Semester VIII

MAJOR COURSE- MJ 20	Atomic, Molecular and Laser Physics	(Theory Credit -03) (Total Marks=60+15)

Course Objective:

1. To understand the principles behind atomic spectra, including space quantization, the relationship between angular momentum and magnetic moment, and the fine structure of spectral lines.
2. To study the coupling schemes like LS and JJ coupling and their applications in atomic spectra.
3. To analyze the quantum theory of the Zeeman and Paschen-Back effects, as well as the Stark effect and hyperfine structure in atomic transitions.
4. To learn about molecular rotation and vibration, and how isotopic substitution affects rotational spectra, with a focus on diatomic molecules and the Born-Oppenheimer approximation.
5. To understand the principles and techniques involved in molecular spectroscopy, including infrared and Raman spectroscopy of diatomic molecules.
6. To explore the fundamental concepts of resonance spectroscopy such as NMR, NQR, ESR, and Mossbauer spectroscopy, and their experimental studies and applications.
7. To introduce the theory of lasers, including the principles of spontaneous and stimulated emission, population inversion, and laser systems, with applications in holography and data storage.

Course Outcomes:

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

1. Understand and explain the principles behind atomic spectra, including space quantization, fine structure of spectral lines, and Zeeman and Stark effects, and apply these concepts to interpret atomic spectra.
2. Describe LS and JJ coupling schemes, and apply the quantum theory of the Zeeman effect to analyze atomic spectra.
3. Analyze molecular rotational and vibrational spectra, and understand the effects of isotopic substitution and the Born-Oppenheimer approximation in molecular systems.
4. Apply the principles of infrared and Raman spectroscopy to analyze the vibrational and rotational spectra of diatomic molecules, and understand the Frank-Condon principle in electronic transitions.
5. Understand the fundamentals of resonance spectroscopy (NMR, NQR, ESR, Mossbauer spectroscopy) and apply them to various experimental and practical scenarios in molecular and atomic physics.
6. Describe the basic principles of laser operation, including population inversion and the Einstein A and B coefficients , and understand the different types of lasers (Ruby, He-Ne, CO2, semiconductor lasers) and their applications.
7. Understand the principles and applications of holography, including its practical use in data storage and other technological applications.

Course Contents:

Atomic Spectra (12 HRS): Space quantization, Relation between angular momentum and magnetic moment, Bohr magnetron. Fine structure of spectral lines, Term symbols of alkali and alkaline earth atoms.LS and JJ coupling. Quantum theory of Zeeman effect (normal and anamolous), Paschen-Back effect, Stark effect (linear and non-linear). Hyperfine structure of spectral lines, X-ray spectra characteristics and absorption.

The Rotation of the Molecule (10 HRS): Rotational spectra-Rigid diatomic molecule, The intensities of spectral lines, Effect of isotopic substitution, the non-rigid rotator, Simple harmonic oscillator, The an-harmonic oscillator, Diatomic vibrating rotator, Born Oppenheimer approximation, Techniques and instrumentation applications.

Molecular Spectra (08 HRS): Infrared and Raman spectra of diatomic molecules using an-harmonic oscillator, non-rigid rotator and vibrating rotator as models. Electronic states and electronic transitions in diatomic molecules, Frank Condon principle.

Resonance Spectroscopy (08 HRS): Nature of spinning particle, Interaction between spin and a magnetic field, Larmor Precession, Theory of NMR, Chemical shift-relaxation Mechanism, experimental study of NMR, Theory and experimental, study of NQR, Theory of ESR, Hyperfine structure and fine structure of ESR, Experimental studies and applications, Mossbauer spectroscopy, Principle- Isomer shift, Quadrupole effect, effect of magnetic field, Instrumentation applications.

Laser and Holography (07 HRS): Spontaneous and stimulated emission, Einstein A and B coefficients, Basic Principles of Laser, Population Inversion-Two level and Three level Laser system, optical pumping-rate equation, modes of resonator and coherence length, The Ruby laser, The He-Ne laser, The CO2 Laser, Semi-conductor Laser, Principle of Holography, Theory Practical applications including data storage.

Reference Books:

1. Kuhn, “Atomic Spectctra”.
2. Arun Kumar, ``Introduction to Solid State Physics’’, PHI Learning Pvt. Ltd.
3. Ghatak&Loknathan, “Quantum Mechanics”.
4. Herzberg, Spectra of diatomic molecules
5. Elements of Spectroscopy: Gupta, Kumar and Sharma, PragatiPrakashan.
6. Fundamentals of Molecular Spectroscopy: Colin and Elaine, TMH.
7. Laser and Non-linear Optics: B.B.Laud, New Age Publications.

MAJOR COURSE- MJ 20	Atomic, Molecular and Laser Physics	(Practical Credit -01) (Total Marks=25)

1. Study of the Zeeman Effect – Observation of spectral line splitting in a magnetic field.
2. Frank-Hertz Experiment – Verification of quantized energy levels in mercury atoms.
3. Raman Spectroscopy – Study of vibrational modes of molecules using Raman scattering.
4. Measurement of Hyperfine Splitting Using Electron Spin Resonance (ESR) – Determining hyperfine interaction in a given sample.
5. Study of the Stark Effect – Observation of spectral line shifts in an external electric field.
6. Simulation of Hydrogen Atom Spectra – Computational plotting of energy levels and transitions.
7. Variational Method for the Helium Atom – Estimation of energy levels using numerical techniques.
8. Molecular Vibration and Rotation Spectra Simulation – Calculating and visualizing IR and Raman spectra.
9. Numerical Solutions of Schrödinger Equation for a Diatomic Molecule – Using finite difference or matrix methods.

ADVANCE MAJOR COURSE- AMJ 1	Nano Science and Technology	(Theory Credit -03) (Total Marks=60+15)

Course Objective:

1. To introduce the fundamental principles of nanoscience and technology, focusing on nanoscale systems and their unique properties.
2. To provide students with an understanding of the various methods of synthesizing nanostructure materials using top-down and bottom-up approaches.
3. To familiarize students with state-of-the-art techniques used for the characterization of nanomaterials, including X-ray diffraction, electron microscopy, and atomic force microscopy.
4. To explore the optical properties and quantum behavior of nanostructures, including excitons, quasi-particles, and the impact of quantum confinement.
5. To discuss the electron transport phenomena in nanostructures, focusing on carrier transport mechanisms and the effects of defects and impurities.
6. To analyze the applications of nanomaterials in diverse fields such as photonic devices, single-electron devices, and nano-electromechanical systems (NEMS)

Course Outcomes:

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

1. **Understand and describe** the various types of nanostructures (1D, 2D, 3D), their formation, and the impact of quantum confinement at the nanoscale.
2. **Identify and differentiate** between the top-down and bottom-up approaches for the synthesis of nanomaterials and explain the techniques such as photolithography, PVD, CVD, and sol-gel synthesis.
3. **Employ characterization tools** such as X-ray diffraction, SEM, TEM, AFM, and STM to analyze nanostructures and interpret experimental data.
4. **Explain the optical properties** of nanostructures, including the role of Coulomb interactions, excitons, and radiative processes, and their applications in photonic devices.
5. **Analyze electron transport mechanisms** in nanomaterials, including Coulomb blockade, tunneling, and thermionic emission, as well as the effects of defects and impurities on conductivity.
6. **Assess and discuss** the various applications of nanomaterials in advanced devices such as quantum dot lasers, solar cells, MEMS, NEMS, and magnetic data storage.

Course Contents:

NANOSCALE SYSTEMS (08 HRS): Length scales in physics, Nanostructures: 1D, 2D and 3D nanostructures (nano dots, thin films, nano wires, nano rods), Band structure and density of states of materials at nanoscale, Size Effects in nano systems, Quantum confinement:, quantum confinement of carriers in 3D, 2D, 1D nanostructures and its consequences.

SYNTHESIS OF NANOSTRUCTURE MATERIALS (08 HRS): Top down and Bottom up approach, Photolithography. Ball milling. Gas phase condensation. Vacuum deposition. Physical vapor deposition (PVD): Thermal evaporation, E-beam evaporation, Pulsed Laser deposition. Chemical vapor deposition (CVD). Sol-Gel. Electro deposition. Spray pyrolysis. Hydrothermal synthesis. Preparation through colloidal methods. MBE growth of quantum dots.

CHARACTERIZATION (06 HRS): X-Ray Diffraction. Optical Microscopy. Scanning Electron Microscopy. Transmission Electron Microscopy. Atomic Force Microscopy.

Scanning Tunneling Microscopy.

OPTICAL PROPERTIES (08 HRS): Coulomb interaction in nanostructures. Concept of dielectric constant for nanostructures and charging of nanostructure. Quasi-particles and excitons. Excitons in direct and indirect band gap semiconductor nanocrystals. Quantitative treatment of quasi-particles and excitons, charging effects. Radiative processes: General formalization-absorption, emission and luminescence. Optical properties of heterostrctures and nanostructures.

ELECTRON TRANSPORT (05 HRS): Carrier transport in nanostrcutures. Coulomb blockade effect, thermionic emission, tunneling and hoping conductivity. Defects and impurities: Deep level and surface defects.

APPLICATIONS (10 HRS): Applications of nanoparticles, quantum dots, nanowires and thin films for photonic devices (LED, solar cells). Single electron devices (no derivation). CNT based transistors. Nanomaterial Devices: Quantum dots heterostructure lasers, optical switching and optical data storage. Magnetic quantum well; magnetic dots - magnetic data storage. Micro Electromechanical Systems (MEMS), Nano Electromechanical Systems (NEMS).

Reference books:

1. C.P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology (Wiley India Pvt. Ltd.).
2. S.K. Kulkarni, Nanotechnology: Principles & Practices (Capital Publishing Company)
3. K.K. Chattopadhyay and A. N. Banerjee, Introduction to Nanoscience and Technology (PHI Learning Private Limited).
4. Richard Booker, Earl Boysen, Nanotechnology (John Wiley and Sons).
5. M. Hosokawa, K. Nogi, M. Naita, T. Yokoyama, Nanoparticle Technology Handbook (Elsevier, 2007).
6. Bharat Bhushan, Springer Handbook of Nanotechnology (Springer-Verlag, Berlin, 2004)

ADVANCE MAJOR COURSE- AMJ 1	Nano Science and Technology	(Practical Credit -01) (Total Marks = 25)

1. Synthesis of at least two different sizes of Nickel Oxide/ Copper Oxide/ Zinc Oxide Nano Particles Using Sol-Gel Method.
2. Polymer synthesis by suspension method / emulsion method
3. B-H loop of nanomaterials.
4. Magnetoresistance of thin films and nanocomposite, I-V characteristics and transient response.
5. Particle size determination by X-ray diffraction (XRD) and XRD analysis of the given XRD spectra.
6. Determination of the particle size of the given materials using He-Ne LASER.
7. Selective area electron diffraction: Software based structural analysis based on TEM based experimental data from published literature..
8. Surface area and pore volume measurements of nanoparticles (a standard sample and a new sample (if available)).
9. Spectroscopic characterization of metallic, semiconducting and insulating nanoparticles.

ADVANCE MAJOR COURSE- AMJ 2	Fiber Optics and its applications	(Theory Credit -03) (Total Marks=60+15)

Course Objective:

1. To introduce the fundamental principles of fiber optics, focusing on light propagation, different fiber types, and key transmission characteristics such as attenuation, scattering, and polarization.
2. To provide a thorough understanding of the various modes of light propagation in optical fibers, with emphasis on mode coupling, intermodal and intramodal dispersion, and their impact on data rates and bandwidth.
3. To explore the principles of optical sources (LEDs, lasers) and detectors (photodiodes, phototransistors), their operation, and the technologies behind optical feedback, laser oscillation, and detector performance.
4. To examine the design and operation of optical communication systems, including multiplexing techniques (OTDM, WDM), system performance metrics (BER, eye pattern), and fiber optic measurement tools (OTDR, optical power meters).
5. To discuss advanced fiber optic applications, including their use in long-haul communication, sensor networks, LANs, and medical or military domains, and analyze the role of fiber optics in modern technologies.
6. To familiarize students with optical amplifiers and network systems, including the operation of semiconductor optical amplifiers (SOAs), EDFAs, and the integration of SONET/SDH networks for high-speed communication.

Course Outcomes:

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

1. **Understand the principles of light propagation** in optical fibers, including meridional and skew ray paths, and analyze key factors affecting fiber transmission such as attenuation, scattering, and polarization.
2. **Identify and analyze** the different modes of light propagation in optical fibers, and evaluate the effects of intermodal and intramodal dispersion, mode coupling, and their influence on data rate and bandwidth.
3. **Describe the operation of optical sources** such as LEDs and lasers, with an understanding of optical feedback, laser oscillation, and the characteristics of quantum-well lasers, including their applications in fiber optic communication systems.
4. **Understand the working principles of optical detectors** (e.g., PIN, avalanche photodiodes), and evaluate their performance in terms of detectability, noise, and bandwidth, along with the design of related detector circuitry.
5. **Design and analyze optical communication systems** utilizing OTDM and WDM techniques, and calculate key performance metrics such as bandwidth, rise time, Bit Error Rate (BER), and interpret eye patterns for system optimization.
6. **Apply fiber optic measurement techniques** and field testing equipment, such as optical power meters and OTDR, to evaluate and troubleshoot fiber optic systems.
7. **Understand the diverse applications of fiber optics** in areas such as long-haul communication, fiber optic sensors, local area networks (LANs), medical and military applications, and other modern technological fields.
8. **Analyze and explain the operation of optical amplifiers** (e.g., EDFAs, semiconductor optical amplifiers) and their use in modern high-speed optical networks, including SONET/SDH, and understand the key technologies that enable high-speed data transmission over optical fiber.

Course Contents:

Light propagation (12 HRS): Ray theory transmission-meridional rays, another alternative path –skew rays, Types, characteristics and data rate in optical fibers, Modes in fibers, Modes coupling, Transmission characteristics in optical fibers- attenuation, absorption, scattering, polarization, dispersion intermodal and intra modal , Bandwidth and data rate, Fiber materials- Fiber fabrication and preparation, splicing, connectors, couplers and switches, connection losses, Mechanical properties of fibers, Installation and handling considerations in fiber types.

Optical absorption and emission (08 HRS): Spontaneous and stimulated emission Optical sources -LED AND LASER-Optical feedback and laser oscillation Quantum –well lasers , their structures and characteristics, Drive Electronics LED drivers - digital and analog, Laser diode drivers.

Optical detectors (07 HRS): Principle of operation –photo detectors, P-N, PIN, Avalanche photodiode, Phototransistor, Delectability, Noise and bandwidth, Detector circuitry and receivers-preamplifier, Automatic gain control.

Fiber Optic communication system (10 HRS): Optical Time Division Multiplexing, Wave length Division Multiplexing- Demultiplexing, Bandwidth and rise time budgets, Noise and Bit Error Rate and eye Pattern, Optical Fiber measurement and field testing- Equipment used in field testing- Optical Power meter, Cut back method, Optical Time Domain Reflectometer (OTDR),Application of Fiber optics- Long –Haul communication, Fiber optic sensors, Local Area Networks, Fiber Distributed Data Interface Telephone communication, Medical and military applications, ISDN.

Optical amplifiers and networks (08 HRS): optical amplifiers, basic applications and types, semiconductor optical amplifiers, EDFA. Optical Networks: Introduction, SONET / SDH, Optical Interfaces, SONET/SDH rings, High – speed light – waveguides.

Reference Books

1. Optical Fiber Communication- Principle and practice John M. Senior, Prentice Hall of India.
2. Fiber optic communication and other applications Henry Zanger & Cynthia Zanger, Maxwell Macmillan International Edition.
3. An Introduction to Optical Fibers Allen H. Cherin, Mcgrow Hill International Edition.
4. Optical Fiber Communication Gerd Keiser, Mcgrow Hill International Edition.

ADVANCE MAJOR COURSE- AMJ 2	Fiber Optics and its applications	(Practical Credit -01) (Total Marks = 25)

1. Experiments on single mode optical fibers.
2. Experiments on multi mode optical fibers.
3. Study on spectral analysis of optical fiber using optical spectrum analyzer.
4. Measurement on end separation, axial misalignment and angular misalignment loss in optical fiber.
5. To Measure the Insertion Losses & Isolation Rate in Fiber Optic Isolator
6. Study of refractive index profile and numerical aperture of graded-index optical fibers using MATLAB.
7. To Measure the Attenuation in Fiber Optic Attenuator.
8. To study different types of fault detection in fiber using OTDR operating at two different wavelengths.
9. To observe and characterize Fiber Bragg gratings as an optical filter.
10. To Observe and characterize Fiber Bragg Grating (FBG) as an optical sensor.

ADVANCE MAJOR COURSE- AMJ 3	Microprocessor and Microcontroller	(Theory Credit -03) (Total Marks=60+15)

Course Objective:

1. To provide students with a comprehensive understanding of the architecture, operations, and components of microprocessors (8085, 8086) and microcontrollers (8051), including memory, I/O devices, and peripheral interfacing.
2. To equip students with the skills to write assembly programs for microprocessors and microcontrollers, covering data transfer, arithmetic operations, logic operations, and advanced techniques such as interrupts, timers, and serial communication.
3. To teach students how to interface peripheral devices (such as LCD, keyboard, ADC, DAC, sensors, and motors) with microprocessors and microcontrollers, including memory and I/O interfacing.
4. To enable students to understand and program the 8086 microprocessor, with an emphasis on addressing modes, memory segmentation, and peripheral interfacing.
5. To provide practical exposure to the 8051 microcontroller, its internal architecture, programming techniques, and interfacing with external devices.
6. To develop the ability to design and implement embedded systems using microprocessors and microcontrollers, with a focus on applications like data acquisition, control systems, and communication systems.

Course Outcomes:

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

1. **Understand Microprocessor Architectures:** Demonstrate a thorough understanding of the architecture, memory organization, and operations of the 8085, 8086, and 8051 microprocessor/microcontroller families.
2. **Write Efficient Assembly Programs:** Write and debug assembly language programs for performing basic arithmetic, logic, and data transfer operations, as well as implementing complex tasks such as time delays, counter operations, and interrupts.
3. **Interface Peripheral Devices:** Interface a variety of peripheral devices (LCD, keyboard, ADC, DAC, sensors, etc.) with microprocessors and microcontrollers, and program them effectively to perform desired operations.
4. **Design Systems with 16-bit Microprocessors (8086):** Design and program systems using the 8086 microprocessor, including memory addressing, segmentation, and peripheral device interfacing.
5. **Program the 8051 Microcontroller:** Write and execute assembly language programs on the 8051 microcontroller, including tasks like I/O operations, serial communication, and interrupt handling.
6. **Apply Microcontroller Knowledge in Embedded Systems:** Develop and implement practical embedded systems by using microprocessor and microcontroller systems, focusing on control, automation, and communication applications.
7. **Implement Practical Applications:** Interface and program external devices such as stepper motors, sensors, and displays, demonstrating the ability to work on real-world applications in embedded systems.

Course Contents:

Introduction to Microprocessor (08 HRS): Microprocessor architecture and its operations, Memory, Input & output devices, The 8085 MPU- architecture, Pins and signals, Timing Diagrams, Logic devices for interfacing, Memory interfacing, Interfacing output displays, Interfacing input devices, Memory mapped I/O.

Basic Programming concepts (09 HRS): Flow chart symbols, Data Transfer operations, Arithmetic operations, Logic Operations, Branch operation, Writing assembly language programs, Programming techniques: looping, counting and indexing. Additional data transfer and 16 bit arithmetic instruction, Logic operation: rotate, compare, counter and time delays, 8085 Interrupts.

16-bit Microprocessors (8086) (08 HRS): Architecture, Pin Description, Physical address, segmentation, memory organization, Addressing modes. Peripheral Devices: 8237 DMA Controller, 8255 programmable peripheral interface, 8253/8254 programmable timer/counter, 8259 programmable interrupt controller, 8251 USART and RS232C.

8051 Microcontroller Basics (10 HRS): Inside the Computer, Microcontrollers and Embedded Processors, Block Diagram of 8051, PSW and Flag Bits, 8051 Register Banks and Stack, Internal Memory Organization of 8051, IO Port Usage in 8051, Types of Special Function Registers and their uses in 8051, Pins Of 8051. Memory Address Decoding, 8031/51 Interfacing With External ROM And RAM. 8051 Addressing Modes.

Assembly programming and instruction of 8051 (10 HRS): Introduction to 8051 assembly programming, Assembling and running an 8051 program, Data types and Assembler directives, Arithmetic, logic instructions and programs, Jump, loop and call instructions, IO port programming. Programming 8051 Timers. Serial Port Programming, Interrupts Programming, Interfacing: LCD & Keyboard Interfacing, ADC, DAC & Sensor Interfacing, External Memory Interface, Stepper Motor and Waveform generation.

Reference Books:

1. Ramesh Gaonkar, "Microprocessor Architecture, Programming, and Applications with the 8085", 6th Edition, Penram International Publication (India) Pvt. Ltd.,2013
2. D. V. Hall : Microprocessors Interfacing, TMH 3rd Edition,
3. Mazidi Ali Muhammad, Mazidi Gillispie Janice, and McKinlay Rolin D., "The 8051 Microcontroller and Embedded Systems using Assembly and C", Pearson, 2nd Edition,2006
4. Kenneth L. Short, "Microprocessors and programmed Logic", 2nd Ed, Pearson Education Inc.,2003
5. Barry B. Brey, "The Intel Microprocessors, 8086/8088, 80186/80188, 80286, 80386, 80486, Pentium, PentiumPro Processor, PentiumII, PentiumIII, Pentium IV, Architecture, Programming & Interfacing", Eighth Edition, Pearson Prentice Hall, 2009.
6. Shah Satish, "8051 Microcontrollers MCS 51 Family and its variants", Oxford,2010

ADVANCE MAJOR COURSE- AMJ 3	Microprocessor and Microcontroller	(Practical Credit -01) (Total Marks = 25)

1. Write a program using 8085 Microprocessor for Decimal, Hexadecimal addition and subtraction of two Numbers. (Through Virtual Lab Link)
2. Write a program using 8085 Microprocessor for addition and subtraction of two BCD numbers. (Through Virtual Lab Link)
3. To perform multiplication and division of two 8 bit numbers using 8085. (Through Virtual Lab Link)
4. To find the largest and smallest number in an array of data using 8085 instruction set.
5. To write a program using 8086 to arrange an array of data in ascending and descending order. (Through Virtual Lab Link)
6. To convert given Hexadecimal number into its equivalent ASCII number and vice versa using 8086 instruction set.
7. To convert given Hexadecimal number into its equivalent BCD number and vice versa using 8086 instruction set.
8. To interface 8253 programmable interval timer and verify the operation of 8253 in six different modes.
9. To write a program to initiate 8251 and to check the transmission and reception of character.
10. Serial communication between two 8085 through RS-232 C port.
11. Write a program of Flashing LED connected to port 1 of the 8051 Micro Controller
12. Write a program to generate 10 kHz square wave using 8051.
13. Write a program to show the use of INT0 and INT1 of 8051.
14. Write a program for temperature & to display on intelligent LCD display.
15. Interfacing of Stepper motor to 8051. 16. Interfacing of ADC to 8051.

***Virtual Lab Link:**
http://vlabs.iitb.ac.in/vlabsdev/labs_local/microprocessor/labs/explist.php