Programme: M. Sc. (Physics)
Course Code: PHSO-311 **Title of the Course:** Phase Transitions and Critical Phenomena
Number of Credits: 4
Effective from AY: 2021-22

Prerequisites for the course:	Basic knowledge of Thermodynamics and Statistical Mechanics	
Objective:	This course is designed to familiarize students with general and specific aspects of phase transitions, teach them the concept of symmetry and spontaneous breaking thereof and theoretical understanding within the realm of Landau's mean field theory.	
Content:	1. Phenomenology of phase transitions The role of symmetry and the onset of order, switching of the degree of order, Example of atomic site ordering, Ferroelectric phase transitions, how to observe a phase transition, Order of a phase transition, General aspects of the thermodynamics of a phase transition, Seeds of a theoretical model, Examples 2. Magnetic phase transitions Macroscopic and microscopic views of magnetism, Non-interacting atoms in a magnetic field: paramagnetism, interacting atoms in a magnetic field: ferromagnetism, Critical exponents revisited, Successes and failures of the mean-field model 3. Landau theory Introduction, Quantification of the free energy, Results for second-order phase transitions, Field-dependence of the order parameter at the transition temperature, Taking account of spatial variations, Validity of Landau theory, Ferromagnetism, the mean-field approximation, and Landau theory, First-order phase transitions, The case when the free energy is allowed to have odd-order terms, Tricritical phase transitions. Examples like phase transitions and elastic strain, ferroelectric phase transition, superfluid Mott insulator phase transition. 4. The role of symmetry Introduction to Symmetry, Point group symmetry operations, Space group symmetry operations, Groups and their representations, Symmetry of the order parameter, Symmetry of the spontaneous strain, Group-subgroup relationships across phase transitions 5. Soft modes and displacive phase transitions Displacive phase transitions, Phenomenology of the soft mode model of displacive phase transitions, Lattice dynamics theory of the soft mode, Lattice dynamical theory of the low-temperature phase, Phase transitions, soft modes, and structure flexibility: the Rigid Unit Mode model	4 hours 4 hours 12hours 12hours 4 hours 4 hours

	6. Order-disorder phase transitions Order–disorder phenomenology, Mean-field theory of order–disorder phase transitions: Bragg–Williams model, Computational methods, Beyond Bragg– Williams theory: the Cluster Variation Method 7. Critical point phenomena The Widom scaling hypothesis: relationships between critical exponents, Introduction to the renormalisation group, Deriving the Widom scaling hypothesis, A sketched example: the 1D Ising model 8. Reconstructive Phase transitions Introduction and definition, Examples, Thermodynamics of reconstructive Phase transitions	4 hours 4 hours
Pedagogy:	lectures/ tutorials/ seminars/ assignments/ presentations/ etc. or a combination of some of these.	
References/Readings	1. Binney, J. J., N. J. Dowrick, A. J. Fisher, and M. E. J. Newman, The theory of critical phenomena: An introduction to the renormalisation group. Oxford: Clarendon Press, (1992). 2. Blundell, S., Magnetism in condensed matter. Oxford: Oxford University Press, (2001). 3. Burns, G. and A. M. Glazer, Space groups for solid state scientists, third edition. Waltham: Academic Press, (2013). 4. Dove, M. T. Structure and dynamics. Oxford: Oxford University Press, (2003). 5. Goldenfeld, N., Lectures on phase transitions and the renormalisation group. Reading, MA: Addison-Wesley, (1992). 6. Muller, U. Symmetry relationships between crystal structures. Oxford: Oxford University Press, (2013). 7. Nishimori, H. and G. Ortiz, Elements of phase transitions and critical phenomena. Oxford: Oxford University Press, (2011). 8. Salje, E. K. H., Phase transitions in ferroelastic and co-elastic crystals, Student Edition, Cambridge University Press, (1993). 9. Tol´edano, J.-C. and P. Tol´edano, The Landau theory of phase transitions. Singapore: World Scientific, (1987). 10. Yeomans, J. M. Statistical mechanics of phase transitions. Oxford: Clarendon Press, (1992).	
Learning Outcome	The student is expected to obtain considerable insight into various types of phase transitions, and their classification; identify phase transition and how these can be described theoretically using Landau mean field theory	