B. SC. (HONOURS) PHYSICS

DISCIPLINE SPECIFIC CORE COURSE – DSC - 16: STATISTICAL MECHANICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Statistical Mechanics DSC – 16	4	4	0	0	Appeared in Semester 5	--

LEARNING OBJECTIVES

Statistical mechanics deals with the derivation of the macroscopic parameters (internal energy, pressure, specific heat etc.) of a physical system consisting of large number of particles (solid, liquid or gas) from knowledge of the underlying microscopic behaviour of atoms and molecules that comprises it. The main objective of this course work is to introduce the techniques of statistical mechanics which has applications in various fields including astrophysics, semiconductor physics, plasma physics, bio-physics etc. and in many other directions.

LEARNING OUTCOMES

By the end of the course, students will be able to,

- Understand the concepts of microstate, macrostate, phase space, thermodynamic probability and partition function.
- Understand the use of thermodynamic probability and partition function for calculation of thermodynamic properties for physical systems (ideal gas, finite level system)
- Understand the difference between the classical and quantum statistics and their applicability.
- Understand the properties and laws associated with thermal radiation.
- Apply the Fermi-Dirac distribution to model problems such as electrons in solids and white dwarf stars
- Apply the Bose-Einstein distribution to model problems such as black-body radiation and liquid helium.

SYLLABUS OF DSC – 16

THEORY COMPONENT

Unit - I **(26 Hours)**

Classical Statistics: Phase space, microstates and macrostates, entropy and thermodynamic probability, concept of ensemble - Introduction to three types, Maxwell-Boltzmann distribution law, partition function, thermodynamic functions of an ideal gas, Gibbs paradox, Sackur-

DISCIPLINE SPECIFIC CORE COURSE – DSC - 17: ATOMIC, MOLECULAR AND NUCLEAR PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Atomic, Molecular and Nuclear Physics DSC – 17	4	4	0	0	Appeared in Semester 5	Light and Matter, Modern Physics and Quantum Mechanics-I of this course or their equivalent

LEARNING OBJECTIVES

This course introduces the basic concepts of atomic, molecular and nuclear physics to an undergraduate student. Advanced mathematics is avoided and the results of quantum mechanics are attempts to explain, or even to predict, the experimental observations of spectroscopy. The student learns to visualize a nucleus, an atom or molecule as a physical entity rather than a series of mathematical equations.

LEARNING OUTCOMES

On successful completion of the module students should be able to elucidate the following main features.

- Stern-Gerlach experiment, electron spin, spin magnetic moments, space quantization and Zeeman effect, spectral notations for atomic and molecular states and corresponding term symbols, understanding of atomic spectra and molecular spectra
- Basic principle of Raman spectroscopy and Franck Condon principle.
- The radioactive processes and the stability of the nuclei, the nuclear models and the nuclear reactions like fission and fusion useful in nuclear reactors.
- The full scientific potential lies on how we are able to interpret the fundamental astrophysical and nuclear data. The acquired knowledge can be applied in the areas of astrophysics, nuclear, medical, geology and other interdisciplinary fields of Physics, Chemistry and Biology. It will enhance the special skills required for these fields

SYLLABUS OF DSC - 17

THEORY COMPONENT

Unit – I - Atomic Physics (20 Hours)

One-electron atoms: Degeneracy of energy levels and selection rules, modes of relaxation of an excited atomic state.

Fine structure of Hydrogenic atoms: Shifting of energy levels, Splitting of spectral lines,

7) Nuclear Physics, S. N. Ghoshal, 1st edition, 2019, S. Chand Publication
8) Introducing Nuclear Physics, K. S. Krane, 2008, Wiley India

Additional Readings:

1) Basic Atomic and Molecular Spectroscopy, J. M. Hollas, Royal Society of Chemistry
2) Molecular Spectra and Molecular Structure, G. Herzberg
3) Basic Ideas and Concepts in Nuclear Physics: An Introductory Approach (Series in Fundamental and Applied Nuclear Physics), K. Heyde (Institute of Physics Publishing 3rd edition
4) Nuclear Physics: principles and applications, John Lilley, 2006, Wiley
5) Schaum's Outline of Modern Physics, 1999, McGraw-Hill Education
6) Introduction to elementary particles, D. J. Griffiths, 2008, Wiley
7) Atomic and molecular Physics, R. Kumar, 2013, Campus Book Int.
8) The Fundamentals of Atomic and Molecular Physics (Undergraduate Lecture Notes in Physics), 2013, Springer

Unit – II **(11 Hours)**

Bayesian Statistics: Conditional probability and Bayes Theorem, Prior and Posterior probability distributions, examples of Bayes theorem in everyday life. Bayesian parameter estimation. Normal, Poisson and Binomial distributions, their conjugate priors and properties. Bayes factors and model selection.

Unit – III **(11 Hours)**

Bayesian Regression: Introduction to Bayesian Linear Regression. Bayesian logistic regression and its applications. Bayesian parameter estimation for regression models. Posterior distribution of model parameters and the posterior predictive distributions.

References:

Essential Readings:

1) Schaum's Outline Series of Probability and Statistics, M. R. Spiegel, J. J. Schiler and R. A. Srinivasan, 2012, McGraw Hill Education
2) Schaum's Outline Series of Theory and Problems of Probability, Random Variables, and Random Processes, H. Hsu, 2019, McGraw Hill Education
3) Bayesian Logical Data Analysis for the Physical Sciences: A Comparative Approach with Mathematica Support, P. Gregory, 2010, Cambridge University Press
4) Linear Regression: An Introduction to Statistical Models, P. Martin, 2021, Sage Publications Ltd.
5) Data Analysis: A Bayesian Tutorial, D. S. Sivia and J. Skilling, 2006, Oxford University Press
6) Data Reduction and Error analysis for the Physical Sciences, P. R. Bevington and D. K. Robinson, 2002, McGraw-Hill Education

Additional Readings:

1) A Guide to the Use of Statistical Methods in the Physical Sciences, R. J. Barlow, 1993, Wiley Publication
2) An Introduction to Error Analysis, J. R. Taylor, 1996, Univ. Sci. Books
3) Applied Multivariate Data Analysis, Volume I: Regression and Experimental Design, J. D. Jobson, 2012, Springer-Verlag
4) Statistical Rethinking A Bayesian Course with Examples in R and STAN, Richard McElreath, 2020, CRC Press
5) Introduction to Bayesian Statistics, W. Bolstad, 2007, John Wiley

PRACTICAL COMPONENT

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

The objective of this lab is to familiarise the students with the techniques of data analysis. The instructors are required to discuss the concepts and the pseudo-codes of the recommended programs in the practical sessions before their implementation. The implementation can be in any programming language. Inbuilt libraries can be used wherever applicable. **All units are mandatory.**

Unit 1 (12 Hours)

Probability Distributions

1) Generate sequences of N random numbers M (at least 10000) number of times from

state j. Compute the transition matrix for $1, 2,..., N$ steps. Following the rule, write a code for Markovian Brownian motion of a particle.

2) Given that a particle may exist in one of the given energy states (E_i, $i = 1, \dots 4$) and the transition probability matrix T, so that T_{ij} gives the probability for the particle to make transition from energy state E_i to state E_j. Determine the long-term probability of a particle to be in state in the state E_f if the particle was initially in state E_i.

References for laboratory work:

1) Data Science from Scratch – First Principles with Python, J. Grus, O'Reilly, 2019, Media Inc.
2) Bayes' Rule with Python: A tutorial introduction to Bayesian Analysis, J. V. Stone, 2016, Sebtel Press
3) Practical Bayesian Inference, B. Jones, 2017, Cambridge University Press
4) Modeling and Simulation in Scilab/Scicos with Scicos Lab 4.4, S. L. Campbell, Jean-P. Chancelier and R. Nikoukhah, Springer.
5) Scilab Textbook Companion for Probability And Statistics For Engineers And Scientists, S. M. Ross, 2005, Elsevier
6) Numerical Recipes: The art of scientific computing, W. H. Press, S. A. Teukolsky and W. Vetterling, 2007, Cambridge University Press

tensor); association of anti-symmetric tensor of rank two with vectors; vector algebra and calculus in tensor notation; differentiation, gradient, divergence and curl of tensor fields; vector identities in tensor notation.

Unit - II **(12 hours)**
Applications of Cartesian Tensors: Equation of a line, angle between lines, projection of a line on another line, condition for two lines to be coplanar and length and foot of the perpendicular from a point on a line; rotation tensor and its properties.
Moment of Inertia Tensor, Stress and Strain Tensors, Elasticity Tensor, Generalized Hooke's Law, Electric Polarizability Tensor.

Unit - III **(18 hours)**
General Tensors: Transformation of co-ordinates and contravariant and covariant vectors. Transformation law for contravariant, covariant and mixed tensors. Kronecker Delta and permutation tensors. Algebra of general tensors. Quotient law general tensors. Symmetric and anti-symmetric tensors. Metric tensor. Reciprocal tensors. Associated tensors. Christoffel symbols of first and second kind and their transformation laws. Covariant derivative, gradient, divergence and curl of tensor fields.

Unit - IV **(18 hours)**
Covariant Formulation of Electrodynamics: Minkowski space, four vectors (four-displacement, four-velocity, four-momentum, four-vector potential, four-current density,). tensorial form of Lorentz transformation. Electromagnetic field-strength tensor, Four rank permutation tensor, dual field-strength tensor, Lorentz transformation of electric and magnetic fields, electromagnetic field tensor, covariance of Maxwell's Equations.

References:
Essential Readings:
1) Vector Analysis and Cartesian Tensors, 3rd edition, D. E. Bourne, P. C. Kendall, 1992
2) Cartesian Tensors, H. Jeffreys, 1931, Cambridge University Press.
3) Mathematical Methods for Physicists, H. J. Weber and G. B. Arfken, 2010, Elsevier.
4) A Brief on Tensor Analysis, J. G. Simmonds, 1997, Springer.
5) Schaum's outlines series on Vector Analysis, M. Spiegel, 2nd edition, 2017.
6) Schaum's Outline Series on Tensor Calculus, D. Kay, Revised 1st edition, 2011.
7) An Introduction to Tensor Calculus and Relativity, D. F. Lawden, 2013, Literary Licensing

Additional Readings:
1) A Student's Guide to Vectors and Tensors, Daniel A. Fleisch, 2011, Cambridge Univ. Press.
2) Matrices and tensors in physics by A. W. Joshi, 1995, New Age International Publications.
3) The Feynman Lectures on Physics, Volume II, Feynman, Leighton and Sands, 2008, Narosa Publishing House.
4) Classical Electrodynamics, J. D. Jackson, 3rd edition, 2009, Wiley Publication.
5) A Primer in Tensor Analysis and Relativity, I. L. Shapiro, 1st edition, 2019, Springer.
6) Gravity-An introduction to Einstein's General Relativity, J. B. Hartle, 2009, Pearson Education.
7) A first course in general relativity, B. F. Schutz, 2004, Cambridge University Press.

multiplication by repeated addition, division by repeated subtraction, block data transfer and checking of parity of a binary number)

References:

Essential Readings:

1) Microprocessor Architecture Programming and applications with 8085, R. S. Gaonkar, 2002, Prentice Hall
2) Microelectronic Circuits, S. Sedra
3) Fundamentals of Microprocessor and Microcomputer, B. Ram, Dhanpat Rai Publications
4) The Intel Microprocessors - Architecture, Programming and Interfacing, B. Brey, 2003, Pearson Education

Additional Readings:

1) Microprocessors and Microcontrollers, M. Ali Mazidi, 2006, Pearson

PRACTICAL COMPONENT

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

At least six experiments to be performed from the following list.

8085 Assembly language programs

1) Add two 8-bit numbers using Direct and Indirect Addressing Mode
2) Subtract two 8-bit numbers using Direct and Indirect Addressing Mode
3) Multiply two 8-bit numbers with and without subroutine
4) Divide two-8 bit numbers with and without subroutine
5) Add a list of 8-bit numbers
6) Transfer a Block of Data
7) Add two 16 bit numbers with DAD and without DAD
8) Convert byte to Nibble
9) Convert nibble to Byte
10) Check the parity of a given number

References for laboratory work:

1) Microprocessor Architecture Programming and applications with 8085, R. S. Gaonkar, 2002, Prentice Hall
2) Microelectronic Circuits, S. Sedra
3) Fundamentals of Microprocessor and Microcomputer, B. Ram, Dhanpat Rai Publications
4) Microprocessors and Microcontrollers, M. Ali Mazidi, 2006, Pearson
5) The Intel Microprocessors - Architecture, Programming and Interfacing, B. Brey, 2003, Pearson Education

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 11: RESEARCH METHODOLOGY

Unit - III – Journals, Database and Research Metrics (7 Hours)

Journals: Free, open source and paid journals, concept of peer reviewed journals, predatory and fake journals

Databases: Indexing databases; citation databases (Web of science, Scopus); experimental physics databases (astrophysics (ADS, NED, SIMBAD, VizieR), biophysics (PubMed), particle physics (INSPIRE, CDS), condensed matter physics (X-ray database))

Research Metrics: Journal impact factor, SNIP, SJR, IPP, cite score; metrics (h-index, g index, i10 index, altmetrics), variations in research metrics across various disciplines, other limitations of the research metrics and impact factors

Unit - IV – Scientific Conduct and Publication Ethics (8 Hours)

Current understanding of ethics; intellectual honesty and research integrity; communicating errors (erratum, correction and withdrawal); records and logs (maintaining records of samples, raw data, experimental protocols, observation logs, analysis calculations, and codes); scientific publication misconducts: plagiarism (concept, importance, methods and ways to detect and avoid plagiarism) and redundant publications (salami slicing, duplicate and overlapping publications, selective reporting and misrepresentation of data); environmental and other clearances (waste management, disposal of hazardous waste).

COPE guidelines on best practices in publication ethics

Unit V – Scientific Writing and Software Tools (5 Hours)

Writing a research paper and report: introduction, motivation, scientific problem, its methodology, any experimental set up, data analysis, discussion of results, conclusions

Referencing formats (APA, MLA) and bibliography management

Graphical software (open source, magic plot, gnu plot, origin); presentation tools (beamer)

Unit VI - Intellectual Property Right and Research Funding (4 Hours)

Basic concepts and types of intellectual property (patent, copyright and trademark)

Role of funding agencies in research, overview of various funding agencies (DST-SERB, UGC, CSIR, BRNS, DRDO), national and international research project grants and fellowships

References:

Essential Readings:

1) Management Research Methodology, K. N. Krishnaswamy, A. I. Sivakumar, M. Mathirajan, 2006, Pearson Education, New Delhi.
2) Research Methodology, Methods and Techniques, C. R. Kothari, 2nd edition, 2008, New Age International Publication.
3) Research Methodology, A step by step guide for beginners, R. Kumar, 6th edition, 2009, Pearson Education
4) Data reduction and error analysis for the physical sciences, P. R. Bevington and D. K. Robinson, 3rd edition, McGraw-Hill
5) Intellectual property: Patents, Trademarks, Copyrights, Trade Secrets, C. J. Holland, 2007, Entrepreneur Press

Additional Readings:

1) Research Methods, R. Ahuja, 2001, Rawat Publications, New Delhi.
2) Research design: Qualitative, quantitative, and mixed methods approaches, J. W. Creswell, and J. D. Creswell, 2017, Sage Publications.

Category II

Physical Science Courses
with Physics discipline as one of the Core Disciplines

(B. Sc. Physical Science with Physics as Major discipline)

Unit – III - Elementary Band Theory **(5 Hours)**
Qualitative understanding of Kronig and Penny model (without derivation) and formation of bands in solids, concept of effective mass, Hall effect in semiconductor, Hall coefficient, application of Hall Effect, basic introduction to superconductivity

Unit – IV - Magnetic Properties of Matter **(6 Hours)**
dia-, para-, and ferro- magnetic materials, classical Langevin theory of dia– and para-magnetism (no quantum mechanical treatment), qualitative discussion about Weiss's theory of ferromagnetism and formation of ferromagnetic domains, B-H curve hysteresis and energy loss

Unit – V - Dielectric Properties of Materials **(3 Hours)**
Polarization, local electric field in solids, electric susceptibility, polarizability, Clausius Mossoti equation, qualitative discussion about ferroelectricity and PE hysteresis loop

References:
Essential Readings:

1) Introduction to Solid State Physics, C. Kittel, 8th edition, 2004, Wiley India Pvt. Ltd.
2) Elements of Solid-State Physics, J. P. Srivastava, 2nd edition, 2006, Prentice-Hall of India
3) Introduction to Solids, L. V. Azaroff, 2004, Tata Mc-Graw Hill
4) Solid State Physics, N. W. Ashcroft and N. D. Mermin, 1976, Cengage Learning
5) Solid State Physics, M. A. Wahab, 2011, Narosa Publications

Additional Readings:

1) Elementary Solid State Physics, M. Ali Omar, 2006, Pearson
2) Solid State Physics, R. John, 2014, McGraw Hill
3) Superconductivity: A very short introduction, S. J. Blundell, Audiobook

PRACTICAL COMPONENT

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

At least six experiments to be performed from the following list

1) Measurement of susceptibility of paramagnetic solution (Quinck's tube method)
2) To measure the magnetic susceptibility of solids
3) To determine the coupling coefficient of a piezoelectric crystal
4) To study the dielectric response of materials with frequency
5) To determine the complex dielectric constant and plasma frequency of a metal using Surface Plasmon Resonance (SPR) technique
6) To determine the refractive index of a dielectric layer using SPR technique
7) To study the PE Hysteresis loop of a ferroelectric crystal
8) To draw the BH curve of iron (Fe) using a Solenoid and determine the energy loss from hysteresis loop
9) To measure the resistivity of a semiconductor (Ge) crystal with temperature (up to 150^{o} C) by four-probe method and determine its band gap
10) To determine the Hall coefficient of a semiconductor sample

DISCIPLINE SPECIFIC ELECTIVE COURSE – PHYSICS DSE 16a: MATHEMATICAL PHYSICS II

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Mathematical Physics II PHYSICS DSE 16a	4	4	0	0	Appeared in Semester 5	Mathematics as Discipline Specific Core course containing linear algebra and calculus.

LEARNING OBJECTIVES

The emphasis of course is to equip students with the mathematical tools required in solving problem of interest to physicists. The mathematical tools might be building blocks to understand the fundamental computational physics skills and hence enable them to solve a wide range of physics problems. Overall, to help students develop critical skills and knowledge that will prepare them not only for doing fundamental and applied research but also prepare them for a wide variety of careers.

LEARNING OUTCOMES

After completing this course, student will be able to,

- Understand algebraic structures in n-dimension and basic properties of the linear vector spaces.
- Apply vector spaces and matrices in the quantum world.
- Learn basic notions of calculus of variations.
- Learn Lagrangian and Hamiltonian of the physical system.
- Learn Fourier Transforms (FTs) and Laplace Transforms (LTs).
- Understand the applications of Fourier Transforms (FTs) and Laplace Transforms (LTs).

SYLLABUS OF PHYSICS DSE – 16a

THEORY COMPONENT

Unit – I **(18 Hours)**

Linear Algebra: Linear vector spaces, inner product of vectors and norm of a vector, Euclidean spaces, unitary spaces and inner product spaces. Properties of inner product spaces, Cauchy-Schwartz inequality, concept of length and distance, metric spaces. Orthogonality of vectors, orthonormal basis. Eigenvalue and Eigenvector, Adjoint of a linear operator, Hermitian or Self adjoint operators and their properties and Unitary Operators. Hilbert Space (Definition Only).

DISCIPLINE SPECIFIC ELECTIVE COURSE – PHYSICS DSE 16b: COMMUNICATION SYSTEM

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Communication System PHYSICS DSE – 16b	4	2	0	2	Appeared in Semester 5	--

LEARNING OBJECTIVES

This paper aims to describe the fundamental concepts of communication systems and communication techniques based on analog modulation, analog and digital pulse modulation. Communication and Navigation systems such as GPS and mobile telephony system are also introduced. This paper will essentially connect the text book knowledge with the most popular communication technology in real world.

LEARNING OUTCOMES

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

- Understand fundamentals of electronic communication system and electromagnetic communication spectrum with an idea of frequency allocation for radio communication system in India.
- Gain an insight on the use of different modulation and demodulation techniques used in analog communication
- Learn the generation and detection of a signal through pulse and digital modulation techniques and multiplexing.
- Gain an in-depth understanding of different concepts used in a satellite communication system.
- Study the concept of Mobile radio propagation, cellular system design and understand mobile technologies like GSM and CDMA.
- In the laboratory course, students will apply the theoretical concepts to gain hands-on experience in building modulation and demodulation circuits; Transmitters and Receivers for AM and FM. Also to construct TDM, PAM, PWM, PPM and ASK, PSK and FSK modulator and verify their results.

SYLLABUS OF PHYSICS DSE – 16b

THEORY COMPONENT

Unit – I - Electronic communication and analog modulation (8 Hours)

Electronic communication: Introduction to communication – means and modes. Need for modulation. Block diagram of an electronic communication system, channels and base-band signals

Analog Modulation: Amplitude modulation, modulation index and frequency spectrum. Generation of AM (emitter modulation), amplitude demodulation (diode detector), Single

6) To study time division multiplexing (TDM)
7) To design pulse amplitude modulator using transistor.
8) To design pulse width modulator using 555 timer IC.
9) To design pulse position modulator using 555 timer IC
10) To study ASK, PSK and FSK modulators and demodulators

References for laboratory work:

1) Electronic Communication system, Blake, Cengage, 5th edition
2) Introduction to Communication systems, U. Madhow, 1st edition, 2018, Cambridge University Press

coherence in laser action), optical resonator (different configurations and stability condition)

Unit 2 – Types of Laser **(8 Hours)**

Doped insulator laser (Nd:YAG laser, Ruby laser)

Semiconductor lasers (GaAs laser): Energy bands and carrier distribution in semiconductors, absorption and emission in a semiconductor, optical gain, laser oscillation, threshold current density, power output

Gas lasers: He-Ne laser, noble gas ion laser, carbon dioxide laser

Unit 3 – Applications of Laser **(10 Hours)**

Properties of laser light: Mono-chromaticity, directionality, line width, beam coherence, intensity, focussing

Applications: Measurement of distance (interferometry method, beam modulation telemetry), Holography (basic principle, coherence, recording and reconstruction method, white light reflection hologram, application in microscopy and character recognition), medical applications, laser tweezers, high energy applications, industrial applications, laser induced nuclear fusion

References:

Essential Readings:

1) Laser Physics, M. Sargent, M. O. Scully and W. E. Lamb Jr., 1974, Western Press
2) Laser Physics and Spectroscopy, P. N. Ghosh, 2016, Levant Books, India
3) Lasers: Fundametnals and applications, K. Thyagarajan and A. K. Ghatak, 2010, Tata McGraw Hill
4) Optical systems and processes, J. Shamir, 2009, PHI Learning Pvt. Ltd.
5) Fundamental of optics, A. Kumar, H. R. Gulati and D. R. Khanna, 2011, R. Chand and Co. Publications
6) Optics, E. Hecht, 4th edition, 2014, Pearson Education
7) Laser applications, M. Ross, 1968, McGraw Hill

Additional Readings:

1) Physics for scientists and engineers with modern physics, Jewett and Serway, 2010, Cengage Learning
2) Optical Physics, A. Lispon, S. G. Lipson and H. Lipson, 4th edition, 1996, Cambridge University Press
3) Fibre optics through experiments, M. R. Shenoy, S. K. Khijwania, et.al. 2009, Viva Books
4) Industrial applications of lasers, J. F. Ready, 2nd edition, 1997, Academic Press
5) Semiconductor optoelectronics, J. Singh, 1995, McGraw Hill

PRACTICAL COMPONENT

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

At least six experiments to be performed from the following list

1) To determine the wavelength and angular spread of laser light by using plane diffraction grating.
2) To determine the wavelength of laser source using diffraction of single slit.
3) To determine the wavelength of laser source using diffraction of double slits.

DISCIPLINE SPECIFIC ELECTIVE COURSE – PHYSICS DSE 16d: RESEARCH METHODOLOGY

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Research Methodology PHYSICS DSE – 16d	4	3	0	1	Appeared in Semester 5	--

LEARNING OBJECTIVES

This course has been designed to explore the basic dimensions of research and to impart quantitative and qualitative knowledge for conducting meaningful research. Starting from the philosophy of research, through awareness about the publication ethics and misconducts, this course covers all the methodological and conceptual issues required for a successful conduct of research. It gives an overview of research techniques, data management and analysis, and commonly used statistical methods in physical sciences.

LEARNING OUTCOMES

After successful completion of this course, students will be sufficiently trained in the following.

- Skills to review literature and frame research problem
- Comprehend the relevance of the tools for data collection and analysis
- Writing a scientific report/research proposal
- Software tools for research in physical sciences
- Research integrity and publication ethics
- Importance of intellectual property rights
- Role of funding agencies in research

SYLLABUS OF Physics DSE – 16d

THEORY COMPONENT

Unit - I - Introduction to research methodology (6 Hours)

Brief history of scientific method and research, role and objectives of research, basic tenets of qualitative research; research problem and review of literature: identifying a research problem (philosophy and meaning of research, identification and definition of research problem, formulation of research problem, sources of prejudice and bias); literature survey (open-source and paid tools for keeping track of the literature)

Unit - II - Data collection, analysis and interpretation (15 Hours)

Methods of data collection: survey, interview, observation, experimentation and case study;
Descriptive statistics: Measures of central tendency (mean, median, mode) and dispersion (range, standard deviation);

Entrepreneur Press

Additional Readings:

1) Research Methods, R. Ahuja, 2001, Rawat Publications, New Delhi.
2) Research design: Qualitative, quantitative, and mixed methods approaches, J. W. Creswell, and J. D. Creswell, 2017, Sage Publications.
3) Intellectual Property: Patents, Trademarks and Copyright in a Nutshell, A. R. Miller and M. H. Davis, 2000, West Group Publishers

PRACTICAL COMPONENT

(15 Weeks with 2 hours of laboratory session per week)
Students should perform at least six practicals from the following list, such that all the units mentioned below are covered.

Unit 1:

1) Identify a research problem, write its brief summary and make a corresponding flow chart
2) Identify a survey-based research problem in physics and create a questionnaire to collect data to perform meaningful research.
3) Write a literature review for a research problem.
4) Create a list of research topics (at least three) and read at least one research paper in each topic.

Unit 2:

1) Attend a research seminar and write a brief summary in 1000 words. Check the extent of plagiarism in this summary by using on-line plagiarism detection tools
2) Read a research paper based on the use of statistics in experimental physics and summarise its importance.
3) Collect publicly available experimental physics data. Identify the independent, dependent and control variables. Fit at least two mathematical models that can describe the data and compare their statistical significance.

Unit 3:

1) Review any three research papers.
    a) List the major strengths and weakness of all of them.
    b) For any one of these, create a referee report assuming you are a reviewer of the paper. Also draft a response to the referee's report assuming you are the author.
2) Review any research paper. Rewrite it as if the work has been done by you for the first time. Use two different referencing and bibliography styles

Unit 4:

1) Take data from any publicly available experimental physics database. Use Microsoft Office tools (such as chart/bar diagrams, equation editor etc. in Word, PowerPoint or Excel) to present, plot and infer relevant information from the data.
2) Write a scientific synopsis of a research paper using LaTeX.
3) Create a presentation using LaTeX and Beamer on any research topic
4) Select a funding agency and any two schemes or fellowships offered by them. Make a report (using LaTeX) describing the objectives, areas of research support and various components of grants offered by them.

Category II

Physical Science Courses (with Electronics)
with Physics and Electronics discipline as Core Disciplines

Unit – III - Elementary Band Theory **(5 Hours)**
Qualitative understanding of Kronig and Penny model (without derivation) and formation of bands in solids, concept of effective mass, Hall effect in semiconductor, Hall coefficient, application of Hall effect, basic introduction to superconductivity

Unit – IV - Magnetic Properties of Matter **(6 Hours)**
dia-, para-, and ferro- magnetic materials, classical Langevin theory of dia– and para-magnetism (no quantum mechanical treatment), qualitative discussion about Weiss's theory of ferromagnetism and formation of ferromagnetic domains, B-H curve hysteresis and energy loss

Unit – V - Dielectric Properties of Materials **(3 Hours)**
Polarization, local electric field in solids, electric susceptibility, polarizability, Clausius Mossoti equation, qualitative discussion about ferroelectricity and PE hysteresis loop

References:
Essential Readings:

1) Introduction to Solid State Physics, C. Kittel, 8th edition, 2004, Wiley India Pvt. Ltd.
2) Elements of Solid-State Physics, J. P. Srivastava, 2nd edition, 2006, Prentice-Hall of India
3) Introduction to Solids, L. V. Azaroff, 2004, Tata Mc-Graw Hill
4) Solid State Physics, N. W. Ashcroft and N. D. Mermin, 1976, Cengage Learning
5) Solid State Physics, M. A. Wahab, 2011, Narosa Publications

Additional Readings:

1) Elementary Solid State Physics, M. Ali Omar, 2006, Pearson
2) Solid State Physics, R. John, 2014, McGraw Hill
3) Superconductivity: A Very short Introduction – Stephen J Blundell - Audiobook

PRACTICAL COMPONENT

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

At least six experiments to be performed from the following list

1) Measurement of susceptibility of paramagnetic solution (Quinck's tube method)
2) To measure the magnetic susceptibility of solids
3) To determine the coupling coefficient of a piezoelectric crystal
4) To study the dielectric response of materials with frequency
5) To determine the complex dielectric constant and plasma frequency of a metal using Surface Plasmon Resonance (SPR) technique
6) To determine the refractive index of a dielectric layer using SPR technique
7) To study the PE Hysteresis loop of a ferroelectric crystal
8) To draw the BH curve of iron (Fe) using a solenoid and determine the energy loss from hysteresis loop
9) To measure the resistivity of a semiconductor (Ge) crystal with temperature (up to 150^{o} C) by four-probe method and determine its band gap
10) To determine the Hall coefficient of a semiconductor sample

DISCIPLINE SPECIFIC ELECTIVE COURSE – PHYSICS DSE 13: RESEARCH METHODOLOGY

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Research Methodology PHYSICS DSE 13	4	3	0	1	Appeared in Semester 5	--

LEARNING OBJECTIVES

This course has been designed to explore the basic dimensions of research and to impart quantitative and qualitative knowledge for conducting meaningful research. Starting from the philosophy of research, through awareness about the publication ethics and misconducts, this course covers all the methodological and conceptual issues required for a successful conduct of research. It gives an overview of research techniques, data management and analysis, and commonly used statistical methods in physical sciences.

LEARNING OUTCOMES

After successful completion of this course, students will be trained in the following.

- Skills to review literature and frame research problem
- Comprehend the relevance of the tools for data collection and analysis
- Writing a scientific report/research proposal
- Software tools for research in physical sciences
- Research integrity and publication ethics
- Importance of intellectual property rights
- Role of funding agencies in research

SYLLABUS OF Physics DSE - 13

THEORY COMPONENT

Unit - I - Introduction to research methodology **(6 Hours)**

Brief history of scientific method and research, role and objectives of research, basic tenets of qualitative research; research problem and review of literature: identifying a research problem (philosophy and meaning of research, identification and definition of research problem, formulation of research problem, sources of prejudice and bias); literature survey (open-source and paid tools for keeping track of the literature)

Unit - II - Data collection, analysis and interpretation **(15 Hours)**

Methods of data collection: survey, interview, observation, experimentation and case study;
Descriptive statistics: Measures of central tendency (mean, median, mode) and dispersion (range, standard deviation);
Inferential statistics: Hypothesis testing, Z test, T test; regression analysis (basic concepts of

Additional Readings:

1) Research Methods, R. Ahuja, 2001, Rawat Publications, New Delhi.
2) Research design: Qualitative, quantitative, and mixed methods approaches, J. W. Creswell, and J. D. Creswell, 2017, Sage Publications.
3) Intellectual Property: Patents, Trademarks and Copyright in a Nutshell, A. R. Miller and M. H. Davis, 2000, West Group Publishers

PRACTICAL COMPONENT

(15 Weeks with 2 hours of laboratory session per week)
Students should perform at least six practicals from the following list, such that all the units mentioned below are covered.

Unit 1:

1) Identify a research problem, write its brief summary and make a corresponding flow chart
2) Identify a survey-based research problem in physics and create a questionnaire to collect data to perform meaningful research.
3) Write a literature review for a research problem.
4) Create a list of research topics (at least three) and read at least one research paper in each topic.

Unit 2:

1) Attend a research seminar and write a brief summary in 1000 words. Check the extent of plagiarism in this summary by using on-line plagiarism detection tools
2) Read a research paper based on the use of statistics in experimental physics and summarise its importance.
3) Collect publicly available experimental physics data. Identify the independent, dependent and control variables. Fit at least two mathematical models that can describe the data and compare their statistical significance.

Unit 3:

1) Review any three research papers.
    a) List the major strengths and weakness of all of them.
    b) For any one of these, create a referee report assuming you are a reviewer of the paper. Also draft a response to the referee's report assuming you are the author.
2) Review any research paper. Rewrite it as if the work has been done by you for the first time. Use two different referencing and bibliography styles

Unit 4:

1) Take data from any publicly available experimental physics database. Use Microsoft Office tools (such as chart/bar diagrams, equation editor etc. in Word, PowerPoint or Excel) to present, plot and infer relevant information from the data.
2) Write a scientific synopsis of a research paper using LaTeX.
3) Create a presentation using LaTeX and Beamer on any research topic
4) Select a funding agency and any two schemes or fellowships offered by them. Make a report (using LaTeX) describing the objectives, areas of research support and various components of grants offered by them.

Modelling of combinational and sequential digital circuits using different levels of abstraction
Hierarchical modelling concepts: Design methodologies, design a 4-bit adder using four 1-bit full adders

Unit – II **(10 Hours)**
Look up Tables: 2-input, 3-input and 4-input LUTs, Implement logic functions with LUT, advantages and disadvantages of lookup tables
Programmable Logic Devices: Difference between PAL and PLA, Realize simple logic functions using PAL and PLA, CPLD and FPGA architectures, types of FPGA, logic cell structure, programmable interconnects, logic blocks and I/O Ports, placement and routing, applications of FPGAs

References:
Essential Readings:

1) Verilog HDL. Pearson Education, S. Palnitkar, 2nd edition, 2003
2) FPGA Based System Design. W. Wolf, Pearson Education
3) Digital Signal processing, S. K. Mitra, 1998, McGraw Hill
4) VLSI design, D. P. Das, 2nd edition, 2015, Oxford University Press.
5) Digital Signal Processing with FPGAs, U. Meyer Baese, Springer, 2004

Additional Readings:

1) Fundamentals of Digital Logic with Verilog Design, S. B. Zvonko Vranesic, 2016, McGraw Hill

PRACTICAL COMPONENT

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

- Session on how to write the design module and test benches using required software and simulate the combinational and sequential circuits.
- Sessions on how to configure FPGA using Verilog HDL for the final implementation of the logic design.

At least six experiments to be performed from the following list

1) Half adder, Full Adder using basic and derived gates.
2) Half subtractor and Full Subtractor using basic and derived gates.
3) Design and simulate 4-bit Adder using Data Flow Modeling.
4) Multiplexer (4x1) and Demultiplexer(1X4) using Data Flow Modeling.
5) Decoder and Encoder using case structure/gates.
6) Clocked D, JK and T Flip flops (with Reset inputs)
7) 4-bit Synchronous up/downCounter
8) To design and study switching circuits (LED blink shift)
9) To interface LCD using FPGA
10) To interface a multiplexed seven segment display.
11) To interface a stepper motor and DC motor.

References for laboratory work:

DISCIPLINE SPECIFIC ELECTIVE COURSE – PHYSICS DSE 15: PHOTONIC DEVICES AND POWER ELECTRONICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Photonic Devices and Power Electronics Physics DSE 15	4	2	0	2	Appeared in Semester 5	--

LEARNING OBJECTIVES

This paper aims to provide students with an in-depth understanding of the principles, concepts, and applications of photonic devices and power electronics. The course covers a range of topics, including, semiconductor lasers, fibre optics, power diodes, power MOSFETs, and power electronics applications. Students will develop the necessary knowledge and skills to design and analyse various photonic and power electronic devices and systems. The course also emphasizes the practical aspects of device design, fabrication, and characterization, preparing students for real-world challenges and opportunities in these fields.

LEARNING OUTCOMES

Upon completion of the course on Photonic Devices and Power Electronics, students are expected to achieve the following learning outcomes.

- Understand the basic principles and concepts of photonic devices and power electronics, including semiconductor lasers, fibre optics, power diodes, power MOSFETs, and power electronics applications.
- Develop the necessary knowledge and skills to design and analyse various photonic and power electronic devices and systems.
- Gain practical experience in device design, fabrication, and characterization.
- Apply the knowledge and skills learned in the course to real-world challenges and opportunities in the fields of photonics and power electronics.
- Develop problem-solving skills, critical thinking skills, and the ability to apply scientific and engineering principles to practical problems.
- Understand the ethical considerations and professional responsibilities associated with the development and use of photonic and power electronic devices and systems.
- Overall, students will gain a comprehensive understanding of photonic devices and power electronics and be well-equipped to pursue careers in these fields or continue their studies at the graduate level.

SYLLABUS OF PHYSICS DSE 15

THEORY COMPONENT

At least six experiments to be performed from the following list

1) Diffraction experiments using a LASER.
2) To determine characteristics of (a) LEDs, (b) Photovoltaic cell and (c) Photodiode.
3) To study the Characteristics of LDR and Photodiode with (i) Variable Illumination intensity, and (ii) Linear Displacement of source.
4) To measure the numerical aperture of an optical fiber.
5) Output and transfer characteristics of a power MOSFET.
6) Study of I-V characteristics of SCR.
7) SCR as a half wave and full wave rectifier with R and R - L loads.
8) AC voltage controller using TRIAC with UJT triggering.
9) Study of I-V characteristics of DIAC.
10) Study of I-V characteristics of TRIAC

References for laboratory work:

1) Power Electronics, P. C. Sen, Tata McGraw Hill.
2) Power Electronics Circuits, Devices & Applications, 3rd edition, M. H. Rashid, Pearson Education
3) A Textbook of Electrical Technology, Vol-II, B. L. Thareja and A. K. Thareja, S. Chand.

Unit – III **(5 Hours)**

WIRELESS NETWORKS:

Introduction: General idea of cellular and wireless systems, current wireless systems, examples of wireless communication systems, idea about global mobile communication system

Unit – IV **(3 Hours)**

Modern wireless communication systems: General idea 2G,3G and wi-fi, 4G and LTE, and 5G wireless networks, wireless local area networks (WLANs), bluetooth and personal area networks (PANs).

Unit – V **(3 Hours)**

Cellular Concept and System Design Fundamentals: Cellular concept and cellular system fundamentals, cellular systems design considerations (qualitative idea only)

References:

Essential Readings:

1) Antenna Theory, Ballanis, 2nd edition, 2003, John Wiley & Sons
2) Electro Magnetic Waves and Radiating Systems, Jordan and Balmain, E. C., 3rd edition, 1968, Reprint (2003), PHI
3) Fundamentals of Wireless Communication, D. Tse and P. Viswanathan, 2014, Cambridge University Press
4) Wireless communication and Networks, U. Dalal, 2015, Oxford University Press.
5) Mobile Communication Design and Fundamentals, Lee, William C.Y., 4th edition, 1999

Additional Readings:

1) Wireless communications, A. Goldsmith, 2015, Cambridge University Press
2) Modern Wireless Communication, H. S. and M. M. Pearson, 3rd edition, 2005

PRACTICAL COMPONENT

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

At least six experiments to be performed from the following list

1) Study of simple dipole and folded dipole (l/2) antenna, plot and compare the radiation pattern of both antennas.
2) Study of simple dipole 5 element Yagi-UDA and folded dipole 5 element Yagi Uda antenna, plot and compare the radiation pattern of both antennas
3) Study of loop antenna and slot antennas and plot their radiation patterns
4) Study the radiation pattern of ground plane antenna and observe the difference in radiation pattern with single element rod, detector and reflector rods
5) To study the variation of radiated field with distance from transmitting antenna.
6) To study modulation of sine wave on RF transmitted and observe the demodulated wave on detector receiver
7) Study of the reciprocity theorem for antennas
8) Study the role of matching stub in antenna transmission.
9) To study working of current sensor and measurement of current in various elements of antenna.
10) To study and measure SWR using various types of antennas.

11) To study different parts of a 4G Volte mobile phone and observe constellation diagram for transmitter and receiver IQ signals
12) To study various types of faults in a 4G volte mobile phone.

References for laboratory work:

1) Antenna Theory, Ballanis, 2nd edition, 2003, John Wiley & Sons
2) Fundamentals of Wireless Communication, D. Tse and P. Viswanathan, 2014, Cambridge University Press
3) Mobile Communication Design and Fundamentals, Lee, William C.Y., 4th edition, 1999