

1128
25/02/20

OARS



Proposal for a new course: Department of Physics

1. **Course Number:** ^{PHY} A6XX
2. **Course Title:** A Physicist's Introduction to Topology and Differential Geometry (Departmental Elective)
3. **Number of Lectures Per Week and Total Number of Classes:** 3 Lectures [Tutorial:0, Laboratory:0, Additional Hours:0], 39
4. **Credit:** 09
5. **Duration of Course:** Full Semester
6. **Proposing Department:** Physics
7. **Other Members Interested in Teaching The Course:** Sagar Chakraborty, Arijit Kundu, Apratim Kaviraj
8. **Proposing Instructor:** Kaushik Bhattacharya
9. **Course Outline**

(a) **Introduction to topology** [6 Lectures]

- Definition of topology
- Various topologies and in particular metric topologies
- The concept of continuity in the general topological setting
- The concept of connected and compact spaces
- The concept of topological bases and second countable topological spaces
- The concept of homeomorphism and isomorphism in topology
- The concept of product topology and its application in physics
- Topological spaces relevant for physics, metric spaces, topological defects in phase transitions, topology in spontaneous symmetry breaking

(b) **Homotopy theory** [6]

- Topological invariants relevant for physics
- Product of based loops
- Loops and their continuous deformations leading to Homotopy
- Introduction to the Fundamental group
- Some basic analysis of higher Homotopy groups and applications of Homotopy groups in physics, their connection with the Lie group manifolds relevant in physics

(c) **Introduction to differentiable manifolds** [4 Lectures]

- Introduction to manifolds as topological spaces and the differentiable structure on them
- Examples of various atlas on the manifold and their connection with physics

- Introduction of tangent vector fields on manifolds and introducing physics on tangent spaces and tangent bundles
 - Introduction of cotangent vector fields on manifolds and introducing physics on cotangent spaces and cotangent bundles
- (d) **Forms and integration on manifolds** [5 Lectures]
- Introduction to exterior algebra on manifolds
 - The exterior and interior derivatives
 - Using the theory of forms in electromagnetism and more general gauge theories in physics
 - Introduction to the theory of integration of top forms on a manifold
 - Working out the theory of Riemannian manifolds and Symplectic manifolds and showing their connection with general theory of relativity and Hamiltonian mechanics.
- (e) **Operations on a manifold** [4 Lectures]
- Introduction to pushforward of a vector field on a manifold
 - Introduction to pullback of a 1-form from a manifold
 - Diffeomorphism as a general pullback on a manifold and connecting the concept with coordinate transformations in general relativity
 - The concept of the Lie derivative along a vector field on a manifold and its connection to evolution of dynamical system in physics
- (f) **Simplicial homology** [7 Lectures]
- Introduction to simplicial homology and the concept of triangulation
 - The concept of simplexes and chains
 - The concept of cycles and boundaries
 - The Homology group
 - Betti numbers and Euler characteristics. Understanding cosmology with Betti numbers. Other applications in physics
- (g) **Cohomology** [7 Lectures]
- Introduction to singular homology
 - Connection of concepts of singular homology and the theory of forms
 - Introduction to cocycles and coboundaries
 - Introduction to the concept of cohomology
 - Application of cohomology in physics

10. **Prerequisites:** Mathematical Method I and some prior knowledge of group theory

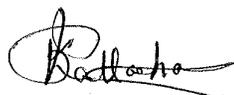
11. **Short summary for the course of study booklet:** While teaching advanced Classical Mechanics or Quantum Mechanics or General Relativity one always comes across terms which can only be understood if someone has basic understanding of Topology. Moreover modern research in Condensed matter physics or High Energy Physics or General Relativity requires basic understanding of Topology. In pure mathematics Topology is taught rigorously and consequently many physics students does not find it palatable.

This course is particularly meant for those students who have not taken a Topology course in the Mathematics department and still wants to know the subject for a better understanding of modern physics.

12. Recommended books:

- Topology by James R. Munkres
- Introduction to Topology and Modern Analysis by George F. Simmons
- Elements of Algebraic Topology by James R. Munkres
- A Physicist's Introduction to Algebraic Structures by Palash B. Pal

Date: 22nd February 2026



Proposer: Kaushik Bhattacharya



DPGC Convener(PHY): Chanchal Sow

The course is approved/not approved

Chairman, SPGC

Date: