1 -Year M. Sc in Physics

SEMESTER – I

MAJOR RESEARCH COURSEWORK ELECTIVE

Course Name : Advanced Quantum Mechanics -II

Course Code: MSCPHSMCE901

Course Name	Course Type	Course Code	L-T-P	Course Credit	CA Marks		ESE Marks		Total
					Practical	Theory	Practical	Theory	
Advanced Quantum Mechanics -II	**MAJOR (Elective)**	**MSCPHSMCE301**	**4-1-0**	**5**	**0**	**30**	**0**	**70**	**100**

Course Objectives

In this course the students will be introduced to advanced concepts in Quantum Mechanics. They will learn about WKB approximation methods and its application to various bound states and tunneling problems. Then they will learn about identical particles – bosons and fermions and their corresponding wavefunctions. They will learn about quantum mechanical formulation of scattering theory, calculation of scattering amplitudes and cross sections under Born approximation and partial wave analysis. A major topic will be relativistic formulation of quantum mechanics, in which Klein-Gordon and Dirac equations will be introduced. They will learn about free particle solutions and non- relativistic limits, Feynman-Stükelberg interpretation of negative energy states. Finally, they will learn about semiclassical theory of radiation- stimulated vs spontaneous emission.

Course Outcomes

Upon successful completion of the course the students will learn about

- Application of WKB methods to bound states and tunneling problems. Its application to α-decay and field emission devices.
- Identical particles, Pauli's exclusion principle, wave functions for singlet and triplet states.
- Elementary theory of scattering, Born approximation, partial wave analysis to obtain scattering amplitudes and cross sections.
- A detailed formulation of relativistic quantum mechanics. Klein-Gordon and Dirac equations and their solutions for free particles. Non-relativistic limits of Klein-Gordon and Dirac equations. Feynman-Stükelberg interpretation of negative energy solutions. Helicity, chirality.
- Semiclassical theory of radiation, stimulated and spontaneous emission.

SYLLABUS

WKB approximation : WKB method ; Connection formulae ; quantization rule ; tunneling through a barrier ; α-decay and field emission devices.

[8 L]

Identical Particles : Distinguishable vs indistinguishable ; Symmetric and anti-symmetric wave function ; Pauli's exclusion principle ; spin statistics connection ; Permutation symmetry ; spin singlet and triplet state.

[10 L]

Elementary theory of scattering : Lippman- Schwinger equation ; scattering amplitude and cross section ; Optical theorem ; Born approximation ; phase shift and partial wave analysis ; S-matrix ; Scattering length ; zero energy scattering and bound state. **[14 L]**

Relativistic quantum mechanics : Klein-Gordon equation – negative probability ; free particle solution ; non-relativistic limit ; Klein-Gordon equation in electromagnetic field. Dirac equation : covariant form ; free particle solution ; Dirac matrices – physical interpretation ; spin operator ; Dirac equation in external electromagnetic field ; non relativistic limit – Zeeman coupling ; spin-orbit coupling ; negative energy states and Feynman-Stükelberg interpretation ; helicity, chirality and charge conjugation ; Majorana and Weyl representation.

[16 L]

Semiclassical theory of radiation : Charged particle in external field ; field as perturbation ; radiation field ; transition between atomic states ; absorption vs stimulated emission ; dipole transition ; Einestein's A, B coefficients ; spontaneous emission.

[12 L]

References

1. J. J. Sakurai, *Modern Quantum Mechanics,* Cambridge University Press (2020)
2. Eugene Merzbacher, *Quantum Mechanics,* Wiley, 3rd Edition
3. H. A. Bethe and R. Jackiw, *Intermediate Quantum Mechanics*, Sarat Book House (2005)
4. J. J. Sakurai, *Advanced Quantum Mechanics,* Pearson (2002)
5. J. D. Bjorken and S. Drell, *Relativistic Quantum Mechanics,* McGraw Hill (1998)

MAJOR RESEARCH COURSEWORK ELECTIVE

Course Name :Advanced Atomic and Molecular Spectroscopy

Course Code: MSCPHSMCE902

Course Name	Course Type	Course Code	L-T-P	Course Credit	CA Marks		ESE Marks		Total
					Practical	Theory	Practical	Theory	
Advanced Atomic and Molecular Physics	**MAJOR (Elective)**	**MSCPHSMCE302**	**4-1-0**	**5**	**0**	**30**	**0**	**70**	**100**

Course Objectives

This course is designed for the fundamental studies on atomic and molecular spectrum. It includes rigorous discussion on interactions of atomic system with externally applied field.

Course Outcome:

- Basic concept of atomic and molecular spectrum is indispensible for advance studies in pure and applied physical science.
- This course can motivate students to pursue research careers especially in material sciences and associated fields.

SYLLABUS

One Electron Atom

Introduction: Quantum States; Atomic orbital; Parity of the wave function; Angular and radial distribution functions.

(6L)

Interaction of radiation with matter

Time dependent perturbation: Sinusoidal or constant perturbation; Application of the general equations; Sinusoidal perturbation which couples two discrete states — the resonance phenomenon. Interaction of an atom with electromagnetic wave: The interaction Hamiltonian — Selection rules; Non-resonant excitation — Comparison with the elastically bound electron model; Resonant excitation — Induced absorption and emission; Einstein A & B coefficients.

(14 L)

Fine and Hyperfine structure

Fine structure of spectral lines; Selection rules; Lamb shift. Effect of external magnetic field - Strong, moderate and weak field.

(12 L)

Rotation and Vibration of Molecules

Solution of nuclear equation; Molecular rotation: Non-rigid rotator, Centrifugal distortion, Symmetric top molecules, Molecular vibrations: Harmonic oscillator and the anharmonic oscillator approximation, Morse potential.

(8 L)

Molecular Electronic States

Concept of molecular potential, Separation of electronic and nuclear wave functions, Born-Oppenheimer approximation, Electronic states of diatomic molecules, Electronic angular momenta, Approximation methods for the calculation of electronic Wave function, The LCAO approach, States for hydrogen molecular ion, Coulomb, Exchange and Overlap integral, Symmetries of electronic wave functions

(12 L)

Spectra of Diatomic Molecules

Transition matrix elements, Vibration-rotation spectra: Pure vibrational transitions, Pure rotational transitions, Vibration-rotation transitions, Electronic transitions: Structure, Franck-Condon principle, Rotational structure of electronic transitions, Fortrat diagram, Dissociation energy of molecules.

(8 L)

Suggested Books:

1. B. H. Bransden and C. J. Joachain, Physics of Atoms and Molecules Pearson (2003)

2. S. Svanberg , Atomic and Molecular Spectroscopy, Springer-Verlag (2004)

3. Max Born, Atomic Physics, Dover Publications Inc.(1989)

4. H.E. White, Introduction to Atomic Spectra, McGraw-Hill Inc.,US (1934)

MAJOR RESEARCH COURSEWORK ELECTIVE

Course Name: Optoelectronics and Laser Science

Course Code: MSCPHSMCE903

Course Name	Course Type	Course Code	L-T-P	Course Credit	CA Marks		ESE Marks		Total
					Practical	Theory	Practical	Theory	
Optoelectronics and Laser Science	MAJOR (Elective)	MSCPHSMCE303	3-0-4	5	30	15	20	35	100

Course Objectives

Optoelectronics, which combines the properties of light with capabilities of micro-electronics, is an essential enabling technology for the information age. In fact, it is said that optoelectronics may be the most significant new technology since semiconductors. The main objective of the course is to formally introduce students to optoelectronics, thereby helping them to guide their studies and career development.

Course Outcome:

- Students will be familiar with different types of advanced light sources and their modulating mechanism widely used in present day information processing.
- Students will also learn about Nonlinear optics (NLO), which is the branch of optics that describes the behaviour of light in nonlinear media.
- This course can motivate students to pursue research careers especially in the field of applied optics and photonics.

SYLLABUS

1. Optoelectronics: ***Source***: Light Emitting Diode (LED), quantum efficiencies (internal and external), responsivities, Characteristics and applications of various kinds of LEDs, dome type LED , homojunction LED, heterojunction LED.

Photodetector : Basic principle of photo detection, Quantum efficiencies (internal and external), responsivities, Characteristics and applications of various kinds of photodetectors, P-I-N photodiode, Avalanche Photodiode.

Optical Fiber: Dispersion and attenuation mechanisms in optical fibers, Different types of coupling procedure of LED with optical fiber. **[12 L]**

2. **Basic principles of Laser and Resonators:**

Einstein's coefficient and their relations, conditions of population inversion. Absorption and amplifications of light in a medium, population inversion and threshold condition for a laser, gain coefficient, Laser Rate Equation, 2- level laser, 3-level and 4-level lasers.

Stability of resonators-'g' parameter, various types of resonators, design aspect of resonator for various types of lasers, unstable resonator and their application. Solid State Laser (Nd:YAG laser and Nd:Glass laser), Gas Laser (CO_2) , and Semiconductor laser. **[12 L]**

3. **Q-switching and Mode Locking:** Different Q-switching techniques: mechanical Q-switching, electrooptic Q-switching, acousto-optic Q-switching, dye Q-switching, Principle of generation of ultrafast pulses (mode locking), basic concepts for measurement of fast processes. [**6 L]**

4. Electro-optic effect: Pockel and Kerr effect, electro-optic phase retardation, electro-optic amplitude modulation, phase-modulation of light. [**5 L]**

5. **Nonlinear interactions of light and matter**

Nonlinear polarization of the medium, Wave equation for nonlinear optical media, Optical susceptibility tensor, Generation of second harmonic, Sum frequency and difference frequency generation, Basic idea of phase matching, quasi-phase matching method, various methods of phase matching (angle, temperature, birefringence etc. Optical rectification, Parametric amplifier and oscillation, Generation of third harmonic, Intensity dependent refractive index, Self-focusing. **[10 L]**

Recommended Books:

1. O. Svelto, Principles of Lasers, *Springer* (2010)
2. A Ghatak and K. Thyagarajan, *Optical Electronics, Cambridge University Press (2003)*
3. A Yariv, Quantum Electronics, Wiley (1989)
4. Y. R. Shen, The principles of Nonlinear Optics, Wiley, New York, (1984)
5. R. W. Boyd, Nonlinear Optics, Academic Press Inc. (2008)

<u>Optoelectronics Laboratory</u>

1. Perform experiment on **Faraday effect** using red/green laser light for a particular wavelength. Hence determine the **Verdet constant**.

2. Perform experiment on **Pockels effect** using red laser/green laser light for a particular wavelength. Hence determine the **Birefringence** as a function of applied voltage. Plot Birefringence versus applied voltage graph.

3. Perform the experiment on the given **Optocoupler**. Hence plot the following curves:

i. Coupling characteristics having LED voltage as independent variable.

ii. Current-voltage characteristics of LED.

iii. Current-voltage characteristics of phototransistor.

4. Perform the experiment on **Phototransistor** in presence of a laser source and hence plot current-voltage characteristics curve. Using a polarizer in between the source and phototransistor record phototransistor currents for different polarizer angles and plot current versus angle curve.

MAJOR RESEARCH COURSEWORK ELECTIVE

Course Name: Spintronics

Course Code: MSCPHSMCE904

Course Name	Course Type	Course Code	L-T-P	Course Credit	CA Marks		ESE Marks		Total
					Practical	Theory	Practical	Theory	
Spintronics	MAJOR (Elective)	MSCPHSMCE304	3-0-4	5	30	15	20	35	100

Course Objectives

Spintronics, a portmanteau meaning "spin transport electronics", where both charge and spin degrees of freedom of electrons are employed simultaneously to produce device with new functionality, is a fascinating and promising field of research. It has potential to revolutionize the field of electronics. Two physical basis of Spintronics, i.e., GMR and TMR have already been commercialized in read heads of hard disk drive. It is extremely important and absolutely necessary to have a clear concept of spintronics so that students get exposure of such modern day cutting edge technology. This course could also play crucial role in the development of understanding of the new research initiative like Opto-Spintronics.

Course outcome:

- Students will develop indepth knowledge in magnetism and spintronics.
- Students will understand spin dependent transport processes in spintronics devices.
- Students will get introduction to Spin transfer Torque and Magnetic Domain Wall motion Memory systems.
- This course will help students in cutting edge research technology like hard disk drive read head and Magnetic Random Access Memories.

SYLLABUS:

An Overview of Spintronics: Introduction to Spintronics, Comparative merit-demerit of Spintronics and Electronics, Evolution of Spintronics, Quantum Mechanics of Spin; Spin-Dependent Band Gap in Ferromagnetic Materials, Basic Principle of Working of all Spintronic devices, Different Branches of Spintronics.

(6 L)

Basic elements of Spintronics: Spin Polarization; Spin Injection; Spin Current, Spin Accumulation, Spin Relaxation; Elliott-Yafet Mechanism, D'yakonov-Perel' Mechanism**,** Spin-orbit interaction; Spin Filter Effect; Spin Valve.

(10 L)

Giant Magnetoresistance (GMR)

Definition of Magnetoresistance; Magnetoresistance of ferromagnetic Transition Metals; Introduction on Giant Magnetoresistance (GMR): Spin-dependent Scattering, Spin-flip Scattering, Physical Origin of GMR: Qualitative Explanation, Quantitative Explanation of GMR, Magnetoresistance Theory, Resistor Network Theory.

(10 L)

Tunneling Magnetoresistance (TMR)

Introduction on Tunneling Magnetoresistance: Magnetic Junctions; Magnetic properties of the electrodes; Theory of Tunneling Magnetoresistance; Measurement of spin relaxation length and time in the spacer layer.

(6 L)

Spin Transfer Torque (STT)

Introduction on Spin Transfer Torque: Landau–Lifshitz–Gilbert Equation, Spin Transfer Torque in Layer Structures; Spin-Transfer-Torque driven Magnetization Dynamics; Experimental Results; Possible applications of spin transfer torques.

(5 L)

Magnetic Domain Wall (DW) Motion

Introduction on Magnetic Domain Wall Motion: Magnetic Domain Wall Motion in Spintronics; Ratchet Effect in magnetic DW motion; Domain wall motion velocity measurements; Current-driven DW motion.

(5 L)

Spintronics Applications

Read Head in Magnetic Data Storage; Spin-tunnel junctions.

(3 L)

Books Recommended:

1. Stephen Blundell, *Magnetism in Condensed Matter,* Oxford Master Series in Condensed Matter Physics (2001)

2. B.D. Cullity and C.D. Graham, *Introduction to Magnetic Materials*, Wiley (2009)

3. D. Jiles, *Introduction to Magnetism and Magnetic Materials*, CRC Press, (1998)

4. S. Bandyopadhyay, M. Cahay, Introduction to Spintronics, CRC Press (2008)

5. D. J. Sellmyer, R. Skomski, Advanced Magnetic Nanostructures, Springer (2006)

6. D.D. Awschalom, R.A. Buhrman, J.M. Daughton, S.V. Molnar, and M.L. Roukes, Spin Electronics, Kluwer Academic Publishers (2004)

7. M. Johnson, Magnetoelectronics, Academic Press (2004)

8. S. Maekawa, Concepts in Spin Electronics, Oxford University Press (2006)

9. Y.B. Xu and S.M.Thompson, Spintronic Materials and Technology, Taylor & Francis, (2006)

Spintronics Laboratory

1. Perform experiment on **Magnetoresistance (MR)** versus Magnetic field (H) of $La_{0.7}Sr_{0.3}MnO_3$ nanoparticles in the magnetic field range of (As per example 0 to ± 1000 Oe). Plot MR versus H and Magnetoconductivity versus H graphs. Hence, calculate surface spin susceptibility of the sample.

2. Perform experiment on **Magnetoimpedance (MI)** versus Magnetic field (H) of $La_{0.7}Sr_{0.3}MnO_3$ nanoparticles in the magnetic field range of (As per example 0 to ± 2000 Oe). Plot MI versus H graph. Hence draw conclusion on the variation of MI (%) with magnetic field at a constant frequency.

3. To find the **Lande g factor** of an electron using **Electron Spin Resonance (ESR).**

MAJOR RESEARCH COURSEWORK ELECTIVE

Quantum Field Theory

Course Code: MSCPHSMCE905

Course Name	Course Type	Course Code	L-T-P	Course Credit	CA Marks		ESE Marks		Total
					Practical	Theory	Practical	Theory	
Quantum Field Theory	**MAJOR (Elective)**	**MSCPHSMCE305**	**4-1-0**	**5**	**0**	**30**	**0**	**70**	**100**

Course Objectives:

This course aims to provide a rigorous introduction to the formulation and applications of quantum field theory as the fundamental framework for describing relativistic particles and their interactions. Students will develop an understanding of field quantization, symmetry principles, gauge theories, and perturbative methods for calculating scattering processes. The course also introduces computational techniques using C++ for solving problems in relativistic kinematics, particle decays, and gamma matrix algebra.

Course Outcomes:

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

- Apply the principles of relativistic quantum mechanics, classical field theory, and Lagrangian formalism to derive field equations and conservation laws.
- Quantize free scalar, Dirac, and electromagnetic fields, and analyze their properties using creation and annihilation operators, propagators, and discrete symmetries.
- Evaluate particle interactions using the interaction picture, S-matrix formalism, Feynman diagrams, and perturbation theory for fundamental scattering and decay processes.
- Explain the role of gauge invariance in quantum electrodynamics and weak interactions, and analyze elementary electroweak processes using Feynman rules.
- Develop and implement C++ programs to perform numerical simulations of relativistic kinematics, particle decays, and gamma matrix calculations relevant to quantum field theory.

SYLLABUS:

Basic Concepts

Relativistic wave equations (Klein-Gordon and Dirac equations); Lorentz transformations and relativistic kinematics; Mandelstam variables; crossing symmetry; phase space; symmetries and conservation laws.

(12L)

Classical Field Theory and Lagrangian Formalism

Fields and field equations; action principle; Lagrangian and Hamiltonian densities; continuous symmetries and Noether's theorem; global and local gauge symmetries.

(12L)

Canonical Quantization of Free Fields

Need for field quantization; field quanta; real and complex scalar fields; Dirac field; electromagnetic field; creation and annihilation operators; propagators; bilinear covariants; projection operators; charge conjugation, parity and time reversal; normal ordering; time-ordered products; Wick's theorem.

(16L)

Interacting Quantum Fields

Interaction picture; S-matrix expansion; Dyson series; Feynman diagrams and Feynman rules; tree-level scattering amplitudes; electron-muon scattering, Møller scattering, Bhabha scattering, Compton scattering, pair annihilation and pair production.

(10L)

Gauge Theories and Applications

Quantum electrodynamics (QED); gauge invariance; Ward identities (elementary level); charged and neutral current weak interactions; Feynman diagrams for weak processes (β-decay, muon decay, neutrino-electron scattering); electron-positron annihilation.

(10L)

Numerical computation using C++:

1) Relativistic Kinematics of Particle Collisions
2) Monte Carlo Simulation of Particle Decays
3) Gamma Matrices Algebra.

Books/References:

1. Introduction to elementary particles by D. Griffiths
2. Quarks and Leptons by F. Halzen and A.D. Martin
3. Introduction to Particle Physics by M.P. Khanna
4. Gauge Theory of Elementary Particle Physics by Ta-Pei Cheng and Ling-Fong-Li
5. Lectures on QFT by Ashok Das
6. Quantum Field Theory by Franz Mandl and Graham Shaw
7. A first book of Quantum Field Theory by Amitabh Pal and Palash N. Pal

MAJOR RESEARCH COURSEWORK ELECTIVE

Course Name: Microwave and Quantum Devices

Code: MSCPHSMCE906

Course Name	Course Type	Course Code	L-T-P	Course Credit	CA Marks		ESE Marks		Total
					Practical	Theory	Practical	Theory	
Microwave and Quantum Devices	MAJOR (Elective)	MSCPHSMCE306	3-0-4	5	30	15	20	35	100

Objective:

To give details working of different microwave sources and waveguides. Both tube and solid state devices are made familiar in this course. To teach students about measurement techniques of microwave power, frequency, and impedance. Introduction to few quantum devices are also included.

Course outcome:

After taking this course, students will be familiar with different techniques of microwave sources and waveguides. They also get knowledge about measuring power, frequency, and impedance in microwave region. They will learn about the working of quantum devices also.

SYLLABUS

Microwave frequencies, characteristic features of microwaves, Applications of Microwaves.
Waveguides: Rectangular waveguide and circular waveguides; Maxwell's equations, TE and TM modes; Resonators: Rectangular waveguide and circular waveguide resonators.

(8 L)

Limitations of conventional tubes for microwave generation; Reentrant cavities, Two cavity Klystron, velocity modulation, bunching process, Efficiency of Klystron; Reflex Klystron, Velocity modulation, condition of maximum energy transfer; Slow wave structure, Helix Travelling wave tube, Amplification process, convection current in the electron beam; Magnetron, Cylindrical Magnetron, Hull cut off magnetic field, Hull cut off voltage, Cyclotron angular frequency, π mode of oscillation, equivalent circuit, power output and efficiency. **(13 L)**

Solid state microwave devices; Gunn Diode: Differential negative resistance, RWH theory, Domain formation, Different modes of operation, LSA diodes; Physical description and principle of operations of Read diodes, IMPATT diodes, TRAPATT diodes; Microwave Tunnel diodes: Principle of operation and microwave characteristics; Heterojunction Bipolar Transistor: Physical structure and operation; High Electron Mobility Transistor (HEMT): Physical Structure and operation.

(12 L)

Microwave Measurements: Detection of microwaves; Diode detectors, Travelling wave detector;

Measurement of VSWR, Impedance, Frequency measurement (electronic technique); Microwave power measurements: Bolometer, Bridge type meters.

(7 L)

Quantum effect devices: Resonant tunnelling Diode: Band diagram, working principle, I-V characteristics; Unipolar Resonant tunnelling transistor: working principle. Simple applications.

(5 L)

Reference Books:

1. Microwave devices and Circuits, Samuel Y. Liao
2. Microwaves, K C Gupta
3. Microwaves, Sisodia and Gupta
4. Microwave devices and applications, Dinesh C Dube
5. Semiconductor Devices, S. M. Sze

MAJOR RESEARCH COURSEWORK ELECTIVE

Course Name: Communication Electronics

Code: MSCPHSMCE907

Course Name	Course Type	Course Code	L-T-P	Course Credit	CA Marks		ESE Marks		Total
					Practical	Theory	Practical	Theory	
Communication Electronics	**MAJOR (Elective)**	**MSCPHSMCE307**	**3-0-4**	**5**	**30**	**15**	**20**	**35**	**100**

Objective:

- To teach students about communication systems, different techniques of modulation and demodulation both digital and analog.
- To give an introduction about information theory.
- To make familiar with working of Radar,
- To give an introduction about satellite and mobile communication and working of TV and TV broadcasting system.

Course Outcome:

After taking the course the students will be familiar with different types of communication systems used in electronics. They will also be familiar with information theory and coding techniques. They will get knowledge about principle of Radar, satellite and mobile communication system. The students will also acquire knowledge about Television.

SYLLABUS

1. **Introduction to communication systems:** Elements of a communication system, Concept of Bandwidth, Sources of information(Speech, Music, Picture, Computer data etc), signal and its classifications(One, two, three and four dimensional signals, Analog and digital signals), Communication channel(elementary idea), guided and free space, Coaxial Cable and Optical fibers, Comparison(advantage and disadvantages), Characteristics of optical fibers, Satelite channel. Fundamental limitations of communication systems(Noise, Bandwidth, Equipment) (**5 lectures**).

2. Modulation and Demodulation Techniques: Multiplexing, TDM, and FDM, Comparison of AM, FM and PM signals in terms of modulation demodulation complexity, power, bandwidth, VSB modulation and its importance.

   Sampling Theorem, Nyquist rate and Nyquist interval, Effect of under sampling(Aliasing), Ideal, naturaland flat top sampling, Aperture effect.

   Pulse code modulation: Quantization, Pulse code modulation(PCM), PCM transmitter and Reciever, Quantizer (uniform, non-uniform) Transmission bandwidth in PCM system, Quantization noise/error in PCM, signal to quantization noise ratio. (**10 Lectures**).
3. Digital Modulation Techniques: ASK, FSK, PSK, DEPSK, QPSK, QASK, MSK, Principle, modulators and demodulators. (**5 lectures**)
4. Noise in Communication System: Types of noise, Sources of Noise, Noise Figure, Performance of AM, FM receivers in the face of noise;(**4 lectures**)
5. Elements of Information Theory: Concept of amount of Information, average information, Entropy, information rate, Effect of coding and coding efficiency; Shanon Fano Algorithm; Shanon's theorem; Channel capacity, Continuous channel, Capacity of a Gaussian channel, Shannon Hartley Theorem, BW-S/N tradeoff, orthogonal signals and Shannon limit.(**5 lectures**)
6. TV Systems: Color TV standards – NTSC, PAL, SECAM; Transmission format of intensity and color signal; Transmitter and receiver systems of TV broadcasting. (**3 Lectures**)
7. RADAR System: Basic Radar system, Radar Range, pulsed radar system – modulators, duplexer indicators, CW radar; MTI radar, Doppler effect, MTI principle, FM radar(**4 lectures**)
8. Satellite Communication: Orbits, basic components of satellite communication system,Constructional features, Station keeping; Path loss calculation; Link calculation; Multipleaccess techniques; Transponders; Effects of nonlinearity of transponders. (**4 lectures)**
9. Advanced Communication Systems: Mobile Communication – Concepts of cell and frequency reuse description of cellular communication standards; Computer communication– Types of networks; Circuit message and packet switched networks; Medium access techniques – ALOHA, Slotted ALOHA, CSMA/CD; Basics of protocol. (**5lectures**)

Books Recommended

1. A B Carlson – Communication Systems.
2. D Roddy and J Coolen – Electronic Communications.
3. Franz and Jain – Optical Communication Systems.
4. A M Dhake – Television and Video Engineering
5. Gulati – Monochrome and Color TV
6. Kennedy and Davis – Electronic Communication Systems

COURSE NAME: RESEARCH METHODOLOGY WITH AI
COURSE CODE: MSCPHSRMAI901

Course Name	Course Type	Course Code	L-T-P	Course Credit	CA Marks		ESE Marks		Total
					Practical	Theory	Practical	Theory	
Research Methodology with AI	**Research Methodology**	MSCPHSRMAI901	**3-0-4**	**5**	**30**	**15**	**20**	**35**	**100**

Course Objective: *The objective is to impart into the students the theoretical idea and understanding on research and its methodology particularly of reviewing and surveying literature, writing research report with required format; testing of hypotheses and sampling for analysis and quantification research outputs, etc in maintaining research ethics.*

Course outcome:

After completion of the course the students will be able to

- *describe important ideas, concepts, and research styles, such as mixed, qualitative, and quantitative approaches*
- *create testable hypotheses or research questions, outline research challenges, and identify research gaps*
- *create a well-thought-out research plan that includes sampling strategies, data gathering procedures, and the right instruments for data processing*
- *use citing tools correctly, synthesize current research findings, and critically evaluate academic literature*
- *plan and carry out investigations involving human or animal subjects by applying ethical principles and comprehending the ethical issues in research*
- *evaluate data and interpret the findings in a meaningful way by using fundamental statistical or thematic analysis and approaches*
- *compose well-organized research papers or reports and explain their findings either orally or visually as well as to gain the capacity to evaluate research papers and procedures critically for validity, reliability, and limitations*
- *maintain research ethics although his/her research activities*

Course Content

Introduction to Research Methodology

Meaning of Research, Objectives of Research, Motivations in Research, Types of Research, Criteria of good Research, What is Research Problem? Basic and Applied research

5 L

Review of Literature and Literature survey

Meaning and Purpose of the Literature Review & Literature Survey, Identification of the related Literature.

5 L

The Research Report

General format of the Research report, style and formatting of writing, typing of the research report. 5 L

Testing of Hypotheses and Sampling design

Definition, Concepts Concerning Testing of Hypotheses, Formulation of hypotheses and related difficulties; Needs of sampling, Random sampling.

5 L

Quantification of research output

Impact Factor, *h*-index, *i10*-index and *i20*-index, *G*-index 5 L

Research ethics

Research Ethics: Ethical principles and responsible conduct of research (RCR); integrity, transparency, and accountability in scientific research. Scientific misconduct (fabrication, falsification, plagiarism), publication ethics, authorship, peer review, and data management. Ethical issues in human and animal research, informed consent, confidentiality, IEC/IRB approval, conflict of interest, and researcher responsibilities

8 L

Artificial Intelligence in Research Methodology

Evolution of AI in scientific research workflows. AI as a cognitive assistant in research. Human–AI collaboration in scholarly inquiry. AI-assisted academic search and semantic retrieval. AI tools for identifying research gaps and novelty. Citation network analysis using AI tools. AI support in exploratory data analysis and visualization. Machine learning concepts relevant to research methodology. AI-assisted pattern recognition and hypothesis refinement. Role of AI in qualitative data analysis including coding and theme extraction. Risks of hallucination and fabricated citations in generative AI. Limitations of AI in scientific argumentation. Distinction between editing support and authorship. Bias detection in datasets using AI tools. Ethical limits of AI-driven inference. Human validation of AI-generated analytical results.

12 L

Recommended books/ Journals:

- *C R Kothari, Research Methodology: Methods and Techniques, New Age International (P)Ltd. (2010), New Delhi Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K., 2002. An introduction toResearch Methodology, RBSA Publishers.*
- *Handbook of Communication and Social Interaction Skills by John O. Greene, Brant Raney Burleson.*
- *W.M.K.Trochim, 2005. Research Methods: the concise knowledge base, AtomicDog Publishing. 270p.*
- *Ranjit Kumar, Research Methodology: A Step-by-Step Guide for Beginners, SAGE Publications*
- *Inderpal Singh, Research Methodology and Statistical Methods, Kalyani Publishers, Ludhiana.*
- *G Kanji, 100 statistical tests, Sage Publications.*
- *R. A. Day (1992) How to write and publish a scientific paper. Cambridge University press. London.*
- Russell, S. and Norvig, P. *Artificial Intelligence : A Modern Approach*, 3rd Edition, Prentice Hall, 2010.
- Floridi, Luciano. *The Ethics of Artificial Intelligence: Principles, Challenges, and Opportunities*, Oxford University Press, 2023.