UNIVERSITY OF CALCUTTA

Notification No. CSR/50/2024

It is notified for information of all concerned that in terms of the provisions of Section 54 of the Calcutta University Act, 1979, (as amended), and, in the exercise of her powers under 9(6) of the said Act, the Vice-Chancellor has, by an order dated 23.07.2024 approved the syllabus for semester-3 to 6 of Physics (Four-year Honours & Honours with Research and 3-year MDC) courses of studies under CCF, 2022, under this University, as laid down in the accompanying pamphlet.

The new CSR shall take effect from semester-3 of Physics (4-year Honours & Honours with Research and 3-year MDC) courses of studies under CCF, which was introduced from the academic session 2023-2024.

01/8/2024

Prof.(Dr.) Debasis Das

Registrar

SENATE HOUSE

Kolkata-700073

01.08.2024

Syllabus for Undergraduate Course in Physics
(Semesters 3 to 6)

Contents

Syllabus for the Undergraduate (B.Sc.) course in Physics (Major)

The structure of the revised syllabus for the B.Sc. course in Physics (Semesters 3 to 6) is as follows.

Each paper carries 4 Credits, equivalent to 100 marks.

Th: Theory, Pr: Practical, Tut: Tutorial

For students with Physics Major

Semester	Paper code	Paper name	Credit
Semester 3	DSC-3	Waves and Optics	Th: 3, Pr: 1
	DSC-4	Mathematical Physics I	Th: 3, Pr: 1
	SEC-3	Arduino / Introductory Data Analysis*	Th: 1, Pr: 3
Semester 4	DSC-5	Modern Physics	Th: 3, Pr: 1
	DSC-6	Electromagnetism	Th: 3, Pr: 1
	DSC-7	Mathematical Physics II	Th: 3, Pr: 1
	DSC-8	Classical Mechanics & Special Theory of Relativity	Th: 3, Pr: 1
Semester 5	DSC-9	Analog Electronics	Th: 3, Pr: 1
	DSC-10	Nuclear & Particle Physics	Th: 3, Tut: 1
	DSC-11	Quantum Mechanics	Th: 3, Pr: 1
	DSC-12	Thermal Physics and Statistical Mechanics	Th: 3, Pr: 1
Semester 6	DSC-13	Digital Electronics	Th: 3, Pr: 1
	DSC-14	Solid State Physics	Th: 3, Pr: 1
	DSC-15	Atomic, Molecular, and Laser Physics	Th: 3, Tut: 1

1 Semester 3

DSC-3 : Waves and Optics

Theory [3 Credits]

1. **Oscillations (4) •**
   Differential equation of simple harmonic oscillation and its solution. Kinetic energy, potential energy, total energy and their time average values. Damped and forced oscillations: Transient and steady states, resonance, sharpness of resonance; power dissipation and Quality Factor.

2. **Superposition of Harmonic Oscillations (3) •**
   Superposition of two collinear Harmonic oscillations having equal frequencies and different frequencies (beats). Superposition of two Perpendicular Harmonic Oscillations for phase difference $\delta = 0, \pi, 2\pi$: Graphical and analytical methods, Lissajous' figures with equal and unequal frequency and their uses.

*The student has to opt for one of them.

3. **Wave motion (2) •**
   Plane and spherical waves. Longitudinal and transverse waves. Plane progressive (travelling) waves. Wave equation for travelling waves. Particle and wave velocities.

4. **Superposition of harmonic Waves (7) •**
   Velocity of transverse vibrations of stretched strings; standing (stationary) waves in a string: fixed and free ends (analytical treatment). Changes with respect to position and time. Energy of vibrating string. Transfer of energy. Normal modes of stretched strings. Plucked and struck strings, Superposition of N harmonic waves. Phase and group velocities.

5. **Fermat's Principle (2) •**
   Fermat's principle, laws of reflection and refraction at a plane and curved surface.

6. **Interference (12) •**
   Huygens principle, division of amplitude and wavefront. Young's double slit experiment. Fresnel's Biprism. Phase change on reflection: Stokes' treatment. Interference in thin films: parallel and wedge shaped films. Fringes of equal inclination (Haidinger fringes); Fringes of equal thickness (Fizeau fringes). Newton's Rings: Measurement of wavelength and refractive index. Michelson interferometer (no detailed theory required), Fabry-Perot interferometer. temporal and spatial coherence.

7. **Diffraction (10) •**
   Fraunhofer diffraction: Single slit, double slit and diffraction grating. Resolving power of grating. Rayleigh criterion for resolution. Circular aperture (qualitative discussion only). Fresnel diffraction: Fresnel's half-period zones for plane wave. Explanation of rectilinear propagation of light. Theory of a Zone Plate: Multiple foci of a Zone Plate.

8. **Polarization (10) •**
   Description of linear, circular and elliptical polarization. Propagation of electromagnetic waves in birefringent medium, polarization in uniaxial crystals. Double refraction. Polarization by double refraction. Nicol prism. Ordinary and extraordinary refractive indices. Phase Retardation plates: Quarter-wave and Half-wave plates. Production and analysis of polarized light, Rotatory polarization, Biot's laws for rotatory polarization. Fresnel's theory of optical rotation. Calculation of angle of rotation. Specific rotation.

Recommended reading

1. The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.

2. Advanced Acoustics, D. P. RayChaudhuri, 1981, Chayan Publisher.

3. Vibrations And Waves, A. P. French, 2003, CBS.

4. Optics, 4th Edn., Eugene Hecht, 2014, Pearson Education Limited.

5. Optics, Ajoy Ghatak, 7th Edn, 2020, Tata McGraw-Hill.

6. Waves: Berkeley Physics Course, vol. 3, Francis Crawford, 2007, Tata McGraw-Hill.

7. Fundamentals of Optics, F.A. Jenkins & H.E. White, 1981, McGraw- Hill.

8. Introduction to Optics, F.L. Pedrotti, L.S. Pedrotti, L.M. Pedrotti, 2014, Pearson Education.

9. Principles of Optics, Max Born & Emil Wolf, 7th Edn., 1999, Pergamon Press.

Practical [1 Credit]

1. To determine the frequency of an electric tuning fork by Melde's experiment and verify $\lambda^2 - T$ law.

2. To study the variation of refractive index of the Material of a prism with wavelengths and hence the Cauchy constants using mercury/helium source.

3. To determine wavelength of sodium light using Fresnel Biprism.

4. To determine wavelength of sodium light/radius of plano convex lens using Newton's Rings.

5. Measurement of the spacing between the adjacent slits in a grating by measuring $\sin\theta$ vs wavelength graph of a certain order of grating spectra.

6. To study the specific rotation of optically active solution using polarimeter.

Recommended reading

1. B.Sc. Practical Physics, C.L. Arora, 2010, S Chand and Company Limited.

2. Advanced Practical Physics, Vol 1, B. Ghosh, K.G.Majumdar, Shreedhar Publishers.

3. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency (P) Ltd.

DSC-4 : Mathematical Physics I

Theory [3 Credits]

1. **Convergence of infinite series (4) •**
   Convergence of power series. Idea of interval of convergence . Different convergence tests of power series: D'Alembert's ratio test, Cauchy's root test, Integral test. Alternating series test. Absolute and conditional convergence.

2. **Fourier Series (6) •**
   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. Applications. Summing of Infinite Series. Term-by-Term differentiation and integration of Fourier Series. Parseval Identity.

3. **Fourier Transform (6) •**
   Fourier Integral theorem. Fourier Transform (FT) with examples. FT of trigonometric, Gaussian, finite wave train, and other functions. Inverse Fourier transform, Properties of FT (translation, change of scale, complex conjugation, etc.). Parseval's identity. Applications of FT in single slit, double slit, rectangular aperture and N-slit grating.

4. **Partial Differential Equations (8) •**
   Solutions to partial differential equations using separation of variables: Solutions of Laplace's equation in problems with cartesian and spherically symmetric cases only. Wave equation and its solution for vibrational modes of a stretched string, Diffusion Equation in one dimension.

5. **Introduction to Probability (8) •**
   Probability for discrete events, and combined probability for uncorrelated events. Mean and variance. Independent random variables: Sample space and Probability distribution functions. Binomial, Gaussian, and Poisson distribution with examples. One dimensional random walk.

6. **Dirac δ-function (4) •**
   Definition of Dirac δ-function. Delta function as limit of different delta-sequence functions. Properties of δ-function: $\delta(-x)$, $\delta(f(x))$. Derivative of the step function. Fourier transform of δ-function. Two- and three-dimensional δ-function. Fourier transform of three-dimensional Coulomb potential, evaluation of $\nabla^2(1/r)$.

7. **Some special integrals (4) •**
   Beta and Gamma functions and relation between them. Expression of integrals in terms of Gamma functions. Error function (probability integral).

8. **Numerical Analysis I (10) •**
   Approximation in numerical computation: Truncation and rounding errors, Fixed and floating-point arithmetic, Propagation of errors: errors in normal distribution as quadrature (uncorrelated) .
   Numerical solution of Algebraic equation: Bisection method, Newton-Raphson method.
   Interpolation: Finite difference operators, Newton (Gregory) forward and backward interpolation, Lagrange's Interpolation.
   Numerical integration: Trapezoidal rule, Simpson's 1/3 rule.
   System of linear algebraic equations: Direct methods: Gaussian elimination; Iterative methods: Gauss-Jacobi method, Gauss-Seidel method. Some qualitative discussion on matrix inversion technique.
   Numerical solution of ordinary differential equation: Euler's method, Runge-Kutta methods (order two and four).
   Curve fitting: Curve fitting by the method of least squares. Fitting of curves of the form $y = ax + b$, $y = ax^b$ and $y = ax^2 + bx + c$.

Recommended reading

1. Mathematical Methods for Physicists: Arfken, Weber, 2005, Harris, Elsevier.

2. Fourier Analysis by M.R. Spiegel, 2004, Tata McGraw-Hill.

3. Differential Equations, George F. Simmons, 2006, Tata McGraw-Hill.
4. Differential Equations, S.L. Ross, 2007, Wiley.
5. Mathematical Physics, P.K. Chattopadhyay,2014, New Academic Science.
6. Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd ed., 2006, Cambridge University Press.
7. Fourier Series and Boundary Value Problems , J.W. Brown and R.V. Churchill, 2017, McGraw Hill Education.
8. Introduction to Mathematical Physics, Charlie Harper, 1978, PHI Learning Pvt. Ltd.
9. Mathematical methods in the Physical Sciences, M. L. Boas, 2005, Wiley.

Practical [1 Credit]

1. Introduction to numpy
    - the numpy array
        - properties: size, shape, ndim, dtype
        - creating arrays: zeros, one(), full(), fill(), arange(), linspace(), logspace(), identity(), eye(),astype()
        - indexing and slicing arrays (view versus copy)
        - important array methods : reshape(), ravel(), flatten(), hstack() and vstack()
        - Element wise functions: native numpy functions,the vectorise() method
        - Aggregate functions: np.sum(), np.prod(), np.mean(), np.std(), np.var(), np.min(),np.max(), np.argmin(), np.argmax()
    - Using numpy for matrix operators (the 2D numpy array)
        - addition, multiplication(dot)
        - Gauss elimination (using partial pivoting) (numpy code): for evaluating the determinant, for solving linear equation
        - Gauss-Seidel method for solving system of linear equations (rearrangement of equations not required)
        - the numpy linalg module for solving equations and diagonalisation
    - Scientific Applications
        - Lagrange's Interpolation, Newton's forward and backward Interpolation
        - Numerical Integration using Trapezoidal and Simpson's $\frac{1}{3}$ rule (for given function and equispaced data)
        - Solution of first and second order ODE using Runge-Kutta method (both RK2 and RK4) (algorithm, numpy code and detailed theory required)
        - Curve fitting using numpy
2. Introduction to mathplotlib (Using the pyplot submodule, 2D Plot Only)
    - figure, axes, subplot

- plot(), scatter(), show()
- labels, legends, titles, styles, ticks
- dynamically updating curves
- saving graphs

Recommended reading

1. Numerical Methods, Arun Kr Jalan, Utpal Sarkar, 2015, University Press
2. Scientific Computing in Python. Abhijit Kar Gupta, 2022, Techno World
3. Physics in Laboratory including python Programming (Semester III), Mandal, Chowdhuri, Das, Das, 2019, Santra Publication
4. Mathplotlib Plotting Cookbook, Alexandre Devert, 2014, PACKT Publishing
5. Programming for Computation-Python, Svein Linge, Hans Petter Lantangen, Springer
6. Numerical Python, Robert Johansson, 2018, Apress Publication
7. Introduction to Numerical Analysis, S.S. Sastry, 5th Edn. , 2012, PHI Learning Pvt. Ltd
8. Elementary Numerical Analysis, K.E. Atkinson, 3rd Edn., 2007, Wiley India Edition
9. An Introduction to computational Physics, T.Pang, 2nd Edn., 2006,Cambridge Univ. Press
10. Computational Physics problem solving with Computers, Landau, Paez, Bordeianu, textbook in Python 3rd Edition, 2015, Wiley-VCH

SEC-3 : Arduino

Prerequisite (10)

1. **Basic Electronics •**
   Familiarity with fundamental electronic components like resistors, capacitors,diodes, and transistors is essential. Understanding concepts like voltage, current, resistance, and Ohm's law is crucial for working with circuits.

2. **Circuit Design •**
   Knowing how to design and analyze simple circuits is important. This includes understanding circuit diagrams, breadboarding, and connecting components properly.

3. **Programming Fundamentals •**
   Basic programming knowledge is necessary since Arduino programming involves writing code in C/C++. Understanding variables, loops, conditional statements, and functions is vital.

4. **Understanding Sensors and Actuators •**
   Arduino projects often involve interfacing with sensors (e.g., temperature, light, motion) and actuators (e.g., motors, LEDs). Understanding how these devices work and how to interface them with the Arduino is essential.

5. **Digital and Analog Signals •**
   Understanding the difference between digital and analog signals, as well as concepts like analog-to-digital conversion (ADC) and pulse-width modulation (PWM), is crucial for working with Arduino.

6. **Serial Communication •**
   Knowing how to communicate between the Arduino and other devices (e.g.,computers, sensors) via serial communication (e.g., UART, I2C, SPI) is important for more advanced projects.

7. **Problem-Solving Skills •**
   Being able to troubleshoot and debug circuits and code is essential. This involves logical thinking and the ability to break down problems into smaller, more manageable parts.

Introduction of Microcontroller & Arduino (5)
Basic Idea about microcontroller; Introduction to Arduino: Brief history of the Arduino; Pin configurations of the board Arduino Uno. Brief idea about Arduino-nano/Arduino R4 Wi-Fi/Arduino MRGA. Sources of constant voltages 5 volt/3.3 volt and ground and corresponding pins of the respective boards. PWM and idea of duty cycle.
Arduino Programming (10)

1. Setting up the arduino board. Installation of IDE inPC/ laptop for Arduino programming (Sketch).

2. Program structure: Data types, variables, constants, operators, control statements, loops, functions, string. Conditional like if elseif; for and while loop. Idea about global variable and local variable. Use of serial monitor for input/output and serial plotter for observation of variation of data.

3. Some Basic Operations: (i) Binary operation through HIGH/LOW status of digital pin. Operation on inbuilt LED/ LED connected externally in series with a resistance e.g.,blinking. (ii) Sending analog voltage. Use of analog pins. Changing brightness of an LED. (iii) Measurement of voltage through appropriate pins

Sample experiments/Projects: [any 10] (25)

1. Attach an LDR (light dependent resistor) to Arduino Uno and employ Arduino Sketch to program it for detecting ambient light levels in the room/environment. When the light falls below a designated threshold, activate a lamp accordingly.

2. Connect an LDR (light dependent resistor) in series with a resistor to create a potential divider circuit. Place an LED facing the LDR to adjust its brightness. Establish a setup where the LED's brightness can be adjusted. Connect terminals across the resistor to Arduino Uno and utilize Arduino Sketch to program it for monitoring the voltage changes corresponding to the LED brightness variation. Display these voltage changes on the serial monitor.

3. Connect an ultrasonic distance sensor (HC-SR04) to Arduino Uno and utilize Arduino Sketch to program the measurement of object distance from the sensor and display it on the serial monitor.

4. Connect an IR sensor (TSOP1838) to Arduino Uno and utilize Arduino Sketch to detect Hex code generated from a TV remote for different button and print them on serial monitor.

5. Connect an HR-SC501 passive infrared (PIR) sensor to Arduino Uno and utilize Arduino Sketch to code for detecting movement in front of the PIR sensor. Illuminate an LED to indicate the detected movement

6. Construct the experimental set up for studying simple pendulum and hence determine the acceleration's due to gravity using appropriate sensor.

7. Attach a Seven Segment Display to Arduino Uno and utilize Arduino Sketch to exhibit a counter that increments from 0 to 9, pausing for 2 seconds between each increment, and continues displaying the count until a key is pressed to halt it. Employ one key to reset the count and another to initiate and halt the counting process.

8. Connect a 1.8-inch TFT/LCD to Arduino Uno and utilize Arduino Sketch to develop a program that print texts and data on that TFT/LCD.

9. Attach a Seven Segment Display to Arduino Uno and utilize Arduino Sketch to exhibit a counter that increments from 0 to 9, pausing for 2 seconds between each increment, and continues displaying the count until a key is pressed to halt it. Employ one key to reset the count and another to initiate and halt the counting process.

10. Connect a Dot Matrix Display to Arduino Uno and employ Arduino Sketch to showcase all numbers from 0 to 9 and the entire English alphabet, both in upper and lower case.

11. Connect a temperature and humidity module such as DHT-11/22, LM35DZ, or DS18B20/LM75 to Arduino Uno and utilize Arduino Sketch to code for reading temperature and humidity. Display the data either on the serial monitor or as a plotted graph showcasing the captured readings from the sensor over a specified duration.

12. Attach an LM393 sound sensor to Arduino Uno and employ Arduino Sketch to program the detection of sound levels surpassing a set threshold, adjustable via the sensor's potentiometer. Within the sketch, illuminate an LED when sound exceeds the threshold, and indicate on the serial monitor whether a new sound has been detected or if the previous sound has ceased.

13. Attach a D.C. motor RS-775 to Arduino Uno along with a motor driver L298N. Write Arduino Sketch to control the speed of the motor.

14. Attach a stepper motor REES-52 UNL2003 5V to Arduino Uno along with a motor driver UNL2003. Write Arduino Sketch to rotate the motor at 10 0 angle after 5 second interval. control the speed of the motor. Employ one key to stop and another to initiate the rotation.

15. Use of Bluetooth module HC-05 and operation through smartphone or voice. [Use available smartphone app: ARDUINO BLUECONTROL/BLUETOOTH SERIAL CONTROLLER].

16. Construct data logger for studying charging and discharging of RC circuit.

Instruments, Equipments, devices etc.

1. **Microcontroller Kit •**
   Arduino Uno

2. **Power Supply •**
   (i) DC +5V Regulated Power supply with max 1-amp current capacity/Custom built power supply with +5V, −5V, +12V, −12V etc, (ii) Transformer 12-0-12, (iii) Rectifier diodes: 1N4007/1N5402/BY126, (iv) Power filters: 1000mfd 35V, (v) Power regulators: 7805, 7905, 7812, 7912 or LM317, LM33.

3. **Sensors •**
   (i) Temperature sensor: DS18B20/LM75/LM35DZ, (ii) Temperature and Humidity sensor: DHT-11/22, (iii) Ultrasonic Sensor HC-SR04, (iv) IR sensor TSOP1838, (v) LDR (Light dependent resistor): TL01289, (vi) Sound sensor: LM393, (vii) Proximity sensor: HR-SC501, (viii) Hall Effect Sensor-ACS712: Current Sensor AC/DC.

4. **Display •**
   (i) Seven Segment Display-CA/CC (LT542/LT543), (ii) 16x2 HD44780 Character LCD Module, 16x2 JHD 162A LCD with 11C/12C serial interface adapter, (iii) 1.8 TFT Display, (iv) 8×8 Dot Matrix with MAX7219. (v) OLED display: SSD1306.

5. **Modules •**
   (i) 5V, 2 Channel relay module, (ii) Magnetic Reed Switch, (iii) Membrane Keypad: Hex or Numeric keypad, (iv) Bluetooth module HC-04/05/06, (v) L293D motor control.

6. **Motors & Semiconductor devices •**
   (i) Geared 12V DC motors, (ii) Stepper Motor, (iii) UNL 2003, (iv) UNL 2008, (v) LM293D H bridge motor driver, (vi) 74LS244/245, (vii) 7406.

Recommended reading

1. Programming Arduino Getting Started with Sketches, Simon Monk, McGraw Hill Education, second edition.

2. Arduino Cookbook, Michael Margolis, 2011, O'Reilly Media

3. Getting Started with Arduino, Massimo Banzi, 2009, O'Reilly Media

4. Arduino as a tool for physics experiments, Giovanni Organtini 2018 J. Phys.: Conf. Ser. 1076 012026

5. `https://www.arduino.cc/en/Guide/HomePage`

6. Physics Today 66, 11, 8 (2013) `https://doi.org/10.1063/PT.3.2160`

7. The Physics Teacher 52, 157 (2014) `https://doi.org/10.1119/1.4865518`

SEC-3 : Introductory Data Analysis

1. **Introduction to Data Analysis (5) •**
   Introduction: Introduction of data analysis, data analytics and data science: relations and differences. Idea of generation of data, data wearhouse and data product. Levels of data measurement (a) nominial (b) ordinal scale (c) interval scale and (d) ratio scale. Type of variables (a) categorical (b)numerical (i) discrete and (ii) continuous. Idea of population and samplings: utility of random sampling.

2. **Operations and Statistical Methods (10) •**
   Arrangement of data, grouped data, frequency distribution. Central tendency: Mean: mean, weighted mean, mean of grouped data, population mean and sample mean, Median: median of raw data, median of grouped data, Mode: mode of raw and grouped data, Quartile and Percentile. Dispersion of data: Mean Absolute Deviation, Variance, Standard Deviation, Range, Inter-quartile range, Coefficient of Variation. (Calculation on both population and sample data). Skewness: coefficient of skewness. Peakness of distribution: Leptokurtic, Mesokurtic and Platykurtic.

3. **Introduction to Pandas (20) •**
   Overview of Pandas and its importance in data analysis, Data Structures in Pandas, Series: Creation, manipulation, and indexing, DataFrame: Introduction, creation from various data sources (CSV, Excel, SQL), indexing, and basic operations. Data cleaning: Handling missing data (NaN values), data type conversion. Data transformation: Sorting, filtering, merging, joining, and concatenating datasets. Reshaping data: Pivot tables, stacking, and unstacking. Descriptive statistics: Summary statistics (mean, median, mode, variance, standard deviation), quantiles, and percentiles. Groupby operations: Aggregation, transformation, and filtering based on group properties.

4. **Introduction to NumPy (8) •**
   Overview of NumPy and its importance in numerical computing., NumPy Arrays, Creating arrays: 1D, 2D, and multidimensional arrays., Array attributes: Shape, size, data type, indexing and slicing arrays, Element-wise operations: Arithmetic, comparison, logical, array broadcasting. Array manipulation, reshaping arrays, joining and splitting arrays, sorting arrays, array Indexing and selection.

5. **Matplotlib and Seaborn (7) •**
   Overview of Matplotlib and its role in data visualization., Line plots: Creating simple line plots, customizing colors, markers, and line styles. Scatter plots: Visualizing relationships between variables, customization options. Bar plots: Creating vertical, horizontal, and grouped bar plots., Overview of Seaborn and its advantages over Matplotlib. Histograms: Visualizing distributions of continuous variables, Box plots: Visualizing distribution quartiles and outliers.

Recommended reading

1. Python for Data Analysis, Wes McKinney, O'Reilly

2. Pandas for Everyone Python Data analysis, Daniel Y Chen, Pearson

3. Hands on Data Analysis and visualization with Pandas, Purna Chandra Rao, Kathula, BPB Publication

4. Hands on Data Analysis with Numpy and Pandas, Curtis Miller, PACKT Publication

5. Scientific Computing in Python. Abhijit Kar Gupta, Techno World

6. https://pandas.pydata.org/docs/

2 Semester 4

DSC-5 : Modern Physics

Theory [3 Credits]

1. **Radiation and its nature (15) •**
   Black body Radiation, Planck's quantum hypothesis, Planck's constant (derivation of Planck formula is not required). Photoelectric effect and Compton scattering — light as a collection of photons. Davisson-Germer experiment. Bohr-Sommerfeld quantization of the form $\oint pdq = nh$. De Broglie wavelength and matter waves. Wave-particle duality. Wave description of particles by wave packets. Group and Phase velocities and relation between them. Probability interpretation: Normalized wave functions as probability amplitudes. Two-slit experiment with photons and electrons. Linear superposition principle as a consequence. Position measurement, γ-ray microscope thought experiment. Heisenberg uncertainty principle (Statement with illustrations). Impossibility of a trajectory of a particle.

2. **Basics of Quantum Mechanics (10) •**
   Quantum measurements- Deterministic vs probabilistic view points. Description of a particle using wave packets. Spread of the Gaussian wave-packet for a free particle in one dimension. Fourier transforms and momentum space wavefunction. Position-Momentum uncertainty. Simultaneous measurements: Compatible and incompatible observables and their relation to commutativity

3. **Schrödinger Equation (8) •**
   Schrödinger equation as a first principle. Probabilistic interpretation of wave function and equation of continuity (in 1-dimension). Time evolution of wave function . Stationary states. Time independent Schrödinger equation as an eigenvalue equation.

4. **Application to one dimensional systems (12) •**
   General discussion of bound states in an arbitrary potential: continuity of wave function, boundary conditions on wave functions and emergence of discrete energy levels. Particle in an infinitely rigid box: energy eigenvalues and eigenfunctions, normalization. Quantum mechanical tunnelling across a step potential and rectangular potential barrier, calculation of reflection and transmission probabilities. α-decay as an example. Application to one dimensional square well potential of finite depth (for bound states only).

5. **Quantum mechanics of simple harmonic oscillator (5) •**
   Setting up the eigenvalue equation for the Hamiltonian. Energy levels and energy eigenfunctions in terms of Hermite polynomials (Solution to Hermite differential equation may be assumed). Ground state, zero-point energy and uncertainty principle.

Recommended reading

1. Feynman Lectures Vol.3, R.P. Feynman, R.B. Leighton, M. Sands, 2008, Pearson Education.
2. Basic Quantum Mechanics, A.K.Ghatak , 2004, Macmillan.
3. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles, Resnick and Eisberg, 2014, Wiley.
4. Introduction to Quantum Mechanics, David J. Griffiths, 2018, Cambridge University Press
5. Quantum Physics, Stephen Gasiorowicz, 2007, John Wiley & Sons, Inc.
6. Six Ideas that Shaped Physics: Particle Behave like Waves, T.A.Moore, 2003, McGraw Hill.
7. Physics for scientists and Engineers with Modern Physics, Jewett and Serway, 2010, Cengage Learning.
8. Schaum's outline, Theory and Problems of Modern Physics, R. Gautreau and W. Savin, 2nd Edn, 2020, Tata McGraw-Hill Publishing Co. Ltd.
9. Quantum Mechanics, Bransden and Joachin, 2004, Pearson .
10. Principles of Quantum Mechanics, R. Shankar, 1994, Kluwer Academic/Plenum Publishers.

Practical [1 Credit]

1. Measurement of Plank constant using LED.
2. Determination of e/m of electrons by using bar magnet.
3. To study the photoelectric effect: variation of photocurrent versus intensity and wavelength of light.
4. To show the tunneling effect in tunnel diode using $I-V$ characteristics.
5. To study the diffraction pattern of a grating with the help of a LASER source and to determine its wavelength.

Recommended reading

1. B.Sc. Practical Physics, C.L. Arora, 2010, S. Chand And Company Limited
2. Practical Physics Vol 1 and Vol 2, B. Ghosh, K. G. Majumder, 2023, Sreedhar Publishers

DSC-6 : Electromagnetism

Theory [3 Credits]

1. **Alternating current (5) •**
   Mean and r.m.s. values of current and emf with sinusoidal wave form; LR, CR series and parallel LCR circuits, reactance, impedance, phase-angle, power dissipation in AC circuit-power factor, Resonance in a series and parallel LCR circuit, Q-factor.

2. **Electrostatics (3) •**
   Gauss' theorem of electrostatics: differential form. Multipole expansion in electrostatics. Dipole and quadrupole moment.

3. **Dielectric properties of matter (6) •**
   Dielectric in an external electric field. Electric Fields inside matter, Electric Polarisation, bound charges, displacement density vector, relation between $\boldsymbol{E}$, $\boldsymbol{P}$ and $\boldsymbol{D}$. Gauss's theorem in dielectrics, linear Dielectric medium, electric susceptibility and permittivity. Electrostatic boundary conditions for $\boldsymbol{E}$ and $\boldsymbol{D}$.

4. **Laplace's and Poisson equations (3) •**
   Laplace's and Poisson equations. Uniqueness Theorems. Earnshaw's theorem. Dirichlet Boundary value problems in electrostatics.

5. **Method of Images and its applications (4) •**
   Plane Infinite metal sheet, Semi-infinite dielectric medium and metal Sphere.

6. **Magnetostatics (6) •**
   Derivation of $\nabla.\boldsymbol{B} = 0$, $\nabla \times \boldsymbol{B} = \mu_0 \boldsymbol{J}$. Magnetic vector potential and magnetic dipole. Multipole expansion of vector potential for line currents. Magnetic field for magnetic dipole. Calculation for vector potential in simple cases (i) infinite straight wire (ii) Infinite Solenoid . Magnetic dipole moment for rotating rod, sphere, ring. Gyromagnetic ratio.

7. **Magnetic properties of matter (5) •**
   (a) Potential and field due to a magnetic dipole. Magnetic dipole moment. Force and torque on a magnetic dipole in a uniform magnetic field. (b) Magnetization, bound currents. Magnetic intensity $\boldsymbol{H}$. Relation between $\boldsymbol{B}$, $\boldsymbol{H}$ and $\boldsymbol{M}$. Linear media. Magnetic Susceptibility and Permeability. Boundary conditions for $\boldsymbol{B}$ and $\boldsymbol{H}$.

8. **Electromagnetic induction (3) •**
   Non-conservative nature of electric field. Faraday's law of induction: simple examples (*e.g.*: Motional EMF, Faraday disc); Lenz's law. Self and mutual inductances in simple cases, energy stored in inductors.

9. **Maxwell's equations (4) •**
   Maxwell's equations. Gauge transformations: Lorenz and Coulomb Gauge. Wave equations. Poynting Theorem and Poynting vector. Electromagnetic (EM) Energy Density.

10. **EM Wave Propagation in unbounded media (4) •**
    Plane EM waves through vacuum and isotropic dielectric medium, transverse nature of plane EM waves, refractive index and dielectric constant, wave impedance. Propagation through conducting media, relaxation time, skin depth.

11. **EM Wave in Bounded Media (7) •**
    Boundary conditions at a plane interface between two media. Reflection and Refraction of plane waves at plane interface between two dielectric media. Laws of reflection and refraction. Fresnel's formulae for perpendicular and parallel polarization cases, Reflection and transmission coefficients, Brewster's law. Total internal reflection, evanescent waves. Metallic reflection (normal incidence).

Recommended reading

1. Feynman Lectures Vol.2, R.P.Feynman, R.B.Leighton, M. Sands, 2008, Pearson Education.

2. Introduction to Electrodynamics, D.J. Griffiths, 4th Edn., 2015, Pearson Education.

3. Electricity and Magnetism, D.Chattopadhyay and P.C.Rakshit, 2011, New Central Book Agency, 2011.

4. Fundamentals of Electricity and Magnetism, B. Ghosh, 2015, Books and Allied (P) Ltd., 4th edition, 2015.

5. Electricity and Magnetism, Edward M. Purcell, 1986 McGraw-Hill Education.

6. Introduction to Advanced Electrodynamics, Kaushik Bhattacharya and Soumik Mukhopadhyay, 2021, Springer

7. Elements of Electromagnetics, M.N.O. Sadiku, 2010, Oxford University Press.

8. Classical Electromagnetism, Jerrold Franklin, 2007, Pearson Education.

Practical [1 Credit]

1. To study series LCR circuit characteristics: resonance curve for two different R, variation with C, Phase angle plot.

2. To study mutual inductance between two coils.

3. To find horizontal component of Earth's magnetic field using magnetometer.

4. To verify Malus law using a pair of polaroids.

5. To verify Fresnel's equation by the reflection on the surface of a prism with help of two polariods.

Recommended reading

1. Advanced Practical Physics, B. Ghosh, K. G. Majumder, 2023, Sreedhar Publication

2. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency (P) Limited

DSC-7 : Mathematical Physics II

Theory [3 Credits]

1. **Solution of 2nd order linear differential equations (15) •**
   Second order inhomogeneous differential equation; Linear independence of solutions: Wronskian, second solution. Singularity analysis at finite points. Power series solution of 2nd order differential equation. Frobenius method and its applications to differential equations. Legendre, Hermite Differential Equations. Properties of Legendre and Hermite Polynomials: Rodrigues Formula, Generating Function, Orthogonality and completeness relation (Statement only). Simple recurrence relations. Expansion of function in a series of Legendre Polynomials.

2. **Linear Vector Space (LVS) (5) •**
   Idea of LVS with 2-d and 3-d cartesian vectors. Introduction to bra and ket vectors. Definition of LVS with examples : 2-d , 3-d vectors, complex numbers, sinusoidal waveforms. Dual space. Inner product, Norm (defined in terms of inner product), Cauchy-Schwarz inequality, metric space. Linear independence and dependence of vectors. Completeness of a set of vectors. Dimension and basis. Orthogonality. Gram-Schmidt method for orthogonalization.

3. **Vectors (5) •**
   Vectors and scalars under rotation. Orthogonal curvilinear coordinates: Jacobian of transformation and its application to gradient, divergence, curl and Laplacian operators.

4. **Introduction to Tensor analysis(4) •**
   Definition of cartesian tensors in 3 dimensions. Transformation properties. Contraction of tensors in 3 dimensions.

5. **Matrices (15) •**
   Representation of linear operator in terms of 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. Similarity transformation. Invariance of trace and determinant under similarity transformation. Transformation of basis. Eigenvalues and eigenvectors (degenerate and non-degenerate). Commuting operators and simultaneous eigenvectors for non-degenerate and degenerate eigenvalues. Cayley-Hamilton Theorem. Diagonalization of matrices. Solutions of coupled linear ordinary homogeneous differential equations. Functions of a matrix, *e.g.*, exponential and trigonometric functions.

6. **Numerical Analysis II (6) •**
   Partial differential equation: Finite difference approximations to partial derivatives ($O(h^2)$). Solution of one dimensional heat conduction equation by explicit method. Qualitative idea of explicit and implicit methods. Laplace equation (2-d) using standard five point formula, Successive relaxation technique. Solution of 1-d Wave equation. Stability criterion — CFL condition (qualitative).

Recommended reading

1. Mathematical Methods for Physicists: Arfken, Weber, 2005, Harris, Elsevier
2. Differential Equations, S.L. Ross, 2007, Wiley
3. Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd ed., 2006, Cambridge University Press
4. Mathematical Methods of Physics. J. Mathews and R.L. Walker, 2004, Pearson
5. Mathematics for Physicists, P. Dennery and A.Krzywicki, 1967, Dover Publications.
6. Matrix Methods: An Introduction , R. Bronson, 1991, Academic Press
7. Vector Spaces and Matrices in Physics , M.C. Jain, 2018, Narosa.
8. Linear Algebra, S. Lipschutz and M.L.Lipson, Schaums Outline Series, 2009 McGraw Hill

Practical [1 Credit]

1. Introduction to Scipy:
   - Interpolation Using scipy.interpolate.lagrange
   - Numerical Integration using: scipy.integrate.quad, scipy.integrate.trapz, scipy.integrate.simps
   - Solving first order and 2nd order ODE by scipy.integrate.odeint().
   - Use of special functions taken from scipy.special. Plotting and verification of the properties of special functions. Orthogonality relations and recursion relations. (Legendre and Hermite Only)
2. Numerically handling improper integrals over infinite intervals over the range $\int_a^\infty$ correct up to given decimal place without using Scipy.
3. Numerically verifying the Gaussian integral result

$$\int_{-\infty}^{\infty} \exp\left(-ax^2 + bx + c\right) dx = \sqrt{\frac{\pi}{a}} \exp\left(\frac{b^2}{4a} + c\right)$$

4. Verifying that $\int_{a-x_1}^{a+x_2} f(x)\delta(x-a)\,dx = f(a)$
5. Evaluate the Fourier coefficients of a given periodic function using scipy.integrate.quad(). Examples: square wave, triangular wave, saw-tooth wave. Plot to see a wave form from scipy.signal and the constructed series along with.
6. Curve Fitting with user defined functions using scipy.optimize module
7. Solution of some basic PDEs
   - Boundary value problems. Finite discrete method with fixed step sizes. Idea of stability. Application to simple physical problems. Dirichlet's Boundary conditions only.

- Laplace equation $\frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial y^2} = 0$, on a square grid with specified potential at the boundaries.
- Wave equation in 1+1 dimension: $\frac{\partial^2\phi}{\partial t^2} = \lambda\frac{\partial^2\phi}{\partial x^2}$. Vibration of a string with ends fixed with given initial configurations: $\phi(x,0)$ and $\left.\frac{\partial\phi}{\partial t}\right|_{(x,0)}$.
- Heat equation in 1+1 dimension, $\frac{\partial u}{\partial t} = \alpha\frac{\partial^2 u}{\partial x^2}$ with specified value of temperature at the boundaries with given initial temperature at the boundaries with given initial temperature profile.

Recommended reading

1. Numerical Analysis, Mathematics of Scientific Computing, David Kincaid, Ward Cheney, Reprint First Indian Edition 2013, American Mathematical Society
2. Numerical Methods for Engineers, 2nd Edition, D.V. Griffiths and I.M. Smith, 2006, Chapman & Hall/CRC, Special Indian Edition
3. An Introduction to computational Physics, T.Pang, 2nd Edn., 2006,Cambridge Univ. Press
4. Scientific Computing in python, Avijit Kar Gupta, 2022, Techno World
5. Physics in Laboratory including python Programming (Semester III), Mandal, Chowdhuri, Das, Das, 2019, Santra Publication
6. Physics in Laboratory python Programming (Semester IV & V), Pradipta Kumar Mandal, 2020, Santra Publication
7. Computational Physics problem solving with Computers, Landau, Paez, Bordeianu, textbook in Python 3rd Edition, 2015, Wiley-VCH
8. Computational Methods for Physics, Joel Franklin, 2013, Cambridge University Press
9. Programming for Computation – Python, Svein Linge, Hans Petter Lantangen, 2016, Springer
10. Numerical Python, Robert Johansson, 2018, Apress Publication

DSC-8 : Classical Mechanics and Special Theory of Relativity

Theory [3 Credits]

1. **Non-inertial Systems (8) •**
   Non-inertial frames and idea of fictitious forces. Equation of motion (EOM) with respect to a uniformly accelerating frame. EOM with respect to a uniformly rotating frame: Centrifugal and Coriolis forces. Applications: Surface of rotating liquid, deflection of falling mass, cyclone.

2. **Rotational Dynamics (10) •**
   The rigid body: Constraints defining the rigid body. Degrees of freedom for a rigid body; Relation between angular momentum and angular Velocity: Moment of inertia tensor.

Calculation of moment of inertia for rectangular, cylindrical and spherical bodies. Equation of motion for rotation about a fixed axis. Principal Axes transformation. Transformation to a body fixed frame. EOM for the rigid body with one point fixed (Euler's equations of motion). Torque-free motion. Kinetic energy of rotation.

3. **Variational calculus in Physics (20) •**
   Basic ideas of functionals. Extremization of action as a basic principle in mechanics. Generalized coordinates, Constraint. Lagrangian formulation. Euler-Lagrange equations of motion for simple systems: harmonic oscillators, simple pendulum, spherical pendulum. Motion under Central force. Cyclic coordinates. Symmetries and conservation laws. Legendre transformations and the Hamiltonian formulation of mechanics. Canonical equations of motion. Applications to simple systems.

4. **Special theory of Relativity (12) •**
   Michelson-Morley Experiment and its outcome. Postulates of Special Theory of Relativity. Invariance of space-time interval. Derivation of Lorentz transformation equations. Length contraction. Time dilation. Simultaneity and order of events. Concept of causality. Relativistic transformation of velocity. Velocity addition. Relativistic dynamics. Energy-momentum dispersion relation. Massless particles. Mass-energy equivalence. Transformation of energy and momentum. Minkowski space-time [(ct, x, y, z) or (x, y, z, ct)] diagram.

Recommended reading

1. Introduction to Classical Mechanics With Problems and Solutions , D. Morin, Cambridge University Press
2. Classical Mechanics, A course of Lectures, A.K. Raychaudhuri, 1983, Oxford University Press
3. Classical Mechanics , N.C. Rana and P. Joag, 2017, McGraw Hill Education
4. Classical Mechanics, Goldstein, Poole and Safko, 2011, Pearson Education
5. Introduction to Special Relativity, R. Resnick, 2010, John Wiley and Sons
6. Introduction to Special Relativity , J.H. Smith, 2003, Dover Publications Inc
7. Introduction to Electrodynamics, D.J. Griffiths, 4th Edn., 2015, Pearson Education
8. Special Relativity: For the Enthusiastic Beginner, D. Morin, 2017, Createspace Independent Pub

Practical [1 Credit]

1. To determine the moment of inertia of a Flywheel.
2. To determine Young's modulus of the material of a rod by method of flexure.
3. To determine the elastic constants of the material of a wire by Searle's method.
4. To determine g using Bar Pendulum.

5. Study of simple pendulum ($x-t$, $v-t$, $x-v$ plot) using video analysis and modeling tool (Tracker software).

Recommended reading

1. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press
2. B.Sc. Practical Physics, C.L. Arora, 2010, S Chand and Company Limited
3. Physics in Laboratory, Mandal, Chowdhury, Das, Das, 2019, Santra Publication
4. Advanced Practical Physics Vol 1, B. Ghosh, K. G. Majumder, Sreedhar Publisher

3 Semester 5

DSC-9 : Analog Electronics

Theory [3 Credits]

1. **Circuits and network (DC) (4) •**
   Discrete components, active and passive components, ideal constant voltage and constant current sources. Network analysis: Kirchhoff's laws, Thevenin's and Norton's theorem, Superposition theorem. Maximum power transfer theorem.

2. **Semiconductor diodes and applications (9) •**
   P and N type semiconductors. Energy level diagram. Conductivity and mobility, concept of drift velocity. PN junction fabrication (simple idea only). Barrier formation in PN junction diode. Static and dynamic resistance. Current flow mechanism in forward and reverse biased diode. Drift velocity. Rectifier diode: Half-wave rectifiers. Centre-tapped and Bridge full-wave rectifiers, Calculation of Ripple Factor and Rectification Efficiency, L and C filter. Circuit and operation of clipping and clamping circuit; principle and structure of LEDs, photodiode, solar cell.

3. **Bipolar junction transistors and biasing (10) •**
   n-p-n and p-n-p transistors. Characteristics of CB, CE and CC configurations. Physical mechanism of current flow. Relations between the current gains of the three modes. Active, cut-off and saturation regions. DC load line and Q-point; Transistor biasing and stabilization circuits. Fixed bias, collector to base bias, emitter or self bias, voltage divider bias. Transistor as 2-port network. h-parameter equivalent circuit. Analysis of a single-stage CE amplifier using hybrid model. Input and output impedance.

4. **Field Effect transistors (3) •**
   JFET and MOSFET (both depletion and enhancement type) as a part of MISFET. Basic structure and principle of operations and their characteristics. Pinch off, threshold voltage and short channel effect.

5. **Regulated power supply (3) •**
   Load regulation and line regulation. Zener diode as a voltage regulator. Problem with the Zener regulator circuit. Requirement of feedback and error amplifier. Study of series regulated power supply using pass and error transistor assisted by Zener diode as a reference voltage supplier.

6. **Amplifiers (5) •**
   Transistor amplifier; CB, CE and emitter follower circuit and their uses. Load Line analysis of transistor amplifier. Classification of class A, B and C amplifiers with respect to placement to Q point. Frequency response of a CE amplifier. Role of series and parallel capacitors for cut off frequencies.

7. **Feedback amplifiers and OPAMP (8) •**
   Effects of positive and negative feedback. Voltage series, current series, voltage shunt and current shunt feedback and uses for specific amplifiers. Estimation of input impedance, output impedance, gain, stability; Operational Amplifiers (black Box approach): Characteristics of ideal and practical OP-AMP (IC 741), Open-loop and closed-loop voltage gain. Frequency response. CMRR. Slew rate and concept of virtual ground. Application of OP-AMP: DC application — inverting and non-inverting amplifiers, inverting and non-inverting adder, differentiator as subtractor, error amplifier, comparator, Schmidt trigger. AC applications: differentiator, integrator.

8. **Multivibrator (5) •**
   Transistor as a switch, Explanation using CE output characteristics. Construction and operation using wave shapes of collector coupled Bistable, Monostable and astable multivibrator circuits, Expression for time period.

9. **Oscillators (3) •**
   Sinusoidal oscillators: Barkhausen's criterion for self-sustained oscillations. RC phase shift oscillator, Wien bridge oscillator, determination of feedback factor and frequency of oscillation. Relaxation oscillator using OP-AMP.

Recommended reading

1. Circuits and Networks, Analysis and Synthesis, A Sudhakar, Shyammohan S Palli, 2017, Tata McGraw-Hill Education Private Ltd.

2. Solid State Electronic Devices, B.G.Streetman & S.K.Banerjee, 6th Edn.,2009, PHI Private Ltd.

3. Fundamental Principles of Electronics, B.Ghosh, 2nd ed, 2008, Books & Allied (P) Ltd.

4. Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata McGraw-Hill Education Private Ltd.

5. Electronic Devices and Circuits, S. Salivahanan, N. Suresh Kumar, 2022, McGraw Hill Education Private Ltd.

6. Learning OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition,2000, Prentice Hall India Private Ltd.

7. Electronic Devices, Thomas L. Floyd, 7/e 2008, Pearson India

8. Fundamentals of Analog Electronics: Theory, Problems and Solutions, U.N. Nandi, 2022, Techno India.

Practical [1 Credit]

1. To study the static characteristics of BJT in CE Configuration.

2. To design and study the frequency response of the BJT amplifier in CE mode.

3. Construction of a series regulated power supply from an unregulated power supply.

4. To study OP-AMP: inverting amplifier, non inverting amplifier, adder, subtractor, comparator, Schmidt trigger, integrator, differentiator.

5. To design a Wien bridge oscillator for given frequency using an OP-AMP.

Recommended reading

1. Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 1994, McGraw Hill

2. Advanced Practical Physics (volume II), B. Ghosh, Shreedhar Publication

3. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency

4. Laboratory Manual for Operational Amplifiers and Linear ICs, David A. Bell, 2006, Prentice Hall of India

DSC-10 : Nuclear and Particle Physics

Theory: [3 Credits]

1. **Rutherford scattering (2) •**
   Calculation of differential cross-section.

2. **Nuclear properties and structure (15) •**
   Mass, charge, size, B.E, spin and magnetic moment of the nucleus; Impossibility of an electron being in the nucleus as a consequence of the uncertainty principle; Isotopes, isobars, isotones. Bainbridge Mass Spectrograph. Nature of nuclear force between nucleons, Stability and binding, N-Z plot. Nuclear models: Liquid Drop model. Bethe-Weizsäcker semi-empirical mass formula and binding energy. Some applications: explanation of α decay by heavy nuclei, mass parabola, explanation of β decay by mirror nuclei. Nuclear shell model and magic numbers, ground state spin parity, Nordheim's Rule (qualitative discussion on phenomenology with examples).

3. **Interaction with and within the nucleus (10) •**
   Radioactivity: α- decay — kinematics, range-energy relationship and Geiger-Nuttall Law; β-decay — energy released, spectrum and Pauli's prediction of neutrino; Energy levels and decay schemes, positron emission and electron capture, selection rules: Fermi and Gamow-Teller transitions. γ-ray emission, nuclear isomerism, energy-momentum conservation: electron-positron pair creation by gamma photons in the vicinity of a nucleus.

4. **Nuclear Reactions (10) •**
   Types of reactions, conservation laws, kinematics of reactions, Q-value, reaction rate, reaction cross-section. Concept of compound and direct reaction, Ghoshal's experiment.

Resonance reaction, fission and fusion: mass deficit and generation of energy. Reaction characteristics, explanation in terms of liquid drop model, fission products and energy release, spontaneous and induced fission, transuranic elements. Chain reaction and basic principle of nuclear reactors. Nuclear fusion: energetics in terms of liquid drop model. Chain reaction and basic principle of nuclear reactors, slow neutrons interacting with U-235, Nuclear Fusion — energetics in terms of liquid drop model (brief qualitative discussions).

5. **Particle accelerators and detectors (3) •**
   Linear accelerator, cyclotron, betatron, gas detectors — GM Counters. Semiconductor detectors.

6. **Particle physics (7) •**
   Elementary particles and their families, interactions and basic features. Symmetry and conservation laws: energy and momentum, angular momentum, parity, baryon number, lepton number, isospin, hypercharge, and strangeness. Wu's experiment and basic idea of parity violation. Gell-Mann–Nishijima formula. The baryon and meson octet and baryon decuplet diagrams. Quark structure of hadrons. Concept of quark model, color quantum number and gluons (qualitative discussion only).

7. **Nuclear Astrophysics (3) •**
   Energy production in stars, p-p chain, CNO cycle. Production of heavier elements (qualitative discussion).

Tutorial [1 Credit]
Students must be given at least one assignment or a small set of problems. On the basis of regularity of submission and evaluation of assignment by the respective teacher, credits should be awarded to the students.

Recommended reading

1. Introductory nuclear Physics by Kenneth S. Krane, 2008, Wiley India
2. Nuclear and Particle Physics, S. Bhattacharyya, 2020, Universities Press .
3. Introduction to Elementary Particles, D. Griffiths, 2008, John Wiley & Sons
4. Basic ideas and concepts in Nuclear Physics - An Introductory Approach by K. Heyde, 2004, IOP Publishing
5. Radiation detection and measurement, G.F. Knoll, 2000, John Wiley & Sons
6. Nuclear Physics, Irving Kaplan, 2002, Narosa
7. Nuclear Physics, An Introduction, S.B. Patel, 2018, New Age International

DSC-11 : Quantum Mechanics

Theory [3 Credits]

1. **Formulation of Quantum Mechanics in vector space language (13) •**
   State as a vector in a complex vector space, inner product, its properties using Dirac bra-ket notation. Physical observables as Hermitian operators on state space; eigenvalues, eigenvectors and completeness property of the eigenvectors — matrix representation of Hermitian operators. Unitary time evolution. Wavefunction as the probability amplitude distribution of a state for the observables with continuous eigenvalues. Position representation and momentum representation of wave-functions and operators. Interpretation of $\psi(\boldsymbol{r}) = \langle \boldsymbol{r}|\psi\rangle$. One dimensional harmonic oscillator by raising and lowering operator method. Matrix representations of position and momentum operators.

2. **Two and three dimensional problems (4) •**
   Two and three dimensional problems in cartesian coordinates: separation of variables. Application for free particle, Particle in 2-d and 3-d box. Degeneracy of energy levels. Concept of symmetry and accidental degeneracy in 2-d box. Isotropic and anisotropic harmonic oscillator. Degeneracy for isotropic harmonic oscillator in 2-d and 3-d.

3. **Angular momentum algebra using Ladder operators (5) •**
   Construction of matrix representation of L_x, L_y, L_z for $\ell = 1$. Algebra with Ladder operators. Addition of angular momenta $\boldsymbol{\ell}_1 + \boldsymbol{\ell}_2$, and their projections. Spin as an intrinsic angular momentum and its relation with the Pauli matrices for spin-$\frac{1}{2}$.

4. **Quantum theory of hydrogen-like atoms (8) •**
   Reduction of a two-body problem to a one body problem. The time independent Schrödinger equation for a particle moving under a central force; the Schrödinger equation in spherical polar coordinates. Separation of variables. Angular equation and orbital angular momentum. Spherical harmonics (solution to Legendre differential equation may be assumed). Radial equation for attractive Coulomb interaction — Hydrogen atom. Solution for the radial wavefunctions (solution to Laguerre differential equation may be assumed). Sketch of probability densities. Orbital angular momentum quantum numbers ℓ and m; s, p, d shells.

Quantum Statistical Mechanics

5. **Systems of identical particles (8) •**
   Collection of non-interacting identical particles. Classical approach and quantum approach: distinguishability and indistinguishability. Composite system postulate and symmetry postulate of quantum mechanics (for a pair of particles only). Bosons and fermions. Symmetric and antisymmetric wave functions. Pauli Exclusion Principle for fermions. Derivation of Bose-Einstein and Fermi-Dirac distribution function using grand canonical ensemble.

6. **Bose-Einstein statistics (6) •**
   Thermodynamic functions of a strongly degenerate Bose gas. Bose derivation of Planck's law. Radiation as a photon gas and thermodynamic functions of photon gas. Chemical potential of photon gas. Bose-Einstein condensation and properties of liquid He-4 (qualitative description only).

7. **Fermi-Dirac statistics (6) •**
   Thermodynamic functions of strongly degenerate Fermi gas, Fermi energy, electron gas in a metal, Specific heat of metals due to electrons (qualitative discussions).

Recommended reading

1. Introduction to Quantum Mechanics, D.J. Griffiths, 2018, Cambridge University Press
2. Introduction to Quantum Mechanics, Krishnendu Sengupta and Palash B. Pal, 2023, Cambridge University Press
3. Quantum Mechanics: Classical Results, Modern Systems, and Visualized Examples, R. Robinett, 2006, Oxford University Press
4. Quantum Mechanics , Bransden and Joachain, 2004, Pearson
5. Quantum Mechanics, Walter Greiner, 4th Edn., 2001, Springer
6. Quantum Mechanics, Leonard I. Schiff, 3rd Edn. 2010, Tata McGraw-Hill

Practical (1 Credit]

1. **Finding eigenstates solving transcendental equation**: To find eigenvalues of the bound state particle of mass in a one dimensional potential well by solving the transcendental equation that appears as the eigenvalue condition (graphs are to be plotted for appropriate guess values, scipy root searching package may be used) and to solve the Schrödinger's equation for the determined eigenvalues to find and plot the eigenfunctions.

2. **Solving boundary problem of 2nd Order ODE using Shooting Algorithm**:
   (scipy.optimize.bisect or scipy.optimize.newton or scipy.optimize.root may be used)

3. **Shooting algorithm for solving bound state problems (solving the Time Independent Schrödinger's equation using both scipy.integrate.odeint and Numerov algorithms)**: conversion to dimensionless variable, eigenvalues and eigenvectors of the ground and first excited states.

   - in one dimension (for example, the Harmonic oscillator, the triangular well, infinite and finite square well)
   - the s wave radial equation for a particle moving in a central potential $\frac{d^2U(r)}{dr^2} = A(r)U(r)$, where $A(r) = \frac{2m}{\hbar^2}(V(r) - E)$
     $V(r) = -\frac{e^2}{r}$ (Coulomb Potential Only)

4. **Solving 1D time independent Schrödinger's equation for bound state using finite difference method** (use numpy.linalg): conversion to dimensionless variable, eigenvalues and eigenvectors of the ground and first excited states for infinite square well, finite square well and simple harmonic oscillator.

Once normalized wave function is obtained computation of $\langle x \rangle$, $\langle x^2 \rangle$, probability density to be done.

Recommended reading

1. An Introduction to Computational Physics, T. Pang, 2nd Edn., 2006, Cambridge Univ. Press
2. Scientific Computing in Python, Abhijit Kar Gupta, 2022, Techno World
3. Physics in Laboratory Python Programming (Semester IV & V), Pradipta Kumar Mandal, 2020, Santra Publication
4. Computational Physics problem solving with Computers, Landau, Paez, Bordeianu, text-book in Python 3rd Edition, 2015, Wiley-VCH
5. Computational Methods for Physics, Joel Franklin, Cambridge University Press
6. Computational Quantum Mechanics, Joshua Izaac, Jingbo Wang, 2019, Springer

DSC-12 : Thermal Physics and Statistical Mechanics

Theory [3 Credits]

Kinetic Theory of Gases

1. **Transport phenomenon in ideal gas (5) •**
   Viscosity, thermal conductivity and diffusion. Brownian motion and its significance (Langevin approach).
2. **Conduction of heat (3) •**
   Thermal conductivity and diffusivity. Variable and steady state; Fourier's equation for heat conduction and its solution for rectilinear flow of heat.
3. **Real gas (4) •**
   Behavior of real gases: Deviations from the ideal gas equation. The Virial equation. Andrew's experiments on CO_2. Critical constants. Continuity of liquid and gaseous state. Vapour and gas. Boyle temperature. Van der Waals' equation of state for real gases. Values of critical constants. Law of corresponding states. Comparison with experiment. P-V diagrams.

Thermodynamics

1. **Thermodynamic Potentials (6) •**
   Generic conditions of stable equilibrium for (V,T) and (P,T) systems. Internal energy, enthalpy, Helmholtz free energy, Gibbs free energy. Use of Legendre transform in these cases. Properties and applications.
2. **Maxwell's thermodynamic relations (7) •**
   Derivation and applications: (i) TdS equations, (ii) Difference of specific heats $C_p - C_v$, (iii) Variation of specific heats $\left(\frac{\partial C_V}{\partial V}\right)_T$ and $\left(\frac{\partial C_P}{\partial P}\right)_T$, (iv) Ratios of volume expansivity β_X where $X = P$ or S, pressure coefficients α_X where $X = V$ or S, compressibilities (or its reciprocal Bulk moduli) κ_X where $X = T$ or S, in terms of C_p/C_v.
   Change of temperature during Adiabatic Process; Joule-Thomson effect. Porous plug experiment: Throttling process. Joule-Thomson effect for ideal and real gases. Temperature of inversion. Joule-Thomson cooling.

3. **Phase transition (3) •**
   Classification of phase transitions; First order phase transitions: Clausius-Clapeyron equation, Second latent heat equation; Continuous phase transitions: Ehrenfest's equation.

4. **Radiation (7) •**
   Classical and quantum aspects: Properties of thermal radiation. Black-body radiation. Temperature dependence. Kirchhoff's law. Stefan-Boltzmann law: thermodynamic proof. Calculation of energy density and pressure of radiation from thermodynamics. Spectral distribution of black-body radiation. Rayleigh-Jeans law and the ultraviolet catastrophe, Planck's quantum postulates. Planck's law of black-body radiation. Deduction of Rayleigh-Jeans law, Stefan-Boltzmann law, Wien's displacement law from Planck's law.

Classical Statistical Mechanics

1. **Macrostate and Microstate (4) •**
   Elementary Concept of Ensemble and Ergodic Hypothesis (statement only). Phase space. Microcanonical ensemble, Postulate of equal *a priori* probability. Boltzmann hypothesis: Entropy and thermodynamic probability.

2. **Canonical ensemble (11) •**
   Partition function, Thermodynamic properties of an ideal gas. Thermodynamic properties of classical and quantum harmonic oscillator in one dimension using canonical ensemble. Classical entropy expression, Gibbs paradox. Equivalence of microcanonical and canonical ensembles. Sackur-Tetrode equation, Law of equipartition of energy (with proof) and its applications. Thermodynamic functions of a two-energy Level system. Negative temperature. Idea of chemical potential and grand canonical ensemble. Application of ideal gas using grand canonical ensemble.

Recommended reading

1. Heat and Thermodynamics, M.W. Zemansky, Richard Dittman, 1981, McGraw-Hill

2. Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger. 1988, Narosa

3. Concepts in Thermal Physics, S.J. Blundell and K.M. Blundell, 2nd Ed., 2012, Oxford University Press

4. Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill Publishing Company Ltd.

5. Statistical Physics, F. Mandl, 2014, Wiley India Pvt. Ltd

6. Thermodynamics and Statistical Mechanics, W. Greiner, 2001, Springer

7. Statistical Mechanics: Theory, Problems and Solutions, U.N. Nandi, 4th Ed., 2024, Techno World

Practical [1 Credit]

1. Determination of the the coefficient of Thermal conductivity of a bad conductor by Lees method.

2. Calibration of a thermocouple by direct measurement of the thermo-emf using potentiometer. [One end of the couple in ice bath and other in a water bath which is to be heated]

3. Determination of the temperature coefficient of resistance by Carey Foster's method.

4. Determination of the temperature coefficient of resistance of platinum by using Platinum resistance thermometer.

5. Verification of Stefan-Boltzmann law using tungsten bulb .

Recommended reading

1. Advanced Practical Physics, B. Ghosh, K. G. Majumder, Sreedhar Publication

2. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency (P) Limited

4 Semester 6

DSC-13 : Digital Electronics

Theory [3 Credits]

1. **Number System (8) •**
   (a) Binary numbers, Decimal to binary and reverse conversions; Binary addition and subtraction (1's Complement and 2's complement method), BCD, octal and hexadecimal numbers; signed and unsigned number representation of binary system. Representation of negative numbers.
   (b) OR, AND, NOT, NOR, NAND, XOR and XNOR gates — Truth tables. Statement of de Morgan's theorem. Realization of OR, AND, NOT using diodes and transistors.

2. **Digital Circuits (15) •**
   (a) Difference between analog and digital circuits. XOR and XNOR gates and application as parity checkers; Introduction to different logics like DTL, TTL.
   (b) Product term and sum term in logical expression; SOP, POS. Minterm and Maxterm in the expressions; Conversion between truth table and logical expression; Simplification of logical expression using Karnaugh Maps (4 variables).

3. **Implementation of different circuits (6) •**
   Half and full adders; subtractors; 4-bit binary adder/subtractor.; use of IC 7483 as adder and subtractor.

4. **Data processing circuits (5) •**
   Basic idea of multiplexers, de-multiplexers, decoders, encoders.

5. **Sequential circuits (6) •**
   Introduction to next state – present state table and excitation table for sequential circuits. SR, D, JK and T Flip-Flops. Clocked (level and edge triggered) Flip-Flops. Preset and Clear operations; Race condition in SR and race-around conditions in JK Flip-Flop. Master-slave JK Flip-Flop.

6. **Registers and Counters (8) •**
   (a) Shift registers: Serial-in-Serial-out, Serial-in-Parallel-out, Parallel-in-Serial-out and Parallel-in-Parallel-out Shift registers (only up to 4 bits).
   (b) Counters (4 bits): Asynchronous counters: ripple counter, Decade counter. Synchronous counter, Ring counter.

7. **Data conversion (2) •**
   D/A (Ladder and weighted resistance) and A/D conversion circuits.

Recommended reading

1. Digital Circuits, Part I & II, D. Raychaudhuri, 2015, Platinum Publishers
2. Digital Logic and Computer Design, M. Morris Mano, 2016, Pearson Education
3. Digital Principles and Applications, A.P. Malvino, D.P. Leach and Saha, 7th Ed., 2011, Tata McGraw-Hill
4. Electronic devices & circuits, S. Salivahanan & N.S. Kumar, 2012, Tata McGraw-Hill
5. Fundamental of Digital Circuits, A. Anand Kumar, 2016, Prentice Hall India Learning
6. Digital Systems, Principles and Applications, R. Tocci, N. S. Widemer, 2022, Pearson Education
7. Modern Digital Electronics, R. P. Jain, 2009, Tata McGraw-Hill
8. Digital Electronics An Introduction to Theory and Practice, W.H. Gothmann, 1982, Prentice Hall India Learning
9. Digital Computer Electronics, A. Malvino & Jerald Brown, 2017, Tata McGraw-Hill

Practical [1 Credit]

1. Construction of OR AND and NOT gates using diode and transistors.
2. Construction of half adder and full adder.
3. Construction of SR, D, JK, FF circuits using NAND gates.
4. Construction of a 4-bit binary counter using D-type/JK Flip-Flop and study timing diagram.
5. Construction of 4 bit shift registers (serial and parallel) using D type FF IC 7476.
6. Construction of 4×1 multiplexer using basic gates and IC 74151

Recommended reading

1. Advanced Practical Physics, B. Ghosh, K. G. Majumder, Sreedhar Publication
2. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency (P) Limited

DSC-14 : Solid State Physics

Theory [3 Credits]

1. **Crystal structure (10) •**
   Solids: amorphous and crystalline materials. Lattice translation vectors. Lattice with a basis; central and non-central elements. Unit cell. Miller indices. Reciprocal lattice. Types of lattices. Brillouin zones. Diffraction of X-rays by crystals. Laue and Bragg's laws and their equivalence. Atomic and geometrical structure factor. Basic idea of crystal indexing: examples with SC, BCC, FCC structure.

2. **Elementary lattice dynamics (7) •**
   Lattice vibrations and phonons: linear monatomic and diatomic chains. Acoustical and optical phonons. Qualitative description of the phonon spectrum in solids. Dulong and Petit's Law, Einstein and Debye theories of specific heat of solids, T^3 law.

3. **Drude's theory (3) •**
   Free electron gas in metals, effective mass, drift current, mobility and conductivity, Hall effect in metals. Thermal conductivity. Lorentz number, limitation of Drude's theory.

4. **Dielectric properties of materials (10) •**
   Polarization. Local electric field at an atom. Depolarization field. Electric susceptibility. Polarizability. Clausius-Mosotti equation. Classical theory of electric polarizability. Normal and anomalous dispersion. Cauchy and Sellmeier relations. Langevin-Debye equation. Complex dielectric constant.

5. **Elementary band theory (8) •**
   Kronig-Penney model. Band gap. Effective mass and effective mass tensor. Conductor, semiconductor (P and N type) and insulator. Conductivity of semiconductor, mobility, Hall effect. Measurement of conductivity (4 probe method) and Hall coefficient.

6. **Magnetic properties of matter (8) •**
   Dia, para, ferri and ferromagnetic materials. Classical Langevin theory of dia- and paramagnetic domains. Quantum mechanical treatment of paramagnetism (using partition function). Curie's law, Weiss's theory of ferromagnetism and ferromagnetic domains. B-H curve and hysteresis. Calculation of energy loss in B-H loop.

7. **Superconductivity (4) •**
   Experimental results. Critical temperature. Critical magnetic field. Meissner effect. Type I and type II superconductors, London equation and penetration depth. Isotope effect.

Recommended reading

1. Introduction to Solid State Physics, Charles Kittel, 8th Edition, 2004, Wiley India Pvt. Ltd.

2. Solid-state Physics, H. Ibach and H. Luth, 2009, Springer Solid State Physics, Rita John, 2014, McGraw Hill

3. Elementary Solid State Physics, M. Ali Omar, 1999, Pearson India

4. The Oxford Solid State Basics, S.H. Simon, 2017, Oxford University Press

5. Solid State Physics, M.A. Wahab, 2011, Narosa Publications

6. Solid State Physics, N.W. Ashcroft and N.D. Mermin, 1976, Cengage Learning

Practical [1 Credit]

1. Drawing of the B-H hysteresis curve of the given ferromagnetic specimen in the form of an anchor ring.

2. Determination of the dielectric constant of given solid material/materials using fixed frequency ac source studying the resonance condition in a LC rejector circuit.

3. Measurement of variation of resistivity in a semiconductor and investigation of intrinsic band gap using linear four probe.

4. Measurement of hall voltage by four probe method.

5. To study temperature coefficient of a semiconductor (NTC thermistor) and construction of temperature controller with comparator and relay switch.

Recommended reading

1. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers

2. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House

3. Elements of Solid State Physics, J.P. Srivastava, 2nd Ed., 2006, Prentice Hall of India

DSC-15 : Atomic, Molecular, and Laser Physics

Theory [3 Credits]

1. **Generalized angular momenta and spin (7) •**
   Generalized angular momentum. Electron's magnetic moment and spin. Gyromagnetic ratio, Bohr Magneton, and the g-factor (derivation not required). Energy associated with a magnetic dipole placed in magnetic field. Larmor's theorem. Stern-Gerlach experiment. L-S and j-j couplings.

2. **Atoms in external magnetic field (4) •**
   Anomalous Zeeman effect. Splitting of spectral lines and selection rules (statement and application only, derivation of level splitting and selection rules not required).

3. **Many electron atoms (8) •**
   Identical particles, Symmetric and antisymmetric wavefunctions with Slater determinant, spin-singlet and spin-triplet states, ortho- and parahelium as an example. Pauli's Exclusion Principle; Hund's Rule; Periodic table. Fine structure splitting. L-S and j-j coupling for many-electron atoms. Spectral notations for atomic states and Term symbols for equivalent and inequivalent electrons; Spectra of alkali atoms (Na etc.): difference between hydrogen spectra and alkali spectra.

4. **Molecular spectra (5) •**
   Diatomic molecules — rotational and vibrational energy levels. Basic ideas about molecular spectra. Raman effect and its application to molecular spectroscopy (qualitative discussion only).

5. **Lasers (18) •**
   Radiative and non-radiative transitions. Absorption, spontaneous and stimulated emission, Einstein's A and B coefficients–their interrelation. Idea of metastable state, population inversion. Necessary condition for lasing, threshold population inversion. Two-level system: unattainability of population inversion. Three-level and four-level systems: rate equations and necessary condition for population inversion. Basic components of a laser system — active medium, pumping system and optical resonator. Free spectral range. Line broadening mechanism — natural broadening and pressure broadening (qualitative discussion), Doppler broadening. Ruby laser, He-Ne laser and semiconductor laser working principle.

6. **Fiber optics (8) •**
   Optical fiber, coherent bundle, numerical aperture. Step index and graded index fibers. Attenuation of optical fibers. Modes of a planar waveguide: TE and TM modes. Physical understanding of modes, Optical fibers: Guided modes of step-index fibers.

Recommended reading

1. Lasers: Theory and Applications, A. Ghatak & K. Thyagarajan, 2010, Springer Science

2. Laser and Non Linear Optics, B.B. Laud, 2011, New Age International (P) Ltd. Publishers

3. Introduction to Fiber Optics, A. Ghatak, 1998, Cambridge University Press

4. Introduction to Quantum Mechanics, D.J. Griffiths, 2018, Cambridge University Press

5. Quantum Mechanics, Bransden and Joachain, 2004, Pearson

6. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles, Resnick and Eisberg, 2014, Wiley.

Tutorial [1 Credit]
Students must be given at least one assignment or a small set of problems. On the basis of regularity of submission and evaluation of assignment by the respective teacher, credits should be awarded to the students.

Syllabus for the Undergraduate (B.Sc.) course in Physics (Multidisciplinary)

The structure of the revised syllabus for the B.Sc. course in Physics (Semesters 3 to 6) is as follows.

Each paper carries 4 Credits, equivalent to 100 marks.

Th: Theory, Pr: Practical, Tut: Tutorial

For students opting for Multidisciplinary Degree

Semester	Paper code	Paper name	Credit
Semester 3	GCC-3 [MDC (major)-3]	Waves and Optics	Th: 3, Pr: 1
	GCC-1 [MDC (minor)-1]	Basic Physics I	Th: 3, Pr: 1
Semester 4	GCC-5 [MDC (major)-4]	Modern Physics	Th: 3, Pr: 1
	GCC-6 [MDC (major)-5]	Electromagnetism	Th: 3, Pr: 1
	GCC-2 [MDC (minor)-2]	Basic Physics II	Th: 3, Pr: 1
Semester 5	GCC-7 [MDC (major)-6]	Analog Electronics	Th: 3, Pr: 1
	GCC-8 [MDC (major)-7]	Nuclear Physics	Th: 3, Tut: 1
	GCC-3 [MDC (minor)-3]	Waves and Optics	Th: 3, Pr: 1
	GCC-4 [MDC (minor)-4]	Mathematical Physics	Th: 3, Tut: 1
Semester 6	GCC-9 [MDC (major)-8]	Digital Electronics	Th: 3, Pr: 1
	GCC-10 [MDC (major)-9]	Instrumentation	Th: 3, Pr: 1
	GCC-5 [MDC (minor)-5]	Modern Physics	Th: 3, Pr: 1
	GCC-6 [MDC (minor)-6]	Electromagnetism	Th: 3, Pr: 1

This table needs some explanation. A student opting for Multidisciplinary Course (MDC) degree may take Physics as a Major subject, with 8 papers, or as a Minor subject, with 6 papers. While the papers are coded as GCC-1 to GCC-10, it is also indicated whether this is a Major MDC paper or a Minor MDC paper.

An MDC Physics Major student has to take 1 course in Semester 3 and 2 courses in Semester 4. In Semesters 5 and 6, (s)he has to take 3 courses, with not more than 2 in any semester. To keep the option open, 4 such MDC (Major) courses are floated for Semesters 5 and 6. The student has to take only 3 of them.

An MDC Physics Minor student has to take 1 course in each of the Semesters 3 and 4, and 2 courses in each of the Semesters 5 and 6.

5 Multidisciplinary papers

GCC-1 : Basic Physics I

[3rd Semester, MDC Minor]
Same as mentioned in the syllabus of the first semester CSR/18/2023 published on 24th July 2023.

GCC-2 : Basic Physics II

[4th Semester, MDC Minor]
Same as mentioned in the syllabus of the second semester CSR/18/2023 published on 24th July 2023.

GCC-3 : Waves and Optics

[3rd Semester, MDC (major)-3, 5th Semester, MDC (minor)-3]

Theory [3 Credits]

1. **Oscillations (6) •**
   Differential equation of simple harmonic oscillation and its solution. Kinetic energy, potential energy, total energy and their time average values. Damped and forced oscillations: Transient and steady states; Resonance, sharpness of resonance; power dissipation and Quality Factor.

2. **Superposition of harmonic oscillations (3) •**
   Superposition of two collinear harmonic oscillations having equal frequencies and different frequencies (beats), Superposition of two perpendicular harmonic oscillation for phase difference $\delta = 0, \pi, 2\pi$.

3. **Wave motion (8) •**
   Plane progressive (traveling) waves. Wave equation for travelling waves . Particle and wave velocities. Velocity of transverse vibrations of stretched strings, standing (stationary) waves in a string. Phase and group velocities. Doppler effect.

4. **Geometrical optics (5) •**
   Fermat's principle. Laws of reflection and refraction at a plane surface, refraction at a spherical surface, lens formula. Combination of thin lenses — equivalent focal length. Dispersion and dispersive power.

5. **Interference (12) •**
   Huygens' principle: explanation of the laws of reflection and refraction. Division of amplitude and wavefront. Young's double slit experiment. Intensity distribution, conditions of interference, Interference in thin films: parallel and wedge shaped films. Fringes of equal inclination (Haidinger fringes); Fringes of equal thickness (Fizeau fringes). Newton's rings: Measurement of wavelength and refractive index.

6. **Diffraction (8) •**
   Fraunhofer diffraction: Single slit, double slit and diffraction grating. Resolving power of grating. Circular aperture (qualitative discussion only)
   Fresnel diffraction: Fresnel's half-period zones for plane waves. Theory of a Zone Plate: Multiple foci of a Zone Plate.

7. **Polarization (8) •**
   Description of linear, circular and elliptical polarization. Propagation of electromagnetic waves in birefringent medium, polarization in uniaxial crystals. Double refraction. Polarization by double refraction. Ordinary and extraordinary refractive indices. Phase Retardation plates: Quarter-wave and Half-wave plates. Rotatory polarization, Biot's laws for rotatory polarization. Specific rotation.

Recommended reading

1. Advanced Acoustics, D. P. Roychowdhury, 1981, Chayan Publisher
2. Waves and Oscillations, N. K. Bajaj, 2017, Tata McGraw-Hill
3. A textbook of Optics, N Subramanyam, B. Lal and M.N.Avadhanulu, 2006, S. Chand Publishing
4. Optics, B. Ghosh, Sreedhar Publications

Practical [1 Credit]

1. Measurement of focal length of a concave lens by combination method.
2. Determination of unknown frequency of a tuning fork by Sonometer.
3. To determine wavelength of sodium light/radius of plano convex lens using Newton's Rings.
4. Measurement of thickness of paper by interference pattern created by a Wedge shaped film.
5. To study the specific rotation of optically active solution using polarimeter.

Recommended reading

1. B.Sc. Practical Physics, C.L. Arora, S Chand and Company Limited
2. Advanced Practical Physics, Vol 1, B. Ghosh, K.G.Majumdar, Shreedhar Publishers
3. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency (P) Ltd

GCC-4 : Mathematical Physics

[5th Semester, MDC (minor)-4]

Theory [3 Credits]

1. **Matrices (18) •**
   (a) 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.
   (b) Eigenvalues and eigenvectors (non-degenerate). Properties of hermitian matrices. Cayley-Hamiliton theorem.

2. **Differential equations (5) •**
   Second order Inhomogeneous differential equations. Particular integral.

3. **Fourier Series (6) •**
   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.

4. **Fourier Transforms (8) •**
   Fourier integral theorem. Fourier Transform. Examples. Fourier transform of box and gaussian functions.

5. **Probability (8) •**
   Independent random variables: Sample space and probability distribution functions. Binomial, Gaussian, and Poisson distribution with examples. Mean and variance.

6. **Partial differential equations (5) •**
   Solutions to partial differential equations using separation of variables (in cartesian coordinates). Solution of wave equation as an example.

Recommended reading

1. Mathematical Physics, H.K. Dass & Verma, 2021, S. Chand

2. Principles of Mathematical Physics, S.P. Kuila, 2015, New Central Book Agency

Tutorial [1 Credit]
Students must be given at least one assignment or a small set of problems. On the basis of regularity of submission and evaluation of assignment by the respective teacher, credits should be awarded to the students.

GCC-5 : Modern Physics

[4th Semester, MDC (major)-4, 6th Semester, MDC (minor)-5]

Theory [3 Credits]

1. **Special Theory of Relativity (8) •**
   Postulates of STR, Lorentz transformation (derivation not required). Derivation of (i) length contraction (ii) time dilation (iii) velocity addition for velocities in the same direction. Energy-momentum dispersion relation. Mass-energy equivalence.

2. **Quantum theory of radiation (8) •**
   Planck's concept, radiation formula (statement only). Photo-electric effect. Bohr's theory. Effect of finite nuclear mass. Compton effect.

3. **Basic Quantum Mechanics (15) •**
   Wave nature of material particles, wave-particle duality, wavelength of de Broglie waves, Heisenberg uncertainty principle, Schrödinger equation, time dependent and independent Schrödinger wavefunction and its probabilistic interpretation. Normalization. Introduction to linear operators. Calculation of various commutation relations. Particle in a one dimensional infinite well: energy eigenvalues. Schrödinger equation for one-dimensional harmonic oscillator. Energy eigenvalues and wavefunctions (only first three wavefunctions, no need to introduce Hermite polynomials, and no detailed derivation required).

4. **Crystal structure (7) •**
   Crystal Structure : Crystalline nature of solid, Miller indices, lattice planes, simple cubic, FCC and BCC lattices. Diffraction of X-ray, Bragg's law; Moseley's law: explanation from Bohr's theory. Continuous and characteristic X-ray.

5. **Structure of solids (6) •**
   Different types of bonding: ionic, covalent, metallic, Van der Waals and hydrogen. Elementary ideas about band structure in conductors, direct and indirect semiconductors and insulators (qualitative discussions).

6. **Magnetic properties of materials (6) •**
   Dia, para and ferro-magnetic properties of solids. Origin of diamagnetism. Langevin theory of paramagnetism and Curie's Law. Domain structure of ferromagnetic materials. B-H loop and hysteresis.

Recommended reading

1. Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill

2. Modern Physics, R.Murugeshan & K.Sivaprasath, 2019, S. Chand Publishing

3. Atomic and Nuclear Physics Volume 1, S.N. Ghoshal, 2010, S. Chand Publishing

4. Theory and Problems of Modern Physics, Schaum's outline, R. Gautreau and W. Savin, 2nd Edn, 2020, Tata McGraw-Hill

Practical [1 Credit]]

1. Measurement of Planck's constant using LED.

2. Determination of e/m of electrons by using bar magnet.

3. To study the photoelectric effect: variation of photocurrent versus intensity and wavelength of light.

4. To show the tunneling effect in tunnel diode using I-V characteristics.

5. Verification of Stefan's law by using a glowing tungsten filament of a torch bulb.

Recommended reading

1. B.Sc. Practical Physics, C.L. Arora, 2010, S. Chand

2. Practical Physics Vol 1 and Vol 2, B. Ghosh, K. G. Majumder, Sreedhar Publishers

GCC-6 : Electromagnetism

[4th Semester, MDC (major)-5, 6th Semester, MDC (minor)-6]

Theory [3 Credits]

1. **Electrostatics (10) •**
   Method of Images and its application to plane Infinite metal sheet. Electric fields inside matter. Electric polarisation, bound charges (no derivation required), displacement density vector, linear dielectric medium, electric susceptibility and permittivity.

2. **Magnetostatics (12) •**
   Divergence and curl of magnetostatic field using Biot-Savart law; Magnetic vector potential for uniform magnetic field. Magnetic fields inside matter, magnetization, bound currents (no derivation required). $\boldsymbol{H}$ and $\boldsymbol{B}$ field. Linear media.

3. **Electromagnetic induction (10) •**
   Non-conservative nature of electric field. Faraday's law of induction: simple examples (eg: motional emf, Faraday disc); Lenz's law. Self and mutual inductances in simple cases, L of single coil, M of two coils. Energy stored in inductors.

4. **Electrodynamics (8) •**
   Maxwell's equations and EM waves: Maxwell's equations, Equation of continuity of current, displacement current, electromagnetic wave propagation through vacuum and isotropic dielectric medium, transverse nature of EM waves, Poynting vector, decay of charge in conducting medium.

5. **Varying currents (4) •**
   Growth and decay of currents in L-R circuit; charging and discharging of capacitor in C-R circuit.

6. **Alternating current (6) •**
   Mean and r.m.s. values of current and emf with sinusoidal wave form; LR, CR and series LCR circuits, reactance, impedance, power factor, vector diagram, resonance in a series LCR circuit, Q-factor.

Recommended reading

1. Foundations of Electricity and Magnetism, B. Ghosh, 2008, Books & Allied Ltd; 3rd Revised edition
2. Electricity and Magnetism, Edward M. Purcell, 1986, McGraw-Hill Education
3. Electricity and Magnetism, D C Tayal, 1988, Himalaya Publishing House
4. Electricity and Magnetism, R.Murugeshan, 2019, S. Chand
5. Electricity and Magnetism, Chattopadhyay and Rakshit, 2011, New Central Book Agency

Practical [1 Credit]

1. To draw the resonance curve of a series LCR circuit.
2. Determination of horizontal component of Earth's magnetic field using magnetometer.
3. To study the ac characteristics of a series RC circuit and calculation of capacitance from current reactance graph.
4. Construction of one ohm coil by measuring resistivity of a sample wire using Carey Foster bridge.
5. To study the variation (with current) of the magnetic field between pole pieces for different distances of an electromagnet using Gaussmeter.

Recommended reading

1. Advanced Practical Physics (Vol 1 and Vol 2), B. Ghosh, K. G. Majumder, Sreedhar Publication.

GCC-7 : Analog Electronics

[5th Semester, MDC (major)-6]
Theory [3 Credits]

1. **Circuits and network (6) •**
   Discrete components, active and passive components, ideal constant voltage and constant current sources. Network analysis: Kirchhoff's laws, Thevenin's and Norton's theorems, Reciprocity theorem, Superposition theorem. Maximum power transfer theorem.

2. **Semiconductor diodes and applications (15) •**
   (a) Semiconductor diodes: P and N type semiconductors. Barrier formation in PN junction diode. Qualitative idea of current flow mechanism in forward and reverse biased diodes. PN junction and its characteristics. Static and dynamic resistance. Principle and structure of LED, Photodiode, Solar cell.
   (b) Application of diodes: Half-wave rectifiers. Centre-tapped and bridge full-wave rectifiers, Ripple factor and Rectification efficiency. Basic idea about capacitor filter. Zener diode and voltage regulation.
   (c) Bipolar junction transistors: n-p-n and p-n-p transistors. Characteristics of CB, CE

and CC configurations. Active, cut-off and saturation regions. Current gains α and β, relations between them. Load line analysis of transistors. DC load line and Q-point. Concept of biasing.

3. **Power supply (3) •**
   Difference between regulated and unregulated power supplies. Load regulation and line regulation. Zener as voltage regulator. Principle of series regulated power supply, IC controlled regulated power supply.

4. **Field Effect transistors (6) •**
   JFET and MOSFET (both depletion and enhancement type) as a part of MISFET. Basic structure and principle of operations and their characteristics. Pinch off, threshold voltage and short channel effect. Comparison of JFET and MOSFET.

5. **Operational Amplifiers (10) •**
   OP-AMP (black box approach): Characteristics of ideal and practical (IC 741) OP-AMPs. Concept of negative and positive feedback. Open-loop and closed-loop voltage Gain. Concept of virtual ground. Application of OP-AMP: Inverting and non-inverting amplifiers, inverting and non-inverting adders, differentiator as subtractor.

6. **Communication systems (10) •**
   Propagation of electromagnetic waves in atmosphere, various layers of atmosphere, ground and sky waves; Transmission of electromagnetic waves: Amplitude and frequency modulation. Optical fiber, core and cladding, numerical aperture, step index and graded index fiber. Satellite communication, microwave link — modem and internet.

Recommended reading

1. Electronic Principle, Albert Malvino, 2008, Tata McGraw-Hill.
2. Electronics: Fundamentals and Applications, D. Chattopadhyay, P.C. Rakshit, New Age Publication.

Practical [1 Credit]

1. Verification of Thevenin's and Norton's theorems, superposition theorem and maximum power transfer theorem for resistive network fed by D.C. power supply.
2. To draw the output characteristics of a transistor in CE-mode and calculate current gain.
3. I-V curve for reversed bias Zener diode. Voltage regulation characteristics using a variable load.
4. To use OP-AMP as inverting, non-inverting amplifier.
5. To use OP-AMP as differentiator and as an adder.

Recommended reading

1. Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 1994, McGraw-Hill

2. Advanced Practical Physics (volume II), B. Ghosh , Shreedhar Publication

3. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency

4. Laboratory Manual for Operational Amplifiers and Linear ICs, David A. Bell, 2006, Prentice Hall of India

GCC-8 : Nuclear Physics

[5th Semester, MDC (major)-7]
Theory [3 Credits]

1. **Atomic spectra (12) •**
   Bohr-Sommerfeld model of hydrogen-like atoms. Fine structure. Stern-Gerlach experiment and spin as an intrinsic quantum number. Vector atom model; Magnetic moment of the electron, Lande g-factor. Space quantization. Zeeman effect. Explanation from vector atom model.

2. **Molecular spectroscopy (4) •**
   Diatomic molecules: rotational and vibrational energy levels. Basic ideas about molecular spectra. Raman effect and its application to molecular spectroscopy (qualitative discussion only).

3. **Atomic nucleus (10) •**
   Nuclear mass, charge, size, binding energy, spin and magnetic moment. Isobars, isotopes and isotones. Radioactivity, successive disintegration, radioactive equilibrium, radioactive dating. Nature of forces between nucleons, nuclear stability and nuclear binding, the liquid drop model (descriptive) and the Bethe-Weizsäcker mass formula. Fission and fusion.

4. **Unstable nuclei (8) •**
   α-decay: α particle spectra – velocity and energy of α particles. Geiger-Nuttall law. β-decay: nature of β- ray spectra, the neutrino, positron emission and electron capture. γ-decay: γ-ray spectra and nuclear energy levels.

5. **Particle accelerators (4) •**
   LINAC, cyclotron.

6. **Particle physics (6) •**
   Fundamental particles and their families. Fundamental particle interactions and their basic features. Symmetries and conservation laws, baryon number, lepton number, isospin, strangeness and charm. Quark model, quark structure of hadrons.

7. **Nuclear Astrophysics (6) •**
   Primordial nucleosynthesis, energy production in stars, p-p chain, CNO cycle. Production of elements (qualitative discussion only).

Recommended reading

1. Nuclear Physics, D. C. Tayal, 2011, Himalayan Publisher.
2. Nuclear and Particle Physics, S. Bhattacharyya, 2020, Universities Press.
3. Introduction to Nuclear and Particle Physics, Mittal, Verma, Gupta, 2016, Prentice Hall India Learning
4. Atomic and and Nuclear Physics Vol 1, S.N. Ghoshal, 2010, S. Chand
5. Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill.
6. Solid State Physics, Puri, Babbar, 2010, S. Chand

Tutorial [1 Credit]
Students must be given at least one assignment or a small set of problems. On the basis of regularity of submission and evaluation of assignment by the respective teacher, credits should be awarded to the students.

GCC-9 : Digital Electronics

[6th Semester, MDC (major)-8]
Theory [1 Credit]

1. **Number system (10) •**
   Binary numbers, decimal to binary and reverse conversions. Binary addition and subtraction (1's Complement and 2's complement method), signed and unsigned number representation of binary system; representation of negative numbers. OR, AND, NOT, NOR, NAND, XOR and XNOR gates — Truth tables. Statement of de Morgan's theorem. Realization of OR, AND, NOT using diodes and transistors.
2. **Digital circuits (10) •**
   Difference between analog and digital circuits. XOR and XNOR gates and application as parity checkers. Product term and sum term in logical expression; SOP, POS and mixed expression. Minterm and Maxterm in the expressions. Conversion between truth table and logical expression. Simplification of logical expression using Karnaugh maps (4 variables).
3. **Implementation of different circuits (5) •**
   Half and full adders; subtractors; 4-bit binary adder/subtractor.; use of IC 7483 as adder and subtractor.
4. **Data processing circuits (5) •**
   Basic idea of multiplexers, de-multiplexers, decoders, encoders.
5. **Sequential circuits (10) •**
   Introduction to next state–present state table and excitation table for sequential circuits. Basic ideas of SR, D, JK and T Flip-Flops. Clocked (level and edge triggered) Flip-Flops. Preset and Clear operations; Race condition in SR and race-around conditions in JK Flip-Flop. Master-slave JK Flip-Flop (basic ideas only).

6. **Registers and counters (10) •**
   Storing of data, registers (up to 4 bits only), parallel and serial loading. Concept of shift register with loading from LSB.

Recommended reading

1. Digital Principles and Applications, A.P. Malvino, D.P. Leach and Saha, 7th Ed., 2011, Tata McGraw-Hill
2. Electronic devices & circuits, S. Salivahanan & N.S. Kumar, 2012, Tata McGraw-Hill
3. Electronics: Fundamentals and Applications, D. Chattopadhyay, P.C. Rakshit, 2022, New Age Publication

Practical [1 Credit]

1. Construction of OR AND and NOT gates using diode and transistors.
2. To verify the truth tables of basic gates and De-Morgan's theorem using IC-chips
3. To construct Half and Full Adder using IC-chips
4. Construction of SR and D Flip Flop circuits using NAND gates.
5. Construction of 4×1 Multiplexer using IC 74151

Recommended reading

1. Advanced Practical Physics, B. Ghosh, K. G. Majumder, Sreedhar Publication
2. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency (P) Limited

GCC-10 : Instrumentation

[6th Semester, MDC (major)-9]
Theory [3 Credits]

1. **Measurements (5) •**
   Accuracy and precision. Significant figures.Types of errors: Gross error, systematic error, random error. Statistical analysis of data (arithmetic mean, deviation from mean, average deviation, standard deviation, least square fitting).
2. **Signals and systems (8) •**
   Periodic and aperiodic signals. Impulse response, transfer function and frequency response of first and second order systems. Fluctuations and noise in measurement system. S/N ratio and noise figure. Noise in frequency domain. Sources of noise: Inherent fluctuations, thermal noise, shot noise, $1/f$ noise.
3. **Shielding and grounding (3) •**
   Methods of safety grounding. Energy coupling. Grounding. Shielding: Electrostatic shielding. Electromagnetic interference.

4. **Transducers and industrial instrumentation (5) •**
   Calibration and characteristics of transducers and sensors. Radiation sensors: Principle of gas filled detectors, ionization chamber, scintillation detector.

5. **Engines (5) •**
   Heat engines, thermal efficiency, indicated horse-power and brake horse-power, Otto cycle and Diesel cycle, four-stroke petrol and diesel engines, calculation of efficiency and comparison.

6. **Digital multimeter (5) •**
   Comparison of analog and digital instruments. Block diagram of digital multimeter, principle of measurement of I, V, C. Accuracy and resolution of measurement.

7. **Vacuum systems (5) •**
   Characteristics of vacuum: Gas law, mean free path. application of vacuum. Vacuum system: Chamber, Mechanical pumps, Diffusion pump and Turbo molecular pump. Pumping speed. Pressure gauges (Pirani, Penning, ionization).

Recommended reading

1. A text book in Electrical Technology, B L Theraja, 1999, S. Chand
2. Physics in Applications: Avijit Lahiri
3. Non-conventional energy sources, G.D Rai, 1988, Khanna Publishers
4. Digital Circuits and systems, Venugopal, 2011, Tata McGraw-Hill
5. Electrical Machines, S. K. Bhattacharya, 2008, McGraw-Hill Education

Practical [1 Credit]

1. Calibration of a thermocouple by inserting junctions at ice and water baths.
2. To measure the internal resistance of an analog voltmeter and to increase its internal resistance by using an OP-AMP.
3. To calibrate a given temperature sensor and to use the sensor to control the temperature of a heat bath.
4. To develop a photo-sensor using a phototransistor followed by an amplifier and to use the same to control the switching of a bulb.
5. Measurement of signal frequency, voltage, duty cycle etc. of a generated waveform by using Digital Oscilloscope.

Recommended reading

1. Advanced Practical Physics, B. Ghosh, K. G. Majumder, Sreedhar Publication
2. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency (P) Limited

Syllabus for the Undergraduate (B.Sc.) course in Physics (Minor)

The structure of the revised syllabus for the B.Sc. course in Physics (Semesters 3 to 6) is as follows.

Each paper carries 4 Credits, equivalent to 100 marks.

Th: Theory, Pr: Practical

For students with other Majors and Physics as a Minor subject

Semester	Paper code	Paper name	Credit
Semester 1	GCC-1	Basic Physics I	Th: 3, Pr: 1
	If Physics is taken as Minor-1		
Semester 2	GCC-2	Basic Physics II	Th: 3, Pr: 1
	If Physics is taken as Minor-1		
Semester 3	GCC-1	Basic Physics I	Th: 3, Pr: 1
	If Physics is taken as Minor-2		
Semester 4	GCC-2	Basic Physics II	Th: 3, Pr: 1
	If Physics is taken as Minor-2		
Semester 5	GCC-3	Waves and Optics	Th: 3, Pr: 1
Semester 6	GCC-5	Modern Physics	Th: 3, Pr: 1

Students with some other Major can take Physics as one of the two Minor subjects. If it is chosen as the first minor paper (Minor-1), they have to take GCC-1 and GCC-2 in the first and second semesters respectively. If it is chosen as the second minor paper (Minor-2), they need to take the identical courses in semesters 3 and 4 respectively. All of them have to take GCC-3 in the 5th semester and GCC-5 in the 6th semester.

6 Minor papers

GCC-1 : Basic Physics I

[1st (3rd) Semester for Minor-1 (Minor-2)]
Same as mentioned in the syllabus of the first semester CSR/18/2023 published on 24th July 2023.

GCC-2 : Basic Physics II

[2nd (4th) Semester for Minor-1 (Minor-2)]
Same as mentioned in the syllabus of the second semester CSR/18/2023 published on 24th July 2023.

GCC-3 : Waves and Optics

[5th Semester for both Minor-1 and Minor-2]
The syllabus is identical to GCC-3 for Multidisciplinary papers.

GCC-5 : Modern Physics

[6th Semester for both Minor-1 and Minor-2]
The syllabus is identical to GCC-5 for Multidisciplinary papers.