Ph.D. MATHEMATICS

Scheme and Syllabus

ACADEMIC SESSION (2010 onwards)

(Updated from July 2020)

DEPARTMENT OF MATHEMATICS

FACULTY OF SCIENCES

J C BOSE UNIVERSITY OF SCIENCE AND TECHNOLOGY, YMCA,
FARIDABAD HARYANA -121006

J C BOSE UNIVERSITY OF SCIENCE AND TECHNOLOGY, YMCA, FARIDABAD

VISION

J C BOSE University of Science and Technology, YMCA aspires to be a nationally and internationally acclaimed leader in technical and higher education in all spheres which transforms the life of students through integration of teaching, research and character building.

MISSION

- To contribute to the development of science and technology by synthesizing teaching, research and creative activities.
- To provide an enviable research environment and state-of-the art technological exposure to its scholars.
- To develop human potential to its fullest extent and make them emerge as world class leaders in their professions and enthuse them towards their social responsibilities

DEPARTMENT OF MATHEMATICS

VISION

To emerge as a department of science, which will provide strong foundations in the areas of Pure and Applied Mathematics in order to develop innovative minds for interdisciplinary research.

MISSION

- To develop strong communication skills among students.
- To develop strong moral values.
- To develop strong foundations in mathematics to have sound analytical and critical thinking ability for innovative solutions in practical problems.
- To continuously improve the basic infrastructure in pursuit of providing necessary environment for academic excellence.
- To develop a nurturing environment for lifelong learning.

ABOUT THE PROGRAM: Ph.D. MATHEMATICS

The PhD program provides an opportunity for graduates to acquire high-level research skills and substantially deepen their knowledge in the area of Mathematics. This doctoral program trains students to use theoretical and computational research methods to solve a wide range of problems from the most abstract to the most applied. Students also develop their skills in presenting and teaching mathematics and its applications. The focus of the program is on substantial research on core areas of mathematics leading to the PhD dissertation.

A PhD in mathematics with a focus in something very quantitative can provide many opportunities that anyone can get with a math PhD but also open a very lucrative world that exists. Mathematics is a vast subject, both in breadth and in depth. As such, there's a significant number of different areas of research as a math student. Pure mathematics, applied mathematics and statistics have a lot of opportunities.

A doctorate in Mathematics not only demonstrates your commitment to continuous learning, but it also provides highly marketable skills. Besides subject-specific skills, many transferable skills which will prove useful in almost all industries like Logical ability to consider and analyse complex issues, Commitment and persistence towards reaching research goals, Outstanding verbal and written skills, Forming and explaining mathematical and logical solutions to a wide range of real-world problems and Exceptional numeracy skills.

JC BOSE UNIVERSITY OF SCIENCE AND TECHNOLOGY, YMCA, FARIDABAD

DEPARTMENT OF MATHEMATICS

SCHEME OF Ph.D. MATHEMATICS (Course Work) (2010)

Subject code	Title	L	T	P	Sessional Marks	Final Exam Marks	Total	Credits	Category Code
PHAS-06	Operation Research	4	0	0	40	60	100	4	DCC
PHAS-07	Fixed Point Theory	4	0	0	40	60	100	4	DCC
PHD-100A	Research Methodology	4	0	0	40	60	100	4	DCC

SCHEME OF Ph.D. MATHEMATICS (Course Work) (2016)

Subject code	Title	L	T	P	Sessional Marks	Final Exam Marks	Total	Credits	Category Code
PHAS-09	Reliability Theory and its Application	4	0	0	40	60	100	4	DCC
PHD-100A	Research Methodology	4	0	0	40	60	100	4	DCC

SCHEME OF Ph.D. MATHEMATICS (Course Work) (2018)

Subject code	Title	L	T	P	Sessional Marks	Final Exam Marks	Total	Credits	Category Code
PHDM-01	Operation Research	4	0	0	25	75	100	4	DEC
PHD-100A	Research Methodology	4	0	0	25	75	100	4	DCC

SCHEME OF Ph.D. MATHEMATICS (Course Work) (2019)

Subject code	Title	L	T	P	Sessional Marks	Final Exam Marks	Total	Credits	Category Code
PHDM-01	Operation Research	4	0	0	25	75	100	4	DEC
PHDM-02	Quantum Optics	4	0	0	25	75	100	4	DEC
PHD-100A	Research Methodology	4	0	0	25	75	100	4	DCC

SCHEME OF Ph.D. MATHEMATICS (Course Work) (2020)

Subject code	Title	L	T	P	Sessional Marks	Final Exam Marks	Total	Credits	Category Code
PHDM-01	Operation Research	4	0	0	25	75	100	4	DEC
PHDM-02	Quantum Optics	4	0	0	25	75	100	4	DEC
PHDM-03	Advanced Mechanics of Solids	4	0	0	25	75	100	4	DEC
PHD-100A	Research Methodology	4	0	0	25	75	100	4	DCC
CPE-RPE	Research and Publication Ethics	2	0	0	25	75	100	2	DCC

DEC: Discipline Elective Course (**Select any one course**)
DCC – Discipline Core Course

Syllabus of Operations Research for Ph.D. Coursework
Code: PHAS-06

			SESSIONAL	: 25
L	T	P	FINAL EXAM	: 75
4	0	0	TOTAL	: 100

UNIT 1: Linear Programming Problem:

(i) Computational procedure of simplex method
(ii) Alternative optimum solutions: unbounded solutions, non-existing feasible solutions.
(iii) Big M method, Two phase method
(iv) Sensitivity Analysis
(v) Revised Simplex Method
(vi) Duality, Dual Simplex Method

UNIT 2: Inventory Models

(i) Various costs
(ii) Deterministic inventory models
(iii) Single period inventory model with shortest cost
(iv) Stochastic models
(v) Application of inventory models
(vi) Economic lot sizes-price breaks

UNIT 3: Queuing theory

(i) Introduction to Queues
(ii) Basic Elements of Queuing Models
(iii) Queue Disciplines
(iv) Role of Exponential and Poisson Distributions
(v) Markovian Process, Erlang Distribution
(vi) Distribution Of Arrivals, Distribution of Service Times
(vii) Definition of Steady and Transient State, Poisson Queues.

UNIT 4: Integer linear programming

(i) Integer Linear Programming Problems
(ii) Mixed Integer Linear Programming Problems
(iii) Cutting Plane Method
(iv) Branch and Bound Method
(v) 0-1 integer linear programming problem.

UNIT 5: Non-linear programming & Quadratic programming

(i) Formulation of non-linear programming problems
(ii) General non-linear programming
(iii) Canonical form of non-linear programming problem
(iv) Kuhn Tucker conditions, non-negative constraints
(v) General quadratic programming problem
(vi) Wolfe's modified simplex method
(vii) Beale's method

UNIT 6: Dynamic Programming

(i) Bellman's Principle of optimality of Dynamic Programming
(ii) Multistage decision problem and its solution
(iii) Solution of linear programming problems as a Dynamic Programming Problem

Books

- Hadley, G.,"Linear Programming, and Massachusetts", Addison-Wesley
- Taha, H.A," Operations Research – An Introduction", Macmillian
- Hiller, F.S., G.J. Lieberman," Introduction to Operations Research", Holden-Day
- Harvey M. Wagner, "Principles of Operations Rsearch with Applications to Managerial Decisions", Prentice Hall of India Pvt. Ltd.
- Swarup K., "Operations Research", S. Chand

Syllabus for Pre-Ph.D. Programme

Fixed Point Theory

Code: PHAS-07

L	T	P		
4	0	0	SESSIONAL	: 25
			FINAL EXAM	: 75
			TOTAL	: 100

Section-I

Metric spaces and topological spaces, neighbourhoods, limit points, open and closed sets, completeness of metric spaces, Cantor's intersection theorem, contraction mappings, contraction principle and its converse, continuous and uniform continuous functions in metric spaces, compact metric spaces.

Section-II

Normed linear spaces, Banach spaces, fixed points, Lipschitz, non-expansive, contractive, contraction mappings and relation between these mappings, retraction mapping, $\in$ - chain and $\in$ - chainable metric spaces. Brouwers and Schauder's fixed point theorems and applications.

Section-III

Probabilistic metric spaces, Fuzzy Metric Spaces, Intuitionistic fuzzy metric Spaces, Various types of mappings such as commuting mappings, compatible mappings and their variants.

Suggested books:

1. Istratescu, V.I., Fixed Point Theory: An Introduction, Springer.

2. Joshi, M.C. and Bose, R.K., Some Topics in Non-Linear Functional Analysis, John Wiley & Sons (Asia).

3. J. Dugundji and A. Granas, Fixed Point Theory, Springer.

4. Agarwal, R.P., Meehan, M., and O' Regan, D., Fixed Point Theory and Applications, Cambridge Tracts in Mathematics, 141, Cambridge University Press.

Reliability Theory And its Application (PHM-101)

Code: PHAS-09

			SESSIONAL	: 25
L	T	P	FINAL EXAM	: 75
4	0	0	TOTAL	: 100

Part-A

Probability generating function: Probability generating function (pgf) of Bernoulli, binomial, Poisson and geometric distributions, Mean and variance of probability distributions using pgf. Mean and variance of probability distributions in terms of Laplace transforms. Stochastic Processes: definition, classification and examples. Markov Chains: definition and examples, transition matrix, order of a Markov chain, Markov chain as graphs.

Part-B

Reliability and Quality. Failure Data Analysis: Failure data, Failure density, Failure rate. Some Important distributions: Exponential, Rayleigh, Weibul, Gamma and Lognormal distributions.

Laplace and Stieltjes transforms and convolutions.

Component Reliability and Hazard Models: Component reliability from test data, Mean time to failure (MTTF), Mean time between failures (MTBF), Time dependent hazard models. Bath-Tub Curve.

Part-C

System Reliability Models: Systems with components in series, Systems with parallel components, k-out-of-m systems, non-series parallel systems, Systems with mixed mode failures. Standby redundancy: Simple standby system, k-out-of-n standby system.

Part-D

Maintainability and Availability: Maintainability function, Availability function, Reliability and availability analysis of a two-unit parallel system with repair using Markov model, Reliability and availability analysis of single-unit and two- unit cold standby systems with constant failure and repair rates using regenerative point and supplementary variable techniques.

Economics of Reliability Engineering: Manufacture's cost, Customer's cost, Reliability achievement and utility cost models, Depreciation cost models and availability cost model for parallel system.

Books Recommended:

1. E. Balagurusami, Reliability Engineering, Tata McGraw Hill, New Delhi, 1984.
2. L. S. Srinath, Reliability Engineering, Affiliated East West Press, New Delhi, 1991.
3. Elsayed A. Elsayed, Reliability Engineering, Addison Wesley Longman. Inc. Publication
4. A. Birolini, Reliability Engineering: Theory and Practical, Springer-Verlag.
5. Jai Singh Gurjar, Reliability Technology, I.K. International Publishing House Pvt. Ltd
6. Charles E Ebeling, An Introduction to Reliability and Maintainability Engineering, Tata McGraw-Hill Publishing Company Limited, New Delhi,2000

Ph.D. MATHEMATICS

CODE: PHDM-01

SUBJECT NAME: OPERATIONAL RESEARCH

NO. OF CREDITS: 4

			SESSIONAL	: 25
L	T	P	FINAL EXAM	: 75
4	0	0	TOTAL	: 100

UNIT 1

Linear Programming Problem: Computational procedure of simplex method, Alternative optimum solutions: unbounded solutions, non-existing feasible solutions. Big M method, Two phase method, Sensitivity Analysis, Revised Simplex Method, Duality, Dual Simplex Method.

UNIT 2

Inventory Models: Various costs, Deterministic inventory models, Single period inventory model with shortest cost, Stochastic models, Application of inventory models, Economic lot sizes-price breaks.

UNIT 3

Assignment problem, mathematical formulation, solution of assignment problem (Hungarian method), Transportation problem, mathematical formulation. Initial basic feasible solution of transportation problem by North-west corner rule, Lowest-cost Entry method and Vogel's approximation method, Optimal solution of transportation problem.

UNIT 4

Integer linear programming: Integer Linear Programming Problems, Mixed Integer Linear Programming Problems, Cutting Plane Method, Branch and Bound Method.

Queuing theory: Introduction to Queues, Basic Elements of Queuing Models, Queue Disciplines, Role of Exponential and Poisson Distributions, Markovian Process, Erlang Distribution, Distribution of Arrivals, Distribution of Service Times, Definition of Steady and Transient State, Poisson Queues.

Books:

- Hadley, G., "Linear Programming, and Massachusetts", Addison-Wesley
- Taha, H.A, "Operations Research – An Introduction", Macmillian
- Hiller, F.S., G.J. Lieberman, "Introduction to Operations Research", Holden-Day
- Harvey M. Wagner, "Principles of Operations Rsearch with Applications to Managerial Decisions", Prentice Hall of India Pvt. Ltd.
- Swarup K., "Operations Research", S. Chand

Ph.D. MATHEMATICS

CODE: PHDM-02

SUBJECT NAME: QUANTUM OPTICS

NO. OF CREDITS: 4

			SESSIONAL	: 25
L	T	P	FINAL EXAM	: 75
4	0	0	TOTAL	: 100

Course Objectives: To provide elementary knowledge of quantum optics and to learn about the basic concepts and techniques of quantum optics and their applications to physical systems.

Course Outcomes: After the successful completion of the course the research scholar shall be able

CO1: To know about quantization of an electromagnetic field and to comprehend the basic state space representation of the electromagnetic field.

CO2: To apply the displacement operator over the vacuum to formulate coherent state as well as to derive coherent state as an eigenstate of the annihilation operator, to analyse the properties of coherent states.

CO3: To analyse the squeezed state properties and to produce the state by applying the squeezing operator over vacuum.

CO4: To evaluate phase space descriptions of the electromagnetic field like P and Q representations and to demonstrate Wigner's phase space density function for different light states.

Unit I

Quantization of the electromagnetic field, Field quantization, Density of modes, Commutation relations, State space for the electromagnetic field: Fock space and Fock or Number states

Unit II

States of the electromagnetic field I, Coherent states and its properties, coherent states are minimum uncertainty states, coherent states are not orthogonal, coherent states are over complete, Displacement operator and its properties, Photon statistics, Coordinate representation

Unit III

States of the electromagnetic field II, The Squeeze operator, Squeezed states and general properties, Squeezed state is an eigen state of a generalized annihilation operator, calculation of moments with squeezed states, quadrature fluctuations, photon statistics, Multimode squeezed states

Unit IV

Phase space description, Q-representation: anti normal ordering, Normalization, Average of anti-normally ordered products, some examples, Density operator in terms of the function Q, Characteristic function, P representation: normal ordering, Normalization, Averages of normally ordered products, Some examples, Wigner distribution: symmetric ordering, Moments

References:

1. P. Meystre and M. Sargent, Elements of Quantum Optics, Springer-Verlag (1990).
2. D. F. Walls and G. J. Milburn, Quantum Optics, Springer-Verlag (1994).
3. G. S. Agarwal, Quantum Optics, Cambridge University Press (2013).
4. Miguel Orszag, Quantum Optics, Springer (2000).
5. M. O. Scully and M. S. Zubairy, Cambridge University Press (2012).
6. R. Loudon, The Quantum Theory of Light, Oxford Science Publications.

Ph.D. MATHEMATICS

CODE: PHDM-03

SUBJECT NAME: ADVANCED MECHANICS OF SOLIDS

NO. OF CREDITS: 4

			SESSIONAL	: 25
L	T	P	FINAL EXAM	: 75
4	0	0	TOTAL	: 100

Course Objectives: The objective of this paper is to introduce the concept of strains tensors, stress tensors and basic concepts of elastic body deformation and to make students familiar about the constitutive relations and field equations. Dynamics of elastic bodies and basic problems related to elastic wave propagation are also introduced.

Course Outcomes:

After the completion of this course, the learner will be able to:

CO1: Understand concept of strains tensors, stress tensors and basic concepts of elastic body deformation.

CO2: Derive the constitutive relations and field equations both mathematically as well as physically.

CO3: Analyse two-dimensional propagation of elastic waves**;** waves of dilatation and waves of distortion.

CO4: Know about the frequency equations of Rayleigh-type and Love-type surface waves and also to under reflection/ transmission phenomena from a solid boundary.

Unit I

Tensors: Summation convention, free and dummy suffixes, coordinate transformation, tensors of several orders, Kronecker's delta, Properties of tensors, equality of tensors, scalar multiple of a tensor, sum and difference of tensors, contraction, quotient laws, isotropic tensors, transpose and inverse of a tensor, symmetric and skew-symmetric tensors, invariants of a tensor, deviatoric tensors, eigen space of tensor, comma notation, gradient, divergence, curl tensor notations, Laplacian of a tensor.

Unit II

Stress and Strain: Deformation in elastic bodies, homogeneous strain and its properties, affine transformation, strain tensors, strain-displacement relations, principal strains, strain invariance, stress tensor, components of stress, Equations of equilibrium, generalised Hooke's Law- relation between

stress and strain, Elastic constants and their physical significance, Strain energy function and its connection with Hooke's Law.

Unit III

Definition of waves and basic terminology, Harmonic waves, Plane waves, Wave equation in 3-Dimensions, D'Alembert's solution of wave equation, Dispersion of waves and group velocity, Elastic waves, reduction of equation of motion to wave equation, P and S waves, Polarization of S wave, Helmholtz decomposition theorem of a vector, Two-dimensional propagation of elastic waves in isotropic solid, equation of motion in classical theory of elasticity.

Unit IV

Introduction to surface waves, Condition of existence and frequency equation of Rayleigh and Love waves, Particle motion of Rayleigh waves, Frequency equations of Rayleigh waves and Love waves, Snell's law of reflection and refraction, Reflection of plane waves (P/SV and SH-waves) from free surface of an elastic half-space, Reflection and transmission at interface of two different elastic solids, Partition of energy at the interface.

References:

1. Narayan, Shanti. *A text book of Cartesian Tensors (with an introduction to general tensors)*, 3rd edition. New Delhi: S. Chand Publications, 1968.
2. Young, E. C., *Vectors and tensor analysis*, 2nd edition, 1993
3. Sokolnikoff, I. S., *Mathematical theory of elasticity*, 2nd edition, McGraw-Hill, 1982.
4. Chandrasekharaiah, D. S. and Debnath, L. *Continuum Mechanics*, Academic Press Inc., San Diego, CA, 1994.
5. Kolsky, H. *Stress waves in Solids*. Dover Publications, 1963.
6. Ghosh, P. K., *Mathematics of waves and vibrations*. New Delhi: The Macmillan Company of India Limited, 1975.
7. Ewing, W. M., W.S. Jardetzky, and F. Press. *Elastic waves in layered media*. McGraw-Hill Book Co., 1957.

Ph.D. MATHEMATICS (COMMON SUBJECT)

CODE: PHD-100A

SUBJECT NAME: RESEARCH METHODOLOGY

NO. OF CREDITS: 4

			SESSIONAL	: 25
L	T	P	FINAL EXAM	: 75
4	0	0	TOTAL	: 100

Course Objectives:

- Understand research process in order to plan a research proposal
- Learn methods to devise and design a research set-up
- Plan and perform data collection methods and its analysis
- Conclude research in report writing

Course Outcomes: The research scholar shall be able to

CO1	Plan a research proposal and design the research.
CO2	Collect data through experiments or surveys as per research requirement.
CO3	Understand and apply sampling and sampling distributions.
CO4	Understand and perform quantitative and qualitative data analysis.
CO5	Write research report with proper citations.

Unit 1 **Introduction to Research**: Definition, need and purpose of research, types of research, research process, approaches to research, planning a research proposal, literature review.

Unit 2 **Measurement Scales**: Indexes vs. Scales, Types of Scale, construction of Scale, Bogardus social distance scale, Thurstone Scale, Likert Scale, Semantic Differential Scale, Guttmann Scale.

Unit 3 **Data Collection Methods:** Experiments and Surveys, Experiments: Classical Experiments, Independent & Dependent Variables, Pre Testing & Post Testing, Double Blind Experiment, Subject Selection, Variation on Experiment Design. Survey Research: Topics appropriate for survey research, Guidelines for asking questions, Questionnaire Construction, Strengths & Weakness of Survey Research, Types of Surveys.

Unit 4 **Sampling**: Types of sampling methods: Non Probability Sampling, Probability Sampling, Theory & Logic of Probability Sampling, Sampling Distributions & Estimates of Sampling Error.

Unit 5 **Data Analysis**: Qualitative v/s Quantitative data analysis, Qualitative Data Analysis: Discovering Patterns, Grounded Theory Method, Semiotics, Conversation Analysis, Qualitative Data Processing. Quantitative Data Analysis: Quantification of Data, Univariate Analysis, Bivariate Analysis, Multivariate Analysis, Regression Analysis, Description Analysis. Hypothesis. Multiple Attribute Decision Making.

Unit 6 **Report Writing, Ethical Issues and Outcomes**: Report Preparation, Structure of Report, Report Writing Skills, Citations, Research Papers, Intellectual Property Rights, Plagiarism, Patent, Commercialization, Ethical Issues.

References:

1. Research Methodology by R. Panneerselvam, 2nd Ed. PHI
2. Research Methodology by C.R. Kothari & Gaurav Garg, 3rd Ed. New Age Publishers
3. Research Methodology and Scientific Writing by C. George Thomas, Ane Books
4. The practice of social research by Earl Babbie, 14th Ed. Cengage
5. Multiple Attribute Decision Making, Gwo-Hshiung Tzeng and Jih-Jeng Huang, CRC Press.
6. Research Methodology by Ranjit Kumar, Sage Publications

Ph.D. MATHEMATICS (COMMON SUBJECT)

CODE: CPE-RPE

SUBJECT NAME: RESEARCH AND PUBLICATION ETHICS

NO. OF CREDITS: 2

			SESSIONAL	: 25
L	T	P	FINAL EXAM	: 75
2	0	0	TOTAL	: 100

- **RPE 01: PHILOSOPHY AND ETHICS (3 hrs.)**

1. Introduction to philosophy: definition, nature and scope, concept, branches
2. Ethics: definition, moral philosophy, nature of moral judgements and reactions

- **RPE 02: SCIENTIFIC CONDUCT (5 hrs.)**

1. Ethics with respect to science and research
2. Intellectual honesty and research integrity
3. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP)
4. Redundant publications: duplicate and overlapping publications, salami slicing
5. Selective reporting and misrepresentation of data

- **RPE 03: PUBLICATION ETHICS (7 hrs.)**

1. Publication ethics: definition, introduction and importance
2. Best practices / standards setting initiatives and guidelines: COPE, WAME, etc.
3. Conflicts of interest
4. Publication misconduct: definition, concept, problems that lead to unethical behavior and vice versa, types
5. Violation of publication ethics, authorship and contributorship
6. Identification of publication misconduct, complaints and appeals
7. Predatory publishers and journals

PRACTICE

- **RPE 04: OPEN ACCESS PUBLISHING (4 hrs.)**

1. Open access publications and initiatives.
2. SHERPA/RoMEO online resource to check publisher copyright & self-archiving policies
3. Software tool to identify predatory publications developed by SPPU
4. Journal finder/ journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester, etc.

- **RPE 05: PUBLICATION MISCONDUCT (4 hrs.)**

A. Group Discussions (2 hrs.)

1. Subject specific ethical issues, FFP, authorship
2. Conflicts of interest
3. Complaints and appeals: examples and fraud from India and abroad

B. Software tools (2 hrs.)

Use of plagiarism software like Turnitin, Urkund and other open source software tools

- **RPE 06: DATABASES AND RESEARCH METRICS (7 hrs.)**

A. Databases (4 hrs.)

1. Indexing databases
2. Citation databases: Web of Science, Scopus, etc.

B. Research Metrics (3 hrs.)

1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score
2. Metrics: h-index, g index, ilO index, altmetrics

References

1. Bird, A. (2006). *Philosophy of Science.* Routledge.
2. MacIntyre, Alasdair (1967) *A Short History of Ethics.* London.
3. P. Chaddah, (2018) Ethics in Competitive Research: Do not get scooped; do not get plagiarized, ISBN:978- 9387480865
4. National Academy of Sciences, National Academy of Engineering and Institute of Medicine. (2009). *On Being a Scientist: A Guide to Responsible Conduct in Research: Third Edition.* National Academies Press.
5. Resnik, D. B. (2011). What is ethics in research & why is it important. *National Institute of Environmental Health Sciences,* 1-10. Retrieved from http://www.niehs.nih.gov/research/resources/bioethics/whatis/index.cfrn
6. Beall, J. (2012). Predatory publishers are corrupting open access. Nature, 489(7415), 179-179. https://doi.org/10.1038/489179a
7. Indian National Science Academy (INSA), Ethics in Science Education, Research and Govemance(2019) , ISBN:978-81-939482-l-7. http://www.insaindia.res.in/pdf/Ethics_Book.pdf

Mapping of the subjects

S. No.	Course Name	Course Code	Employability	Entrepreneurship	Skill Development
1.	Operation Research	PHDM-01	✓	✓	-
2.	Quantum Optics	PHDM-02	✓	-	✓
3.	Advanced Mechanics of Solids	PHDM-03	✓	-	✓
4.	Research Methodology	PHD-100A	✓	-	✓
5.	Research and Publication Ethics	CPE-RPE	✓	-	-