FACULTY OF
INTER-DISCIPLINARY AND APPLIED SCIENCES (FIAS)

PROGRAM SYLLABUS FOR

M.Sc (Electronics)
M.Tech (Microwave Electronics)
Ph.D (Electronics)

Department of Electronic Science
University of Delhi South Campus
Benito Juarez Road, Dhaula Kuan
New Delhi - 110021, India
Master of Science (ELECTRONICS) - Two-year degree programme

The M.Sc. Electronics is a four semester programme initially started in 1984 with the aim to provide necessary theoretical background and practical experience in the field of Electronics.

**Semester I**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>1.1</td>
<td>High-level Computer Language and Operating System</td>
<td>50</td>
</tr>
<tr>
<td>1.2</td>
<td>Engineering Mathematics</td>
<td>50</td>
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<tr>
<td>1.3</td>
<td>Network Analysis and Synthesis</td>
<td>50</td>
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<td>1.4</td>
<td>Advanced Analog and Digital Circuit Design</td>
<td>50</td>
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<tr>
<td>1.5</td>
<td>Practical I : High level Computer Languages and Operating Systems</td>
<td>25</td>
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<tr>
<td>1.6</td>
<td>Practical II : Electronic Circuits</td>
<td>25</td>
</tr>
<tr>
<td>1.7</td>
<td>Practical III : Microprocessors</td>
<td>25</td>
</tr>
<tr>
<td>1.8</td>
<td>Practical IV : Computational Techniques</td>
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<td><strong>Semester I total</strong></td>
<td></td>
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**Semester II**

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<tr>
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<tbody>
<tr>
<td>2.1</td>
<td>Electromagnetics, Antenna and Propagation</td>
<td>50</td>
</tr>
<tr>
<td>2.2</td>
<td>Semiconductor Devices and Materials</td>
<td>50</td>
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<tr>
<td>2.3</td>
<td>Microprocessors</td>
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<td>2.4</td>
<td>Signal Systems and Control</td>
<td>50</td>
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<tr>
<td>2.5</td>
<td>Practical I : Electromagnetics</td>
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<td>2.6</td>
<td>Practical II : Materials and Semiconductor Devices</td>
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<td>Practical III : Circuit Design and Simulation</td>
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<td>2.8</td>
<td>Practical IV : Electrical Machines and Control Systems</td>
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<td><strong>Semester II total</strong></td>
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**Summer Training (8 weeks)**

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**Semester III**

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<tbody>
<tr>
<td>3.1</td>
<td>Optical Electronics</td>
<td>50</td>
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<td>3.2</td>
<td>Integrated Circuit Technology</td>
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<tr>
<td>3.3</td>
<td>Digital Signal Processing</td>
<td>50</td>
</tr>
<tr>
<td>3.4</td>
<td>Communication Systems</td>
<td>50</td>
</tr>
<tr>
<td>3.5</td>
<td>Practical I : Optical Electronics</td>
<td>25</td>
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<tr>
<td>3.6</td>
<td>Practical II : Science and Technology of Semiconductor Devices</td>
<td>25</td>
</tr>
<tr>
<td>3.7</td>
<td>Practical III : Digital Signal Processing</td>
<td>25</td>
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<tr>
<td>3.8</td>
<td>Practical IV : Communication Systems</td>
<td>25</td>
</tr>
<tr>
<td><strong>Semester III total</strong></td>
<td></td>
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**Semester IV**
Detailed Syllabus

1.1 High-level Computer Languages and Operating Systems

Operating Systems: familiarity with various operating systems like DOS, OSII, GUI like Windows, UNIX & LINUX. Details of one operating system such as UNIX: introduction, multitasking, multiuser capabilities, UNIX basis, files and directories, understanding the UNIX shell, text processing in the UNIX environment, editors like VI, EMAC, SED. Programming languages (one high level language such as C++) : introduction to C++ and object oriented programming, development environment, compiling and linking the source code, brief look at crout, comments,’ variable and constants, expressions and statements, functions, classes, pointers, references, overloading, arrays, inheritance, special classes and functions, streams and files, the preprocessor, object-oriented analysis and design, templates, exceptions & error handling, standard libraries and bit manipulation.

1.2 Engineering Mathematics


1.3 Network Analysis and Synthesis


1.4 Advanced Analog and Digital Circuit Design

Practical Analog and Digital Circuit Design of amplifiers (single and multistage, audio and RF range) and power amplifiers. Design process as a troubleshooting tool. Oscillators, Mixers and PLL. Review of Logic families tabular and computer aides minimisation procedures. Programmable Logic Array. Clock mode sequential machines, incompletely specified sequential machines and fundamental mode sequential machines.

1.5 Practical I: High level Computer Languages and Operating Systems-
2.1 **Electromagnetics, Antenna and Propagation**
Transmission lines: transmission line equation in time and frequency domain, losses and dispersion, reflection from an unknown load; quarter wavelength, single stub and double stub matching; Smith Chart and its applications. Maxwell’s equations, constitutive relations, wave equation, plane wave functions, rectangular waveguide, circular waveguide, dielectric slab waveguide surface guide waves. Antenna parameters, radiation from simple dipole and aperture, concept of antenna arrays, end fire and broadside arrays, horn antenna, microstrip antenna, parabolic disc antenna. Ground wave, space wave and ionospheric propagation. Communication link budget for ground transmission.

2.2 **Semiconductor Devices and Materials**

2.3 **Microprocessors**
Microprocessor based design, design constraints, microprocessor selection, hardware implementation, software implementation, hardware debugging, software debugging. Introduction to 8086, 8088, 80186, 80188, 6800, 68000 and other latest chips of Intel/Motorala microprocessors. 8086 Internal architecture, introduction to programmable parallel ports and hand-shake, input-output, interfacing the microprocessor to keyboards, alphanumeric displays and high power devices. The 8086 Maximum code, DMA data transfer interfacing and refreshing dynamic RAM, processors with integrated peripherals, the 80186, the 8087 math coprocessor. Multiple bus microcomputer system.

2.4 **Signal Systems and Control**
Introduction with examples of various kinds of continuous and discrete time signals and their mathematical representation. Signal energy and power. Even and odd signals. Periodic, exponential and sinusoidal signals. Unit impulse and unit step functions for both discrete and continuous time signals. Examples and mathematical representation of continuous and discrete time systems. Difference equation. Basic vector matrix form of state equation. Basic system properties. Discrete time Linear Time Invariant (LTI) systems with convolution sum. Continuous time LTI system with convolution integral. Fourier series and transform application to analysis of signals and systems.

Introduction to control with examples of feedback control systems from several fields.
Block diagram, transfer function and signal flow graph. Mathematical modelling of physical systems. Time domain and frequency domain analysis of control systems. Stability criteria, root locus techniques.

2.5 Practical I: Electromagnetics
2.6 Practical II: Electronic Materials and Semiconductor Devices
2.7 Practical III: Circuit Design and Simulation
2.8 Practical IV: Electrical Machines and Control Systems
3.1 Optical Electronics


3.2 Integrated Circuit Technology

Material purification. Epitaxial growth: LPE, VPE, MBE. Clean room specifications and requirements. Vacuum technology, sputtering, oxidation, growth mechanism and kinetics (thin and ultrathin oxides), oxidation techniques, redistribution of dopants at the interface and oxidation induced defects. Diffusion: Fick’s law, diffusion mechanism, measurement techniques, diffusion in SiO₂. Ion Implantation: systems and dose control, ion range, ion stopping, knock on ranges, metalization choices. Etching: dry etching, pattern transfer, plasma etching, sputter etching, control of etch rate and selectivity, control of edge profile. Process simulation and process integration. Lithography: optical, electron beam, ion beam, X-ray lithography, lift off, dip pen. Pattern generation. Fabrication of few devices like MMIC, laser diode etc.

3.3 Digital Signal Processing


3.4 Communication Systems

Frequency allocation and standards. Analog Transmission: AM, FM and PM (modulation, demodulation techniques and noise Analysis), AM and FM transmitters and receivers. Digital transmission: sampling and digital multiplexing techniques, PAM, PWM, PPM, PCM, DM, line codes, Information theory, ASK, FSK, PSK and QAM.

3.5 Practical I: Optical Electronics

3.6 Practical II: Science and Technology of Semiconductor Devices

3.7 Practical III: Digital Signal Processing

3.8 Practical IV: Communication Systems
4.1 Quantum Electronics


4.2 VLSI Circuit Design and Device Modeling

Passive elements design, design of silicon integrated circuits. Basic MOS inverter design, transfer characteristics, logic threshold, NAND & NOR logic, transit time and inverter time delay, depletion and enhancement modes, CMOS inverter, inverting and non-inverting type super buffers. Optimization of NMOS and CMOS inverters, noise margins MOS design rules. MOS layers, Stick diagrams, NMOS design layout diagrams, CMOS design, design rules and layout. Lambda bases design rules. Scaling of MOS Circuits. Functional Limitations to scaling, scaling of wires and interconnections. MOS memories and programmable logic arrays, non-volatile semiconductor memories with MOS technology. General considerations associated with VLSI design. Design of a four-bit shifter, design of an ALU subsystem. Physical model for Si VLSi, MOSFET modeling, short channel structures, scaled down MOS performance. Packaging of VLSI devices, packaging types. Packaging design consideration, VLSI assembly technology and fabrication technologies. Mechanism of yield loss in VLSI, modeling of yield loss mechanism, reliability requirements for VLSI. Failure mechanism in VLSI. Fault finding in VLSI chips.

4.3 Modern Communication Systems

Data transfer and computer networking: packet switching, ISDN, ATM, LAN, WAN, Internet and WAP. Digital Radio Communication Systems; Transmission media, sampling, multiplexing, digital modulation and multiple access techniques.

Satellite Communication Systems: principles of satellite communication, modulation, multiplexing and; multiple access techniques; satellite services like DBS, VSAT etc. Mobile communication: specifications, design approach and details. Optical Communication Systems: network topologies, Fiber Distributed Data Interface (FDDI) network, Synchronous Optical Network (SONET/SDH), Asynchronous Transfer Mode (ATM), Wavelength Division Multiplexing (WDM) and its network implementation.
4.4 **Microwave Electronics**
Introduction to microwaves and their publications; Klystron amplifiers: operation and analysis, power and efficiency, multi cavity klystron. Reflex klystrons: operation and analysis, electronic admittance, electronic tuning, power output and deficiency. Magnetrons: operation and analysis. Travelling Wave Tubes: operation, gain bandwidth, coupling and focusing methods, applications. Avalanche Diode, Gunn effect and Gunn diode oscillators. Solid state microwave amplifiers, oscillators and mixers. Microwave components: attenuator, phase shifter, slotted lines, frequency meter, directional couplers, E-plane Tee, Magic Tee and Ferrite devices basic measurements of frequency, SWR, impedance and power at microwave frequencies. Principles of microwave LOS communication. Introduction to RADAR.

4.5 **Seminar**
4.6 **Lectures from Industry**
4.7 **Project**
M. Sc (Electronics)

Course Outcomes

COs of the course “High-level Computer Language and Operating System”

CO1 The emphasis is to provide a rigorous theoretical background in high level computer language and operating system.

CO2 Helps students to get jobs in software industry, in telecom industry etc and to pursue higher studies in this field.

COs of the course “Engineering Mathematics”

CO1 The course provides a theoretical background in advanced engineering mathematics which provides a good background for other theoretical courses.
CO2 It is aimed at honing the analytical skills which are helpful to those which join industry or go for higher studies.

COs of the course “Network Analysis and Synthesis”

CO1 This is a rigorous course which focuses both on analysis and synthesis

CO2 Provides a good background to students who wish to join industry or those who want to go for higher studies as the course forms an important background for other electronics courses as well.

CO3 It is particularly useful for students who wish to join industry as analog or digital layout engineers

COs of the course “Advanced Analog and Digital Circuit Design”

CO1 The course focuses on theoretical skills in the area of analog and digital circuit design

CO2 It is in keeping with the current trends and is particularly useful for students who wish to join industry as analog or digital layout engineers

COs of the course “Practical I : High level Computer Languages and Operating Systems”

CO This course provides practical knowledge to supplement paper High level Computer Languages and Operating Systems

COs of the course “Practical II : Electronic Circuits”
CO This course provides practical knowledge to supplement paper 1.3 and 1.4 and provides rigorous training to students in circuit design and simulation of analog and digital circuits.

**COs of the course “Practical III : Microprocessors”**

CO1 The laboratory course provides a system level understanding of the 8086 microprocessor involved in the design of microprocessor based electronic equipment.

CO2 It involves in depth studies of software architecture, instruction set and assembly level programming with PC interfacing

**COs of the course “Practical IV : Computational Techniques”**

CO This supplements paper Engineering Mathematics

**COs of the course “Electromagnetics, Antenna and Propagation”**

CO1 This provides a good theoretical background for basic electromagnetics and transmission lines.

CO2 Is particularly useful for students planning to join photonics and microwave industry

**COs of the course “Semiconductor Devices and Materials”**

CO 1 The course provides an understanding of electronic materials, and devices used in the semiconductor industry.

CO2 Equips students with understanding of devices used in the semiconductor industry.

**COs of the course “Microprocessors”**

CO1 This course provides rigorous background in microprocessors and microcontrollers.

CO2 Enhances understanding of concepts useful in Embedded systems.

**COs of the course “Signal Systems and Control”**

CO1 This paper develop understanding of various kinds of signals

CO2 Explains how these are useful in describing the electronic power and energy.

**COs of the course “Practical I - Electromagnetics”**

CO This supplements paper Electromagnetics, Antenna and Propagation

**COs of the course “Practical II - Materials and Semiconductor Devices”**

CO This supplements paper Semiconductor Devices and Materials

**COs of the course “Practical III - Circuit Design and Simulation”**

CO This hones the practical knowledge in the areas of circuit design and simulation tools used for analog/digital applications
COs of the course “Practical IV : Electrical Machines and Control Systems”

CO This supplements paper Semiconductor Devices and Materials

COs of “Summer Training”

CO1 Students undergo 2 months training in industry and R&D organizations CO2 This provides the necessary exposure to the current trends in industry and R&D

COs of the course “Optical Electronics”

CO1 This paper covers various optical effects and the design, operation of optical devices

COs of the course “Integrated Circuit Technology”

CO1 This course provides necessary background in the IC technology

CO2 This course provides the required exposure which is useful to students looking forward to join the semiconductor or fabrication industry.

COs of the course “Digital Signal Processing”

CO1 Signal and System as well DSP is backbone of modern electronics.

CO2 In this course students are trained rigorously in transforming discrete time domain signal into frequency domain signal using Z-transform.

CO3 Students are exposed to various structures of both infinite impulse response as well as FIR (finite impulse response), Digital filters which are the ultimate base of this course.

CO4 Since we in an era where fast computation is mandatory the students are also exposed to digital Fourier transform, which is backbone of FFT algorithm.

COs of the course “Communication Systems”

CO1 This provides background for students who wish to join communication, telecom, space industry

COs of the course “Practical I : Optical Electronics”

CO1 This supplements paper Optical Electronics

COs of the course “Practical II : Science and Technology of Semiconductor Devices”

CO1 This supplements paper Integrated Circuit Technology

COs of the course “Practical III : Digital Signal Processing”

CO This supplements paper Digital Signal Processing

COs of the course “Practical IV : Communication Systems”

CO This supplements paper Communication Systems
COs of the course “Quantum Electronics”

CO1 This course provides a rigorous study of quantum phenomena taking place in devices at nanoscale regime

CO2 This paper enhances understanding of devices operating in this regime.

COs of the course “VLSI Circuit Design and Device Modelling”

CO1 This course provides a rigorous theoretical background in the areas of VLSI device and circuit technology

CO2 Is extremely helpful to students who wish to join the semiconductor, VLSI industry.

COs of the course “Modern Communication Systems”

CO1 This provides background for students who wish to join communication, telecom, space industry

COs of the course “Microwave Electronics”

CO1 This provides background for students who wish to join microwave and space industry

COs of “Seminar”

CO1 Students are required to give presentations in current trends in industry and R&D.

COs of “Lectures from Industry”

CO Department invites experts from Industry and R&D organizations to give lectures and seminars to provide exposure to students to the current trends and an exam is held at the end of the semester

COs of “Project”

CO As a part of Curriculum, students perform projects with their respective mentors in order to enhance their understanding in the electronics and practical problems

Program Specific Outcomes (PSO)

PSO1 Computer knowledge: computer facilities in the department can provide computational techniques, understanding of numerical techniques and efficient practices in programming languages.

PSO2 Engineering knowledge: The knowledge of mathematics, electronic engineering fundamentals, and modelling of electronic devices specialization to the solution of complex electronic problems.
**PSO3 Analytical skills:** The courses like engineering mathematics enhance the analytical skills which serve a useful background for other courses as well and is useful to those who wish to pursue higher studies in the areas of modeling and theoretical studies etc.

**PSO4 Electronic Material Fabrication and Characterizations:** The material laboratory provides experimental set ups to fabricate/develop electronic materials and facilities for characterization.

**PSO5 Network Analysis & Synthesis and Analog/Digital Circuit Design** The course provides rigorous theoretical and practical background in the areas of network analysis and synthesis and analog/digital circuit design which is extremely useful to students who wish to join industry, R&D organizations or want to pursue higher studies.

**PSO6 VLSI Circuit Design & Device Modeling** The course provides rigorous theoretical and practical background in the area of semiconductor devices, circuits etc which is extremely important and helpful to students who wish to join semiconductor industry, R&D organizations or want to pursue higher studies. The course enhances the knowledge which is useful for application in these areas and also updates about the current technological trends in industry.
Master of Technology (MICROWAVE ELECTRONICS) - Two-year degree programme

The M.Tech programme in Microwave Electronics is a four semester, i.e., a two year programme. This programme was initially sponsored by the Department of Electronics, Government of India in 1976. The aim of the programme is to provide necessary theoretical background and practical experience in the fields of Microwave Devices and Circuits, Microwave Communication, Electromagnetics and Antennas, Microwave Integrated Circuit (MIC), and CAD for Microwaves.

Semester I

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<thead>
<tr>
<th>Course</th>
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<tr>
<td>1.1 Electromagnetic Theory and Transmission Lines</td>
<td>100</td>
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<td>1.2 Microwave and MM-Wave Planar Transmission Lines</td>
<td>100</td>
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<tr>
<td>1.3 Microwave Measurement Techniques and Industrial Microwaves</td>
<td>100</td>
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<tr>
<td>1.4 Microwave Devices</td>
<td>100</td>
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<tr>
<td>1.5 Microwave Measurements Laboratory</td>
<td>100</td>
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<td><strong>TOTAL</strong></td>
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Semester II

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<th>Course</th>
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<tr>
<td>2.1 Microwave Passive Components</td>
<td>100</td>
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<tr>
<td>2.2 Antenna Theory and Techniques</td>
<td>100</td>
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<tr>
<td>2.3 Communication Theory and Wave Propagation</td>
<td>100</td>
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<td>2.4 Computational Electromagnetics</td>
<td>100</td>
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<td>2.5 Computational Laboratory</td>
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<td><strong>TOTAL</strong></td>
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Semester III

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<tr>
<td>3.1 Microwave Active Circuits</td>
<td>100</td>
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<tr>
<td>3.2 Communication Systems</td>
<td>100</td>
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<tr>
<td>3.3 Microwave Integrated Circuits</td>
<td>200</td>
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<tr>
<td>(CAD, Fabrication and Measurements)</td>
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<td><strong>TOTAL</strong></td>
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Semester IV

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<td>4.1 Major Project (six months duration)</td>
<td>400</td>
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<td><strong>TOTAL (FOUR SEMESTERS)</strong></td>
<td><strong>1800</strong></td>
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Detailed Syllabus

1.1 Electromagnetic Theory and Transmission Lines

Maxwell’s equations, generalized current concept, energy and power, complete power, singularities of the field; Introduction to waves: Plane waves in dielectric and conducting media, reflection and refraction of waves; Basic theory of transmission lines; Computation of RLCG parameters of two wire and classical lines; Smith chart and its applications; Scalar, vector and Hertz potentials and their relations to fields, and gauges; Theorems and concepts: The source concept, duality, uniqueness, image theory, the equivalence principle, fields in half space, reciprocity, construction of solutions; Concept of modes, rectangular wave guide, rectangular cavity, partially filled wave guides, dielectric slab guide, surface guided waves, non-resonant dielectric(NRD) guide; Modal expansion of fields and its applications.

1.2 Microwave and MM-Wave Planar Transmission Lines

Review of development and application of the modern transmission line structures as interconnect and as a medium for realization of components for the MIC and MMIC; Quasi-static and frequency dependent closed form models of microstrip line for effective relative permittivity, characteristic impedance, and dielectric and conductor losses; Effect of conductor thickness, top shield and side-walls on the propagation characteristics of a microstrip line; Closed form models for the coplanar waveguide line for effective relative permittivity, characteristic impedance, and dielectric and conductor losses; Introduction to slot line; Characteristics of coupled microstrip and coupled coplanar waveguide; Circuit models of discontinuities in microstrip lines and the coplanar waveguides: Open ended, short, gap, step, bent, T--Junction. Microstrip line resonator; Microstrip patch resonators-rectangular, circular and ring; Quasistatic space domain and spectral domain analysis of microstrip line, coupled microstrip line and coplanar waveguide.

1.3 Microwave Measurement Techniques and Industrial Microwaves

Microwave Waveguide Components: Attenuators, phase shifters, matched loads, detectors and mounts, slotted-sections, E-plane tee, H-plane tee, hybrid tees, directional doublers, tuners, circulators and isolators; Signal generators: Fixed frequency, sweep frequency and synthesized frequency oscillators;

Noise sources and noise meters used in microwave measurements; Frequency meters and VSWR meters; Measurements of frequency, attenuation, VSWR and impedance; Cavity measurements: Q--factor, bandwidth; Dielectric and magnetic properties of materials: Cavity and Waveguide methods; Measurements of power: Calorimetric and Microwave bridges; Principles of time domain and frequency domain reflectometry, spectrum analyser and network analyser; Measurement of Scattering parameters of passive and active devices.

Microwave in process control instrumentation; Microwave waste disposal; Microwave in agriculture and medicine, hyperthermia etc.; Microwave heating; Microwave absorbers; EMC and EMI.

1.4 Microwave Devices

Microwave Transistor; Microwave Tunnel Diode; Varactor Diode; Schottky Diode; MESFET: Principle of operation, equivalent circuit, cut off frequency, power frequency limitations; MOS Structures; MOSFET: mechanism, modes of operation, transconductance,
max operating frequency and microwave applications; HEMT: Structure, operation, characteristics, transconductance and cut off frequency, microwave applications; Charge Coupled Devices (CCD); Transferred Electron Devices: Gunn Diode, LSA Diode, modes of operation, Microwave Generation and Amplification; Avalanche Effect Devices: Read diode, carrier current and external current; IMPATT diodes.

Klystron: Velocity modulation process, bunching process, output power and beam loading; Reflex Klystron: power output and efficiency; Traveling Wave Tubes; Magneto
1.5 Microwave Measurements Laboratory

2.1 Microwave Passive Components and Circuits

The transmission line section as a basic component; Application of Thevenin’s theorem to a transmission line; Transfer function of a transmission line section; T and PI representation of a transmission line section; Analysis of two ports and multiports network by using Z, Y and transmission matrix; S-parameter analysis of the microwave circuits; Conversion of Z, Y, transmission parameters and S-parameters; Matching networks: Reactive matching network using the lumped elements; Quarter wavelength transformer, multi section transformer matching section; Lumped planar components like capacitor, inductor and balun; Power divider, Branch line coupler, hybrid ring coupler, directional coupler; Analysis of these components using the S-parameters; Richard transformation and Kurda identities; Inverters, Design of microwave planar filters; Planar Non reciprocal devices: Circulator, delay lines and phase shifters; MEMS technology based microwave components like switches, filters, phase shifters and delay lines.

2.2 Antenna Theory and Techniques

Theory of electromagnetic radiation; Coordinate system and transformation of field quantities in different coordinate system; Basic concept and definition: Directive gain, side lobe, back lobe, polarization, co-polarization and cross polarization level, beam width, input impedance, bandwidth, efficiency; Various kind of antenna with applications; Formulation of radiation integrals and its application to analysis of wire, loop and helix type antenna; Theory of aperture antenna, including the Fourier transform method and application to slot, waveguide and horn antenna; Design consideration of parabolic reflector antenna; Microstrip antenna: Rectangular and circular patch; Feed to microstrip antenna: probe feed, microstrip line feed, aperture feed, electromagnetically fed microstrip patch; Circularly polarized microstrip antenna; Theory of linear array: Two element and multi element array, isotropic and non-isotropic array, Binomial and Chebyshev distribution; Planar array, phased array and adaptive antenna; Feed network of microstrip antenna array; Antenna for mobile communication: handset antenna and base station antenna.

2.3 Communication Theory and Wave Propagation

Probability and random variables; Baye’s theorem; Probability density and probability distribution functions, statistical expectation, moments and characteristic functions, various distributions, multiple random variables, transformation of PDFs; Random Processes: Basic concept, description of random process, correlation functions, Stationary and non-stationary process, ergodic process, power and energy; Multiple random process; Random processes in frequency domain; Fourier transform of random processes, power spectrum of stochastic processes; Gaussian and White processes; Markov process; Various modulation systems and multiple access systems like FDMA, TDMA and CDMA. Wave Propagation: Free space propagation model, ground reflection; Earth and its effect on propagation, terrain formation considerations and its effects on free transmission, Diffraction and scattering from obstacles; Atmospheric attenuation; Practical link budget; Troposphere propagation; Tropo system fading characteristics; Troposcatter loss calculations; Fading in LOS troposcatter; Statistical behavior of fading; Diversity techniques.
2.4 Computational Electromagnetics

Review of analytical methods; Green’s function; Finite difference methods: Various finite difference schemes, finite differencing of PDEs, accuracy and stability of FD solutions; applications to guided structures such as transmission lines, waveguides; Finite Difference Time Domain Method (FDTD): Yee’s FD algorithm, accuracy and stability, lattice truncation conditions, initial fields, programming aspects, absorbing boundary conditions for FDTD; Method of Moments: Introduction, Integral equations, Green’s functions, applications to quasi-static problems, radiation problems, mutual impedance between linear elements, mutual coupling in arrays, rectangular arrays, grating lobe considerations; Applications of FDTD and Method of Moments to wave guide, fin line, planar lines and planar antennas.

2.5 Computational Laboratory

3.1 Microwave Active Circuits

Introduction to RF and Microwave active circuits and its application to MMIC; Description of a complete system; Signal flow diagram; Equivalent circuit and models of microwave diode and transistor. S-parameter description of active devices; Classification of RF amplifiers for low noise, medium power and high power application; Biasing, stability and Noise consideration; Matching considerations for maximum power and minimum reflection; Design of microwave amplifier circuits: Narrow band amplifiers; broad band amplifiers, broadband matching; Classification and Design of microwave oscillators: characteristics and performance evaluation; Phase locked loop circuit; Basic mixer concept: Frequency domain characteristics, Single ended mixer design, Single and double balanced mixer. Design consideration and evaluation of a complete receiver and transmitter system.

3.2 Communication Systems

Introduction to Wireless Communication Systems; Global system for mobile(GSM): Cellular concept, System design, Transmission system; Receiving system; Frequency reuse; Channel interference and system capacity; Outdoor and indoor propagation models, small scale and multipath fading; practical link budget; Digital modulation with reference to wireless communication; Spread spectrum modulation; Modulation performances in fading and multipath channel; Multiple access techniques as applied to wireless communication; Pocket Radio system; Wireless networking: 1G, 2G, 3G wireless networks, traffic routing; wireless data service.

Introduction to Satellite Systems; Orbiting satellites, satellite frequency bands, communication satellite systems, satellite modulation and multiple access formats; Satellite systems in India; Satellite receiving systems, G/T ratio; Satellite uplink and downlink analyses in C, Ku and Ka bands; Spot beam, multiple beam, frequency reuse; Satellite transponder; Satellite front end.
Introduction to Optical Communication Systems; Optical fibers, sources and detectors; Analog and Digital systems; Modulation and multiplexing; Power budget analysis; Synchronous optical networks (SONET/SDH); Fiber distributed data interface (FDDI).

3.3 Microwave Integrated Circuits
CAD of Microwave Integrated Circuits, fabrication and measurements.

4.1 Major Project (six months duration).

M. Tech (Microwave Electronics)

Course Outcomes

COs for the course "Electromagnetic Theory and Transmission Lines"
CO1 Provides a good understanding of Electromagnetic Theory basics
CO2 allows detailed study of Transmission Line, with the use of EM Theory, Maxwell equations and Smith chart
CO3 helps to develop understanding in the propagation of EM waves

COs for the course "Microwave and MM-Wave Planar Transmission Lines"
CO1 gives introduction of Microwave planar transmission lines
CO2 describes the properties and behaviour of various transmission lines like microstrip line, strip line, coupled line and coplanar waveguide

COs for the course "Microwave Measurement Techniques and Industrial Microwaves"
CO1 describes the requirements of microwave parameters and their measurements using Microwave Instruments.
CO2 describes the exposure to Basic microwave measurement set up and helps to understand the propagation of microwaves and the role of each microwave components.
CO3 describes design and measurements for Electromagnetic Interference free environment.

COs for the course "Microwave Devices"
CO1 describes the basic construction details, working and operation of solid state devices, vacuum tubes based devices
CO2 helps to understand the non-linear applications in microwaves like amplifier, oscillator, mixer etc. using these devices
**COs for the course "Microwave Measurements Laboratory"**

CO1 supplements the learning developed by paper 1.1 - 1.4.

**COs for the course "Microwave Passive Components and Circuits"**

CO1 provides exposure to design microwave passive component, Transmission Line section basic component, microwave Filters, Non Reciprocal devices etc.
CO2 describes basics of MEMS Technology based Microwave Components.

**COs for the course "Antenna Theory and Techniques"**

CO1 describes working principle, parameters of antenna and antenna array
CO2 helps to understand the design aspect and application of different antennas like patch, horn antenna, array etc.

**COs for the course "Communication Theory and Wave Propagation"**

CO1 describes various Wave Propagation mechanism (Reflection, Diffraction, Scattering)
CO2 gives Concept of Random variables in Communication System Design

**COs for the course "Computational Electromagnetics"**

CO describes 2D and 3D Electromagnetic Solution Methods
CO2 provides the solution methods (FDTD, MOM, Green’s Functions) used in various E-M solver software to solve different microwave structures.

**COs for the course "Computational Laboratory."**

CO1 provides an opportunity to design and analyze the various microwave passive components and use computational electromagnetic methods.

**COs for the course "Microwave Active Circuits."**

CO1 helps to learn the design techniques of active microwave circuits like amplifiers, oscillators, mixers.
CO2 develops understanding in deciding the features of such active components for certain applications

**COs for the course "Communication Systems."**

CO1 gives understanding in design requirement and types of various communication modes like Wireless Communications, Satellite Communications, Optical Fibre Communication.
**COs for the course "Microwave Integrated Circuits (CAD, Fabrication and Measurements)"**

CO1 provides design, fabricate and test the microwave components by the students.  
CO2 helps to develop various interpersonal skills like independent thinking, analytical, practical approach etc.

**COs for the course "Major Project (six months duration)"**

CO1 engages the students with external organization for their on-site training and exposure.  
CO2 exposes students to most advanced facility available in the Microwave field.

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**Program Specific Outcomes (PSO)**

**PSO1 Computer knowledge:** computer facilities in the department can provide computational techniques, understanding of numerical techniques and efficient practices in programming languages.

**PSO2 Engineering knowledge:** The knowledge of mathematics, electronic engineering fundamentals, and modelling of electronic devices specialization to the solution of complex electronic problems.

**PSO3 Analytical skills:** The courses like engineering mathematics enhance the analytical skills which serve a useful background for other courses as well and is useful to those who wish to pursue higher studies in the areas of modeling and theoretical studies etc.

**PO4 Microwave Integrated Circuits:** Design and simulation of passive components using 3D simulation tools
Ph.D in Electronics

**Key Research Areas:** Micro Electronics Device Simulation, Photovoltaic, Opto Electronics, Semiconductor Materials and Devices Characterization, Photonics Simulation Design and Applications, Microwave Electronics.

**Ph.D. COURSE WORK**

**PREAMBLE**

The Department of Electronic Science is offering the following **five courses** (each of 4 credits) as Ph.D. Course work for students admitted to the Ph.D. Programme in Department of Electronic Science:

1. Research Methodology (ES-1)
2. Fabrication, Characterization Techniques for Electronic Materials (ES-2)
3. Mathematical and Computational Techniques (ES-3)
4. Modeling and Simulation of Semiconductor Devices (ES-4)
5. Microwave Antennas (ES-5)

These are advanced level courses specifically designed for the doctoral programme and cater to the requirements of all research areas offered by the Department. As per UGC Regulations 2016 and Ordinance VI of University of Delhi the credits assigned to Ph.D. Course work shall be a minimum of 08 credits and maximum of 16 credits. Course No. ES-I on Research Methodology which covers quantitative methods, computer applications, research ethics and review of published research in the relevant field is compulsory for all students. In addition the research scholars have to take at least one additional course from the Ph.D. courses offered by the Department or by other Departments of the Faculty of Interdisciplinary Science. However, on recommendation of the Research Advisory Committee the research scholar may be required to take additional courses.

The Course work is a prerequisite for PhD. Preparation.
ES – 1 Research Methodology
(Credits: 04)

Unit-I
Introduction: Introduction and definition of Research. Classification of research- Experimental and Theoretical, Fundamental and Applied, Quantitative and Qualitative. Motivation for research. Research Methodology - definition of Problem, aim and objectives, historical background of investigation, issues and concerns related to scientific investigation.


Various tools for Literature review: Idea about print and digital resources, Common E-search engines for literature, Scopus, HEP-spires, Google Scholar, Scirus, SciFinder. Search for publications related to institutes/society (APS, AIP, IOP, IEEE, OSA, IEE etc.) or publishers (Elsevier-Science direct, etc.).

Unit-II
Measurements and Analysis: Designing an experiment, generation and recording of data. Numbers, units, abbreviations and nomenclature used in scientific writing. Accuracy and precision. Significant figures.

Error and uncertainty analysis: Types of errors: Gross error, systematic error, random error. Statistical analysis of data (Arithmetic mean, deviation from mean, average deviation, standard deviation, chi-square). Correlation and regression. Least square curve fitting, spline fitting, Gaussian distribution.

Graphical Representation: Introduction to software for drawing and analysis of graphical representation of data like MS-Excel, ORIGIN, etc. Incorporation of error bars in graphs.

Unit-III
Scientific Writing: Art of scientific writing and presentation. Writing references. Research and scientific writing ethics- Importance, basic principle, issues of authorship (in a group or collaborative work), plagiarism, conflict of interest, research misconduct.

Intellectual Property: Introduction to intellectual property, patent, copyright, definition of invention and discovery, idea about patentability, importance of academia-industry interaction, marketing of research outcome.

Presentation: Preparation of Power point scientific presentation and Poster presentation.

Unit-IV
MATLAB or other related software: Problem solving based on MATLAB or any other related Software.

MATLAB problems to be decided by the faculty involved in the course.

Examination mode:
- Internal Assessment : 20 Marks
- Final Examination : 50 Marks
- Presentations : 30 Marks

Suggested Reading:
ES-2 Fabrication, Characterization Techniques for Electronic Materials
(Credits: 04)

Unit-I
Lecture-15
Basic Parameters: Miller Index, Energy Bands, Resistivity, Carrier Doping Density, Mobility, Carrier Lifetime, Contact Resistance, Series Resistance. Defects: Surface Defects, Deep Defects, Oxides and Interface traps.
Elementary ideas of Material Synthesis: Physical Vapor deposition, Chemical Vapor Deposition, Spin Coating etc. With idea on Vacuum units/pumps (Rotary, Diffusion, Turbo molecular, Getter, Cryogenic and Ion pumps), Vacuum measurement system. Doping methods.
Heterojunctions and Nanostructures: Heterojunctions in devices, Quantum well and Superlattice structures, Quantum dots, Nano-tubes and Nano-rods etc.

Unit-II
Lecture-15
Spectral Characterization Techniques: UV-Vis Spectroscopy, Fourier Transform Spectroscopy (FTIR), Photoluminescence (PL), Raman Spectroscopy.
Electrical Characterization: Four-Point Probe, I-V characteristics of devices, C-V plots, Hall Effect.

Unit-III
Lecture-15
XRD data analysis: Crystal orientation, texture factor, grain size and stress evaluation.
Evaluation of Optical Spectroscopy Data: Direct and In-direct band-gap, Urbach tail, refractive index and Defects analysis.
Electron Microscopy and XPS data inference: Grain size, morphology, orientation, Laue pattern, chemical composition and stoichiometry.

Unit-IV
Lecture-15
Probability Density Distributions: Binomial, Poisson, Gaussian, Uniform, Landau and Multi-Dimensional Distribution
Errors: Gaussian errors, Combination of errors and Systematic Errors
Estimators: Likelihood Function, Maximum Likelihood and Least Squares
Method of Least Squares: Linear Regression, Fitting Binned Data, chi square distribution and Non-linear Least squares

Examination mode: Internal Assessment: 50 Marks
Final Examination: 50 Marks

Suggested Reading:
ES – 3 Mathematical and Computational Techniques

(Credits: 04)

Unit-I
Lecture-15

Solutions of Equations \( f(x) = 0 \) by Iteration: Fixed point iteration, Bisection method, Newton-Raphson method, Secant method.

Interpolation: Lagrange interpolation, Newton’s divided differences interpolation.

Numerical Integration and Differentiation: Trapezoidal rule, Simpson’s rule, Gauss integration formulas, Numerical differentiation formulas.

Unit-II
Lecture-15
Ordinary Differential Equations: Introduction to first order, second order, homogeneous, non-homogeneous equations, system of equations.


Unit-III
Lecture-15

Matrix Eigenvalue Problems: Power Method, Jacobi’s method.

Unit-IV
Lecture-15
Partial Differential Equations: Classification of partial differential equations. Homogeneous and non-homogeneous boundary conditions. Solutions by separation of variables and series expansion methods


Examination mode:
Internal Assessment: 50 Marks
Final Examination : 50 Marks

Suggested Reading:
ES-4 Modeling and Simulation of Semiconductor Devices
Credits -04)

Lecture-60

Unit I
MOSFET Device Physics and Operation, MOS capacitor – Interface charges, threshold voltage, MOS capacitance, Basic MOSFET operation, Scaling and Short channel effects, Introduction to non-classical MOSFET architectures – Silicon on Nothing (SON) MOSFET, Gate Electrode Engineered MOSFET, Dielectric Pocket (DP) MOSFET, Recessed channel MOSFET, Gate All Around (GAA) MOSFET and Junctionless (JL) Transistor

Unit-II
MOSFET modeling – simple charge control model, Meyer model, capacitance models, small signal modeling, non-ideal effects, short channel effects, gate leakage and effective oxide thickness, Unified MOSFET CV model, MOSFET long channel approximation, drain current in linear region & saturation region, channel length modulation, dynamic elements – high frequency figure of merits, operation in subthreshold region, MOS device physics in short channel, effect of velocity saturation, threshold reduction, body effect, mobility degradation, transit time effect, SPICE Models.

Unit-III

Unit-IV (Lab session)
Introduction to TCAD tools, ATLAS device simulation software. Online Simulation resources–NANOHub. Simulation of n-channel MOSFET; Silicon on Insulator.

Suggested Reading:
Unit-II - http://homepages.rpi.edu/~sawyes/Models_review.pdf
Research papers to be provided for each device architectures other than course material

Fundamentals of III-V Devices, HBTs, MESFETs, and HFETs/HEMTs, William Liu, Wiley-Inter Science Publication.

Unit-IV - https://nanohub.org/resources/tools
https://www.silvaco.com/content/kbase/device.pdf
https://www.silvaco.com/examples/windows/GuidetoTCAD_PC.pdf

Examination mode: Internal Assessment: 50 Marks
Final Examination : 50 Marks
ES-5 Microwave Antennas

(Credits-04)

Unit-I
Electromagnetic Waves: Maxwell equations, Electromagnetic spectrum, RF and Microwave region and band designations, RF and Microwaves applications.
Basic Transmission Line parameters: Lumped and distributed circuits, Transmission lines - propagation characteristics, reflection coefficient, VSWR, power, return loss, insertion loss, scattering parameters and Smith chart applications to RF and Microwave characterization.
Introduction of various transmission lines like two conductor line, coaxial line, microstrip line, coplanar waveguide (CPW), slotline, rectangular and circular waveguides.

Unit-II
Antenna fundamentals and parameters:
Radiation Pattern, Radiation Power Density, Radiation Intensity, Beamwidth, Directivity, Antenna Efficiency, Gain, Beam Efficiency, Bandwidth, Polarization, Input Impedance, Antenna Radiation Efficiency, Maximum Directivity and Maximum Effective Area, and Antenna Polarization, Antenna Apertures, and near-field and far-field concepts.
Types of Antennas, Radiation Mechanism and Current Distribution on a Thin Wire Antenna.
Antenna Measurement: Basics of Antenna measurement techniques, Antenna ranges, Radiation pattern, Gain, directivity and return loss measurement, Anechoic chamber.

Unit-III
Radiation Integrals, Auxiliary Potential Functions and dipole:
Introduction to Broadband Dipoles: Biconical Antenna, Bow-Tie, and Folded Dipole.

Unit-IV
Antennas Arrays: Two Element Array, N-Element Linear Array- Uniform amplitude and Spacing, Broadside Array, Ordinary End-Fire Array, Phased Array.
Introduction to modern antennas: Inverted F Antenna, MIMO antenna, UWB antenna, Circularly polarized antenna, Reconfigurable antennas and Mobile antennas.

Examination mode:
Internal Assessment: 50 Marks
Final Examination: 50 Marks

Suggested Books
1. Pozar D M, Microwave Engineering, Wiley
2. Collin R E, Foundations for Microwave Engineering, McGraw Hill International