Birla Institute of Technology & Science, Pilani
Hyderabad Campus

FIRST SEMESTER 2021-2022

Course Handout Part II

Date: 20-08-2021

In addition to part-I (General Handout for all courses appended to the time table) this portion gives further specific details regarding the course.

Course No. : ***PHY F423***
Course Title : **Special Topics in Statistical Mechanics**
Instructor-in-Charge : Swastik Bhattacharya

Scope and Objective of the Course: This course aims to develop a modern understanding of Phase transition and Critical Phenomena by means of statistical mechanical techniques. The related issue of how the physical description of a system changes as one moves towards or away from the critical point will also be discussed from the perspective of Renormalisation Group Flow Equations. The course would proceed mainly by developing the theory for simple models, e.g. lattice models like Ising model, Heisenberg model and continuum- theory based models like the scalar field model. The Quantum Field Theoretic calculations discussed will necessarily be non-rigorous and mainly developed through analogy with the lattice models, which are easier to grasp. The hope is that the mathematical precision and rigour thus sacrificed will be more than compensated by the gain in physical understanding of these topics, which play a central role in most of the important developments in modern physics. This course deals with advanced topics in Statistical Mechanics. Hence a foundation in the basics of Statistical Mechanics is necessary to engage with the topics to be covered in this course. Students who have not credited the basic Statistical Mechanics course are advised against registering for this course.

Textbooks:

1. Lectures on Phase Transitions and Renormalisation Group: Nigel Goldenfeld
2. Fundamentals Of Statistical And Thermal Physics: F. Reif
3. Statistical Mechanics: K. Huang
4. A few pdf files to be shared that will serve as classnotes

Reference books

1. An Introduction to Quantum Field Theory: Peskin-Schroeder
2. Gauge, Fields and Strings: A. Polyakov
3. Field Theories of Condensed Matter Physics: E. Fradkin
4. Restricted portion of some review articles on these topics to be mentioned in the class

Course Plan:

Lecture No.	Learning objectives	Topics to be covered	Chapter in the Text Book
1-2	Review of the basics of Statistical Mechanics	Microcanonical, canonical and Grand canonical Distributions, MB, BE Statistics	Reif Chapters 2,3, 6,9; Huang Chapters 4,6,7,8,12
3-9	Ising Model in 1 and 2 dimensions	Partition function calculation for 1D Ising model, Transfer matrix method, Impossibility of Phase Transition at finite temperature in 1D Ising model, a brief introduction to 2D Ising model, Pierels argument, connection of 2D Ising model to Field Theory in 2D by means of correlation functions, very brief introduction to Q.F.T.	Goldenfeld Chapter 2; Huang Chapters 14,15; Polyakov Chapter 1; Classnotes
10-13	Phase Transition and Critical Point: A Phenomenological Description	What is a Phase Transition, 1st order and 2nd order Phase transition, susceptibilities near the critical point, scaling and power laws, Widom scaling	Goldenfeld Chapters 1,2,3,4,6; Huang Chapter 16 Classnotes
14-19	Phase Transition within a Phenomenological Approach: Mean Field Theory	Mean Field Theory near the Critical point of a system, examples to be discussed: Mean Field Theory for an Ising model(2D), Lattice Gas model, Heisenberg Model(Magnetism), Discrete systems can be approximated as continuum models	Goldenfeld Chapters 2,3,4; Huang Chapters 16, 17
20-29	Phase Transition within a Phenomenological Approach: Spontaneous Symmetry Breaking and Landau-Ginzberg Theory	Spontaneous Symmetry Breaking and the Order Parameter, Landau-Ginzberg Theory near the critical point, Discrete symmetry breaking : Z2 model(Magnetism), Continuous Symmetry Breaking: O(3) model(Magnetism), U(1) model(Superconductivity, Superfluidity), correlations and Susceptibilities from M.F.T,, Critical Exponents from M.F.T., Gaussian Fluctuations and the Ginzberg Criterion, Goldstone Bosons from Spontaneous Symmetry Breaking	Goldenfeld Chapters 5,6,11; Huang Chapters 16, 17 Peskin Chapter 11; classnotes
30-32	Phase Transition within a Phenomenological Approach: Spontaneous Symmetry Breaking and Higgs-Anderson mechanism in Abelian Gauge Theory	A very brief Introduction to Abelian Gauge Theory, Higgs Field, Higgs Mechanism and massive gauge boson in Abelian Gauge theory, Connection to the Theory of Superconductivity, Meissner effect	Peskin Chapter 20; classnotes
33-40	Microscopic Theory near Critical point, Fluctuations beyond M.F.T,	The need to go beyond the phenomenological theories, Kadanoff scaling(Ising model in 2D) and correlation functions in the continuous limit, RG in position space, RG in momentum	Goldenfeld Chapters 9 and 12; Huang

	Renormalisation Group Flow in position and Momentum space	space(Wilsonian RG): Main Idea, calculation performed for very simple models(mainly Ising) if time permits, Effective Hamiltonian, Universality Class, Relevant, Marginal and Irrelevant operators, scaling dimension and anomalous scaling dimension, Perturbative RG and epsilon expansion(up to order epsilon) for Ising model(D=2), Wilson-Fischer fixed point and RG flow equation	Chapter 18; Peskin Chapters 11, 12; Fradkin chapter 14, classnotes

Evaluation Scheme:

Component	Duration	Weightage (%)	Date & Time	Nature of Component
Quiz	50 mins	10	To be conducted before Midsem Examination	Open book
Assignments	1 month	15	To be conducted after Midsem Examination	Open Book
Midsem	90 Min.	35	18/10/2021 11.00 - 12.30PM	Open Book
Comp. Exam	2 Hours	40	11/12 AN	Open Book

Chamber Consultation Hour: To be announced.

Notices: Notices and solutions of tests & Final Comprehensive Examination will be displayed only on the **Physics** notice board.

Make-up Policy: : It is applicable to the following two cases and it is permissible on production of evidential documents.

(i) Debilitating illness.

(ii) Out of station with prior permission from the Institute

Academic Honesty and Integrity Policy: Academic honesty and integrity are to be maintained by all the students throughout the semester and no type of academic dishonesty is acceptable.

INSTRUCTOR-IN-CHARGE