Course: Core Paper VIII–HPHCR4082T & HPHCR4082P

Semester	IV
Paper Number	HPHCR4082T & HPHCR4082P
Paper Title	Mathematical Physics III
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	This course aims at: i) Enabling students to extend their knowledge of real analysis to the complex domain. ii) Equipping the students with techniques of Contour Integration, enable the students to evaluate a very broad class of definite integrals, whose indefinite forms cannot be evaluated using analytical means. iii) Helping students to learn Fourier integrals at an early stage, which will enable students to appreciate concepts of wave packets, dispersion relations and the like when they appear in Quantum Mechanics. iv) Enabling a student to move between time and frequency (or energy) domain which is an extremely valuable skill for solving Differential Equation and appreciating spectral analysis v) In the second module of this course, Linear Algebra is introduced which forms the mathematical framework of a wide array of subjects, most importantly Quantum Mechanics. The idea is to equip the students enough to be able to make use of it to apply it for solving QM problems at a later stage. vi) A combination of strategies are developed to address diverse area in Mathematics & Physics which rely on the principle of superposition.
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:

HPHCR4082T –MATHEMATICAL PHYSICS III(Credits – Theory – 04, Practicals – 02)

Module A **[26 lectures]**

Complex Analysis

Brief Revision of Complex Numbers and their Graphical Representation. Euler's formula, De Moivre's theorem, Roots of Complex Numbers. Functions of Complex Variables.Analyticity and Cauchy-Riemann Conditions.Examples of analytic functions. Singular functions with examples : poles and branch points, order of singularity, branch cuts. **[26 lectures]**

Module B **[26 lectures]**

Integral Transforms

Idea of integral transforms, Kernel, Example - Fourier Transforms :Fourier Integral theorem. Fourier Transform. Examples.Fourier transform of trigonometric, Gaussian, finite wave train & other functions.Representation of Dirac delta function as a Fourier Integral. Fourier transform of derivatives, Inverse Fourier transform. Properties of Fourier transforms (translation, change of scale, complex conjugation, etc.). Application of Fourier Transforms to differential equations: One dimensional Wave Equations. **[12 Lectures]**

Matrices:

Addition and Multiplication of Matrices.Null Matrices.Diagonal, Scalar and Unit Matrices. Transpose of a Matrix. Symmetric and Skew-Symmetric Matrices.Conjugate of a Matrix.Hermitian and Skew- Hermitian Matrices.Singular and Non-Singular matrices.Orthogonal and Unitary Matrices.Trace of a Matrix.Inner Product**.** **[8 lectures]**

Eigenvalues and Eigenvectors:

Diagonalization of Matrices.Cayley- Hamilton Theorem. Solutions of Coupled Linear Ordinary Differential Equations **[6 lectures]**

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. Mathematics for Physicists, P. Dennery and A.Krzywicki, 1967, Dover Publications.
3. Complex Variables and Applications, J.W. Brown & R.V. Churchill, 7th Ed. 2003, Tata McGraw-Hill.
4. First course in complex analysis with applications, D.G. Zill and P.D. Shanahan, 1940, Jones & Bartlett.
5. Complex Variables, Spiegel, Schaum Series.

HPHCR4082P - Mathematical Physics III Lab; Credits – 2(39 periods)

1. Solution of First and second order Ordinary Differential equations: Euler, modified Euler and RungeKutta (RK) second and fourth order methods
   i. Radioactive decay
   ii. Classical equations of motion: 1 and 2 dimensional motion

   Attempt following problems using RK 4 order method

1. Solve the coupled differential equations

$$\frac{dx}{dt} = y + x - \frac{x^3}{3}; \frac{dy}{dt} = -x$$

For four initial conditions $x(0) = 0, y(0) = -1, -2, -3, -4$.
Plot $x\ vs\ y$ for each of the four initial conditions on the same screen for $0 \leq t \leq 15$

2. The differential equation describing the motion of a nonlinear pendulum is

$$\frac{d^2\theta}{dt^2} = -\sin\theta$$

The pendulum is released from rest at an angular displacement αi. e. $\backslash theta(0) = \alpha$, and $\theta'(0) = 0$.

Solve the equation for α = 0.1, 0.5 and 1.0 and plot θas a function of time in the range $0 \leq t \leq 8\pi$. Also plot the analytic solution valid for smallθ $(sin(\theta) = \theta)$

3. Study of oscillators: application to LCR circuits.

4. Boundary value Problems – Solve, e.g. $x^2 \frac{d^2y}{dx^2} - 4x\,(1+x)\frac{dy}{dx} + 2(1+x)y = x^3$with the boundary condition at$x = 1, y = \frac{1}{2}e^2$, in the range $1 \leq x \leq 3$. Plot y and $\frac{dy}{dx}$ against $x$in the given range in the same graph.

5. Partial differential equations - Heat Equation, Laplace Equation, Wave equation, Poisson equation

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. A Guide to MATLAB, B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 2014, 3rd Edn., Cambridge University Press.

Paper Structure

(a) (i) One computation examination – **20 marks**
(ii) L.N.B. – 10 marks
(b) Grand Viva – **8 marks**
(c) Attendance – **2 marks**