

ANNEXURE-2

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DEPARTMENT OF PHYSICS AND ASTROPHYSICS
Semester-VI

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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	3	1	0	Class XII pass with Physics and Mathematics as main subjects	Thermal physics and quantum mechanics papers of this course or their equivalents. Basics of probability and statistics

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 is to introduce the techniques of statistical mechanics which has applications in various fields including astrophysics, semiconductor physics, plasma physics, biophysics etc. and in many other directions. All the problems of different units should be done in the tutorial classes.

LEARNING OUTCOMES

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

- Understand the concepts of phase space, macrostate, microstate, 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 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 blackbody radiation and liquid Helium.

SYLLABUS OF DSC – 16

THEORY COMPONENT

Unit - I

(22 Hours)

Classical Statistics: Phase space, macrostates and microstates, 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-Tetrode equation. Saha's ionization formula, Law of equipartition of energy (with proof) – Applications to specific heat of gases (monoatomic and diatomic), solids and its

limitations, thermodynamic functions of a finite level system, negative temperature

Unit – II

(5 Hours)

Radiation: Blackbody radiation and its spectral distribution. Kirchhoff law (No Proof), Planck's quantum postulates, Planck's law of blackbody radiation, deduction of Wien's distribution law, Rayleigh-Jeans law, Stefan-Boltzmann law and Wien's displacement law from Planck's law, ultraviolet catastrophe

Unit – III

(9 Hours)

Bose-Einstein Statistics: Bose-Einstein distribution law, thermodynamic functions of a strongly degenerate Bose gas (non-relativistic), Bose-Einstein condensation, properties of liquid He (qualitative description), Radiation as a photon gas and thermodynamic functions of photon gas. Bose derivation of Planck's law

Unit – IV

(9 Hours)

Fermi-Dirac Statistics: Fermi-Dirac distribution law, thermodynamic functions of a completely and strongly degenerate fermions (non-relativistic), specific heat of metals, relativistic Fermi gas, white dwarf stars, Chandrasekhar mass limit.

References:

Essential Readings:

- 1) Statistical Mechanics, R. K. Pathria and P. D. Beale, Academic Press
- 2) Introductory Statistical Mechanics, R. Bowley and M. Sanchez, Oxford Univ. Press
- 3) Statistical Physics, F. Mandl, Wiley
- 4) A treatise on Heat, M. N. Saha and B. N. Srivastava, Indian Press
- 5) Problems and Solutions on Thermodynamics and Statistical Mechanics, Lim Yung-Kou, Sarat Book House
- 6) An Introduction to Thermal Physics, D. Schroeder, Pearson
- 7) Statistical Physics, Berkeley Physics Course, F. Reif, McGraw-Hill

Additional Readings:

- 1) An Introduction to Statistical Physics, W. G. V. Rosser, Wiley
- 2) Thermal Physics, Kittel and Kroemer, CBS
- 3) Concepts in Thermal Physics, Blundell and Blundell, Oxford University Press
- 4) Statistical and Thermal Physics, Loknathan and Gambhir, PHI
- 5) Thermodynamics, Kinetic theory and Statistical thermodynamics, Sears and Salinger, PHI
- 6) Statistical Mechanics, G. Sanon, Alpha Science International Ltd.

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	3	1	0	Class XII pass with Physics and Mathematics as main subjects	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, stability of the nuclei and the nuclear models
- 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

(15 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, relativistic correction to kinetic energy, spin-orbit term, Darwin term, fine structure spectral lines, Lamb shift (qualitative idea).

Atoms in external magnetic fields: Larmor's theorem, Stern-Gerlach experiment, normal Zeeman Effect, Paschen Back effect, anomalous Zeeman effect, Lande g-factor.

Unit - II – Molecular Physics**(15 Hours)**

Molecular structure: The Born-Oppenheimer approximation, Concept of bonding and anti-bonding molecular orbitals, Concept of Potential energy curve for a diatomic molecule, Morse potential, Classification of molecular states of diatomic molecule, The Franck-Condon principle

Molecular spectra of diatomic molecule: Rotational Spectra (rigid and non-rigid rotor), Vibrational Spectra (harmonic and anharmonic), Vibration-Rotation Spectrum of a diatomic molecule, Isotope effect, Intensity of spectral lines

Raman Effect: Classical theory (with derivation) of Raman effect, pure rotational Raman Lines, Stoke's and Anti-Stoke's Lines, comparison with Rayleigh scattering.

Unit – III – Nuclear Physics**(15 Hours)**

Nucleus stability: *Alpha decay*: Energetics of alpha-particle decay, barrier penetration model, Geiger-Nuttall rule, α - decay spectroscopy, decay Chains. *Beta Decay*: Q-values for beta decay, β -spectrum, positron emission, electron capture, neutrino hypothesis, Qualitative idea about Fermi theory, Fermi and Gamow-Teller decays, the role of angular momentum and parity, electron capture, and selection rules. *Gamma decay*: Gamma-ray production, and multipolarities, Weisskopf estimates, the role of angular momentum and parity, internal conversion.

Nuclear models: Evidence of shell structure in nuclei, Magic numbers, nuclear mean field, single particle shell model, spin-orbit splitting, shell model configurations for nuclear ground states, and low-lying excited levels

References:**Essential Readings:**

- 1) Physics of Atoms and Molecules, B. H. Bransden and C. J. Joachain, 2nd edition, Pearson
- 2) Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, 1994, Tata McGraw – Hill
- 3) Atomic physics, J. B. Rajam and foreword by Louis De Broglie, 2010, S. Chand & Co.
- 4) Atoms, Molecules and Photons, W. Demtroder, 2nd edition, 2010, Springer
- 5) Introduction to Spectroscopy, D. L. Pavia, G. M. Lampman, G. A. Kriz and J. R. Vyvyan, 5th edition, 2014, Brookes/Cole
- 6) Concept of Nuclear Physics, B. L. Cohen, 2003, Tata McGraw – Hill
- 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

DISCIPLINE SPECIFIC CORE COURSE – DSC - 18: STATISTICAL ANALYSIS IN PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Statistical Analysis in Physics DSC – 18	4	2	0	2	Class XII pass with Physics and Mathematics as main subjects	Basic understanding of statistics and probability

LEARNING OBJECTIVES

This course provides an elementary introduction to the principles of Bayesian statistics and working knowledge of some of the data analysis techniques. The objective is to equip the students with certain techniques so that they may successfully apply these to the real world problems, in their research areas as well as in industry.

LEARNING OUTCOMES

After completing this course, students will be able to,

- Understand the fundamental concepts in statistical data analysis.
- Define in a Bayesian context, the likelihood, prior and posterior distributions and their role in Bayesian inference and hypothesis testing.
- Estimate the parameters of a distribution from sample.
- Perform hypothesis testing and validate a model.
- Apply multi-linear and logistic models to real life situation.

In the practical component, students will be able to

- Learn basic data analysis techniques such as linear and non-linear fittings
- Apply hypothesis testing techniques in physics
- Perform multi-linear and logistic regression analysis for a given data
- Understand the concept of gradient descent and use it for the regression analysis
- Understand the stochastic processes, Markov chains and transition probability matrix.

SYLLABUS OF DSC - 18

THEORY COMPONENT

Unit – I

(8 Hours)

Random variables, Discrete and Continuous Probability Distributions. Bivariate and multivariate random variables, Joint Distribution Functions (with examples from Binomial, Poisson and Normal). Mean, variance and moments of a random vector, covariance and correlation matrix, eigendecomposition of the covariance matrix (bivariate problem). Cumulative Distribution Function and Quantiles. Point Estimation, Interval estimation, Central Limit Theorem (statement, consequences and limitations).

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 different distributions (e.g. Binomial, Poisson, Normal). Use the arithmetic mean of each random vector (of size N) and plot the distribution of the arithmetic means. Verify the Central Limit Theorem (CLT) for each distribution. Show that CLT is violated for the

Cauchy-Lorentz distribution.

- 2) Given a data for two independent variables (x_i, y_i). Write a code to compute the joint probability in a given sample space. Verify the same for the data generated by random number generator based on a given probability distribution of pair of independent variables (both discrete and continuous).

Unit 2 (16 Hours)

- 1) Hypothesis testing

Make a random number generator to simulate the tossing of a coin n times with the probability for the head being q . Write a code for a Binomial test with the Null hypothesis H_0 ($q = 0.5$) against the alternative hypothesis H_1 ($q \neq 0.5$).

- 2) Bayesian Inference

- a) In an experiment of flipping a coin N times, M heads showed up (fraction of heads $f = M/N$). Write a code to determine the posterior probability, given the following prior for the probability of f :
 - i. Beta Distribution $B(a, b)$ with given values of a and b .
 - ii. Gaussian Distribution with a given mean and variance.
- b) Using the Likelihood of Binomial distribution, determine the value of f (fraction of heads) that maximizes the probability of the data.
- c) Plot the Likelihood (normalised), Prior and Posterior Distributions.

Unit 3 (20 hours)

Regression Analysis and Gradient Descent:

- 1) Given a dataset (X_i, Y_i). Write a code to obtain the parameters of linear regression equation using the method of least squares with both constant and variable errors in the dependent variable (Y). The data obtained in a physics lab may be used for this purpose. Also obtain the correlation coefficient and the 90% confidence interval for the regression line. Make a scatter plot along with error bars. Also, overlay the regression line and show the confidence interval.
- 2) Write a code to minimize the cost function (mean squared error) in the linear regression using gradient descent (an iterative optimization algorithm, which finds the minimum of a differentiable function) with at least two independent variables. Determine the correlation matrix for the regression parameters.
- 3) Write a code to map a random variable X that can take a wide range of values to another variable Y with values lying in limited interval say $[0, 1]$ using a sigmoid function (logistic function). Considering the Log Loss as the cost function of logistic regression, compute its minimum with gradient descent method and estimate the parameters.

Unit 4 (12 Hours)

Markov Chain (Any one)

- 1) Write a code to generate a Markov chain by defining (a finite number of) M (say 2) states. Encode states using a number and assign their probabilities for changing from state i to 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 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

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 9: ADVANCED MATHEMATICAL PHYSICS II

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Advanced Mathematical Physics II DSE – 9	4	3	1	0	Class XII pass with Physics and Mathematics as main subjects	DSC Mathematical Physics-I and Mathematical Physics-II of this course or their equivalent

LEARNING OBJECTIVES

The emphasis of the course is to acquire advanced mathematical inputs while solving problems of interest to physicists. The course aims to introduce the students to the principles of tensor analysis and equip them to use the concept in modelling of continuous media, electrodynamics, elasticity theory and the general theory of relativity. The mathematical skills developed during course will prepare them not only for doing fundamental and applied research but also for a wide variety of careers.

LEARNING OUTCOMES

After completing this course, student will,

- Have a knowledge and understanding of tensor analysis and tensor calculus
- Be able to do computation with tensors, both in coordinates and in coordinate-free form.
- Understand the transformation properties of covariant, contravariant and mixed tensors under general coordinate transformation.
- Be able to apply the concepts of tensors in anisotropic media with examples of moment of inertia tensor, elasticity tensor and polarizability tensor.
- Understand physical examples of tensors such as Moment of Inertia and Elasticity of asymmetrical physical systems.
- Be able to write down the Lorentz Transformation in four vector notation.
- Understand inner product and outer product of general tensors.
- Understand the concept of covariant derivatives.

SYLLABUS OF DSE - 9

THEORY COMPONENT

Unit - I

(12 Hours)

Cartesian Tensors: Transformation of co-ordinates under rotation of axes. Einstein's Summation Convention. Relation between direction cosines. Transformation Law for a tensor of rank n . Sum, inner product and outer product of tensors, contraction of tensors, Quotient Law of tensors, symmetric and anti-symmetric tensors. Invariant tensors (Kronecker and Alternating 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**(9 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.

Unit - IV**(12 hours)**

Christoffel Symbols of first and second kind and their transformation laws. Covariant derivative, gradient, divergence and curl of tensor fields.

Minkowski Space, Four Vectors (four-displacement, four-velocity, four-momentum, four-vector potential, four-current density,). Tensorial form of Lorentz Transformation.

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
- 8) Matrices and tensors in physics by A. W. Joshi, 1995, New Age International Publications.

Additional Readings:

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

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 10: MICROPROCESSOR

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Microprocessor DSE – 10	4	2	0	2	Class XII pass with Physics and Mathematics as main subjects	Basics of Digital Electronics

LEARNING OBJECTIVES

Students will be able to outline the types and the functions of storage, learn the characteristics of RAM and ROM and their architecture, describe the architecture of 8085 microprocessors and develop programs for microprocessor 8085

LEARNING OUTCOMES

At the end of the course, students will develop ability to,

- Define storage state the types and functions of storage
- Describe the characteristics of RAM and ROM and their architecture.
- Describe memory organization, addressing, interfacing and mapping
- Describe the architectures of 8085 microprocessors
- Draw timing diagram
- Write programs using 8085

SYLLABUS OF DSE - 10

THEORY COMPONENT

Unit – I - Introduction to 8085 Microprocessor Architecture (16 Hours)

Introduction to microprocessor: Basic computer system organization, introduction, classification and applications of microprocessors, types of memory-primary memory types (SRAM, DRAM, PROM, EPROM, EEPROM), secondary memory (SSD, Optical Drive) memory organization and addressing

Microprocessor 8085 Architecture: Features, architecture-block diagram, general purpose registers, register pairs, flags, stack pointer, program counter, types of buses, multiplexed address and data bus, generation of control signals, pin description of microprocessor 8085, basic memory interfacing concepts, Memory mapped I/O and I/O mapped I/O.

Unit – II - 8085 Programming (14 Hours)

Operation code, operand and mnemonics, instruction set of 8085, instruction classification, addressing modes, instruction format, data transfer instructions, arithmetic instructions, increment & decrement instructions, logical instructions, branch instructions and machine control instructions, subroutine, call and return instructions, timing diagrams-instruction cycle, machine cycle, T- states, basic idea of interrupts, assembly language programming examples (addition with and without carry, subtraction with and without borrow, double addition, 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

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Research Methodology DSE – 11	4	3	0	1	Class XII pass with Physics and Mathematics as main subjects	Basic ICT related skills

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 DSE - 11

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 multiple linear regression analysis and theory of attributes); Curve fitting using linear and nonlinear regression (parameter space, gradient search method)

and Marquardt method);

Role of simulation, calibration methods, error analysis, and background handling in experimental design

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.
- 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.