UNIVERSITY OF DELHI

N O T I F I C A T I O N

Sub: Amendment to Ordinance V

In continuation to the Notification No. CNC-II/093/1/2026/Misc./31 dated 12.01.2026 regarding minor changes with respect to the courses offered in B.Sc. (Hons.) Physics Programme of Department of Physics and Astrophysics, the syllabi of the following courses are being revised and notified herewith for the information of all concerned as per *Annexure-1*:

(i) Mathematical Physics -II – DSC-4- Semester-II
(ii) Thermal Physics – DSC-11 – Semester-IV

REGISTRAR

DEPARTMENT OF PHYSICS & ASTROPHYSICS
Category-I
BSc. (H) Physics

> # DISCIPLINE SPECIFIC CORE COURSE – 4: MATHEMATICAL PHYSICS II

Course title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Mathematical Physics II DSC – 4	4	3	0	1	Class XII Pass	-----

LEARNING OBJECTIVES

The emphasis of course is on applications in solving problems of interest to physicists. The course will also expose students to fundamental computational physics skills enabling them to solve a wide range of physics problems. The skills developed during course will prepare them not only for doing fundamental and applied research but also for a wide variety of careers.

LEARNING OUTCOMES

After completing this course, student will be able to,

- Use curvilinear coordinates to solve problems with spherical and cylindrical symmetries
- Represent a periodic function by a sum of harmonics using Fourier series
- Obtain power series solution of differential equation of second order with variable coefficient using Frobenius method
- Understand the properties and applications of Legendre and Hermite polynomials
- Learn about gamma and beta functions and their applications
- In the laboratory course, the students will learn to
    - Apply appropriate numerical method to solve selected physics problems both using user defined and in-built functions from Scilab/ Python
    - Solve non-linear equations
    - Perform least square fitting of the data taken in physics lab by user defined functions.
    - Interpolate a data by polynomial approximations
    - Generate and plot a function by its series representation
    - Generate and plot Legendre polynomials and verify their properties.
    - Generate and plot Hermite polynomials and verify their properties.
    - Numerically integrate a function and solve first order initial value problems numerically.

SYLLABUS OF DSC – 4

UNIT – I (13 Hours)

Orthogonal Curvilinear Coordinates: Orthogonal Curvilinear Coordinates. Scale factors, element of area and volume in spherical and cylindrical coordinate Systems. Derivation of Gradient, Divergence, Curl and Laplacian in Spherical and Cylindrical Coordinate Systems

UNIT – II (10 Hours)

Fourier Series: Periodic functions, Orthogonality of sine and cosine functions, Convergence of Fourier series and Dirichlet Conditions (Statement only), Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients, Even and odd functions and their Fourier expansions (Fourier Cosine Series and Fourier Sine Series), Parseval's Identity.

UNIT – III (12Hours)

Frobenius Method and series solution of Differential Equations: Singular Points of Second Order Linear Differential Equations and their importance, Frobenius method for finding series solution and its applications, Legendre Differential Equations and its solution. Properties of Legendre Polynomials: Rodrigues Formula, Generating Function, Orthogonality of Legendre Polynomials, Simple recurrence relations, Expansion of function in a series of Legendre Polynomials.

UNIT – IV (10 Hours)

Hermite Differential Equations and its solution. Properties of Hermite Polynomials: Rodrigues Formula, Generating Function, Orthogonality of Hermite Polynomials, Simple recurrence relations, Expansion of function in a series of Hermite Polynomials
Some Special Integrals: Beta and Gamma Functions and relation between them, Expression of Integrals in terms of Gamma and Beta Functions.

References:
Essential Readings:
1) Mathematical Methods for Scientists and Engineers, D. A. McQuarrie, 2003, Viva Book.
2) Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
3) Essential Mathematical Methods, K. F. Riley and M. P. Hobson, 2011, Cambridge Univ. Press.
4) Vector Analysis and Cartesian Tensors, D. E. Bourne and P. C. Kendall, 3 Ed., 2017, CRC Press.
5) Vector Analysis, Murray Spiegel, 2nd Ed., 2017, Schaum's Outlines Series.
6) Fourier analysis: With Applications to Boundary Value Problems, Murray Spiegel, 2017, McGraw Hill Education.
7) Differential Equations, George F. Simmons, 2006, Tata McGraw-Hill.
8) Mathematical Methods for Physicists, G. B. Arfken, H. J. Weber, F. E. Harris, 7 Ed., 2013, Elsevier.

Additional Readings:
1) Introduction to Electrodynamics, Chapter 1, David J. Griffiths, 4 Ed., 2017, Cambridge University Press.
2) The Feynman Lectures on Physics, Volume II, Feynman, Leighton and Sands, 2008, Narosa Publishing House.
3) Advanced Engineering Mathematics, D. G. Zill and W. S. Wright, 5 Ed., 2012, Jones and Bartlett Learning.
4) Introduction to Vector Analysis, Davis and Snider, 6 Ed., 1990, McGraw Hill.
5) Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.
6) Mathematical Physics, A. K. Ghatak, I. C. Goyal and S. J. Chua, 2017, Laxmi Publications Private Limited.

PRACTICAL COMPONENT – 　　　　　　　　　　　　　　　　　　　　**30 Hours**

The aim of this laboratory is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics. The course will consist of practical sessions and lectures on the related theoretical aspects of the laboratory. Assessment is to be done not only on the programming but also on the basis of formulating the problem.
- **Every student must perform 8 programs covering atleast one programme per unit.**
- The list of recommended programs is suggestive only. Students should be encouraged to do more practice. Emphasis should be given to formulate a physics problem as mathematical one and solve by computational method
- The implementation can be either in Python/ C++/ Scilab

Unit 1: Root Finding: Bisection, Newton Raphson and secant methods for solving roots of equations, Convergence analysis.
(a) Determine the depth up to which a spherical homogeneous object of given radius and density will sink into a fluid of given density.
(b) Solve transcendental equations like $\alpha = \tan(\alpha)$.
(c) To approximate nth root of a number up to a given number of significant digits.

Unit 2: Least Square fitting: Algorithm for least square fitting and its relation to maximum likelihood for normally distributed data.
a) Make a function for least square fitting, use it for fitting given data (x, y) and estimate the parameters a, b as well as uncertainties in the parameters for the following cases.
   i.　Linear $(y = ax + b)$
   ii.　Power law $(y = ax^b)$
   iii.　Exponential $(y = ae^{bx})$
b) Weighted least square fitting of given data (x, y) with known error/uncertainty-values using user defined function.

Unit 3: Generating and plotting of a function using series representation:
a) To approximate the elementary functions (e.g. exp(x), sin(x), cos(x), ln(1+x), etc.) by a finite number of terms of Taylor's series and discuss the truncation error. To plot the function as well the nth partial sum of its series for various values of n on the same graph and visualise the convergence of series.

b) Generating and plotting Legendre Polynomials using series expansion and verifying recurrence relation

c) Generating and plotting Hermite Polynomials using series expansion and verifying recurrence relation

Unit 4: **Interpolation:** Concept of Interpolation, Lagrange form of interpolating polynomial,

(a) Write program to determine the unique polynomial of a degree n that agrees with a given set of $(n+1)$ data points (x_i, y_i) and use this polynomial to find the value of y at a value of x not included in the data.

(b) Generate a tabulated data containing a given number of values $(x_i, f(x_i))$ of a function $f(x)$ and use it to interpolate at a value of x not used in table.

Unit 5: **Numerical Integration:** Newton Cotes Integration methods (Trapezoidal and Simpson rules) for definite integrals, derivation of composite formulae for these methods and discussion of error estimation.

(a) Given acceleration at equidistant time values, calculate position and velocity and plot them.

(b) Use integral definition of ln(x) to compute and plot ln(x) in a given range. Use trapezoidal, Simpson and Gauss quadrature methods and compare the results.

(c) Verify the rate of convergence of the composite Trapezoidal and Simpson methods by approximating the value of a given definite integral.

(d) Verify the Orthogonality of Legendre Polynomials.

(e) To evaluate the Fourier coefficients of a given periodic function (e.g. square wave, triangle wave, half wave and full wave rectifier etc.). To plot the function as well the nth partial sum of its series for various values of n on the same graph and visualise the convergence of series. Study of Gibbs phenomenon.

(f) Verify the properties of Dirac Delta function using its representation as a sequence of functions.

Unit 6: Numerical Solutions of Ordinary Differential Equations: Euler, modified Euler, and Runge-Kutta (RK) second and fourth order methods for solving first order initial value problems (IVP) and system of first order differential equations,

(a) Solve given first order differential equation (Initial value problems) numerically using Euler RK2 and RK4 methods and apply to the following physics problems:
  i.   Radioactive decay
  ii. Current in RC and LR circuits with DC source
  iii. Newton's law of cooling

(b) Write a code to compare the errors in various numerical methods learnt by solving a first order IVP with known solution.

(c) Solve a system of first order IVP numerically using Euler and Runge-Kutta methods. Application to physical problems.

References (for Laboratory work):

1) Documentation at the Python home page (https://docs.python.org/3/) and the tutorials there (https://docs.python.org/3/tutorial/).
2) Documentation of NumPy and Matplotlib: https://numpy.org/doc/stable/user/ and https://matplotlib.org/stable/tutorials/
3) Computational Physics, Darren Walker, 1st Edn., Scientific International Pvt. Ltd (2015).
4) Elementary Numerical Analysis, K. E. Atkinson, 3rd Edn., 2007, Wiley India Edition.
5) An Introduction to Computational Physics, T. Pang, Cambridge University Press (2010).
6) Introduction to Numerical Analysis, S. S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.
7) Applied numerical analysis, Cutis F. Gerald and P. O. Wheatley, Pearson Education, India (2007).
8) Numerical Recipes: The art of scientific computing, William H. Press, Saul A. Teukolsky and William Vetterling, Cambridge University Press; 3rd edition (2007)
9) Computational Problems for Physics, R. H. Landau and M. J. Páez, 2018, CRC Press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – DSC - 8: THERMAL PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Thermal Physics DSC – 8	4	2	0	2	Class 12th Pass	NIL

LEARNING OBJECTIVES

This course deals with the relationship between the macroscopic and microscopic properties of physical systems in equilibrium. It reviews the concepts of thermodynamics learnt at school from a more advanced perspective and how to develop them further to build new concepts. The course gives an understanding about the fundamental laws of thermodynamics and their applications to various systems and processes. It also includes a basic idea about the kinetic theory of gases, transport phenomena involved in ideal gases, phase transitions and behaviour of real gases. The students will be able to apply these concepts to several problems on heat. The lab course deals with providing the knowledge of the concepts of thermodynamics studied in the theory paper with the help of experiments and give the students a hands-on experience on the construction and use of specific measurement instruments and experimental apparatuses used in the Thermal Physics lab, including necessary precautions.

LEARNING OUTCOMES

At the end of this course, students will be able to

- Comprehend the basic concepts of thermodynamics, the first and the second law of thermodynamics.
- Understand the concept of reversibility, irreversibility and entropy.
- Understand various thermodynamic potentials and their physical significance with respect to different thermodynamic systems and processes.
- Deduce Maxwell's thermodynamical relations and use them for solving various problems in Thermodynamics.
- Understand the concept and behaviour of ideal and real gases.
- While doing the practical, the students will have an opportunity to understand and hence use the specific apparatus required to study various concepts of thermodynamics. Hence, the student will be able to comprehend the errors they can encounter while performing the experiment and how to estimate them.

SYLLABUS OF DSC - 8

THEORY COMPONENT

Unit – I
Zeroth and First Law of Thermodynamics (5 Hours)
Fundamental idea of thermodynamic equilibrium and Zeroth Law of Thermodynamics, concept of work and heat, First law of Thermodynamics and its differential form, internal energy, applications of First law: General relation between C_P and C_v, work done during various processes (all four) and related problems, adiabatic lapse rate, Compressibility and Expansion Co-efficient for various processes.

Second law of Thermodynamics (5 Hours)
Reversible and Irreversible processes, Carnot engine and Carnot's cycle, Refrigerator, efficiency of Carnot engine and refrigerator, Second Law of Thermodynamics: Kelvin-Planck and Clausius statements and their equivalence, Carnot's theorem, Applications of Second Law of Thermodynamics in the light of Phase Change, Thermodynamic Scale of Temperature and its equivalence to Perfect Gas Scale.

Entropy (5 Hours)
Concept of Entropy, Entropy changes in Reversible and Irreversible processes with examples, Clausius Theorem, Clausius inequality, Second Law of Thermodynamics in terms of Entropy. Temperature-Entropy diagrams for Carnot's cycle and related problems, Entropy of perfect and real gases, conceptual problems related to Entropy during a Phase Change, Nernst Heat Theorem: Unattainability of Absolute Zero and Third Law of Thermodynamics.

Real Gases (3 Hours)
Behaviour of Real Gases: Deviations from the ideal gas equation, Andrew's experiments on CO_2 Gas, Virial equation, Continuity of liquid and gaseous states, Boyle temperature, Van der Waals equation of state for real gases (derivation not required).

Unit – II
Thermodynamic Potentials and Maxwell's Relations (12 Hours)
Basic concept of Thermodynamic Potentials, Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy, Magnetic work and basic idea about cooling due to adiabatic demagnetization, Phase Transitions : First order and Second order Phase Transitions with examples, Clausius Clapeyron Equation, Ehrenfest Equations, Derivation of Maxwell's Thermodynamic Relations and their applications in Clausius Clapeyron Equation, value of $C_P – C_v$, TdS equations, Energy equations, evaluation of C_P /C_v and Ratio of Adiabatic to Isothermal elasticity.

References:

Essential Readings:
1) Heat and Thermodynamics: M. W. Zemansky and R. Dittman, Tata McGraw-Hill, 1981
2) Thermal Physics: S. C. Garg, R. M. Bansal and C. K. Ghosh, 2nd Edition, Tata McGraw-Hill.
3) Thermodynamics, Kinetic Theory and Statistical Thermodynamics: Sears and Salinger, Narosa, 1988
4) Concepts in Thermal Physics: Blundell and Blundell, 2nd Edition, Oxford University Press, 2009
5) Thermal Physics, A. Kumar and S. P. Taneja, R. Chand Publications, 2014
6) A Text Book of Heat and Thermodynamics for Degree Students, J. B. Rajam, S. Chand, 1981

Additional Readings:
1) An Introduction to Thermal Physics: D. Schroeder, Oxford University Press (earlier published by Pearsons), 2021
2) Thermal Physics: C. Kittel and H. Kroemer, 2nd Edition, W.H. Freeman, 1980
3) Heat, Thermodynamics and Statistical Physics, Brij Lal, N. Subrahmanyam and P. S. Hemne, S. Chand and Company
4) Thermal Physics: Concepts and practices, A. L. Wasserman, Cambridge University Press, 2012
5) Fundamentals of Thermal and Statistical Physics, Frederick Reif, McGraw-Hill, 1965

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

At least seven experiments to be done from the following:

1) To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
2) To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.
3) To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method using steam or electrical heating.
4) To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT) using Carey Foster's Bridge.
5) To determine the Temperature Coefficient of Resistance using Platinum Resistance Thermometer (PRT) by Callender-Griffith Bridge.
6) To study the variation of thermo-e.m.f. of a thermocouple with difference of temperature of its two junctions using a null method.
7) To calibrate a thermocouple to measure temperature in a specified range by direct method and/or by using Op Amp and to determine Neutral Temperature.
8) To determine the coefficient of thermal conductivity of Copper (Cu) by Angstrom's method.

References (for Laboratory Work):
1) Advanced Practical Physics for students: B. L. Flint and H. T. Worsnop, Asia Publishing House, 1971

2) A Text Book of Practical Physics : Indu Prakash and Ramakrishna, 11th Edition, Kitab Mahal

3) Advanced level Practical Physics: Nelkon and Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers

4) An Advanced Course in Practical Physics: D. Chattopadhyay and P. C. Rakshit, New Central Book Agency, 1990

5) Practical Physics: G. L. Squires, Cambridge University Press, 1985

6) B. Sc Practical Physics: Harnam Singh, P. S. Hemne, revised edition 2011, S. Chand and Co.

7) B. Sc Practical Physics: C. L. Arora, 2001, S. Chand and Co.

8) B.Sc. Practical Physics: Geeta Sanon, R. Chand and Co.