DEPARTMENT OF PHYSICS AND ASTROPHYSICS

Undergraduate Curriculum Framework 2022

B. Sc. Physical Sciences with Electronics as one of the Core Disciplines

FOR MAJOR IN ELECTRONICS

Semesters VII and VIII

Note:

1. Here,

    DSC: Discipline Specific Core
    DSE: Discipline Specific Elective
    SBC: Skill-based Course

1. * Research Methodology is the same as notified as a DSE for Sem VI (DU Notification dated 16.5.2024).

2. ** Are SEC notified on 28.3.2023.

3. Students should ensure that they do not repeat a SEC course as SBC.

4. As it is NOT permissible to choose courses having similarity of the content to the tune of 30% or more, students should ensure that while opting DSEs.

B. Sc. Physical Sciences with Electronics as one of the Core Disciplines

DISCIPLINE SPECIFIC CORE COURSE – DSC 7-1: ELECTROMAGNETIC THEORY

Course Title and Code	Credits	Credit Distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Electromagnetic Theory DSC 7-1	4	3	0	1	

COURSE OBJECTIVES

This core course develops further the concepts learnt in the electricity and magnetism course to understand the properties of electromagnetic waves in vacuum and different media.

LEARNING OUTCOMES

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

- Apply Maxwell's equations to deduce wave equation, electromagnetic field energy, momentum and angular momentum density
- Understand electromagnetic wave propagation in unbounded media: Vacuum, dielectric medium, conducting medium, plasma
- Understand electromagnetic wave propagation in bounded media: reflection and transmission coefficients at plane interface in bounded media
- Understand polarization of electromagnetic waves: Linear, circular and elliptical polarization. Production as well as detection of waves in laboratory
- Learn the features of planar optical wave guide
- In the laboratory course, the students will get an opportunity to perform experiments with polarimeter, Babinet compensator, ultrasonic grating and simple dipole antenna. Also, to study phenomena of interference, refraction, diffraction and polarization

<u>SYLLABUS OF DSC 7-1</u>
<u>THEORY COMPONENT</u>
(Hours: 45)

Unit – I **(6 Hours)**

Review of Maxwell's equations; Coulomb gauge and Lorentz gauge; Poynting's theorem and Poynting's vector; electromagnetic (em) energy density; physical concept of electromagnetic field energy density

Unit – II **(19 Hours)**

EM wave propagation in unbounded media: Plane em waves through vacuum and isotropic dielectric medium: transverse nature, refractive index, dielectric constant, wave impedance. Plane em waves through conducting medium: relaxation time, skin depth, attenuation constant; Wave propagation through dilute plasma: electrical conductivity of ionized gases, plasma frequency, refractive index, skin depth.
EM waves in bounded media: Boundary conditions at a plane interface between two media; reflection and refraction of plane em waves at plane interface between two dielectric media - Laws of reflection and refraction; Fresnel's formulae for perpendicular and parallel polarization, Brewster's law; reflection and transmission coefficients; total internal reflection, evanescent waves; metallic reflection (normal incidence).

Unit – III **(13 Hours)**

Polarization of EM waves: Propagation of em waves in an anisotropic media; symmetric nature of dielectric tensor; Fresnel's formula; uniaxial and biaxial crystals; light propagation in uniaxial crystal; double refraction; polarization by double refraction; Nicol prism; ordinary and extraordinary refractive indices; production and detection of plane, circular and elliptically polarized light; phase retardation plates: quarter wave and half wave plates.
Optical rotation; Biot's laws for rotatory polarization; Fresnel's theory of optical rotation; specific rotation

Unit – IV **(7 Hours)**

Wave guides: Planar optical wave guides; planar dielectric wave guide ($-d/2 < x < d/2$); condition of continuity at interface; phase shift on total reflection; Eigenvalue equations; phase and group velocity of guided waves; field energy and power transmission (TE mode only)

PRACTICAL COMPONENT: ELECTROMAGNETIC THEORY

(Hours: 30)

- Mandatory sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the lab, including necessary precautions.
- Mandatory sessions on the review of experimental data analysis, sources of error and their estimation in detail, writing of scientific laboratory reports including proper reporting of errors.
- Application to the specific experiments done in the lab.

At least six experiments to be performed from the following list

1. To verify the law of Malus for plane polarized light.
2. To determine the specific rotation of sugar solution using polarimeter.
3. To analyse elliptically polarized light by using a Babinet's compensator.
4. To study the elliptical polarized light using Fresnel rhomb.
5. To determine the wavelength and velocity of ultrasonic waves in a liquid (Kerosene Oil, Xylene, etc.) by studying the diffraction through ultrasonic grating.
6. To study the reflection and refraction of microwaves
7. To study polarization and double slit interference in microwaves.
8. To determine the refractive index of liquid by total internal reflection using Wollaston's air-film.
9. To determine the refractive index of (1) glass and (2) a liquid by total internal reflection using a Gaussian eyepiece.
10. To verify the Stefan's law of radiation and to determine Stefan's constant.
11. To determine Boltzmann constant using V-I characteristics of PN junction diode.
12. To find numerical aperture of an optical fibre.
13. To use a prism shaped double refracting crystal to determine the refractive indices of the quartz/ calcite corresponding to ordinary and extra-ordinary rays.
14. To measure birefringence of Mica
15. To determine the dielectric constant of solids using microwaves

REFERENCES

Essential Readings for the Theory Component

1) Introduction to Electrodynamics, D. J. Griffiths, 3rd edition, 1998, Benjamin Cummings.
2) Electromagnetic Field and Waves, P. Lorrain and D. Corson, 2nd edition, 2003, CBS Publisher
3) Classical Electrodynamics, J. D. Jackson, 3rd edition, 2010, Wiley
4) Principle of Optics, M. Born and E. Wolf, 6th edition, 1980, Pergamon Press
5) Optics, A. Ghatak, 6th edition, 2017, McGraw-Hill Education, New Delhi

Additional Readings for Theory Component

1) Electricity, Magnetism and Electromagnetic Theory, S. Mahajan, and S. R. Choudhary, 2017, TMH
2) Principles of Electromagnetic Theory, C. Jain, 2017, Narosa Publishing House
3) Elements of Electromagnetics, M. N. O. Sadiku, 2001, Oxford University Press.
4) Fundamentals of Electromagnetics, M. A. W. Miah, 1982, Tata McGraw Hill
5) Problems and solution in Electromagnetics, A. Ghatak, K. Thyagarajan and Ravi Varshney, 2015
6) Electromagnetic field Theory, R. S. Kshetrimayun, 2012, Cengage Learning
7) Engineering Electromagnetic, W. H. Hayt, 8th edition, 2012, McGraw Hill.
8) Electromagnetics, J. A. Edminster, Schaum Series, 2006, Tata McGraw Hill.
9) 2008+ Solved Problems in Electromagnetics, S. A. Nasar, 2001, SciTech

References for the Laboratory Work

1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House
2) Advanced level Physics Practicals, M. Nelson and J. M. Ogborn, 4th edition, reprinted 1985, Heinemann Educational Publisher
3) Electromagnetic Field Theory for Engineers & Physicists, G. Lehner, 2010, Springer
4) Practical Physics, G. L. Squires, 4th edition, 2015, Cambridge University Press
5) Engineering Practical Physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning India Pvt. Ltd

B. Sc. Physical Sciences with Electronics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 7-1: NUMERICAL ANALYSIS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Numerical Analysis DSE 7-1	4	2	0	2	

COURSE OBJECTIVES

The main objective of this course is to introduce the students to the field of numerical analysis, enabling them to solve a wide range of physics problems. The skills developed during the 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 be able to,

- Analyse a physics problem, establish the mathematical model and determine the appropriate numerical techniques to solve it.
- Derive numerical methods for various mathematical tasks such as solution of non-linear algebraic and transcendental equations, system of linear equations, interpolation, least square fitting, numerical differentiation, numerical integration, eigen value problems and solution of initial value and boundary value problems.
- Analyse and evaluate the accuracy of the numerical methods learned.
- In the laboratory course, the students will learn to implement these numerical methods in Python/C++/Scilab and develop codes to solve various physics problems and analyze the results.

SYLLABUS OF DSE 7-1
THEORY COMPONENT
(Hours: 30)

Unit I **(3 Hours)**

Approximation and Errors in computing: Introduction to numerical computation, Taylor's expansion and mean value theorem. Floating Point Computation, overflow and underflow. Single and double precision arithmetic. Rounding and truncation error, absolute and relative error, error propagation.

Unit II **(8 Hours)**

Linear Systems: Solution of linear systems by Gaussian elimination method, partial and complete pivoting, LU decomposition, norms and errors, condition numbers, Gauss-Seidel method, diagonally dominant matrix and convergence of iteration methods. Solution of Tridiagonal systems; Eigenvalue Problem: Power method, inverse power method.

Unit III **(12 Hours)**

Interpolation: Lagrange and Newton's methods (divided difference) for polynomial interpolation, theoretical error of interpolation. Inverse Interpolation. Optimal points for interpolation and Chebyshev Polynomials. Minimax Theorem (Statement only). Numerical Integration: Newton Cotes quadrature methods. Derivation of Trapezoidal and Simpson (1/3 and 3/8) rules from Lagrange interpolating polynomial. Error and degree of precision of a quadrature formula. Composite formulae for Trapezoidal and Simpson methods.
Gauss Quadrature methods. Legendre, Lagaurre and Hermite quadrature methods.

Unit IV **(7 Hours)**

Initial and Boundary Value Problems: Solution of initial value problems by Euler, modified Euler and Runge Kutta (RK) methods. Local and global errors, comparison of errors in the Euler and RK methods.
Finite difference and shooting method for solving two-point linear boundary value problems.

PRACTICAL COMPONENT: NUMERICAL ANALYSIS
(Hours: 60)

The aim of this lab is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics. Assessment is to be done not only on the programming but also on the basis of formulating the problem. The list of recommended programs is suggestive only. Students should be encouraged to do more physics applications. Emphasis should be given to formulate a physics problem as mathematical one and solve by computational methods. The students should be encouraged to develop and present an independent project. At least 10 programs must be attempted (taking at least two from each topics). The implementation can be either in Python/ C++/Scilab.

Linear Systems

a) Solve a system of linear equations using Gauss Elimination method with pivoting (application to electric networks).
b) Solve a system of linear equations using Gauss-Seidel method and study the convergence (application to spring mass system).
c) Determine the inverse of a square matrix using Gauss-Jordan method.
d) Solve a tri-diagonal system of linear equations.
e) Study an example of ill-conditioned systematic
f) Find the LU equivalent of a matrix.
g) Determine the largest and smallest eigenvalues using Power and inverse power methods. Consider a case where power method fails.

Interpolation

a) Given a dataset (x, y) with equidistant x values, prepare the Newton's forward difference, backward difference and divided difference tables.
b) Given a dataset (x, y) corresponding to a physics problem, use Lagrange and Newton's forms of interpolating polynomials and compare. Determine the value of y at an intermediate value of x not included in the data set. This may be done with equally spaced and non-equally spaced x-values.
c) Given a tabulated data for an elementary function, approximate it by a polynomial and compare with the true function.
d) Compare the interpolating polynomial for a given dataset (following a known form e.g. exponential) with the approximation obtained by least square fitting.
e) Compare the interpolating polynomial approximating a given function in a given range obtained with uniformly spaced points and by Chebyshev points.
f) Compare the Chebyshev and Maclaurin series expansions of an exponential or sinusoidal function.

Integration

a) Use integral definition of error function to compute and plot erf(x) in a given range. Use Trapezoidal, Simpson and Gauss Legendre methods and compare the results for small and large values of x.
b) Use the definition of erf(x) and numerically take the limit x going to infinity to get the value of Gaussian integral using Simpson method. Compare the result with the value obtained by Gauss Hermite and Gauss Lagaurre methods.
c) Verify the degree of precision of each quadrature rule.
d) Use Simpson methods to compute a double integral over a rectangular region.

Initial Value Problems (IVP)

a) Compare the errors in Euler, RK2 and RK4 by solving a first order IVP with known solution. Reduce the step size to a point where the round off errors takes over.
b) Solve a system of n first order differential equations by Euler and RK methods. Use it to solve an nth order IVP. Solve a damped free and forced harmonic oscillator problem using this.
c) Solve a physics problem like free fall with air drag or parachte problem using

RK method.

d) Solve a compound spring system (3 springs) by solving a system of differential equations using Euler and RK for a given set of i1nitial conditions.
e) Obtain the current flowing in a series LCR circuit with constant voltage for a given set of initial conditions.

Boundary value problems (BVP)

a) Solve a linear BVP using shooting and finite difference method and compare the results.
b) Solve a non-linear BVP using the finite difference and shooting method and compare the results.
c) Determine the temperature distribution along a rod made of two dissimilar materials (of different thermal conductivities) welded together when temperatures at two ends are maintained at given temperatures.
d) Design a physics problem that can be modelled by a BVP and solve it by any method.

REFERENCES

Essential Readings for Theory Component

1) Applied numerical analysis, Cutis F. Gerald and P. O. Wheatley, Pearson Education, India, 2007
2) Advanced Engineering Mathematics, Erwin Kreyszig, Wiley India, 2008
3) Introduction to Numerical Analysis, S. S. Sastry, 5th Edition, PHI Learning Pvt. Ltd, 2012
4) Elementary Numerical Analysis, K. E. Atkinson, 3rd Edition, Wiley India Edition, 2007

Additional Readings for Theory Component

1) Numerical Recipes: The art of scientific computing, William H. Press, Saul A. Teukolsky and William Vetterling, Cambridge University Press; 3rd Edition, 2007
2) Numerical methods for scientific and engineering computation, M. K. Jain, S. R. K. Iyenge

References for Laboratory Work

1) Documentation at the Python home page (https://docs.python.org/3/) and the tutorials there (https://docs.python.org/3/tutorial/).
2) Documentation of NumPy and Matplotlib: https://numpy.org/doc/stable/user/ and https://matplotlib.org/stable/tutorials/
3) Computational Physics, Darren Walker, 1st Edition, Scientific International Pvt. Ltd, 2015
4) An Introduction to Computational Physics, T. Pang, Cambridge University Press, 2010
5) Computational Problems for Physics, R. H. Landau and M. J. Páez, CRC Press, 201

B. Sc. Physical Sciences with Electronics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 7-2: PHYSICS OF MATERIALS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Physics of Materials DSE 7-2	4	2	0	2	

COURSE OBJECTIVES

This course intends to provide knowledge of emerging topics in condensed matter physics. In addition, this course aims to provide a general introduction to advanced topics by covering polymers, liquid crystals, carbon-based materials, and Diluted Magnetic Semiconductors. More importantly, the students will be exposed to different characterization techniques used in experimental condensed matter physics.

LEARNING OUTCOMES

After completion of this course the students should be able to

- Identify different materials of technological importance in appliances and objects around us
- Explain the importance of concepts like density of states and its role in determining device characteristics
- Elucidate the ferroelectric, piezoelectric and pyroelectric materials and their applications.
- Explain the properties of liquid crystals and their application.
- Differentiate between different forms of carbon based materials and their applications
- Introduce the importance of dilute magnetic semiconductors as a new technologically advance material for electronic devices
- Explain various characterisation techniques used in understanding properties of different material

SYLLABUS OF DSE 7-2
THEORY COMPONENT
(Hours: 30)

Unit I **(4 Hours)**

Semiconductors

Basic concept of mobility and conductivity, density of states, determination of electron and hole concentration in doped semiconductor, Fermi level, Fermi energy, Fermi temperature, Fermi wavelength, Fermi surface.

Unit II **(9 Hours)**

Dielectric and magnetic materials

Dielectrics, Ferroelectric, Piezoelectric and Pyroelectric materials, applications of ferroelectrics in capacitors and memory device, Piezoelectrics in micro positioner and actuator, Pyroelectrics in radiation detectors and thermometry. Classification and applications of soft and hard magnetic materials, application in transformers, memory device, introduction of spintronics based systems (spin transport)

Unit III **(9 Hours)**

Polymers, Liquid crystals, Carbon based materials

Polymers: Chemical structure of polymers of few thermoplastic (polyethylene, PVC, PTFE, PMMA, Polyester, Nylons) and thermosetting (Epoxy resin) polymers, conducting polymers- application in organic electronics

Liquid crystals: Classification of liquid crystals, structural and orientational ordering (isotropic to Nematic), thermotropic liquid crystals, Phases and phase transitions; anisotropic; Birefringence and display devices

Carbon based materials: Structure and properties of Fullerenes, C_{60}, single walled and multi walled CNTs, Graphene and their energy band diagram.

Unit IV **(8 Hours)**

Synthesis of materials

Ceramic (Calcination, Sintering, Grain), thin films (general idea of vacuum, thermal evaporation, molecular beam epitaxy, pulsed laser deposition), Crystals (qualitative idea of zone refining and Czochralski method), Polymers (Polymerization mechanism).

PRACTICAL COMPONENT: PHYSICS OF MATERIALS

(Hours: 60)

At least six experiments to be performed from the following list

1. Study phase transition in a ferroelectric sample by measuring its dielectric constant as a function of frequency and temperature.
2. Study dielectric properties of given polymer sample as a function of frequency and temperature.
3. Study dielectric properties of given piezoelectric sample as a function of frequency and temperature.
4. Determine the coupling coefficient of a given piezoelectric crystal.
5. BH Hysteresis of different ferromagnetic materials (Loop Tracer).
6. Analyse the XRD spectra of a given ferroelectric ceramic sample and determine its lattice parameter.
7. Analyse the XRD spectra of a given ferromagnetic sample (basically ferrites, Fe_3O_4, $CoFe_2O_3$) and determine its lattice parameter.
8. Analyse the XRD spectra of a given compound semiconductor (ZnO, TiO_2, etc) thin film/ceramic sample and determine its lattice parameter.
9. Analyse the UV-Vis spectra of a given wide band gap semiconductor and determine its bandgap.
10. Study the IV characteristics of a polymer material by depositing/painting Aluminum electrodes.
11. To determine the g-factor of a sample by ESR Spectrometer.
12. Analyse the given SEM/TEM/AFM micrographs of the deposited thin film or nanostructure of any material and determine surface roughness, crystallinity, particle size etc.
13. Deposition of any kind of thin film by any technique available in the lab.
14. Liquid crystals (reading project)

REFERENCES

Essential readings for the Theory Component

1. Solid State Physics, M. A. Wahab, 2011, Narosa Publishing House
2. Elementary Solid State Physics, M. Ali Omar, 2006, Pearson
3. Semiconductor Devices: Physics and Technology, S. M. Sze, 2^{nd} edition, 2002, Wiley India
4. Introduction to Polymer Physics, U. Eisele and S. D. Pask, 1990, Springer-Verlag
5. The physics of liquid crystals, Pierre-Gilles de Gennes, 2^{nd} edition, 2003, Oxford University Press
6. Introduction to Liquid Crystals, P. J. Wojtowicz, E. Priestly and P. Sheng, 1975, Plenum Press
7. Dielectric Phenomenon in solids with Emphasis on Physical Concepts of Electronic Processes, K. C. Kao, Elsevier.
8. Physics of Ferroelectrics A Modern Perspective, K. M. Rabe Charles H. Ahn Jean-

Marc Triscone, Springer
9. Carbon Nanotubes: Properties and Applications, M. J. O'Connell, 2006, CRC Press
10. Dilute Magnetic Semiconductors, M. Jain, World Scientific.

Additional readings for the Theory Component

1. Encyclopaedia of materials characterization: surfaces, interfaces, thin films, R. C. Brundle et al., 1992, Butterworth-Heinemann
2. Physical Methods for Materials Characterization, P. E. J. Flewitt, R. K. Wild, (2nd Ed., CRC Press, 2015).
3. Dilute magnetic semiconducting materials, Br. R. Saravanan, MRF

References for the Laboratory Work

1. Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
2. A Text Book of Practical Physics, I. Prakash and Ramakrishna, 11^{th} edition, 2011, Kitab Mahal
3. Elements of Solid State Physics, J. P. Srivastava, 2^{nd} edition, 2006, Prentice-Hall of India
4. Elements of X-Ray Diffraction, B. D. Cullity and S. R. Stock
5. Physical Methods for Materials Characterization, P. E. J. Flewitt, R. K. Wild, 2^{nd} edition, 2015, CRC Press
6. Encyclopedia of materials characterization: surfaces, interfaces, thin films, R. C. Brundle et al., 1992, Butterworth-Heinemann

B. Sc. Physical Sciences with Electronics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 7 - 3 : QUANTUM MECHANICS

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Quantum Mechanics DSE 7-3	4	3	1	0	

COURSE OBJECTIVES

The development of quantum mechanics has revolutionized human life. In this course, students will be exposed to the probabilistic concepts of basic non-relativistic quantum mechanics and its applications to understand the subatomic world.

LEARNING OUTCOMES

After completing this course, the students will be able to

- Solve Schrödinger equation for different 1-d potentials, such as finite square potential well, potential steps and barriers and distinguish between scattering and bound states.
- Use the algebraic method to solve the Schrödinger equation for quantum harmonic
- Solve the 3-D Schrodinger equation in spherical coordinates.
- Understand the spectrum and eigenfunctions for hydrogen atom
- Understand the angular momentum operators in position space, their commutators, eigenvalues and eigenfunctions.
- Explain the concept of spin, use Pauli matrices to describe spin-½ systems, and construct the singlet and triplet spin states for two-particle systems.

SYLLABUS OF DSE 7-3
THEORY COMPONENTS
(Hours: 45)

Unit I **(20 Hours)**

Schrödinger Equation for 1- dimensional systems
General solution of 1-D Schrödinger equation for time independent potentials, Solution of Schrödinger equation for a particle in a finite square potential well, reflection and transmission across a step potential and a rectangular potential barrier.
General discussion of bound states in an arbitrary potential: Continuity of wave function, boundary conditions and emergence of discrete energy levels with Application to energy eigenstates for a particle in a finite square potential well.
Momentum space wavefunction, Time evolution of Gaussian Wave packet, Superposition Principle, linearity of Schrodinger Equation, General solution as a linear combination of discrete stationary states, Observables as operators, Commutator of position and momentum operators, Ehrenfest's theorem.
Harmonic oscillator
Energy eigenvalues and eigenstates of a 1-D harmonic oscillator using the algebraic method (ladder operators). Zero-point energy and the uncertainty principle.

Unit II **(12 Hours)**

Schrödinger Equation in three dimensions
Probability and probability densities in 3D. Schrödinger equation in spherical polar coordinates, its solution for the Hydrogen atom solution using separation of angular and radial variables. Solution of angular equation, Spherical harmonics.
Solution of radial equation using Frobenius method, Radial wavefunctions, Probability densities for ground and first excited states, quantum numbers *n*, *l* and *ml*.

Unit III **(7 Hours)**

Angular Momentum: Orbital Angular momentum operators (**Lx**, **Ly** and **Lz**) and ladder operators **L+** and **L-** as differential operators in cartesian coordinates and their commutation relations, Orbital angular momentum operators in spherical polar coordinates, their eigenvalues, eigenfunctions and identification of these with spherical harmonics.

Unit IV **(6 Hours)**

Concept of spin: Spin angular Momentum Operator, Pauli matrices, algebraic theory of spin, General state for spin-1/2 particles, Total spin for a system of two spin-1/2 particles, singlet and triplet states.

REFERENCES

Essential Readings

1. Quantum Mechanics: Theory and Applications, Ajoy Ghatak and S. Lokanathan, Laxmi Publications (2019).
2. Introduction to Quantum Mechanics, D.J. Griffith, Pearson Education (2005).
3. A Textbook of Quantum Mechanics, P.M. Mathews and K. Venkatesan, McGraw-Hill (2010).
4. Quantum Mechanics, B. H. Bransden and C. J. Joachain, Prentice Hall (2000).
5. Quantum Mechanics: Concepts and Applications, Nouredine Zettili, John Wiley and Sons, Ltd. (2009).

Additional Readings

1. Quantum Mechanics for Scientists & Engineers, D.A.B. Miller, Cambridge University Press (2008).
2. Introduction to Quantum Mechanics, R. H. Dicke and J. P. Wittke, Addison-Wesley Publications (1966).
3. Quantum Mechanics, Leonard I. Schiff, Tata McGraw Hill (2010).
4. Quantum Mechanics, Robert Eisberg and Robert Resnick, Wiley (2002).
5. Schaum's Outlines of Quantum Mechanics, Yoav Peleg, Reuven Pnini, Elyahu Zaarur, Eugene Hecht, NcGrawHill (2010).
6. Introductory Quantum Mechanics, R. L. Liboff; 4th Ed., Addison Wesley (2003).

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DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 7 - 4 : VERY LARGE SCALE INTEGRATED CIRCUIT DESIGN

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Very Large Scale Integrated Circuit Design DSE 7-4	4	3	0	1	

COURSE OBJECTIVES

The paper discusses basic principle of MOS Transistor operation for digital design, SPICE model, MOS transistor and Inverter layout, CMOS layout. Inverter design, CMOS inverter, inverter characteristics and specifications. MOS Logic design, pass transistor logic, static & dynamic latches, flip flops, static & dynamic registers.

LEARNING OUTCOMES

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

1. Understand the concept of models of MOS devices and their implementation in designing of CMOS inverter.
2. Measure the performance parameters like threshold voltage, noise margins, time delays etc.
3. Familiarize with the techniques and components involved in combinational MOS circuit designs.

SYLLABUS OF DSE 7-4

THEORY COMPONENTS

(Hours: 45)

Unit I **(10 Hours)**
Metal Oxide Semiconductor (MOS)
Introduction to basic principle of MOS transistor, large signal MOS models (long channel) for digital design.

Unit II **(10 Hours)**
MOS SPICE model, MOS device layout
Integrated circuit technology- SSI, MSI, LSI, VLSI, Transistor layout, Inverter layout, CMOS digital circuit layout.

Unit III **(15 Hours)**

MOS Inverter

Inverter principle, Depletion and enhancement load inverters, the basic CMOS inverter, transfer characteristics, logic threshold, Noise margins, Propagation Delay and Power Consumption.

Unit IV **(10 Hours)**

Combinational MOS Logic Design

Static MOS design, Pass Transistor logic, complex logic circuits. Sequential MOS Logic Design - Static latches, Flip flops & Registers

PRACTICAL COMPONENT: VERY LARGE SCALE INTEGRATED CIRCUIT DESIGN

(Hours: 30)

Basic VLSI Design Lab (PSpice/Similar Simulation software)

Students should perform at least four practicals from the following list:

1. To plot the (i) output characteristics & (ii) transfer characteristics of an n-channel and p-channel MOSFET.
2. To design and plot the static (VTC) and dynamic characteristics of a digital CMOS inverter.
3. To design and plot the output characteristics of a 3-inverter ring oscillator.
4. To design and plot the dynamic characteristics of 2-input NAND, NOR, XOR and XNOR logic gates using CMOS technology.
5. To design and plot the characteristics of a 4x1 digital multiplexer using pass-transistor logic.
6. To design and plot the characteristics of a positive and negative latch based on multiplexers.
7. To design and plot the characteristics of a master-slave positive and negative edge triggered registers based on multiplexers

REFERENCES

1. Kang & Leblebigi ―CMOS Digital IC Circuit Analysis & Design‖- McGraw Hill, 2003.
2. Rabey, ―Digital Integrated Circuits Design‖, Pearson Education, Second Edition, 2003.
3. Weste and Eshraghian, ―Principles of CMOS VLSI design‖ Addison-Wesley, 2002.
4. Basic VLSI design: Douglas A Pucknell, Kamran Eshraghian, PHI, 3rd edition

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SKILL BASED COURSE – SBC 7-1: ARDUINO PROGRAMMING

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Arduino Programming SBC 7-1	2	0	0	2	

COURSE OBJECTIVES

- To introduce students to the fundamentals of embedded systems using the Arduino platform.
- To develop programming skills in C/C++ for microcontroller-based applications.
- To foster logical thinking and problem-solving through real-world electronic projects.
- To lay the foundation for interfacing sensors and actuators using digital and analog I/O.

LEARNING OUTCOMES

- Explain the architecture and features of the Arduino Platform.
- Set up and use the Arduino IDE to write, debug using Serial Monitor, and upload code to an Arduino board.
- Write basic programs involving digital and analog I/O, loops, functions, and conditional statements.
- Implement simple tasks such as blinking LEDs, reading buttons, generating PWM signals, and reading analog voltages.
- Understand serial communication and use the Serial Monitor for debugging.
- Design small-scale automation and control programs using Arduino logic.

SYLLABUS OF SBC 7-1
(Hours: 60)

Unit I **(24 Hours)**

Introduction to Arduino
- Overview of Arduino and its applications.
- Understanding microcontrollers and development boards.

- Introduction to the Arduino IDE.
- Installing the Arduino IDE.
- Connecting Arduino to your computer.
- First program: Blink an LED (Hello World of Arduino).

Basic Electronic Components

- Basic concepts of electronic components- Resistors, capacitors, diodes, transistors, LEDs.
- Breadboards and prototyping techniques.
- Ohm’s Law and calculating resistor values for LEDs.
- Controlling LEDs with Arduino.
- Switches and Buttons: Digital inputs and outputs. Using push buttons with Arduino.

Unit II **(36 Hours)**

Programming Fundamentals

- Arduino Programming Basics: Structure of an Arduino sketch (setup and loop functions), Variables, data types, and operators.
- Control Structures: Conditional statements (if, else, switch). Loops (for, while, do-while).
- Functions and Libraries: Writing and using functions. Introduction to Arduino libraries.
- Debugging and Troubleshooting: Common errors and debugging techniques. Serial communication (Serial Monitor) for debugging.

List of Experiments

1. Blink an LED. Also modify blink rate.
2. Button-Controlled LED. Turn an LED on/off using a push button.
3. Debounce a Button. Implement debounce to handle noisy button presses.
4. LED Fading to control LED brightness.
5. Potentiometer-Controlled LED. Adjust LED brightness using potentiometer and analog Read().
6. Serial Monitor Interaction. Display text and sensor readings on the Serial Monitor.
   16x2 LCD Display. Display "Hello, World!" and temperature data.

Project-based learning to be encouraged.

SUGGESTED READINGS

“Getting Started With Arduino” By Massimo Banzi and Michael Shiloh. Shroff/Maker Media; fourth edition (2022). ISBN-13 : 978-9391043858

B. Sc. Physical Sciences with Electronics as one of the Core Disciplines

DISCIPLINE SPECIFIC CORE COURSE – DSC 8-1: DIGITAL AND OPTICAL COMMUNICATION

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Digital and Optical Communication DSC 8-1	4	3	0	1	

COURSE OBJECTIVES

This course aims to provide students with a comprehensive understanding of the principles and applications of digital and optical communication systems. It covers the fundamentals of signal processing, various digital modulation techniques, and the operation of optical communication components such as lasers, LEDs, and photodetectors. The course also introduces the characterization of optical fibers and addresses key performance parameters such as noise, signal-to-noise ratio, and bit error rate.

LEARNING OUTCOMES

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

- Explain the principles of sampling, multiplexing, and the statistical behavior of random processes in communication systems.
- Describe and analyze various digital modulation schemes including ASK, FSK, PSK, QPSK, QAM, and M-ary coding techniques.
- Understand the working and characteristics of optical sources and detectors used in fiber-optic communication, such as laser diodes, LEDs, and photodiodes.
- Evaluate the characteristics and performance of optical fibers, including measurements of core radius, numerical aperture, and cut-off wavelength.
- Assess the impact of noise and signal degradation on communication performance, including calculation of SNR and BER in digital and optical systems.

SYLLABUS of DSC 8-1
THEORY COMPONENT
(Hours: 45)

Unit I **(8 Hours)**
An overview of sampling theorem and multiplexing (digital Systems)
Random processes, stationary processes, mean, correlation, and covariance functions: autocorrelation function, cross-correlation function, Power spectral density

Unit II **(11 Hours)**

Digital Modulation Schemes: ASK (Amplitude Shift Keying), FSK (Frequency Shift Keying), PSK (Phase Shift Keying), DPSK(Differential Phase Shift Keying), QPSK (Quadrature Phase Shift Keying), QAM(Quadrature Amplitude Modulation), M-ary coding.

Unit III **(15 Hours)**

Sources and detectors for optical fibre communication: Optical Communication requirements, LASER fundamentals: Absorption and emission of radiation, condition for amplification of radiation. Basics of semiconductor lasers, laser diode characteristics, LED characteristics. Principle of optical detection, PIN photodetector, responsivity and quantum efficiency, speed of response, avalanche photodetector

Unit IV **(11 Hours)**

Characteristics of fiber optic communication system: Characterization of an optical fiber: measurement of its radius, numerical aperture, cut-off wavelength (Marcuse's formula) Analog and digital modulation (direct), noise in detection process: shot noise, thermal noise, SNR, Bit error rate (BER).

<u>PRACTICAL COMPONENT: DIGITAL AND OPTICAL COMMUNICATION</u>
(Hours: 30)

Students should perform at least six experiments from the following list:

1. Study Sampling theorem using software.
2. Study of Amplitude Shift Keying (ASK).
3. Study of Frequency Shift Keying (FSK).
4. Study Phase Shift Keying (PSK)- Binary Phase Shift Keying (BPSK)- and Quadrature Phase Shift Keying (QPSK)
5. Study of Quadrature amplitude Modulation (QAM).
6.To study the characteristics of LED.
7. To study the characteristics of semiconductor laser diode.
8. To study the characteristics of Silicon and Germanium photo-detectors.
9. To measure the parameters of a single mode optical fiber: radius, numerical aperture, cut-off wavelength.

<u>REFERENCES</u>

Essential readings

1. W. Tomasi, Electronic Communication Systems: Fundamentals through Advanced, Pearson Education (2024), 5th Edition
2. S. Haykin, Digital Communication, John Wiley India (Circa 2021), 3rd Edition
3. B. Sklar, Digital Communication, 2nd Edition, Pearson Education (2024)
4. J.G. Proakis, Fundamentals of Communication Systems, Pearson Education (2024), 2nd Edition

5. Ajoy Ghatak and K Thyagarajan, Introduction to Fiber Optics, Cambridge University Press, New Delhi (2024)
6. D.K. Mynbaev and Lowell L. Scheiner, Fiber-Optic Communication Technology, Pearson Education (2024).

Additional readings

1. L. W. Couch II, Digital and Analog Communication Systems, Pearson Education (2005)
2. H. P. Hsu, Analog and Digital Communications, Tata McGraw Hill (2006)
3. J. M. Senior, Optical fiber communication systems: principles and practice, Pearson Education in south Asia, (2009).
4. J. Gower, Optical communication systems, Pearson Education
5. G. Keiser, Optical communications, McGraw Hills education (2003)

B. Sc. Physical Sciences with Electronics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 8-1: CONSUMER ELECTRONICS IN DAILY LIFE

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Consumer Electronics in Daily Life DSE 8-1	4	3	0	1	

COURSE OBJECTIVES

This course aims to familiarize students with the basic principles, functioning, and practical applications of commonly used consumer electronic devices encountered in daily life. It provides an overview of sound and audio systems, television and video technologies, electronic gadgets, home appliances, and office automation tools, along with hands-on training for installation, operation, and basic troubleshooting.

LEARNING OUTCOMES

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

- Understand the basic characteristics of audio signals and the components involved in sound systems, including microphones, amplifiers, and loudspeakers.
- Explain the functioning and standards of television and video systems, including analog and digital formats.
- Describe the working principles of common household electronic gadgets and appliances such as air conditioners, washing machines, and microwave ovens.
- Demonstrate familiarity with office automation devices like laser printers, projectors, and video conferencing systems.
- Perform basic measurements, installations, interfacing, and market analysis of consumer electronic devices through practical exposure.

SYLLABUS OF DSE 8-1
THEORY COMPONENT
(Hours: 45)

Unit I **(15 Hours)**

Basic characteristics of sound signal: Audio level metering, Decibel Level in acoustic measurement, Level and Loudness, Pitch, Frequency response, Fidelity, Sensitivity and selectivity. Audio systems: PA system, Microphone, Amplifier, Loudspeakers. Radio receivers, AM/FM. Audio recording and reproduction, Cassettes, CD and MP3.

Unit II **(11 Hours)**

TV and Video systems: Television standards, BW/Colour, CRT/HDTV. Video system, VCR/VCD/DVD players, MP4 players, LCD, Plasma & LED TV. Projectors: DLP, Home Theatres, Remote Controls

Unit III **(11 Hours)**

Electronic Gadgets and Domestic Appliances (Basic working): Digital clock, Digital camera, Home security system, CCTV. Air conditioners, Refrigerators, Washing Machine/Dish Washer, Microwave oven, Vacuum cleaners

Unit IV **(8 Hours)**

Office Automation appliances (Basic Working): Laser Printer, Smart Interactive Board, LED Projector, Video conferencing system

PRACTICAL COMPONENT: CONSUMER ELECTRONICS IN DAILY LIFE
(Hours: 30)

Students should perform at least five experiments from the following list:

1. Testing and measurement of the various parameters of a microphone.
2. Test the given speaker and plot its frequency response.
3. Installation of Audio /Video systems – site preparation, electrical requirements, cables and connectors.
4. Market Survey of Products (at least one from each module)
5. To Interface and configure LED projector using various controls.
6. Study of PA systems for various situations – Public gathering, closed theatre /Auditorium, Conference room, Prepare Bill of Material (Costing)
7. Interface the laser printer to the desktop computer and identify various controls.

REFERENCES

Essential references

1. R. P. Bali Consumer Electronics Pearson Education (2008)
2. R. G. Gupta Audio and Video systems Tata McGraw Hill (2004)
3. Electronic Instrumentation by H.S Kalsi, McGraw Hill
4. Instrumentation measurements and analysis by Nakra & Choudhary
5. Measurement & Instrumentation- DVS Murthy
6. Electronic Sensor Circuits and Projects, III Volume, Forrest M Mims, Master Publishing Inc.

B. Sc. Physical Sciences with Electronics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 8-2: PHYSICS OF FIELD EFFECT DEVICES

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Physics of Field Effect Devices DSE 8-2	4	3	0	1	

COURSE OBJECTIVES

The objective of this course is to provide a comprehensive understanding of the principles, operation, and characteristics of Field Effect Transistors (FETs), including JFETs, MOSFETs, and advanced structures, while developing the analytical and practical skills needed to model, design, and analyze FET-based circuits in analog and digital systems.

LEARNING OUTCOMES

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

- Explain the operating principles, structural differences, and characteristics of various FET types, including JFETs and MOSFETs.
- Analyze I-V characteristics and apply small-signal models to understand FET behavior in different configurations.
- Design, simulate, and evaluate FET-based amplifier and switching circuits for analog and digital applications.
- Describe advanced FET technologies such as MESFETs and FinFETs, and critically assess challenges related to device scaling and performance.
- Apply knowledge of CMOS technology and nanoelectronic concepts to understand the role of FETs in integrated circuits and emerging electronic systems.

SYLLABUS OF DSE 8-2
THEORY COMPONENT
(Hours: 45)

Unit I **(11 Hours)**

Junction Field Effect Transistors (JFETs)
Overview of the structure and operational principles of JFETs, emphasizing voltage-controlled conduction via gate-source bias. Analysis of output and transfer characteristics, pinch-off voltage,

and drain current saturation. Study of various JFET biasing techniques and comparison with Bipolar Junction Transistors (BJTs). Applications of JFETs as amplifiers in Common Source (CS), Common Gate (CG), and Common Drain (CD) configurations.

Unit II **(12 Hours)**

Metal-Oxide-Semiconductor Field Effect Transistors (MOSFETs)
Detailed study of depletion-mode and enhancement-mode MOSFETs. Construction and operation of n-channel and p-channel MOSFETs. Analysis of MOS capacitors covering accumulation, depletion, and inversion modes, along with corresponding energy band diagrams. Concepts of threshold voltage, effects of work function differences, and interface charges. C-V characteristics, sub-threshold conduction, and MOSFET biasing techniques. Introduction to power MOSFETs, focusing on their high-voltage/current capabilities and switching performance.

Unit III **(11 Hours)**

Advanced FETs and Applications
Introduction to MESFETs including their structure, types, and short-channel behavior. Discussion of I-V modeling, field-dependent mobility, and two-region/two-dimensional models. High-frequency characteristics such as current cut-off frequency. Study of GaAs MESFETs. Overview of High Electron Mobility Transistors (HEMTs), including modulation doping and the formation of two-dimensional electron gas (2-DEG) at the AlGaAs/GaAs interface. Advantages and applications of HEMTs.

Unit IV **(11 Hours)**

FETs in Integrated Circuits and Nanoelectronics
Exploration of CMOS technology including structure and operation of nMOS, pMOS, and CMOS inverters. Introduction to VLSI design and the impact of channel length scaling. Effects such as body effect, thermal considerations, and reliability concerns. Fundamentals of hetero-epitaxial structures and emerging nanoelectronic components like quantum dots, nanowires, and two-dimensional layered materials.

PRACTICAL COMPONENT: FIELD EFFECT TRANSISTORS
(Hours: 30)

Students should perform at least six experiments from the following list:

1. Analyze the transfer and output characteristics of a Junction Field Effect Transistor (JFET).
2. Investigate the drain and transfer characteristics of an enhancement-mode MOSFET.
3. Examine the operating characteristics of a depletion-mode MOSFET.
4. Implement and evaluate the use of a MOSFET as an amplifier.
5. Study the frequency response of FET amplifiers in Common Source (CS), Common Gate (CG), and Common Drain (CD) configurations.
6. Perform load-line analysis for various FET circuit configurations.
7. Simulate FET-based circuits using SPICE or equivalent circuit simulation tools.
8. Characterize the behavior and switching properties of a CMOS inverter.

9. Determine the threshold voltage and transconductance of a MOSFET.
10. Investigate the switching characteristics of MOSFET devices under different operating conditions.
11. Simulate or measure the I-V characteristics of a High Electron Mobility Transistor (HEMT) and observe the formation of 2DEG.
12. Analyze the high-frequency response and current cut-off behavior of a MESFET using simulation.

REFERENCE

Essential Readings for the Theory Component

- B. G. Streetman, *Solid State Electronic Devices*, PHI.
- S. M. Sze, *Physics of Semiconductor Devices*, John Wiley & Sons.
- Neil Weste & David Harris, *CMOS VLSI Design*, Pearson.
- P. Valizadeh, *Field Effect Transistors: A Comprehensive Overview*, Wiley-Blackwell.
- R. F. Pierret, *Semiconductor Device Fundamentals*, Pearson Education.

Additional Reading for the Theory Component

- Kelly Fotheringham, *MOSFET and GaN FET Application Handbook*, Nexperia UK Ltd.

Essential Readings for the Lab Component

- Stephen A. Campbell, *The Science and Engineering of Microelectronic Fabrication*, Oxford University Press.
- Paul Horowitz and Winfield Hill, *The Art of Electronics*, 3rd Edition, Cambridge University Press.
- B. Somanathan Nair, *Electronic Devices and Applications*, PHI Learning.
- N. N. Bhargava, D. C. Kulshreshtha, S. C. Gupta, *Laboratory Manual for Electronic Devices and Circuits*, Tata McGraw-Hill

B. Sc. Physical Sciences with Electronics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 8-3: NANOSCIENCE AND NANOTECHNOLOGY

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Nanoscience and Nanotechnology DSE 8-3	4	3	0	1	Quantum Mechanics

COURSE OBJECTIVES

The objective of this course is to introduce students to the fundamental principles of nanoscience and nanotechnology, with a focus on size-dependent properties of materials and their interdisciplinary applications. It aims to develop an understanding of nanomaterial synthesis, characterization techniques, and emerging applications in electronics, energy, environment, and healthcare.

LEARNING OUTCOMES:

Upon successful completion of this course, students will be able to:

- Explain the fundamental concepts of nanoscience and the distinct properties of nanomaterials compared to bulk materials.
- Classify nanomaterials based on their dimensions and understand quantum confinement effects on their behavior.
- Apply suitable top-down and bottom-up techniques for the synthesis of nanomaterials.
- Use standard characterization methods (e.g., XRD, SEM, TEM, UV-Vis) to analyze structural and optical properties of nanomaterials.
- Evaluate the potential of nanomaterials in real-world applications such as electronics, energy devices, sensors, and environmental solutions.

SYLLABUS OF DSE 8-3
THEORY COMPONENT
(Hours: 45)

Unit I **(12 Hours)**

Introduction to Nanoscience and Nanomaterials
Basic Concepts of Nanoscience and Nanotechnology: Introduction to nanoscience and its implications in Physics, Chemistry, Biology, and Engineering. Classification of nanostructured

materials: 0D (quantum dots), 1D (nanowires, nanotubes), 2D (thin films, graphene), and 3D (multi-layered materials, superlattices). Comparison of nanomaterials with bulk materials (metals, semiconductors, ceramics, polymers).
Properties at Nanoscale: Overview of mechanical, electronic, optical, magnetic, and thermal properties at nanoscale (qualitative). Effects of size reduction on these properties. Introduction to quantum confinement and its role in altering Bandgap widening, enhanced reactivity, and surface-to-volume ratio effects.

Unit II **(6 Hours)**

Nanoscale Systems and Their Properties
Band structure and density of states in 3D, 2D, 1D, and 0D systems (detailed for 3D and 2D, qualitative for 1D and 0D). Quantum confinement effects on electronic and optical properties.

Unit III **(15 Hours)**

Synthesis and Characterization of Nanomaterials
Synthesis Techniques: Top-down vs. bottom-up approaches. Top-down: Ball milling, lithography. Bottom-up: Physical Vapor Deposition (PVD) - thermal evaporation, sputtering; Chemical Vapor Deposition (CVD); Spin coating; Preparation of colloidal solutions (metals, metal oxides). Chemical and electrochemical synthesis of conducting polymers (intrinsic and extrinsic).
Characterization of Nanomaterials: Basic techniques for characterizing nanomaterials: Structural (e.g., SEM, TEM, AFM, XRD), optical (e.g., UV-Vis spectroscopy), and electronic properties (e.g., conductivity measurements).
Nanomaterials in Electronics: Introduction to carbon-based nanomaterials (CNTs, graphene) for electronic applications. Conductance quantization in 1D and 2D systems and their relevance to nanoelectronics.

Unit IV **(12 Hours)**

Applications of Nanomaterials
Nanomaterials in Energy and Environment: Nanotechnology for sustainable energy: Nanomaterials in solar cells (silicon-based, LEDs for displays), fuel cells, and electrochemical storage (primary, secondary, lithium, solid-state batteries). Environmental applications: Photocatalysts, nanomaterial-based membranes, and adsorbents for water/wastewater treatment (metal oxide surfaces, hybrid adsorbents).
Nano Devices and Sensors: Gas sensors: Chemiresistive (semiconducting metal oxides, CNT-based), electrochemical, and optical sensors.
Applications: Medical diagnostics (nanoprobes, targeted drug delivery), consumer products (sunscreens, lotions, paints).

PRACTICAL COMPONENT: NANOSCIENCE AND NANOTECHNOLOGY
(Hours: 30)

At least 05 experiments from the following:
1. Synthesis of metal/metal oxide nanoparticles by chemical route and study its optical absorption properties.

2. Synthesis of semiconductor (CdS/ZnO/TiO2/Fe2O3 etc) nanoparticles and study its XRD.
3. Analysis of XRD pattern of given nanomaterial and estimate lattice parameters and particle size.
4. Growth of thin films using thermal evaporation/spin coating or any available technique in lab.
5. Investigation of grain size/ particle size distribution from SEM/TEM images using imagej software (free ware: https://imagej.en.softonic.com/).
6. Prepare a ceramic disc of a given compound and study I-V characteristics / measure its dielectric constant with frequency or other property.
7. To study variation of resistivity or sheet resistance with temperature of the fabricated thin films using four probe method.

REFERENCES

Essential Readings for the theory component

1. C.P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology 1st edition (2003) Wiley India Pvt. Ltd..
2. S.K. Kulkarni, Nanotechnology: Principles & Practices 2nd edition (2011) (Capital Publishing Company)
3. K. K. Chattopadhyay and A. N. Banerjee, Introduction to Nanoscience and Technology (2009) (PHI Learning Private Limited).
4. Introduction to Nanoelectronics, V. V. Mitin, V.A. Kochelap and M.A. Stroscio,2011, Cambridge University Press.
5. Richard Booker, Earl Boysen, Nanotechnology for Dummies (2005) (Wiley Publishing Inc.).
6. Introductory Nanoscience by Masaru Kuno, (2012) Garland science Taylor and Francis Group
7. Electronic transport in mesoscopic systems by Supriyo Datta (1997) Cambridge University Press.
8. Fundamentals of molecular spectroscopy by C. N. Banwell and E. M. McCASH, 4th edition, McGrawHill.
9. Introduction to Nanomaterials and Devices, Omar Manasreh, Wiley, 1st Edition, 2011
10. Textbook of Nanoscience and Nanotechnology, B.S. Murty, P. Shankar, Baldev Raj, B.B. Rath, James Murday, 2013, Springer, e-ISBN 978-3-642-28030-6

Additional Readings for the theory component

1. Quantum Transport in semiconductor nanostructures by Carla Beenakker and HenK Van Houten (1991) (available at arXiv: cond-mat/0412664) Open Source
2. Sara Cronewett Ph.D. thesis (2001) for extra reading (Available as Arxiv).
3. Solid State Physics by J. R. Hall and H. E. Hall, 2nd edition (2014) Wiley

References for the laboratory work

1. C.P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology 1st edition (2003) Wiley India Pvt. Ltd..
2. S. K. Kulkarni, Nanotechnology: Principles & Practices 2nd edition (2011) (Capital

Publishing Company)
3. K. K. Chattopadhyay and A. N. Banerjee, Introduction to Nanoscience and
4. Technology (2009) (PHI Learning Private Limited).
5. Richard Booker, Earl Boysen, Nanotechnology for Dummies (2005) (Wiley Publishing Inc.)

B. Sc. Physical Sciences with Electronics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 8-4 : SEMICONDUCTOR DEVICES - FABRICATION AND APPLICATIONS

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Semiconductor Devices - Fabrication and Applications DSE 8-4	4	2	0	2	

COURSE OBJECTIVES

- This course provides a review of basics of semiconductors such as energy bands, doping, defects etc. and introduces students to various semiconductor and memory devices.
- Thin film growth techniques and processes including various vacuum pumps, sputtering, evaporation, oxidation and VLSI processing are described in detail.
- By the end of the syllabus, students will have an understanding of MEMS based transducers.

LEARNING OUTCOMES

At the end of this course, students will be able to achieve the following learning outcomes:

- Learn to distinguish between single crystal, polycrystalline and amorphous materials based on their structural morphology and learn about the growth of single crystals of silicon, using Czochralski technique, on which a present day electronics and IT revolution is based. Students will understand about the various techniques of thin film growth and processes.
- Appreciate the various VLSI fabrication technologies and learn to design the basic fabrication process of R, C, P- N Junction diode, BJT, JFET, MESFET, MOS, NMOS, PMOS and CMOS technology.
- Gain basic knowledge on overview of MEMS (MicroElectro-Mechanical System) and MEMS based transducers.

SYLLABUS OF DSE 8-4

THEORY COMPONENT

(Hours: 30)

Unit I **(9 Hours)**

Introduction: Review of energy bands in materials. Metal, Semiconductor and Insulator. Doping in Semiconductors, Defects: Point, Line, Schottky and Frenkel. Single Crystal, Polycrystalline and Amorphous Materials. Czochralski technique for Silicon Single Crystal Growth. Silicon Wafer Slicing and Polishing.
Vacuum Pumps: Primary Pump (Mechanical) and Secondary Pumps (Diffusion, Turbomolecular, Cryopump, Sputter - Ion)– basic working principle, Throughput and Characteristics in reference to Pump Selection. Vacuum Gauges (Pirani and Penning).

Unit II **(10 Hours)**

Thin Film Growth Techniques and Processes: Sputtering, Evaporation (Thermal, electronBeam), Pulse Laser Deposition (PLD), Chemical Vapor Deposition (CVD). Epitaxial Growth. Thermal Oxidation Process (Dry and Wet) Passivation. Metallization. Diffusion.

Unit III **(7 Hours)**

VLSI Processing: Clean Room Classification, Line width, Photolithography: Resolution and Process, Positive and Negative Shadow Masks, Photoresist, Step Coverage, Developer. Electron Beam Lithography. Etching: Wet Etching. Dry etching (RIE and DRIE). Basic Fabrication Process of R, C, P-N Junction diode, BJT, JFET, MESFET, MOS, NMOS, PMOS and CMOS technology. Wafer Bonding, Wafer Cutting, Wire bonding and Packaging issues (Qualitative idea).

Unit IV **(4 Hours)**

Micro Electro-Mechanical System (MEMS): Introduction to MEMS, Materials selection for MEMS Devices, Selection of Etchants, Surface and Bulk Micromachining, Sacrificial Subtractive Processes, Additive Processes, Cantilever, Membranes. General Idea MEMS based Pressure, Force, and Capacitance Transducers.

PRACTICAL COMPONENT: SEMICONDUCTOR DEVICES - FABRICATION AND APPLICATIONS

(Hours: 60)

At least 6 experiments from the following:

1. Fabrication of thin films via dip-coating technique, deposition of metal contacts through thermal evaporation and investigation of their current–voltage (I–V) characteristics.
2. Fabrication of thin films via spin-coating technique, deposition of metal contacts through thermal evaporation and investigation of their current–voltage (I–V) characteristics
3. Fabrication of p-n junction using either p or n type substrate along with

appropriate semiconducting layer and study its current-voltage (I-V) Characteristics.
4. Generation of vacuum in small tubes (varying volumes) using a mechanical rotary pump and measurement of pressure using vacuum gauges.
5. Selective etching of Different Metallic thin films using suitable etchants of different concentrations.
6. Wet chemical etching of Si for Micro-Electro-Mechanical Systems (MEMS) applications using different concentrations of etchant.
7. Calibrate semiconductor type temperature sensor (AD590, LM 35, LM 75).
8. To measure the resistivity of a germanium (Ge) semiconductor crystal with temperature (up to 150 ^oC) by four-probe method.
9. Capacitance measurements of ceramics using LCR meter.
10. Capacitance measurements of dielectric thin film capacitor using LCR meter

<u>REFERENCES</u>

Essential Readings for the theory component

1. Physics of Semiconductor Devices, S. M. Sze. Wiley-Interscience.
2. Fundamentals of Semiconductor Fabrication, S.M. Sze and G. S. May, John-Wiley and Sons, Inc.
3. Introduction to Semiconductor materials and Devices, M. S. Tyagi, John Wiley & Sons VLSI Fabrication Principles (Si and GaAs), S. K. Gandhi, John Wiley & Sons, Inc.

Additional Readings for the theory component

Handbook of Thin Film Technology, Leon I. Maissel and Reinhard Glang.

Essential Readings for the practical theory component

1. The science and Engineering of Microelectronics Fabrication, Stephen A. Champbell, 2010, Oxford University Press.
2. Introduction to Semiconductor Devices, Kelvin F.

B. Sc. Physical Sciences with Electronics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 8-5: SENSORS AND DETECTORS

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Sensors and Detectors DSE 8-5	4	3	0	1	

COURSE OBJECTIVES

To make students familiar with the constructions and working principle of different types of sensors and transducers. To make students aware about the measuring instruments and the methods of measurement and the use of different transducers.

LEARNING OUTCOMES

At the end of the course, a student will be able to:

- Use concepts in common methods for converting a physical parameter into an electrical quantity.
- Classify and explain with examples of transducers, including those for measurement of temperature, strain, motion, position and light.
- Choose proper sensor comparing different standards and guidelines to make sensitive measurements of physical parameters like pressure, flow, acceleration, etc.
- Predict correctly the expected performance of various sensors.
- Locate different type of sensors used in real life applications and paraphrase their importance.
- Set up testing strategies to evaluate performance characteristics of different types of sensors and transducers and develop professional skills in acquiring and applying the knowledge outside the classroom through design of a real-life instrumentation system.

SYLLABUS OF DSE 8-5
THEORY COMPONENT
(Hours: 45)

Unit I **(13 Hours)**

Transducers, Classification of transducers on different basis, Types of transducers (Basic idea of Mechanical, resistive, capacitive, inductive, piezoelectric, optical and digital).
Sensor, Components of sensor, Direct and complex sensor (Basic idea)
Distinction between Sensor and Transducer, Characteristics of Transducers/Sensor: Static characteristics and static calibration (Calibration accuracy and component error), Dynamic characteristics.
Inductive sensor: Variable Inductance Sensors, Plunger type displacement sensor, Variable Gap Sensor, LVDT: Construction, working, output characteristics. Idea of RVDT (Qualitative).
Capacitive sensors: Variable distance-parallel plate type, variable area- parallel plate (serrated plate/teeth type), variable dielectric constant type; Sensitivity of capacitive sensors, Stretched diaphragm type

Unit II **(9 Hours)**

Magnetic Sensors: Magnetoresistive Sensors and Hall effect sensor (performance and characteristics).
Temperature sensor: RTD (construction, working and temperature coefficient), thermistor, categories of thermistor (PTC and NTC: material, shape, ranges, RT curve and accuracy specification), Thermo emf sensor (thermoelectricity generation, thermos-emf measurement, Thermocouples (construction, characteristics), and Pyroelectric sensors (pyroelectric effect and output voltage-temperature relationship).

Unit III **(13 Hours)**

Pressure sensors: Direct versus indirect pressure measurement, Different types of gauges and their working range, Mechanical gauges (McLeod Gauge), Thermal Conductivity Gauges (Thermocouple and Pirani gauges) and Ionization gauges (hot & cold cathode), advantages and limitations of various types of gauges, Gauge calibration (Static: Manometric method and dead-beat tester, dynamic calibration).
Radiation Sensors: Basic Characteristics (Concept of Work Function, Spectral Sensitivity, Spectral threshold, Quantum yield, time lag, linearity, Status and dynamic response), Types of Photodetectors: Photoemissive Cell, Photo Multiplier, Photo conductive Cell (LDR), Photovoltaic cells, photodiodes. Detection of Nuclear Radiation: Qualitative treatment of Geiger Muller counters and Scintillation detectors.

Unit IV **(10 Hours)**

Applications of Sensors and detectors: Basic principles of Remote sensing, Introduction to LiDAR (principles, applications and benefits), Types of LiDAR (air-borne and ground based)
Applications of motion sensors in accelerometers and gyroscopes (qualitative analysis of

working principle).
Biomedical Sensor: Electrochemical sensor (electrochemical cell, cell potential, three electrodes system, working principle).

PRACTICAL COMPONENT: SENSORS AND DETECTORS
(Hours: 30)

At least 5 experiments to be done from the list below:

1. Characteristics of LDR as a function of distance from light source.
2. Light characteristics of Photodiode.
3. Measurement of Strain using Strain Gauge.
4. To study the characteristics of a Linear Variable Differential Transformer (LVDT).
5. To study the characteristics of a Resistance Temperature Device (RTD).
6. To study the frequency response of a loudspeaker.
7. Determine characteristics of an Infrared (IR) emitter-receiver module.
8. Create vacuum in a small chamber using a mechanical (rotary) pump and/or secondary pump and measure the chamber pressure using a pressure gauge – Pirani and/or CC gauge.
9. Measurement of thermos-emf in thermopile and to calculate the Seebeck coefficient.
10. Study the pyroelectric effect and generation of induced voltage with temperature change.

REFERENCES

Essential Readings for the Theory Component

1. Experimental Methods for Engineers, J.P. Holman, McGraw Hill
2. Introduction to Measurements and Instrumentation, A.K. Ghosh, PHI Learning Pvt. Ltd.
3. 3.Transducers and Instrumentation, D.V.S. Murty, 2nd Edition, PHI Learning Pvt. Ltd.
4. Instrumentation Devices and Systems, C.S. Rangan, G.R. Sarma, V.S.V. Mani, Tata
5. McGraw Hill
6. Electronic circuits: Handbook of design & applications, U.Tietze, Ch.Schenk, Springer
7. Electronic Instrumentation by H. S. Kalsi (Mc Graw Hill Publisher)
8. Sensors and Transducers, D Patranabis, PHI Learning Pvt. Ltd.
9. An Introduction to Sensors and Instrumentations, Sobnath Singh, Narosa
10. Handbook of Modern Sensors, Jacob Fraden, Springer
11. Handbook of Thion film Technology, Maissel and Glang, Tata McGraw Hill
12. Instrumentation, Measurement and Analysis, Nakra and Chaudhry, McGraw Hill

Additional Readings for the Theory Component

1. Radiation detection and measurement, G.F. Knoll, Wiley

2. Measurement, Instrumentation and Experiment Design in Physics & Engineering, M.Sayer and A. Mansingh, PHI

References for the Practical Component

1. Electronic circuits: Handbook of design and applications, U. Tietze and C. Schenk, Springer
2. Basic Electronics: A text lab manual, P. B. Zbar, A. P. Malvino, M. A. Miller, McGraw

B. Sc. Physical Sciences with Electronics as one of the Core Disciplines

SKILL BASED COURSE – SBC 8-1: INTERFACING WITH ARDUINO

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Interfacing with Arduino SBC 8-1	2	0	0	2	SBC 7-1: Arduino Programming

COURSE OBJECTIVES

- Explain the architecture and features of the Arduino Platform.
- Set up and use the Arduino IDE to write, debug, and upload code to an Arduino board.
- Write basic programs involving digital and analog I/O, loops, functions, and conditional statements.
- Implement simple tasks such as blinking LEDs, reading buttons, generating PWM signals, and reading analog voltages.
- Understand serial communication and use the Serial Monitor for debugging.
- Design small-scale automation and control programs using Arduino logic.

LEARNING OUTCOMES

- Identify and describe the working principles of common sensors (e.g., temperature, light, distance) and actuators (e.g., motors, buzzers).
- Interface sensors (LDR, DHT11, ultrasonic, IR, etc.) with Arduino and acquire data.
- Control actuators (relays, DC motors, stepper motors, servos, buzzers) using digital output and PWM.
- Design simple projects such as automatic lighting systems, object detection alarms, or temperature monitors.
- Implement basic feedback and control systems (e.g., temperature-based fan control).
- Troubleshoot common hardware and communication issues in Arduino circuits.

<u>SYLLABUS OF SBC 8-1</u>
(Hours: 60)

Apart from common experiments for all students on the listed topics, project-based learning (group activities) to be encouraged.

Unit I **(24 Hours)**

Interfacing with Sensors and Actuators

- Working with Sensors: Introduction to sensors (temperature, humidity, light, magnetic field etc.). Reading analog values.
- Analog and Digital Inputs/Outputs: Analog vs. Digital signals. Working with potentiometers, photoresistors, and thermistors.
- Interfacing with Motors: Controlling DC motors. Introduction to servos and stepper motors.
- Using Displays and Keypads: Interfacing with 7-segment displays and LCDs. Using keypads for input.
- Sound and Audio Output: Working with buzzers and speakers. Generating sound with Arduino.

Unit II **(36 Hours)**

Communication Protocols and Advanced Topics.

- Serial Communication: Understanding UART and Serial Communication. Communication between Arduino and computer.
- I2C and SPI Communication: Introduction to I2C and SPI protocols. Interfacing with external modules (e.g., sensors, displays).
- Wireless Communication: Introduction to wireless modules (Bluetooth, Wi-Fi). Simple projects using wireless communication.
- Data Logging: Reading and storing data from sensors. SD card modules and data logging projects.
- Introduction to IoT with Arduino: Basics of the Internet of Things (IoT). Simple IoT project: Sending data to a web server.
- Planning and designing your project.

<u>SUGGESTED READINGS</u>

"Getting Started With Arduino" By Massimo Banzi and Michael Shiloh. Shroff/Maker Media; fourth edition (2022). ISBN-13 : 978-9391043858

B. Sc. Physical Sciences with Electronics as one of the Core Disciplines

SKILL BASED COURSE – SBC 8-2: WEATHER FORECASTING

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Weather forecasting SBC 8-2	2	1	0	1	

COURSE OBJECTIVES

The aim of this course is not just to impart theoretical knowledge to the students but to enable them to develop an awareness and understanding regarding the causes and effects of different weather phenomenon and basic forecasting techniques.

LEARNING OUTCOMES

The student will gain the following:

- Acquire basic knowledge of the elements of the atmosphere, its composition at various heights, variation of pressure and temperature with height.
- Learn basic techniques to measure temperature and its relation with cyclones and anti-cyclones.
- Knowledge of simple techniques to measure wind speed and its directions, humidity and rainfall.
- Understanding of absorption, emission and scattering of radiations in atmosphere; Radiation laws.
- Knowledge of global wind systems, jet streams, local thunderstorms, tropical cyclones, tornadoes and hurricanes.
- Knowledge of climate and its classification. Understanding various causes of climate change like global warming, air pollution, aerosols, ozone depletion, acid rain.
- Develop skills needed for weather forecasting, mathematical simulations, weather forecasting methods, types of weather forecasting, role of satellite observations in weather forecasting, weather maps etc. Uncertainties in predicting weather based on statistical analysis.
- Develop ability to do weather forecasts using input data.
- In the laboratory course, students should be able to learn: Principle of the working of a weather Station, Study of Synoptic charts and weather reports, Processing and analysis of weather data, Reading of Pressure charts, Surface charts, Wind charts and their analysis.

SYLLABUS OF SBC 8-2
THEORY COMPONENT
(Hours: 15)

Unit -1 **(8 Periods)**

Introduction to atmosphere: Elementary idea of atmosphere: physical structure and composition; compositional layering of the atmosphere; variation of pressure and temperature with height; air temperature; requirements to measure air temperature; temperature sensors: types; atmospheric pressure: its measurement
Measuring the weather: Wind; forces acting to produce wind; wind speed direction: units, its direction; measuring wind speed and direction; humidity, clouds and rainfall, radiation: absorption, emission and scattering in atmosphere; radiation laws.

Unit-2 **(7 Periods)**

Weather systems: Global wind systems; air masses and fronts: classifications; jet streams; local thunderstorms; tropical cyclones: classification; tornadoes; hurricanes.
Climate and Climate Change: Climate: its classification; causes of climate change; global warming and its outcomes; air pollution and its measurement, particulate matters PM 2.5, PM 10. Health hazards due to high concentration of PM2.5; aerosols, ozone depletion.
Basics of weather forecasting: Weather forecasting: analysis and its historical background; need of measuring weather; types of weather forecasting; weather forecasting methods; criteria of choosing weather station; basics of choosing site and exposure; satellites observations in weather forecasting; weather maps; uncertainty and predictability; probability forecasts.

PRACTICAL COMPONENT: WEATHER FORECASTING
(Hours: 30)

Demonstrations and Experiments:

1. Study of synoptic charts & weather reports, working principle of weather station.
2. Processing and analysis of weather data:
   (a) To calculate the sunniest time of the year.
   (b) To study the variation of rainfall amount and intensity in different seasons.
   (c) To examine the maximum and minimum temperature throughout the year.
   (d) To study the relative humidity of the day and seasons and the entire year.
   (e) Development and movement of low and high Pressure system over Indian/global region.
3. Exercises in chart reading: Plotting of constant pressure charts, surfaces charts, upper wind charts and its analysis.
4. Formats and elements in different types of weather forecasts/ warning (both aviation and non-aviation).
5. Simulation of weather system

6. Field visits to India Meteorological department and National center for medium range weather forecasting

REFERENCES

Essential Readings

1. Aviation Meteorology, I.C. Joshi, 3rd edition 2014, Himalayan Books
2. The weather Observers Hand book, Stephen Burt, 2012, Cambridge University Press.
3. Meteorology, S.R. Ghadekar, 2001, Agromet Publishers, Nagpur.
4. Text Book of Agro meteorology, S.R. Ghadekar, 2005,Agromet Publishers, Nagpur.
5. Atmosphere and Ocean, John G. Harvey, 1995, The Artemis Press.

Additional Reading:

1. PM2.5 diminution and haze events over Delhi during the COVID-19 lockdown period: an interplay between the baseline pollution and meteorology, Nature- Scientific Reports, 10(13442). https://doi.org/10.1038/s41598- 020-70179-8., S. K. Dhaka, Chetna, V. Kumar, V. Panwar, A. P. Dimri, N. Singh, P. K. Patra, Y. Matsumi, M. Takigawa, and T. Nakayama (2020)
2. Chapter 1 - Composition and thermal structure of the earth's atmosphere, Atmospheric Remote Sensing, Principles and Applications, Earth Observation, 2023, Pages 1-18, https://doi.org/10.1016/B978-0-323-99262-6.00023-7. SK Dhaka and Vinay Kumar.
3. Climatic trends in temperature, relative humidity, and wind speed over Indian landmass and isle in Andaman Nicobar and Lakshadweep during 1981-2021, MAPAN-Journal of Metrology Society of India, (2024), DOI: 10.1007/s12647-024-00743-4, Shristy Malik, A.S. Rao, S K. Dhaka.
4. Decoding temporal patterns and trends of PM10 pollution over Delhi: A multi-year analysis (2015–2022). Environmental Monitoring and Assessment, 196(6), 500. https://doi.org/10.1007/s10661-024-12638-7, Chetna, Dhaka, S. K., Walker, S.-E., Rawat, V., & Singh, N. (2024).