Syllabus of the Ph.D. Course Work

Centre for Theoretical Physics
Jamia Millia Islamia
(First Semester: July – December, 2010)

GRADUATE SCHOOL – MATHEMATICAL PHYSICS – I

1. THEORY OF COMPLEX VARIABLES
   Laurent series, zeros of analytic functions, isolated singularities, removable singularities, poles, essential singularities, Picard's theorem, non-isolated essential singularities, residues, calculating residues, Cauchy's residue theorem, real trigonometric integrals, improper integrals, the Cauchy principal value, Jordan's lemma.

2. POWER SERIES SOLUTIONS AND SPECIAL FUNCTIONS
   Second Order Linear Equations. Ordinary Points, Regular Singular Points
   Gauss's Hypergeometric Equation

3. FOURIER SERIES AND ORTHOGONAL FUNCTIONS
   The Fourier Coefficients, the Problem of Convergence, Even and Odd Functions. Cosine and Sine Series, Extension to Arbitrary Intervals Orthogonal Functions

4. PDE AND BOUNDARY VALUE PROBLEMS AND GREEN'S Function
   Eigenvalues, Eigenfunctions, the Wave Equation, The Heat Equation , The Dirichlet Problem for a Circle, Poisson's Integral **, separation of variables and other METHODS, Green's Functions and Sturm–Liouville Theory**

5. SOME SPECIAL FUNCTIONS OF MATHEMATICAL PHYSICS (Any two)
   Legendre Polynomials Properties of Legendre Polynomials, Bessel Functions. The Gamma Function, Properties of Bessel functions, **Chebyshev Polynomial**

6. NONLINEAR EQUATIONS
   Autonomous Systems, the Phase Plane and Its Phenomena, Types of Critical Points. Stability Stability by Liapunov's Direct Method

7. VECTOR SPACE & LINEAR TREANSFORMATION
   Vector spaces, linear independence and dependence of vectors, inner products, Linear transformations, Systems of linear equations-consistency and inconsistency, rank of a matrix, Eigen values and eigenvectors of a matrix, diagonalization of a matrix.

BOOKS

1. **Churchill R.V., Brown J.W Complex variables and applications (MGH)**
2. **G. F. SIMMONS, DIFFERENTIAL EQUATIONS (MGH)**
3. ARFKEN & WEBER, MATHEMATICAL METHODS FOR PHYSICISTS (ACADEMIC PRESS)
4. **Gilbert Strang: Linear Algebra and Its Applications -**

Syllabus for Quantum Field Theory

1. Introduction :
   (a) Relativistic Wave equations (b) Lagrangian formulation of Particle Mechanics (c) Noether's theorem for relativistic fields

2. Field Quantization :
   (a) Scalar Field (b) Dirac field (c) Electromagnetic field

3. Perturbation Theory :
   (a) Scattering Matrix – In and Out states (b) Reduction Formalism
   (c) Wick's theorem (d) Feynman Diagrams in Momentum space
   (d) Cross sections and application to scattering

4. Renormalisation :
   (a) Divergences in Feynman integrals (b) Higher Order Corrections (c) Counter terms (d) Dimensional Regularisation
   (e) One loop renormalization

* 5. Path Integral formulation of Quantum Mechanics, Generating functionals of Green Functions

*6. Path Integral for a free scalar field, Fermi field – Grassmann algebra

*7. Path integral quantization of Gauge fields. Ward –Takahashi Identities in QED.

* Depending on the interest and requirement of students these topics may be included.

General Relativity and Cosmology - I

Graduate School - First Semester

Outline of the Course

0. **Historical Perspective**
1. **Special Relativity**
    - Theoretical and Observational formulation
    - Lorentz Transformations
    - Relativistic Mechanics
    - Classical field theory (symmetries and conservation laws)
2. **Mathematical Formulation**
    - Equivalence principle
    - Manifolds, Tensors, affine connection, Metric
    - Derivative operator, Riemann curvature, Geodesics
    - Killing Vectors
3. **Einstein Field Equations**
    - Einstein Equations
    - Lagrangian formulation of GR
    - Symmetries and conservation laws in GR
    - Exact Solutions
      (Schwarzschild, Tolman, Vaidya, Friedmann model of the Universe)
4. **Applications of General Relativity**
    - Solar System
    - Gravitational Collapse: Black Holes and Visible Singularities
    - Gravitational Waves

NOTE: *There are several excellent books on GR in library. I recommend you stick to one of them, using others as reference, and avoid getting lost in notation and signature change of metric etc.*

References:

1.Landau & Lifshitz: Classical Theory of Fields, 2. S. Weinberg: General Relativity and Cosmology, 3. R. d'Inverno: General Relativity, 4. B. F. Shutz: First Course in General Relativity, 5. J. L. Synge: General Theory of Relativity, 6. J. Hartle: General Relativity, 7. Notes on GR which are recent and follow modern notation: **S. Caroll: General Relativity (available online)**

Structure and Evolution of Scientific Thought

Brief outline of course:

1. Logical positivism and Empiricism
2. Kuhn's philosophy of scientific revolution and concept of paradigm.
3. The concept of research traditions a la Kuhn, Laudan , Popper and Anderson
4. Basics of Critical Relativism, Constructivism and irrationalism.
5. Glimpses of Scientific realism.