CONCEPTS IN MAGNETISM AND SUPERCONDUCTIVITY

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INTENDED AUDIENCE: B Tech, BE, M Tech, ME, MSc, PhD

PREREQUISITES: Modern physics and elementary quantum mechanics, basic ideas in condensed matter or solid-state physics

INDUSTRY SUPPORT: Microsoft, IBM, AT&T, Accenture, google quantum AI, Philips, DRDO, Intel, BEL, Infineon technologies, Samsung, LG, Silfab and such others

COURSE OUTLINE:

The course aims to introduce and work through the underlying concepts behind magnetism and superconductivity. Starting from an electron in a magnetic field, the magnetic response of a collection of atoms in a solid are all worked out. Magnetization and susceptibility in para and diamagnetic cases, their applications and excitations are discussed. Superconductivity: zero resistance, Meissner effect, perfect diamagnetism; BCS theory, energy gap, isotope effect and tunneling experiments worked out. Josephson junctions and their applications, qubits and quantum chips discussed. Novel high-TC superconductor introduced. The emphasis is on working things out from very simple physical concepts.

ABOUT INSTRCTOR:

Prof. A Taraphder is Professor and former HoD, Dept of Physics and Centre for Theoretical Studies, IIT Kharagpur

PhD: IISc Bangalore 1991

PhD guidance: 7 completed 1 submitted

Postdoctoral Associate in the Condensed Matter Physics Group, Rutgers University, USA: Aug. 1991 - Jan. 1993

Visiting Scientist, NEC Research Institute, Princeton, USA: Aug. 1991 - Jan. 1993

Visiting Scientist, LEPES, CNRS, Grenoble, France: Feb. 1993 – July 1994

Visiting Professor, Michigan State University, July 1999

Visiting Professor, University of Neuchatel, Switzerland

Visiting Professor, Michigan State University, Feb. 2001-Apr.

2001

Visiting Associate, ICTP, Trieste Italy, May 2001-July 2001 Visiting Professor, Michigan State University, May 2001- July 2001

Visiting Professor, Humboldt University, Berlin, May 2003 Visiting Associate, ICTP, Trieste Italy, June 2003-Aug 2003 Visiting Professor, University of Neuchatel, Switzerland, Aug-Sep 2003

Visiting Professor, ICMM, CSIC, Madrid, Spain Oct. 2003- Sep. 2004

Guest Scientist, Max Planck Institute for Physics of Complex Systems, Dresden, Germany, Oct. 2004 - Dec. 2004

Guest Scientist, Max Planck Institute for Physics of Complex Systems, Dresden, Germany, May 2005 - July 2005

Guest Scientist, Max Planck Institute for Physics of Complex Systems, Dresden, Germany, May 2006 - July 2006

Guest Scientist, Max Planck Institute for Physics of Complex Systems, Dresden, Germany, May 2007 - July 2007

Guest Scientist, Max Planck Institute for Physics of Complex Systems, Dresden, Germany, Jan 2008 - April 2008

Guest Scientist, Max Planck Institute for Physics of Complex Systems, Dresden, Germany, May 2009 – July 2009

Guest Scientist, Max Planck Institute for Physics of Complex Systems, Dresden, Germany, May 2010 – July 2010

Visiting Professor, Michigan State University, June 2013- July 2013

Visiting Professor, University of Witswatersrand, Johannesburg, Aug 2014

Academia Sinica Foreign Expert, Yangchen Institute of Technology, China, Dec. 2014, June 2015

Research Interests:

Problems in Condensed-Matter Physics -- Correlated and disordered electronic systems, Phase transitions, Statistical mechanics including biological and other complex systems

COURSE PLAN:

Week 1: The magnetic moment, Bohr magneton, Bohr-van Leeuwen theorem. Magnetisation and susceptibility; an isolated atom in a magnetic field, dia, para and ferromagnetic susceptibilities. Hund's rules. Van Vleck paramagnetism.

Week 2: Magnetization of a collection of independent ions: Curie's Law. Adiabatic demagnetization, Pauli paramagnetism. Ions in a solid: Crystal field, Orbital quenching, Jahn-Teller effect.

Week 3: Magnetic resonance technique: concepts of NMR, ESR. Magnetic interactions, relevant energy scales, dipolar interaction and origin of exchange.

Week 4: 2-electron system, spin Hamiltonian. Direct, super, indirect and itinerant exchange. Magnetic impurity, RKKY and the concept of GMR.

Week 5: 1D Ising model: mean-field and exact solution. Mermin-Wagner theorem. FM Heisenberg model, AFM and the concept of frustration.

Week 6: Superconductivity: discovery and phenomena. Zero resistance and Meissner effect. London equation and two fluid description. Cooper problem.

Week 7: BCS theory, energy gap, isotope effect, transition temperature, Specific Heat. Type-I, Type-II superconductors, Abrikosov vortices.

Week 8: Quantum interference, Josephson effect, superconducting junctions, squid and its applications, qubits and quantum chips. Novel superconductors.