# ST. ALOYSIUS COLLEGE(AUTONOMOUS), JABALPUR

*Reaccredited 'A++ 'Grade by NAAC(CGPA:3.58/4.00)*
*College with Potential for Excellence by UGC*
*DST-FIST Supported & STAR College Scheme by DBT*

# Faculty of Science

## Bachelor of Science (B.Sc.)

## SUBJECT: PHYSICS

## B.Sc. I Semester

## Paper-Major 1

## MATHEMATICAL PHYSICS AND SPECIAL THEORY OF RELATIVITY

### Course Outcomes

| | Course Outcomes | Cognitive Level |
|---|---|---|
| CO-I | Learner will understand the contribution of Great Indian Mathematician in Mathematics and Physics. | U, R |
| CO-II | Learner will be able to apply mathematical methods such as differential equations and vector calculus to solve problems in physics. | U, Ap,An, E |
| CO-III | Learner will be able to resolve a variety of physics issues using differential equations. | U, Ap, An, E |
| CO-IV | Learner will be able to (a) explain the necessity of different coordinate system and (b) calculate and construct Fourier analysis of given function. | U, Ap, C |
| CO-V | Learner will be able to apply relativistic mechanics and postulates of special theory of relativity to analyse the energy-momentum relationship and dynamics of high-velocity systems. | Ap, An |

***R-Recall, U-Understand, Ap-Apply, An-Analyse, E-Evaluate, C-Create***

## Credit and Marking Scheme

| | Credits | Marks | | Total Marks |
|---|---|---|---|---|
| | | Internal | External | |
| **Theory** | 6 | 30 | 70 | **100** |
| **Practical** | - | - | - | **-** |
| **Total** | 6 | 100 | | |

## Evaluation Scheme

| | Marks | |
|---|---|---|
| | **Internal** | **External** |
| **Theory** | 3 Internal Exams of 15 Marks (During the Semester, Best 2 will be taken) | 1 External Exam (At the End of Semester) |
| **Practical** | ------ | ---------- |

# Content of the Course

## Theory

**No. of Lectures (in hours per week):** 4.5 Hrs. per week

**Total No. of Lectures:** 60 Hrs. **Maximum Marks:** 70

| Units | Topics | No. of Lectures |
|---|---|---|
| I | **Historical Background** *[iii]*<br>1. Overview of the historical contributions of Indian mathematics and its cultural significance.<br>2. A brief biography of Aryabhata and Bhaskaracharya second with their major contribution to science and society.<br>3. Discussion about Bhaskaracharya second's mathematics in Solving Physics Problems.<br>4. Ancient Indian units of time as mentioned in the Shrimad Bhagavat Purana, Calculation of the speed of light by Sayana based on the Rigveda.<br><br>**Activities:**<br>1. Ask students to create a timeline showcasing the major Indian mathematicians and their contributions.<br>2. Provide students with historical time units (e.g., Yuga, Kalpa) and ask them to convert them into modern SI units.<br><br>***Keywords:*** *Bhaskaracharya second's mathematics, Indian units of time* | 12 |
| II | **Differential Equations and Vector Algebra** *[vii]*<br>1. **First Order Differential equations:** (variable separable, homogeneous, nonhomogeneous), Exact and non-exact differential equations and Integrating Factor.<br>2. **Second Order Differential Equations:** Introduction, Complimentary Functions and Particular Integral, Partial Differential Equation: Introduction and solution using separation of variable technique<br>3. **Vector Algebra:** Properties of vectors, Scalar product and vector product, Scalar triple product and their interpretation in terms of area and volume, Scalar and Vector fields.<br>**Activities:** | 15 |

| | | |
|---|---|---|
| | 1. Assign students real-world problems involving first-order differential equations (e.g., population growth, RC circuits) for derivation and solution.<br>**2.** Assign students to demonstrate real-life applications of vector algebra, such as: Torque, Magnetic force on a moving charge, Work done by a force.<br>**3.** Apply Mathematica to solve differential equations and scalar and vector products.<br>**4.** Printing and plotting of data using Mathematica.<br><br>***Keywords**: Integrating Factor, Complimentary function, Particular Integral.* | |
| **III** | **Vector Calculus** *[vii]*<br>**1. Vector Calculus:** Vector Differentiation, Directional derivatives and normal derivatives, Gradient of a scalar field and its geometrical interpretation, Divergence and curl of a vector field and its geometrical interpretation, Del and Laplacian operators, Vector identities.<br>**2. Vector Integration:** Ordinary Integrals of Vectors, Double and Triple integrals, change of order of integration, Notion of infinitesimal line, surface and volume elements, Line, surface and volume integrals of Vector fields, Flux of a vector field, Gauss' divergence theorem, Green's theorem and Stokes theorem.<br>**Activities:**<br>1. Give students a set of vector fields and ask them to: Identify if they are irrotational (zero curl) or solenoidal (zero divergence).<br>2. Ask students to sketch gradient, divergence, and curt using vector arrows for different vector fields.<br>3. Application of Mathematica to finding gradient, divergence, curl and evaluation of vector integration.<br>***Keywords:** Gradient, Divergence and curl, Green's theorem and Stokes Theorem.* | **15** |
| **IV** | **Curvilinear Coordinates and Fourier Analysis** *[vii]*<br>1. Introduction to Orthogonal Curvilinear Coordinates, Differential operators in terms of Orthogonal Curvilinear Coordinates, Representations of Gradient, Divergence, Curl and Laplacian operator in Spherical and Cylindrical Coordinate Systems. | 14 |

| | | |
|---|---|---|
| | 2. Periodic functions, Determination of Fourier coefficients, Fourier analysis of sine, cosine, square, rectangular, saw tooth waves, plucked strings, half wave, and full wave rectifier wave forms.<br>**Activities:**<br>1. Assign students specific coordinate systems and ask them to derive gradient, divergence, and curl for different physical scenarios (e.g., electric fields, fluid flow)<br>2. Ask students to analyse square wave signal in terms of Fourier series.<br>3. Fourier analysis and plotting using Mathematica.<br>***Keywords:*** *Curvilinear Coordinates, Fourier coefficients.* | |
| **V** | **Special Theory of Relativity**<br>1. Inertial and non-inertial frame of reference, Galilean transformation, Michelson-Morley Experiment and explanation of its negative results, Postulates of Special Theory of Relativity, Lorentz Transformations, Simultaneity, Length contraction, and Time dilation. Relativistic transformation of velocity, acceleration, frequency, and wave number.<br>2. **Relativistic Kinematics:** Variation of mass with velocity, Massless Particles, Mass-energy Equivalence, Relativistic Doppler effect (transverse and longitudinal), Decay problems and Compton Effect.<br>**Activities:**<br>1. Ask the students to prepare a poster in which the comparison between transformations is presented. Galilean and Lorentz<br>2. Assign students to calculate how much mass increases for a spaceship moving at 80% of speed of light.<br>***Keywords:*** *Simultaneity, Length contraction, dilation, Mass-energy Equivalence, Doppler effect. Time Dilation* | **14** |

***Code Details****: Gender – [i], Environment & Sustainability – [ii], Human Values – [iii], Professional Ethics – [iv], Employability – [v], Entrepreneurship - [vi], Skill Development -[vii]*

## References

**Suggested Readings**:

1. Pandey R. C., "Suryasiddhanta", Chaukhamba Surabharati Prakashan, Varanasi.

2. History of Science in Sanskrit Sentences, NCERT, 2018.
3. Bhaskara II, "Siddhanta Shiromani", (1150 CE).
4. Dongre N. G., Nene S. G., "Physics in Ancient India", National Book Trust, India.
5. Arfken G.B., Weber H.J., Harris F.E., "Mathematical Methods for Physicists", 2013, 7th Edition, Elsevier.
6. Kreyszig Erwin, "Advanced Engineering Mathematics", 2008, Wiley India.
7. Simmons George F., "Differential Equations", 2007, McGraw Hill.
8. Riley K.F., Hobson M.P. and Bence S.J., "Mathematical Methods for Physics and Engineering " A Comprehensive Guide, 2006, Cambridge University Press.
9. Spiegel M. R., "Vector Analysis: Schaum Outline Series", 2017, McGraw Hill Education.
10. George B. Thomas, Jr., Ross L. Finney, "Calculus and Analytical Geometry", 9th Edition, Addison-Wesley Publishing Company.
11. Pal S., Bhunia S.C., "Engineering Mathematics, 2015, Oxford University Press.
12. Books published by Madhya Pradesh Hindi Granth Academy, Bhopal.
13. Programing in Mathematica: Roman Maeder, Addison Wesley

**Web Links:**
**Suggested equivalent online courses:**

1. https://www.eshiksha.mp.gov.in/mpdhe/ Learning Management System, Department of higher education, Government of Madhya Pradesh (M.P.).
2. https://nptel.ac.in/courses/115/103/115103036/ Mathematical Physics by Dr. Saurabh Basu, Department of Physics, Indian Institute of Technology Guwahati.
3. www.wolfram.com
4. http://demonstrations.wolfram.com/HeatCapacityOfSolidsInTheDebyeApproximation/