Course: Core Paper V - HPHCR3052T & HPHCR3052P

Semester	III
Paper Number	HPHCR3052T &HPHCR3052P
Paper Title	MATHEMATICAL PHYSICS II
No. of Credits	06 (Theory – 4, Lab – 2)
Theory/ Composite	Composite
No. of periods assigned	Th:4 periods/week Pr:3 periods/week
Name of Faculty member(s)	
Course description/ objective	The first module of this course deals with the methods of solving second order ordinary differential equations (ODE)s, partial differential equations (PDE)s and linear systems of ODEs and offers an overview of their applications in physics.On completion of this course, the students will be able to do the following: i) Describe the applications of differential equations in physics. ii) Obtain power series solutions about ordinary points of second order linear ODEs, solve linear, second order ODEs with variable coefficients using the Frobenius method and recall the classical functions (Bessel, Laguerre, etc.). iii) Perform operations with Bessel, Legendre, Hermite and Laguerre differential equations along with the corresponding recurrence formulas of different functions. iv) Use the Wronskian to determine if a set of functions is linearly independent or not, demonstrate their understanding of how physical phenomena are modelled by second order differential equations and dynamical systems. v) Solve linear PDEs using the method of separation of variables. vi) Solve the wave equation for vibration of stretched strings and membranes, analyse the phenomenon of diffusion and solve mathematically the diffusion equation. The second module consists of parts providing different kinds of perspectives on mathematical structures and techniques to a physics student. i) The discussion on beta and gamma functions will prepare a student to handle special kind of integrals which occur frequently in physics. ii) The subpart on theory of errors will provide very useful insights on the measure of dependability of an experiment. iii) The theory of errors will also expose a student in the correct way of graphical representation of the experimental data. iv) The subpart on variational calculus will introduce the idea of Lagrangian and Hamiltonian formulation as a parallel formulation to Newtonian mechanics. v) The students will be exposed to the concept of Legendre transformation used in various areas of physics, most commonly in classical mechanics and thermodynamics. vi) The subpart on Fourier series will equip the students to apply this technique in the relevant areas and will teach them to appreciate the power and efficiency of this technique.
Syllabus	As enclosed
Texts	As enclosed
Reading/ Reference Lists	As enclosed
Evaluation	Total – 100 (Theory – 60, Practical – 40) Theory – CIA – 10 Semester Examination – 50 Group A (25 marks) Group B (25 marks) One 10 marks qs out of two qs One 10 mark qs out of two qs Three 5 mark qs out of five qs Three 5 mark qs out of five qs

Syllabus:

HPHCR3052T - MATHEMATICAL PHYSICS II (Credits – Theory – 4, Practicals – 2)

Module A **[26 lectures]**

Frobenius Method and Special Functions

Ordinary Points and Singular Points of Second Order Linear Differential Equations and their importance. Power series solution of second order linear differential equation: Solution of Legendre and Hermite Differential Equations.

Frobenius method and its applications to second order differential equations: Solution of Bessel and Laguerre Differential Equations. **[17 lectures]**

Partial Differential Equations

Solutions to partial differential equations using separation of variables: Laplace's Equation in problems of rectangular, cylindrical and spherical symmetry. Wave equation and its solution for vibrational modes of a stretched string, rectangular and circular membranes. Diffusion Equation

[9 lectures]

Module B [26 lectures]

Some Special Integrals

Beta and Gamma Functions and Relation between them. **[3 lectures]**

Theory of errors

Systematic and Random Errors.Propagation of Errors.Normal Law of Errors.Standard and Probable Error.Leastsquares fit. Error on the slope and intercept of a fitted line. **[3 lectures]**

Variational calculus in physics

Functionals.Basic ideas of functionals.Extremization of action as a basic principle in mechanics.Lagrangianfomulation. Euler's equations of motion for simple systems: harmonic oscillators, simple pendulum. Cyclic coordinates. Symmetries and conservation laws.Legendre transformations and the Hamiltonian formulation of mechanics. Canonical equations of motion **[12 lectures]**

Fourier Series

Periodic functions. Orthogonality of sine and cosine functions, Dirichlet Conditions (Statement only).Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients.Complex representation of Fourier series.Expansion of functions with arbitrary period.Expansion of non-periodic functions over an interval.Even and odd functions and their Fourier expansions.Application.Parseval Identity.

[8 lectures]

Reference Books

1. Mathematical Methods in the Physical Sciences , M.L. Boas, Wiley.
2. Fourier Analysis, M.R. Spiegel, 2004, Tata McGraw-Hill.
3. Elementary Differential Equations and Boundary Value Problems, Boyce and Di Prima, Wiley.
4. Mathematical Physics, P. K. Chattopadhyay, 2014, New Academic Science.
5. Mathematical Physics, Binoy Bhattacharyya, New Central Book Agency.

6. Fundamentals of Mathematical Physics, Tarashankar Nag. Mc-Graw Hill Education.
7. Classical Dynamics of particles & systems, Marion & Thornton, Cengage Learning.
8. Classical Mechanics, Rana & Joag, Tata McGraw-Hill Education.

HPHCR310P - Mathematical Physics Lab (Credits – 2) (39 periods)

1. **Introduction to Numerical computation using Python (numpy and scipy modules)** Introduction to the python numpy module. Arrays in numpy, array operations, array item selection, slicing, shaping arrays. Basic linear algebra using the linalgsubmodule. Introduction to online graph plotting using matplotlib: Graphical visualisation of Legendre Polynomials and Bessel Function. Introduction to the scipy module. Uses in optimization and solution of differential equations.

2. **Numerical Methods**
   a) Interpolation by Newton Gregory Forward and Backward difference formula, Error estimation of linear interpolation Evaluation of trigonometric functions e.g. sin θ, cos θ, tan θ, etc.
   b) Numerical differentiation (Forward and Backward difference formula) and Integration (Trapezoidal and Simpson rules), Monte Carlo method Given Position with equidistant time data to calculate velocity and acceleration and vice versa. Find the area of B-H Hysteresis loop

3. **Curve Fitting, Least square fit, Goodness of fit, standard deviation**
   Ohm's law to calculate R, Hooke's law to calculate spring constant. Calculation of error for each data point of observations recorded in experiments done in previous semesters (choose any two), Calculation of least square fitting manually without giving weightage to error. Confirmation of least square fitting of data through computer program.

Reference Books

1. Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd ed., 2006, Cambridge University Press.
2. Complex Variables, A.S. Fokas& M.J. Ablowitz, 8th Ed., 2011, Cambridge Univ. Press.
3. Numpy beginner's guide, Idris Alba, 2015, Packt Publishing.
4. Computational Physics, D.Walker, 1st Edn., 2015, Scientific International Pvt. Ltd.
6. Computational Physics Mark Newman, CreateSpace Independent Publishing Platform (2012).
7. Computational Physics: Problem Solving with Python, 3 rd Edition, Rubin Landau, Manuel J. Paez, Cristian C. Bordeianu, Wiley-VCH.

Paper Structure

(a) (i) One computation examination – 20 marks
(ii) L.N.B. – 10 marks

(b) Grand Viva – 8 marks
(c) Attendance – 2 marks