BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE-PILANI, HYDERABAD CAMPUS

SECOND SEMESTER 2021-2022

15.01.2022

Course Handout

Course No. : PHY F431

Course Title : Geometrical Methods in Physics

Instructor-in-Charge : Sashideep Gutti

*Course Description* : The course begins with defining manifold. This is followed by defining geometric objects called tensors (scalars, vectors and higher order tensors). The differential forms are defined with lot of examples from physics. Lie group theory is discussed in a geometric way. Idea of metric and Riemannian geometry is the discussed. Aspects of topology and the relevance to physics is then discussed. The idea of integration on a manifold is covered, and derivation of Gauss’s theorem and Stokes theorem are done using integrals of differential forms. Fiber Bundles and the idea of a connection is discussed along with the interpretation of magnetic vector potential using the new language. The application of the above topics to Classical Mechanics, Electrodynamics, Gravitation, Quantum mechanics, Quantum Field Theory is discussed.

*Scope & Objectives* : This is a course in which a geometrical understanding is obtained for various ideas in physics like quantum mechanics, gravitation, classical mechanics and quantum field theory. The course helps in an intuitive and exact interpretation of many results and concepts in physics. A lot of ambiguity that exists in defining quantities in physics is eliminated due to the precise geometric way these quantities are interpreted. A student aspiring to understand physics in a geometric and intuitive way will find this course highly beneficial because of the fundamental interpretations presented in of the course.

*Learning Objectives:* 1) Manifolds 2) Scalars, Vectors, General Tensors. 3) One forms as gradients, n forms, exterior algebra 4) Lie derivatives 5) Lie group theory and Symmetries 6) Differential Forms 6) Topology, Cohomology 7) Fiber Bundles and Connections 8) Applications in Physics.

*Text Book*: Geometrical Methods of Mathematical Physics, Bernard Schutz, Cambridge University Press, 1979

*Reference Books***:**

1. Gauge Fields, Knots and Gravity, John Baez and Javier P Munian, World Scientific. 1994.

2. Topology, Differential Geometry and Group Theory for Physicists, by Sunil Mukhi and N Mukunda, Wiley Eastern Limited, 1990.

## *Course Plan:*

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| Lecture  No. | Learning Objectives | Topics to be covered | Chapter in the Text Book |
| 1-2 | Manifolds , curves, functions on manifolds | Definitions, examples of manifolds. Spacetime as manifold | 2.1-2.5 |
| 3-7 | Vectors, tensors, fibers | Definitions and Interpretation . Physical Objects as tensors. Metric Tensor, Inertia Tensor, Stress tensor, Energy Momentum Tensor, Riemann Tensor | 2.5-2.11 |
| 8-12 | Integral Curves, Lie Brackets, One Forms | Lie Brackets, Applications | 2.12-2.31 |
| 13-20 | Lie Derivatives and Lie Groups | Lie Derivative, Symmetries, Killing Vectors, Lie Algebras, Lie Groups | 3.1-3.18 |
| 21-26 | Differential Forms | Algebra and Integral Calculus of forms, Volume and Integration on Manifolds, Differential Calculus of forms | 4.1-4.13 |
| 27-33 | Exterior Differentiation | Closed and Exact forms, Stoke’s theorem, Gauss Theorem, Conservation Laws. | 4.14-4.29 |
| 34-36 | Homotopy | Loops and Homotopies, Fundamental Groups, Higher Homotopy Groups, Arahanov Bohm Effect, Ampre’s law, Gauss theorem. | 2.1-2.3 Sunil Mukhi Lecture Notes |
| 37-41 | Applications to Physics | Hamiltonian dynamics using Geometry, Thermodynamics, Derivation of maxwell’s equation using guage principle, Yang-Mills theory using symmetries, Connection two forms and curvatures. | Chapter 5,Schutz |
| 42 | Unsolved issues in physics |  |  |

Evaluation:

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| EC No. | Evaluation  Component. | Duration. | Weightage | Date, Time & Venue. | Nature of Component. |
| 1 | Mid-semester test | 90 mins | 35% | 15/03 9.00am to10.30am | Open Book |
| 2 | Assignments |  | 25% |  | Open Book |
| 3 | Comprehensive Examination | 120 mins | 40% | 17/05 FN | Open Book |
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*Chamber Consultation Hour:*To be announced in the class.

*Notices:*Notices concerning the course will be put up on the CMS.

*Make-up Policy:*Make-up for the tests will be granted only for genuine cases of health problems or urgency for going out of town.

**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