Department of Physics

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Ph.D. Admissions January–May 2027 — Research Topics Provided by Faculty

S.No	Faculty	Topic	Students	Title	Abstract
1	**Dr. Prabhat R Pujahari**	EXPERIMENT	2	TITLE I **Electromagnetic and ultra-peripheral collisions with the CMS experiment at the LHC**	Ultraperipheral collision (UPCs) are the ultimate energy frontier for electromagnetic interactions. UPC (heavy ions and protons) can address some interesting physics areas: Nuclear shadowing, nuclear structure - Beyond the Standard Model and many others. The student will take part in data taking at CERN and work towards UPC physics analysis for his/her PhD.
				TITLE II **Collective Phenomena with CMS detector at the LHC**	Surprising discoveries by experiments like CMS show that long-range azimuthal correlations, strangeness enhancement, and flow-like patterns also emerge in small collision systems (such as high-multiplicity pp and p-Pb collisions, and oxygen-oxygen collisions), forcing a rethink of the minimum system size required to form QGP-like dynamics. The student will work in CMS experiment data taking activities, detector hardware and physics data analysis.
2	**Dr. Ayana Ghosh**	THEORY	2	TITLE I **Physics-Aware AI for tailoring coupled functionalities in materials**	In complex oxides and layered materials, functional properties such as ferroelectricity, magnetism, and their coupling emerge from competing lattice, charge, spin, and orbital degrees of freedom encoded in the underlying energy landscape. Inferring the governing mechanisms from data remains fundamentally underdetermined, as data-driven models often admit multiple equivalent structure-property relationships without clear physical interpretability. Resolving this requires embedding constraints from symmetry, thermodynamics, and physically meaningful order parameters. This PhD topic focuses on developing and implementing physics-aware AI approaches to identify mechanism-level descriptors and enable targeted tailoring of functional responses. Such capabilities remain inaccessible through the sole use of either first-principles simulations or experiments. By integrating AI/ML architectures with symbolic learning, causal inference, and domain-informed constraints, the approach aims to uncover interpretable pathways linking structure to functionality, and provide material-specific prescriptions for controlling coupled phenomena. The outcome is aimed towards establishing a route toward predictive, mechanism-driven design of multifunctional materials.
				TITLE II **Interpretable Machine Learning for Symmetry-Driven Spin Textures in Low-Dimensional Systems**	Spin textures in low-dimensional systems arise from the interplay of symmetry, electronic structure, competing exchange interactions, where reduced dimensionality, interfacial symmetry breaking stabilize nontrivial magnetic states. Capturing these effects requires resolving underlying mechanisms beyond phenomenological or purely predictive models. This PhD project focuses on developing symmetry-driven fingerprints combined with interpretable machine learning to identify mechanism-level descriptors governing magnetic ordering, anisotropy, and noncollinear spin textures. By encoding symmetry operations, local coordination, electronic structure, the methodology distinguishes regimes of itinerant, localized magnetism, while revealing regions of competing interactions associated with frustration, emergent spin configurations. Application to layered materials, oxide interfaces, heterostructures enables systematic analysis of strain, confinement, symmetry breaking in stabilizing complex magnetic phases. First-principles calculations provide validation of predicted crossovers, magnetic phase boundaries, spin textures. This work is aimed at establishing a symmetry-resolved, mechanism-driven framework for understanding, predicting spin textures in low-dimensional systems.
3	**Dr. Yasir Iqbal**	THEORY	2	TITLE I **Frustrated Magnetism Beyond Flat Space: Hyperbolic Lattices and New Quantum Materials**	Nearly everything we know about frustrated magnetism comes from lattices in flat, Euclidean space. Recent experiments in circuit QED and electric circuits have now built hyperbolic lattices, which are tilings of negatively curved space. In these lattices the boundary is as large as the bulk, ordinary translation symmetry is replaced by non-Abelian Fuchsian groups, and familiar ideas about phases and phase transitions need to be rethought. We are looking for PhD students to explore quantum magnetism in this new setting, and to connect the ideas with frustrated magnets that chemists are synthesizing now. Possible projects include: Spin liquids in curved space. Extend the projective symmetry group framework to hyperbolic space groups. Classify the quantum spin liquids that hyperbolic lattices allow, and ask which are stable and what their excitation spectra look like. Phases and criticality on hyperbolic tilings. Map out the ground-state phase diagrams of frustrated Heisenberg models with semiclassical and quantum many-body methods. Identify phases and transitions that have no flat-space counterpart. Theory for new frustrated materials. Develop microscopic models of recently synthesized antimonate magnets (the Mn/Co–Sb_2O_7 family). Combine first-principles exchange parameters with many-body calculations to explain thermodynamic and neutron-scattering data. This program sits where condensed matter physics, mathematical physics (group theory and geometry) and computational physics meet. Students will gain broad training and a research direction that is still largely open. We welcome applicants with a strong foundation in quantum mechanics, statistical mechanics and mathematical methods, and an interest in both analytical and numerical work.
				TITLE II **Quantum Spin Liquids: From Symmetry to Entanglement**	When magnetic frustration is strong, the spins in a quantum magnet can stay fluctuating all the way down to absolute zero. They never settle into an ordered pattern. Instead they form a quantum spin liquid. This state has long-range entanglement, fractionalized excitations and emergent gauge fields. We are looking for motivated PhD students to help classify and identify these phases, both in model Hamiltonians and in real materials. Projects combine field theory, group theory and large-scale numerics: Symmetry classification. Use projective symmetry group (PSG) methods to list every allowed spin liquid on lattices such as the spin-1 diamond lattice and the Shastry–Sutherland lattice with Dzyaloshinskii–Moriya interactions. Then work out what each one predicts for experiments. Variational Monte Carlo and entanglement. Build and optimize Gutzwiller-projected wavefunctions. Extract the topological entanglement entropy to tell gapped spin liquids from gapless ones without ambiguity. Dirac spin liquids in triangular Yb magnets. Test whether the U(1) Dirac spin liquid survives with realistic anisotropic exchange. Compute signatures that neutron scattering and thermal transport can measure. Students will learn group theory, parton mean-field theory, Monte Carlo methods and high-performance computing. They will also work closely with experimental groups. A strong background in quantum mechanics and statistical physics is expected. Programming experience (Python, Julia or C++) is a plus.
4	**Dr. Sudakar Chandran**	EXPERIMENT	2	TITLE I **2D magnetic materials**	Designing 2D materials exhibiting interesting physical properties suitable for spintronic devices is a challenging. This project will explore fabricating, testing, and tailoring the properties of 2D materials and their heterostructures for spintronic devices
				TITLE II **2D Halide perovskite for optoelectronics**	The project aims to explore and develop two-dimensional (2D) halide perovskites by leveraging their unique optoelectronic properties, including tunable bandgaps, zero-phonon-line emission, ambipolar charge transport, favorable defect characteristics, and solution processability, for applications in photonic and optoelectronic devices. It also seeks to advance the fundamental understanding of the optoelectronic properties of 2D halide perovskites.

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5	**Dr. Harish Kumar**	EXPERIMENT	1	TITLE I **Magnetoelectronic Materials**	Spintronics or Magnetoelectronics is an attempt to integrate magnetics with electronics. In a spintronic device spin polarized charge carriers from a magnetic thin film layer are injected into a non-magnetic metallic/semiconducting/Insulating layer and collected by another magnetic layer. The flow of spin polarized charge carriers is regulated by the application of a magnetic field. For efficient spin transport in such devices, materials with 100% spin polarized electrons at the Fermi level, known as “Half Metals” in which their spin up (or down) band metallic and the spin down (or up) band is semiconducting is required. In some materials in addition to the half metallic gap in one spin channel the other spin channel may show either a pseudo gap or partial overlap of valence and conduction band near the Fermi level which are called Spin Gapless Semiconductors and Spin Semimetals respectively. The Ph.D. work involves the synthesis of such novel magnetoelectronic material and investigation of their structural, magnetic and transport properties.
6	**Dr. Siddharth Dhomkar**	BOTH	1	TITLE I **Electron–Nuclear Spin Control for Enhanced Quantum Sensing**	Solid-state spin systems are promising platforms for quantum technologies, particularly quantum sensing. While interactions with surrounding nuclear spins often limit electron-spin coherence, they can also be harnessed to enhance sensing performance by exploiting nuclear spins as long-lived quantum memories and ancillary qubits. This project will investigate and leverage electron-nuclear spin interactions in material systems such as diamond and hexagonal boron nitride (hBN) to develop improved magnetic resonance and quantum sensing protocols. The work will combine theoretical and numerical modelling with the development of precision quantum sensing experiments, followed by data acquisition and analysis. It offers an opportunity to work at the intersection of quantum physics, optics, microwave engineering, and experimental instrumentation. Further reading: 1. A. Rana, P. Lamba, B. Mistri, D. Suter, S. Dhomkar, R. K. Kamineni, Spin bath mediated long-lived coherent oscillations of NV centers in diamond, arXiv:2606.30146 (2026). 2. B. Mistri, S. Mahajan, F. Donaldson, R. K. Kamineni, S. Dhomkar, Identifying optimal magnetic field configurations for decoherence mitigation of boron vacancies in hexagonal boron nitride, Physical Review B, 112, 245141 (2025). 3. P. R. Zangara, S. Dhomkar, A. Ajoy, K. Liu, R. Nazaryan, D. Pagliero, D. Suter, J.A. Reimer, A. Pines, C. A. Meriles, Dynamics of frequency-swept nuclear spin optical pumping in powdered diamond at low magnetic fields. Proceedings of the National Academy of Sciences 116, 2512 (2019).
7	**Dr. Prahallad Padhan**	EXPERIMENT	1	TITLE I **Investigation of High-Frequency Rectification Using Hall-Bar Devices for Energy Applications:**	The development of efficient and sustainable energy technologies requires innovative approaches to convert and utilize electrical energy. One emerging area of research is high-frequency rectification using Hall-bar devices, which offers new possibilities for energy conversion and electronic applications. A Hall bar is a specially designed device, typically made from a thin conducting material, through which electrical current flows. It is commonly used to study the electrical properties of materials and the behaviour of charge carriers. Under suitable conditions, its electrical response can be explored for rectification, a process in which an alternating electrical signal (AC) is converted into a direct electrical signal (DC). This research aims to investigate the potential of Hall-bar structures for high-frequency rectification and explore their suitability for future energy applications. The study will focus on understanding how electrical signals at high frequencies interact with the Hall-bar structure and how this interaction can be utilized to achieve efficient AC-to-DC conversion. Particular attention will be given to the influence of material properties, device geometry, operating frequency, applied voltage, and temperature on rectification performance. Various material systems and device configurations may be investigated to identify factors influencing rectification efficiency and electrical response. The proposed research will involve theoretical understanding, device fabrication, electrical characterization, and experimental investigation of Hall-bar-based rectifiers. By examining their performance under different operating conditions, the study will seek to understand the underlying physical mechanisms responsible for rectification and identify opportunities to improve energy conversion efficiency. Here are some of our recent research (https://doi.org/10.1039/D6MH00180G, https://doi.org/10.1002/adfm.202507191)
				TITLE II **Exploring High-Figure-of-Merit Materials for Energy Applications**	The growing demand for clean, sustainable, and efficient energy technologies has created a need for advanced materials that can improve the way energy is generated, converted, and utilized. The performance of energy-related materials is often evaluated using a parameter known as the Figure of Merit. In simple terms, the Figure of Merit is a measure used to assess how effectively a material performs a particular function. A higher Figure of Merit generally indicates better performance for the intended application, although the specific definition depends on the type of energy technology being considered. This research aims to explore and investigate advanced materials with high Figures of Merit for potential energy applications. The study will focus on understanding the relationship between the structural, electrical, thermal, optical, and other physical properties of materials and their overall energy-related performance. Different classes of functional materials, including semiconductors, nanostructured materials, and emerging advanced materials, may be investigated to identify promising candidates for improved energy technologies. The research will involve the study of material properties through theoretical analysis, computational modelling, and/or experimental characterization. Particular attention will be given to identifying the important physical parameters that determine the Figure of Merit, understanding the mechanisms responsible for enhanced performance, and exploring possible approaches to optimize material properties. Depending on the selected material system and application, the investigation may focus on energy harvesting, thermoelectric energy conversion, solar energy utilization, or other emerging energy technologies. Here are some of our recent research (ACS Applied Energy Materials 2025, 8, 14, 10658-10670, ACS Applied Energy Materials 2025, 8, 20, 15241-15257 and ACS Applied Energy Materials 2026, 9, 3, 1680-1691)
8	**Dr. Abhishek Misra**	EXPERIMENT	1	TITLE I **Opto-electronic devices from 2D van Der Waals Heterostructures.**	In this project, student will be working on the device fabrication and detailed opto-electronic characterizations involving van der Waals (vdW) layered materials. The aim of the research is to explore many body (excitons, trions, biexcitons) corelations in vdW heterostructure devices. Student will have the opportunity to learn device fabrication techniques such as electron beam lithography, metallization etc. The devices will be characterized using Raman and Photoluminescence spectroscopy at cryogenic temperatures.
9	**Dr. Manu Jaiswal**	EXPERIMENT	2	TITLE I **Ionic transistors and angstrom-scale confinement in 2D materials**	In the interlayer spaces of 2D materials, ions and molecules show an unconventional response. There is a surge of interest in this topic since the ultra-confinement enables a new class of ionic transistors and molecular separation devices, besides exploring rich confinement physics. This is an experimental project. See our recent papers Anjan Das et al., Energy Fuels (2026) 40 (17): 9445–9457, Anjan Das et al., Nanoscale Adv. (2023) 5 (18): 4901–4910; and Vikas Yadav et al. Faraday Discuss. (2026) 266: 150–168.
				TITLE II **Spectroscopy and Transport in CVD-grown 2D materials**	The candidate will study exotic properties of CVD-grown 2D materials, including transition metal dichalcogenides, graphene, and other systems. The samples will be grown using in-house facilities. The candidate will examine the role of twist angle, local curvature, defects, and grain boundaries on the excitonic, electrical sensing, and/or thermal properties of 2D materials and their van der Waals heterostructures. The experimental tools will include Raman/PL and electrical instruments. See our recent papers: B. Pothal et al., ACS Appl. Mater. Interfaces (2026) 18 (36): 50089–50103, A. Sampanraj et al., Phys. Rev. B,111, 075423, 2025, and L. Devendar et al., Surfaces and Interfaces 50 (2024) 104470
10	**Dr. Anil Kumar Singh**	EXPERIMENT	1	TITLE I **Charge Transport and Low-Frequency Noise in Two-Dimensional Materials**	The project involves investigating charge transport in 2D-material-based field-effect transistors, with an emphasis on temperature-dependent transport, interfacial charge trapping, hysteresis, and (1/f) noise. The student will receive hands-on training in 2D-material device preparation, electrical transport measurements, variable-temperature experiments, low-frequency noise spectroscopy, and quantitative data analysis.

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11	**Dr. Prafulla Kumar Behera**	EXPERIMENT	1	TITLE I **Study of CMOS silicon sensor for development of next generation pixel detector and it's application in imaging**	As the LHC will be upgraded to HL_LHC (High Luminosity LHC) with higher radiation and pile-up for the pixel detector, there is a need for a high-tolerance, radiation-hard pixel detector. Using CMOS techonology, we will develope next generation pixel detector with higher radiation tolerance. The sensor will be tested at the detector lab at IITM.
12	**Dr. Murugavel P**	EXPERIMENT	1	TITLE I **Integration and investigation of single crystalline oxide film on Si and flexible substrate for their novel physical properties.**	The project involves the fabrication of epitaxial thin films of multifunctional oxides by the pulsed laser deposition technique and transferring them onto Si and flexible substrates via a sacrificial layer. The transferred films will be investigated for their multifunctional properties suitable for device applications in the field of energy storage, energy harvesting and electronic devices.
13	**Dr. Aravind G**	EXPERIMENT	1	TITLE I **Probing Coulombic decay using a Cold-Target Recoil ion Mass spectrometer**	This project involves probling intermolecular Coulombic decay between cluster molecules. Understanding the energy pooling in such a process has implications on fundamental physics and light harvesting too. We will build a COLTRIMS to measure the Coulombic decay.
14	**Dr. Santhosh PN**	EXPERIMENT	1	TITLE I **Magnetic and structural investigation of Double perovskites and their potential use in oxygen evolution reaction electrocatalysts and supercapacitors**	Double perovskite oxides with A2BB′O6 are promising materials with unique crystal structure that allows for tunable electrical transport and magnetic character. Design of these novel oxides for oxygen evolution reaction (OER) and supercapacitor applications will be explored and the magnetic and structural studies will give crucial insights into the science of these materials. Design and synthesis of few these novel oxides will form the initial part of the research. Rietveld analysis for crystal and magnetic structure investigation will be routinely carried out. Squid Magnetometer, Physical Property Measurement System, X-ray photoelectron spectroscopy, Raman spectroscopy etc. will be routinely used to study the physical properties. Electrochemical studies will be carried out to find the use of these oxides in the fields of OER and supercapacitor applications. Suitable samples will be studied in their thin film form based on their magnetotransport characteristics
15	**Dr. Chandra Kant Mishra**	THEORY	1	TITLE I **Gravitational Waveforms from Post-Newtonian and Black Hole Perturbation Approaches — Effects of Spins on Eccentric Orbits**	Gravitational waves are ripples in spacetime produced by some of the most energetic events in the Universe, including the merger of black holes. These signals offer a unique opportunity to explore gravity under extreme conditions and understand the dynamics of compact objects. While much of the current research focuses on binaries moving along nearly circular orbits, eccentric orbits and the spins of black holes can introduce rich and complex features into gravitational wave signals. This PhD project aims to develop and study gravitational waveforms using two complementary theoretical approaches: post-Newtonian theory and black hole perturbation theory. The research will explore how spin and orbital eccentricity influence the dynamics and gravitational wave emission of compact binaries, contributing to the development of more accurate waveform models for future gravitational-wave observations. The project offers an exciting opportunity to work at the intersection of theoretical physics, analytical calculations, and gravitational-wave astronomy.
16	**Dr. Nimmi Das Anthuparambil**	EXPERIMENT	1	TITLE I **Non-Equilibrium Dynamics and Dynamical Arrest in Biomolecular Condensates**	Biomolecular condensates offer a fascinating platform for investigating nonequilibrium phenomena in soft condensed matter. Their transitions from fluid-like states into gels, glasses, or fibrillar structures present fundamental questions in statistical mechanics, polymer physics, and glass dynamics. This research aims to investigate whether early-time dynamical signatures can predict the pathways of phase transformation and dynamical arrest in biomolecular condensates. Drawing on concepts of physical aging, viscoelasticity, percolation, and dynamic scaling, the project will explore the role of relaxation dynamics in governing these transitions. Using diffusing wave spectroscopy, X-ray scattering, UV-Spectroscopy and interpretable machine learning, the study will seek to establish predictive physical frameworks and universal scaling laws governing non-equilibrium phase behavior in living soft matter with applications in material science, bio-nanotechnology, and biomedicine.
17	**Dr. Vidya Praveen Bhallamudi**	EXPERIMENT	2	TITLE I **Cryogenic Scanning NV magnetometer for studying quantum materials and devices**	In this project the scholar will be working with a team towards the development of a state-of-art cryogenic scanning probe microscope and use it for study of quantum materials and devices with nanometer spatial resolution. This challenging project is a key deliverable and is funded under the National Quantum Project. It is aimed at developing a microscopy technique based on nitrogen-vacancy (NV) centers/defects in diamond. The project combines multiple microscopies into one to perform cutting edge magnetic sensing at the nanoscale. The scholar will develop hand-on skills in pulsed electron spin resonance, confocal optical microscopy, sensitive scanning probe (Atomic force microscope family), low noise measurements and towards quantum-limited measurement and cryogenics. The instrument will be a critical tool is studying emerging quantum materials and devices that are needed for various quantum technologies.
				TITLE II **Inductively and optically-detected pulsed electron spin resonance**	We are establishing an X-band pulsed electron spin resonance facility at IIT Madras under the National Quantum Mission, which will among the very few in the country. Pulsed ESR is a valuable tool for understanding coherence properties of spins in various materials. Understanding these properties are extremely important for quantum technologies. The scholar will gain hands-on knowledge in using this national facility. Their scientific goals will be to understand diamond and under quantum materials. The scholar will also be involved optically detected EPR based sensing measurements in our lab.
18	**Dr. Somnath Chanda Roy**	EXPERIMENT	1	TITLE I **Growth of nanostructures under magnetic field: achieving spin polarisation and directionality for better solar energy harvesting**	Recombination of the photogenerated charges is one of the main bottlenecks towards achieving higher efficiency in solar energy devices. Recent research shows that creating specific spin arrangement (spin polarization) positively affect the recombination rates. Some of the recent work from our lab shows that the growth of nanostructures under an applied magnetic field help in achieving a certain degree of spin polarization in the materials. In addition, solution phase growth also results in directional growth in nanostructures, when carried out under a magnetic field. In the proposed work, we shall explore the growth of Fe2O3, Fe3O4, NiO nanorods/nanowires under magnetic field (about 1 Tesla) and measure their magnetization behaviour with respect to those grown under no magnetic field. Finally, the samples with better magnetization will be used solar energy devices to assess the enhancement in efficiency. On the fundamental side, the work will establish the correlation between applied magnetic field with other growth parameters; while, on the applied side, we will develop magnetically active solar energy materials for higher performance.
19	**Dr. Vaisakh Vadakkumbatt**	EXPERIMENT	1	TITLE I **Probing 2DES Dynamics on Liquid Helium using Microdisk Resonators**	Two-dimensional electron systems (2DES) on the surface of liquid helium offer unprecedented electron mobility and long coherence times, making them ideal candidates for quantum information architectures. This PhD project will investigate the dynamics of two-dimensional electron system on the surface of helium using high-Q microdisk resonators. By coupling trapped electrons with whispering-gallery cavity modes, we aim to measure the collective plasma modes. The project includes microfabrication of integrated resonator-electrode chips, developing cryogenic platforms, and microwave/optical spectroscopy.
20	**Dr. Sivarama Krishnan**	EXPERIMENT, BOTH	2	TITLE I **Experimental and computational quantum photonics**	In this project, we will work on exploiting the unique opportunities provided by quantum optics and photonics to realise quantum technologies in sensing, imaging and communication. The key to this is the realization of efficient entangled-photon sources and single-photon detectors. We will leverage the opportunities provided by photonic metastructures to this end. Quantum-sensors, -spectroscopy, -microscopy, -imaging and -transduction schemes will be target applications. These will be implemented using pulsed or continuous wave lasers. This project will be carried out in collaboration with world-renowned labs in addition to local efforts at IIT-Madras.

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				TITLE II **In this project, we will work on exploiting the unique opportunities provided by quantum optics and photonics to realise quantum technologies in sensing, imaging and communication. The key to this is the realization of efficient entangled-photon sources and single-photon detectors. We will leverage the opportunities provided by photonic metastructures to this end. Quantum-sensors, -spectroscopy, -microscopy, -imaging and -transduction schemes will be target applications. These will be implemented using pulsed or continuous wave lasers. This project will be carried out in collaboration with world-renowned labs in addition to local efforts at IIT-Madras.**	The 2023 Nobel prize in physics was awarded to the pioneers of attosecond science. In this project, we will take forward our efforts to research quantum dynamics on atto- and femto-second timescales. For this, we will use in-house femtosecond laser systems as well as world-leading synchrotron and xray free-electron laser facilities. We are almost the only group in India to pursue this line of research on this scale with demonstrated success through publications in top-journals like Phys. Rev. Lett., Rep. Prog. Phys., Advanced Science, Advanced Optical Materials, Optics Letters, J. Chem. Phys. Lett. and more which are well cited. The incoming student will get ample international exposure, paving way to post-doctoral opportunities in leading labs as previous members of this group have done. This project will be worked on both experimental and computational aspects.
21	**Prof. B. R. K. Nanda**	THEORY	1	TITLE I **High order solvers for Condensed Matter Physics and Material sciences**	The last two to three decades has been immensely advancing for high precision and high fidelity numerical scheme development. This is mainly attributed to the mathematical community for emphasising on underlying inherent structures in evolutionary mathematical models while designing numerical approximations. While these developments have advanced the field of scientific computing and numerical analysis drastically, the same could not be said about their applicability for problems they were supposed to be addressing. We propose to incorporate many of the advances to the field of material sciences, in-order develop high precision, fast and high fidelity solvers catering to direct needs of the community, thus extending the academic numerical models to complicated practical problems. Proposed Co-Guide: Prof. Saurav Samantaray, Department of Mathematics, IIT Madras