Exam. Code : 209002
Subject Code: 5387

M.Sc. Physics 2nd Semester

STATISTICAL MECHANICS

Paper—Phy-453

Time Allowed—3 Hours] [Maximum Marks—100

Note :— Section A is compulsory. Attempt **ONE** question each from Sections B, C, D and E. All questions carry equal marks.

SECTION—A

(Each question carries 2 marks)

1. What is Langevin function and discuss its behaviour at low and high temperatures ?
2. For canonical ensemble, express specific heat at constant volume (C_v) and mean energy (U) in terms of Helmholtz free energy (A).
3. Write expression for the partition function for 1-D harmonic oscillator.
4. Write an expression for the energy fluctuation in the canonical ensemble.

5. How is grand canonical partition function related to the canonical partition function ?
6. What is expectation value of the σ_z for an electron in magnetic field ?
7. A system has three energy levels E_1, E_2 and E_3 with degeneracies 2,1,1 respectively. Write partition function and expression for mean value of energy.
8. What is Debye T^3 law in solids ?
9. How is Fermi energy fixed for the system having level density g(E) and particle number N ?
10. Differentiate between microcanonical ensemble and grand canonical ensemble.

SECTION—B

(Each question carries 20 marks)

1. What is Gibbs paradox and how was it resolved ?
2. Discuss the statistical mechanics of the classical ideal gas.

SECTION—C

(Each question carries 20 marks)

1. Derive the statistics of Pauli paramagnetism.
2. Discuss q-potential and how is it related to grand canonical partition function. How the thermodynamical quantities can be written in terms of q-potential ?

SECTION—D

(Each question carries 20 marks)

1. Discuss the quantum mechanical statistics of microcanonical, canonical and grand canonical ensembles.
2. What is the expectation value of the Hamiltonian for a free particle in a box ?

SECTION—E

(Each question carries 20 marks)

1. Discuss the quantum mechanical statistics of ideal gas in microcanonical ensemble.
2. Discuss Bose-Einstein condensation in ultra-cold atomic gases.

Exam. Code : 209002
Subject Code : 5388

M.Sc. Physics 2nd Semester

ATOMIC & MOLECULAR SPECTROSCOPY

Paper—Phy-454

Time Allowed—3 Hours] [Maximum Marks—100

Note :— Section A is compulsory. Attempt one question from each of the Sections B, C, D and E.

SECTION—A

1. (a) Which one term is possible out of the terms 3^2D_2 and 4^3F_4? Write the values of quantum numbers n, l, s and j for a possible term.

   (b) What are fundamental and hot bands ?

   (c) What do you mean by band centre, P and R branches ?

   (d) What are the conditions for a diatomic molecule to be infrared active ?

   (e) Write Morse formula for potential energy and draw Morse curve for a diatomic molecule.

   (f) What do you understand by the fine structure of atomic spectra ?

   (g) Distinguish between simple, compound and anomalous triplets.

(h) Express g-factor in terms of quantum numbers.

(i) What is spin-orbit correction factor in case of Paschen-Back effect ?

(j) What do you mean by normal and inverted triplet ?

2×10=20

SECTION—B

2. (a) What is the basis of origin of vector model of an atom ? What are its salient features ? How they can be experimentally verified ? 10

(b) Compute the terms for two equivalent d-electrons using Briet's scheme. Show that for a 3d4s electronic configuration, the total ^2D separation is same in both L-S and J-J couplings. 10

3. (a) Derive an expression for the interaction energy due to spin-orbit interaction in two valance electron system. 12

(b) What are qualitative and quantitative rules of relative intensity in case of doublet system ? Also determine the relative intensity of spectral lines arising from the transition $^2D_{5/2,\,3/2}$ to $^2P_{3/2,\,1/2}$. 8

SECTION—C

4. (a) Describe briefly the line broadening due to external effects like collision damping, asymmetry and pressure effects. 10

(b) Illustrate with the help of diagrams the splitting of ^2D levels of sodium when :

(i) a weak magnetic field

(ii) a strong magnetic field is applied. 10

5. (a) Define Lande's splitting factor. Derive its expressions under L-S and J-J coupling schemes in two valance electron system. 10

(b) Explain Stark effect under strong weak electric field for hydrogen atom. 10

SECTION—D

6. (a) How can electromagnetic radiations leads to change the rotational levels of a molecule ? What are the rotational selection rules ? What conditions determine the intensity of rotational spectral lines ? 10

(b) Discuss the spectra of CO molecule, when the bond is assumed to be non-rigid bond. 10

7. (a) What do you mean by the presence of anharmonicity in the actual vibrating molecules ? How it effects the vibrational levels and selection rules ? 10

(b) Discuss the IR spectra of a diatomic vibrating rotator. 10

SECTION—E

8. (a) Describe the chief characteristics of vibrational and pure rotational Raman spectra. 10

   (b) How the combined Raman and IR spectroscopy is useful in determining the structure of molecules ? Discuss with examples. 10

9. (a) Define Franck-Condon Principle. Discuss the intensity distribution in the absorption and emission bands from Frank-Condon Principle. 10

   (b) Write a note on dissociation energy and dissociation products. 10

Exam. Code : 209004
Subject Code : 5409

M.Sc. Physics 4th Semester

PARTICLE PHYSICS

Paper–Phy-551

Time Allowed—3 Hours] [Maximum Marks—100

Note :– Section A is compulsory. Attempt at least **one** question each from Sections B, C, D and E.

SECTION–A

1. (a) Give two common properties shared by quarks and leptons with explanation.

   (b) Give two differences between quarks and leptons with explanation.

   (c) Draw a labelled Feynman diagram at the quark level for the reaction

   $$K^+ = \pi^0 + e^+ + \nu_e$$

   (d) What are the values of the spin, isospin, charge and strangeness quantum numbers of s-quark ?

   (e) What is the relationship between the hypercharge, the strangeness and the baryon number of a particle ? What is the value of the hypercharge for a strange quark ?

(f) Which interaction is responsible for the decay $K^0 = \pi^+ + \pi^-$ and why ?

(g) What are quark contents of the Ξ^- and Ω^- ?

(h) A positive kaon at rest decays into a muon, μ^+ and neutrino ν_μ, according to

$$K^+ = \mu^+ + \nu_\mu$$

What is the energy of muon ? Masses of kaon and muon are 494 and 106 MeV/c^2, respectively; the neutrino is effectively massless.

(i) What is the effect of charge conjugation operator ? How do angular momentum and linear momentum change under that operation ?

(j) Explain how symmetry constraints allow only one of the two reactions

$$\rho^0 = \pi^+ + \pi^-$$

$$\rho^0 = \pi^0 + \pi^0$$

The ρ^0 is a spin 1 meson while the pion has spin 0.

2×10=20

SECTION–B

2. Determine experimentally the spin and parity of all the charged as well as neutral pions. 20

3. Consider the reactions :

(a) $\pi^+ + p \rightarrow \Delta^{++} \rightarrow \pi^+ + p$

(b) $\pi^- + p \rightarrow \Delta^0 \rightarrow \pi^- + p$

(c) $\pi^- + p \rightarrow \Delta^0 \rightarrow \pi^0 + n$

These reactions, which conserve isospin can occur with $I = \frac{3}{2}\hbar$ or $I = \frac{1}{2}\hbar$. Calculate the ratio of their cross-section i.e. $\Gamma_a : \Gamma_b : \Gamma_c$. 20

SECTION–C

4. Indicate, with an explanation, whether the following interactions proceed through the strong, electromagnetic or weak interactions, or whether they do not occur at all.

(a) $\pi^0 \rightarrow \gamma + \gamma$

(b) $\tau^+ \rightarrow \mu^+ + \nu_\mu$

(c) $\Xi^- \rightarrow \pi^- + \Lambda$

(d) $\Delta^{++} \rightarrow p + \pi^+$

(e) $\Omega^- \rightarrow K^- + n$

(f) $n + K^+ \rightarrow \pi^+ + \Lambda$

(g) $n + K^- \rightarrow \pi^- + \Lambda$

(h) $\mu^+ + \mu^- \rightarrow \bar{\nu}_\tau + \nu_\tau$ 20

5. (a) The combination of quarks which can form a baryon are dictated by symmetry constraints. Explain these constraints in terms of the spin, flavour (or isopin) and colour wevefunction of the quarks. 12

(b) Baryons composed of two light (u or d) quarks and one s-quark form, spin ½ baryons (Σ^+, Σ^0, Σ^-, Λ) and spin 3/2 baryons state. With justification, what the flavour and spin wavefunctions are for the light quarks in the spin ½ baryons ? Explain clearly why there is no spin 3/2 singlet (equivalent to the Λ). 8

SECTION–D

6. (a) Quark flavour is conserved in the strong interaction, while the weak interaction allows the decay of heavy quarks into lighter ones. Explain how such decays are permitted according to Cabibbo theory. What is the significance of the magnitude of different elements of the matrix for these decays ? 10

(b) Can the charm quark decays into a (b, s, u or d) quark ? For each case state with an explanation whether the decay is forbidden, allowed but unlikely or likely to occur. Draw a fully-labelled Feynman diagram of the most probable decay mode. 10

7. With the help of Dirac spinors, establish the vector, axial-vector interactions prevailing in weak decay. 20

SECTION–E

8. Establish the Euler-Lagrange equation for the fields and hence construct the Proca-Lagrangian for an electromagnetic field. 20

9. Firstly state with explicit notations and diagrams the Feynman rules and hence write down the Matrix element for Bhabha scattering. 20

Exam. Code : 209004
Subject Code: 5410

M.Sc. Physics 4th Semester

CONDENSED MATTER PHYSICS—II

Paper—Phy-552

Time Allowed—3 Hours] [Maximum Marks—100

Note :— Attempt all the questions from Section-A and attempt **ONE** question from each of the Sections B, C, D and E.

SECTION—A

1. (i) Define magnetic susceptibility and give its physical significance.

   (ii) Define Larmor theorem.

   (iii) Neither Mn nor Cr are ferromagnetic by themselves, yet some of their alloys with other elements are ferromagnetic. Why ?

   (iv) Can the domain structure in a ferromagnetic substance be detected by X-ray diffraction ? Give appropriate evidence of your answer.

   (v) What are the consequences of magnetostriction effect in ferromagnetic materials ?

(vi) Give one example of superconductivity for designing of technical device.

(vii) What is coherence length and how it determines the superconducting behaviour of a given material ?

(viii) Discuss the formation of Cooper pair.

(ix) Compare optical properties of metals and non-metals.

(x) Compare the exciton absorption with free carrier absorption. 2×10=20

SECTION—B

2. (i) Describe quantum theory of paramagnetism. 12

(ii) How the quenching of orbital angular momentum takes place ? 8

3. (i) Describe the Gouy's method to measure magnetic susceptibity. 10

(ii) Describe the paramagnetic susceptibility of conduction electrons. 10

SECTION—C

4. (i) Discuss the formation of ferromagnetic domain. 10

(ii) Describe the neutron magnetic scattering. 10

5. (i) Find the thickness and energy of Bloch wall. 10

(ii) Describe the origin of anisotropy energy. 10

SECTION—D

6. Describe the structure and properties of high temperature superconducting materials. 20

7. (i) Explain the thermodynamics of superconductors in comparison to normal conductors. 15

(ii) What is the significance of BCS ground states ? 5

SECTION—E

8. (i) Write a short note on following :—

(a) Sulphide phosphor

(b) Thallium activated alkali halides. 10

(ii) Describe the application of interaction of light with solids. 10

9. (i) Distinguish between direct and indirect band gap. 10

(ii) Describe absorption process involved in materials containing impurities. 10

Exam. Code : 209004
Subject Code : 5412

M.Sc. Physics 4th Semester

RADIATION PHYSICS

Paper—Phy-562

Time Allowed—3 Hours] [Maximum Marks—100

Note :— Section A is compulsory. Attempt **ONE** question from each of the Sections B, C, D and E. All questions carry equal marks.

SECTION—A

1. (a) What do you mean by dose equivalent ?

   (b) Define the term kerma.

   (c) What is quality factor ?

   (d) List the names of different dosimeters.

   (e) Which are the general applications of dosimeters ?

   (f) What is Relative Biological Effectiveness (RBE) ?

   (g) Which are the acute biological effects of radiations ?

   (h) Name some radiation shielding materials.

   (i) What is point source ?

   (j) What is buildup factor ?

SECTION—B

2. Discuss various sources of ionizing radiations.

3. State and discuss Bragg-Gray principle.

SECTION—C

4. What do you mean by dosimeter ? Discuss solid state dosimeter (TLD).

5. Compare chemical detector with neutron detectors.

SECTION—D

6. Discuss stochastic and non-stochastic biological effects of radiations.

7. Name the sources of radiation waste and discuss the disposal of radiation waste.

SECTION—E

8. Discuss thermal and biological shields.

9. What do you mean by radiation attenuation ? Discuss radiation attenuation from a plane source.

Exam. Code : 209004

Subject Code : 5413

M.Sc. Physics 4th Semester

REACTOR PHYSICS

Paper—Phy—563

Time Allowed—3 Hours] [Maximum Marks—100

Note :– Section A is compulsory. Attempt one question from each of the Sections B, C, D and E. All questions carry equal marks.

SECTION—A

1. (a) What is point source ?

   (b) What is transport mean free path ?

   (c) What is the difference between diffusion and drift ?

   (d) What is slowing down density ?

   (e) What do you mean by critical size of a nuclear reactor ?

   (f) List some applications of nuclear reactor.

   (g) What is the role of moderator in nuclear reactor ?

   (h) Name different fuels obtained from breeder reactor.

   (i) Define breeding ratio.

   (j) Name any five reactors in India.

SECTION—B

2. What do you mean by neutron diffusion ? In thermal diffusion obtain steady state equation.

3. Find the solution of diffusion equation for an infinite plane source in a finite medium.

SECTION—C

4. Discuss the energy distribution of thermal neutrons.

5. What is the difference between thermal and fast neutrons ? Derive Fermi age equation.

SECTION—D

6. Discuss neutron cycle and then derive four factor formula.

7. What do you mean by buckling ? Discuss geometrical buckling taking the case of any type of geometry.

SECTION—E

8. Discuss fast breeder reactors in detail.

9. Name the conditions affecting the reactivity of a nuclear reactor and then discuss the effect of temperature.

Exam. Code : 211002
Subject Code : 5540

M.Sc. (Mathematics) 2nd Semester

REAL ANALYSIS—II

Paper—MATH-561

Time Allowed—Three Hours] [Maximum Marks—100

Note :— Attempt any **TWO** questions from each unit. Each question carries equal marks.

UNIT—I

1. State and prove Arzela's theorem.
2. Suppose K is compact and $\{f_n\}$ is a sequence of continuous functions on K and $\{f_n\}$ converges pointwise to a continuous function f on K. Also, $f_n(x) \geq f_{n+1}(x)$, $\forall\ x \in K$, $n = 1, 2, 3, \ldots$. Then $f_n \to f$ uniformly on K.
3. The sequence of functions $\{f_n\}$ defined on E, converges uniformly on E if and only if for every $\varepsilon > 0$ there exists an integer N such that $m \geq N$, $n \geq N$, $x \in E$ implies $| f_n(x) - f_m(x) | \leq \varepsilon$.
4. Define equicontinuity. If K is compact and $f_n \in \mathcal{C}(K)$ for $n = 1, 2, 3, \ldots$ and if $\{f_n\}$ is pointwise bounded and equicontinuous on K, then $\{f_n\}$ is uniformly bounded on K and contains a uniformly convergent subsequence.

UNIT—II

5. Define a measurable set. Prove that outer measure of an interval is its length.
6. If m is a countably additive, translation invariant measure defined on a σ-algebra containing the set P, then m[0, 1) is either zero or infinity.
7. If A is countable then show that $m^*A = 0$.
8. Show that the interval (a, ∞) is measurable.

UNIT—III

9. Define a measurable function. Let c be a constant and f and g be two real valued measurable functions defined on the same domain, then $f \pm g$, $f + c$ and cf are also measurable.
10. Define a characteristic function and a simple function. Prove that $\chi_{A \cap B} = \chi_A \cdot \chi_B$ and $\chi_{\bar{A}} = 1 - \chi_A$.
11. Define almost everywhere. If f is measurable function and $f = g$ a.e., then g is measurable.
12. State and prove Egoroff's theorem.

UNIT—IV

13. Give an example of a function which is Lebesgue integrable but not Riemann integrable.
14. State and prove monotone convergence theorem.
15. State and prove bounded convergence theorem.
16. Let f be a non-negative measurable function. Show that $\int f = 0$ implies $f = 0$ a.e.

UNIT—V

17. State and prove Vitali's lemma.
18. If f is integrable on [a, b] and $\int_a^x f(t)\,dt = 0$, for all $x \in [a, b]$, then $f(t) = 0$ a.e. in [a, b].
19. Define absolute continuity. Show that every absolutely continuous function is the indefinite integral of its derivative.
20. Let f be an increasing real valued function on the interval [a, b]. Then f is differentiable almost everywhere. The derivative f' is measurable and $\int_a^b f'(x)\,dx \le f(b) - f(a)$.