximation.

e) Show that the parity operator commute with the orbital angular momentum operator.

f) The second-order correction to the energy of the ground state is always negative. Why?

g) Prove the optical theorem, which relates the total cross-section to the imaginary part of the forward scattering amplitude: $\sigma = \frac{4\pi}{k} Im[f(0)]$.

Question Number 2. (2X7=14)

a) A particle of mass m moves in one dimension in a harmonic-oscillator potential: $H = \frac{p^2}{2m} + \frac{1}{2} m\omega^2 x^2$. Find the position operator in the Heisenberg picture at time t.

b) Conservation of angular momentum is a consequence of the rotational invariance of the system. Substantiate.

c) Consider two non-interacting electrons described by the Hamiltonian: $H = \frac{p_1^2}{2m} + \frac{p_2^2}{2m} + V(x_1) + V(x_2)$ where $V(x) = 0$ for $0 < x < a$; $V(x) = \infty$ for $x < 0$ and for $x > a$. If both the electrons are in the same spin state, determine the lowest energy and eigenfunction of the two-electron system?

Question Number 3. (2X7=14)

a) A particle of mass m and charge e oscillates along x-axis in a one-dimensional harmonic potential with an angular frequency ω. If an electric field ε is applied along the x-axis, evaluate the first and second order corrections to the energy of the nth state.

b) A particle, initially (i.e., $t \to -\infty$) in its ground state in an infinite potential well whose walls are located at $x = 0$ and $x = a$, is subject at time $t = 0$ to a time-dependent perturbation $V(t) = \epsilon\, \hat{x} e^{-t^2}$ where ∈ is a small real number. Calculate the probability that the particle will be found in its first excited state after a sufficiently long time (i.e., $t \to \infty$).

c) Estimate the ground state energy of a one-dimensional harmonic oscillator of mass m and angular frequency ω using a gaussian trial function.

Question Number 4. (2X7=14)

a) Evaluate the scattering amplitude in the Born approximation, for scattering by the Yukawa potential: $V(r) = \frac{V_0 e^{-\alpha r}}{r}$, where V_0 and α are constants. Also show that $\sigma(\theta)$ peaks in the forward direction ($\theta = 0$) except at zero energy and decreases monotonically as θ varies from 0 to π.

b) A particle is scattered by a central potential $V(r) = V_0 r e^{-\mu r}$, where V_0 and μ are positive constants. If the momentum transfer $\vec{q}$ is such that $q = |\vec{q}| \gg \mu$, evaluate the dependency of the scattering cross section on q in the Born approximation, as $q \to \infty$

Use $\int x^n e^{ax} dx = \frac{d^n}{da^n} \int e^{ax} dx$].

c) Consider the potential $V(\vec{r}) = \sum_i V_0 a^3 \delta^{(3)}(\vec{r} - \vec{r}_i)$, where $\vec{r}_i$ are the position vectors of the vertices of a cube of length a centered at the origin and V_0 is a constant. If $V_0 a^2 \ll \frac{\hbar^2}{m}$ then calculate the total scattering cross-section in the low-energy limit.

Question Number 5. (2X7=14)

a) Prove that the operator $c\alpha$, where α stands for Dirac matrix, can be interpreted as the velocity operator.

b) A particle of mass m is in a potential $V = \frac{1}{2} m\omega^2 x^2$, where ω is a constant. Let $\hat{a} = \sqrt{\frac{m\omega}{2\hbar}}\left(\hat{x} + \frac{i\hat{p}}{m\omega}\right)$. Calculate $\frac{d\hat{a}}{dt}$ in the Heisenberg picture.

c) For a Dirac Particle moving in a central potential, show that the orbital angular momentum is not a constant of motion.