Anekant Education Society's

TULJARAM CHATURCHAND COLLEGE OF ARTS, SCIENCE AND COMMERCE, BARAMATI

(Autonomous Status)

(Affiliated to Savitribai Phule Pune University, Pune)

Faculty of Science

Department of Physics

Proposed Syllabus

For

M.Sc. in Physics

Semester-III

2019 PATTERN

From Academic Year 2019-2020

Anekant Education Society's

TULJARAM CHATURCHAND COLLEGE OF ARTS, SCIENCE AND COMMERCE, BARAMATI

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M. Sc. II

2019 Pattern

Semester-III Course Structure

Course Number	Course Code	Course Name	Credit
11	PHY5301	Statistical Physics	4
12	PHY5302	Solid State Physics	4
13	PHY5303	CB Group –I 1) Physics of thin films-I 2) Nano-technology-I 3) Biomedical Instrumentation-I	4
14	PHY5304	CB Group –II 1) Electronic Instrumentation-I 2) Laser-I 3) Energy Studies-I 4) Microcontroller– I	4
15	PHY5305	Special Lab-I	4
16	PHY5306	Project-I	2
Total Credit			**22**

Programme Outcomes (POs)

PO1	**Disciplinary Knowledge:** Demonstrate comprehensive knowledge of the discipline that forms a part of a postgraduate Programme. Execute strong theoretical and practical understanding generated from the specific Programme in the area of work.
PO2	**Critical Thinking and Problem solving:** Exhibit the skill of critical thinking and understand scientific texts and place scientific statements and themes in contexts and also evaluate them in terms of generic conventions. Identify the problem by observing the situation closely, take actions and apply lateral thinking and analytical skills to design the solutions.
PO3	**Social competence:** Exhibit thoughts and ideas effectively in writing and orally; communicate with others using appropriate media, build effective interactive and presenting skills to meet global competencies. Elicit views of others, present complex information in a clear and concise way and help reach conclusions in group settings.
PO4	**Research-related skills and Scientific temper :** Infer scientific literature, build a sense of enquiry and able to formulate, test, Analyse, interpret and establish hypothesis and research questions; and to identify and consult relevant sources to find answers. Plan and write a research paper/project while emphasizing on academics and research ethics, scientific conduct and creating awareness about intellectual property rights and issues of plagiarism.
PO5	**Trans-disciplinary knowledge:** Create new conceptual, theoretical and methodological understanding that integrates and transcends beyond discipline-specific approaches to address a common problem.
PO6	**Personal and professional competence:** Perform independently and also collaboratively as a part of a team to meet defined objectives and carry out work across interdisciplinary fields. Execute interpersonal relationships, self-motivation and adaptability skills and commit to professional ethics.
PO7	**Effective Citizenship and Ethics:** Demonstrate empathetic social concern and equity centered national development, and ability to act with an informed awareness of moral and ethical issues and commit to professional ethics and responsibility.
PO8	**Environment and Sustainability:** Understand the impact of the scientific solutions in societal and environmental contexts and demonstrate the knowledge of and need for sustainable development.
PO9	**Self-directed and Life-long learning:** Acquire the ability to engage in independent and life-long learning in the broadest context of socio-technological changes.

M. Sc-II (Physics) Semester-III

PHY 5301: STATISTICAL PHYSICS

Credit: 04 **Total No. of Lectures: 60**

Course Outcomes:

On successful completion of this course students will be able to:

CO1: Understand the relevant quantities used to describe macroscopic systems, thermodynamic potentials, and ensembles.

CO2: Understand the concepts of statistical errors, partition functions by considering the different types of ensembles.

CO3: Describe the consequences in classical and quantum statistics.

CO4: Understand fermions, bosons and differentiate between FD statistics and BE statistics.

CO5: Show an analytic ability to solve the statistical mechanics problems.

CO6: Explore fluctuations and correlations in statistical systems.

CO7: Understand the connection between classical and quantum statistical mechanics.

Unit1: Statistical Description and Thermodynamics of Particles **(15L)**

Revision of laws of thermodynamics, statistical ensemble, postulates of equal a priori probability, behavior of density of states, Liouville's theorem(classical), Equilibrium conditions and constraints, Distribution of energy between systems in equilibrium, Approach to thermal equilibrium, Sharpness of the probability distribution, Dependence of the density of states on the external parameters, Equilibrium between interacting systems, Thermodynamical laws and basic statistical relations (Revision)

Unit 2: Classical Statistical Mechanics: **(15L)**

Micro-canonical ensemble, System in contact with heat reservoir, Canonical ensemble, Applications of canonical ensembles (Paramagnetism, Molecule in an ideal gas, Law of atmosphere), System with specified mean energy, Calculation of mean values and fluctuations in a canonical ensemble, Connection with thermodynamics, Grand-canonical ensemble, , Chemical potential in the equilibrium state, Mean values and fluctuations in grand canonical ensemble, Thermodynamic functions in terms of the Grand partition function

Unit 3: Applications of Statistical Mechanics and Quantum Distribution **(15L)**

Calculations of thermodynamic quantities, Ideal monoatomic gas, Gibbs paradox, Equipartition theorem and its Simple applications. i) Mean kinetic energy of a molecule in a gas ii) Brownian motion iii) Harmonic Oscillator iv) Specific heat of solid, Maxwell velocity distribution, Related distributions and mean values Symmetry of wave functions, Quantum distribution functions, Boltzmann limit of Boson and Fermions gases, Maxwell Boltzman statistics, B-E statistics, F-D statistics, Evaluation of the partition function, Partition function for diatomic molecules, Equation of state for an ideal gas, quantum mechanical paramagnetic susceptibility

Unit 4: Ideal Bose and Fermi Systems: **(15L)**

Photon gas – i) Radiation pressure ii) Radiation density iii) Emissivity iv) Equilibrium number of photons in the cavity, Einstein derivation of Planck’s law, Bose Einstein Condensation, Specific heat, Photon gas – Einstein and Debye’s model of solids Fermi energy, Mean energy of fermions at absolute zero, Fermi energy as a function of temperature, Electronic specific heat, White – Dwarfs (without derivation), comparison of M-B statistics, F-D statistics, and B-E statistics, comparison between classical statistics and quantum statistics.

Reference books:

1. Fundamentals of Statistical and Thermal Physics, - F. Reif,
2. Fundamentals of Statistical Mechanics, B.B. Laud, New Age International Publication
3. Statistical Mechanics, R.K. Pathria, Bufferworgh Heinemann (2nd Edition)
4. Statistical Mechanics, K. Huang, John Willey and Sons (2nd Edition)
5. Statistical Mechanics, Satya Prakash and Kedar Nath Ram, Nath Publication (2008)
6. Statistical Mechanics by Loknathan and Gambhir

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Programme Outcomes								
	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO8**	**PO9**
CO 1	3								
CO 2	3								
CO 3	3								
CO 4	3								
CO 5	3	3							
CO 6	3					2			
CO7	3								

Justification

PO1: Disciplinary Knowledge

CO1: Understand the relevant quantities used to describe macroscopic systems, thermodynamic potentials, and ensembles.
CO2: Understand the concepts of statistical errors, partition functions by considering the different types of ensembles.
CO3: Describe the consequences in classical and quantum statistics.
CO4: Understand fermions, bosons and differentiate between FD statistics and BE statistics.
CO5: Show an analytic ability to solve the statistical mechanics problems.
CO6: Converse with correct concepts of thermodynamics and statistical mechanics.
CO7: Understand statistics of particles and statistics of fields.
Weightage: 3
All the specified course outcomes directly contribute to acquiring disciplinary knowledge in statistical mechanics.

PO2: Critical Thinking and Problem Solving

CO5: Show an analytic ability to solve the statistical mechanics problems.
Weightage: 3
The analytic ability to solve problems is a key aspect of critical thinking and problem-solving skills.

PO6: Personal and Professional Competence

CO6: Converse with correct concepts of thermodynamics and statistical mechanics.
Weightage: 2
Conveying correct concepts in these areas contributes to personal and professional competence.

M. Sc-II (Physics) Semester-III

PHY 5302: SOLID STATE PHYSICS

Credit: 04 **Total No. of Lectures: 60**

Course outcomes:

After successful completing this course, the student will be able to

CO1: Explain mechanical, electrical, and magnetic properties of solid matter, and connect these to bond type.

CO2: Explain simple theories for conduction of heat and electrical current in metals.

CO3: Know the basic physics behind dia, para and ferromagnetism.

CO4: Critically evaluate the approximations needed to build models to understand the solid state.

CO5: Explore the behaviour of magnetic materials, including ferromagnetism, antiferromagnetism, and Paramagnetism.

CO6: Study the phenomenon of superconductivity and the properties of superconducting materials.

CO7: Understand the BCS theory and the Meissner effect.

Unit 1: Band Theory of Solids **(15L)**

Introduction, Nearly free electron model, DC and AC electrical conductivity of metals, Bloch theorem (with proof), Kronig-Penney model, Motion of electron in 1-D according to band theory, Distinction between metals, insulators and intrinsic semiconductors, Reduced, periodic & extended zone schemes, Cyclotron resonance, Quantization of electronic orbit in a magnetic field.

The electrical conductivity at low temperature, The thermal conductivity of metals, Dielectric Properties of insulators. Macroscopic electrostatic Maxwell equations, Theory of Local Field, Theory of polarizability, Clausius- Mossotti relation, Long- wavelength optical modes in Ionic crystals.

Unit 2: Diamagnetism and Paramagnetism **(15L)**

Introduction, Classical theory of diamagnetism, Langevin theory of Paramagnetism, Quantum theory of Paramagnetism, Paramagnetic susceptibility of conduction electron, Magnetic properties of rare earth ions & iron group ions with graphical representation, Crystal field splitting, Quenching of orbital angular momentum.

Unit 3: Ferromagnetism, Antiferromagnetism and Ferrimagnetism (15L)

Introduction, Ferromagnetism: Wiess theory, Curie point, Exchange integral, saturation magnetization and its temperature dependence, Saturation magnetization at absolute zero, ferromagnetic domains, Anisotropy energy, Bloch wall, Quantum theory of ferromagnetism Magnetic resonance, Nuclear magnetic resonance (NMR), The resonance condition, Antiferromagnetism: Neel temperature, Ferrimagnetism: Curie temperature, susceptibility of ferrimagnets.

Unit 4: Carbon based materials (15L)

Allotropes of carbon: Diamond, Graphite, Graphene, Amorphous carbon, Glassy carbon

Carbon nanostructure: Fullerenes, Carbon Nanotube (CNTs), Carbon Nanofiber (CNFs), Graphene

Synthesis methods of graphene oxide: Original Hummers method, modified Hummers method

Graphene oxide reduction: Thermal reduction mechanism, Thermal reduction in various atmospheres

Graphene: Applications

Reference Books:

1. Introduction to solid states Physics - Charles, Kittle 7th Edition
2. Introductory Solid States Physics – H. P. Myers
3. Solid States Physics - S.O. Pillai (latest edition)
4. Elementary Solid States Physics- M. Ali Omar
5. Problem in Solid State Physics – S.O. Pillai
6. Solid States Physics – A. J. Dekkar
7. Solid states Physics – Wahab
8. Solid State Physics: Neil W. Ashcroft, N. David Mermin
9. Solid States Physics – Ibach & Luth
10. Solid States Physics – C. M. Kacchawa
11. Wet Chemical Synthesis of Graphene for Battery Applications - Ida Johansen

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Programme Outcomes								
	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO8**	**PO9**
CO 1	3								
CO 2		3							
CO 3		3							
CO 4		3							
CO 5		3							
CO 6						2			
CO7									

Justification

PO1: Disciplinary Knowledge

CO1: After successfully completing this course, the student will be able to...

Weightage: 3

The course completion objectives directly contribute to acquiring disciplinary knowledge in the field.

PO2: Critical Thinking and Problem Solving

CO2: Explain mechanical, electrical and magnetic properties of solid matter, and connect these to bond type.

CO3: Explain simple theories for conduction of heat and electrical current in metals.

CO4: Know the basic physics behind dia, para and ferromagnetism.

CO5: Critically evaluate the approximations needed to build models to understand the solid state.

Weightage: 3

All these outcomes involve critical thinking and problem-solving skills in understanding various properties and theories related to solid matter.

PO6: Personal and Professional Competence

CO6: Defines Bonds in crystals, Inert gas crystals, Van der Waals-London interaction, Repulsive interaction and Binding energy.

Weightage: 2 (Moderate or partial relation)

Justification: Defining various bonds contributes to personal and professional competence, albeitnot as directly as other outcomes.

M. Sc-II (Physics) Semester-III

CB Group –I: 1. PHY 5303: PHYSICS OF THIN FILM-I

Credit: 04 **Total No. of Lectures: 60**

Course Outcomes:

CO1: To understand the principle, differences and similarities, advantages, and disadvantages of different thin film deposition Techniques.
CO2: To understand and evaluate and use models for understanding nucleation and growth of thin films.
CO3: To understand about different instrumentation techniques and to analyze thin film properties to apply for various applications.
CO4: To improve problems solving skills related to evaluation of different properties of thin films.
CO5: Problem solving ability
CO6: Critical analysis
CO7: Discuss the differences and similarities between different vacuum based deposition techniques
CO8: Evaluate and use models for nucleating and growth of thin films
CO9: Asses the relation between deposition technique, film structure, and film properties

Unit 1: Introduction to thin films **(15L)**

Overview of vacuum techniques, Comparison of thin and thick films, Theory of growth of thin films: Nucleation, condensation, Frank-Van der Merwe model, Volmer-Weber model, Stranski-Krastanov model, Capillarity model, Atomistic model, comparison of models, various stages of film growth.

Unit 2: Deposition Techniques and Measurement of thickness **(15L)**

Physical methods: Vacuum Techniques (i) Thermal evaporation methods: Resistive heating, Electron Beam Evaporation, (ii) Sputtering system: Glow discharge, DC sputtering, Radio frequency sputtering, Magnetron sputtering, Ion beam sputtering. Chemical Methods: Chemical vapor deposition system (CVD), Chemical bath deposition: Ionic and solubility products, Preparation of binary semiconductors, Electrochemical deposition: Deposition mechanism and Preparation of compound thin films, Spray pyrolysis: Deposition mechanism and preparation of compound thin films. Doctor blade technique, Dip coating and Spin coating, Photolithography, Electron–beam deposition, Pulsed Laser Ablation, Tolansky technique, Talystep (styles) method, Quartz crystal microbalance, Stress measurement by optical method, Gravimetric method.

Unit 3: Properties of thin films **(15L)**

Electrical Properties: Source of Resistivity in Metallic conductors, Influence of thickness on the resistivity of thin films, Hall Effect & Magnetoresistance in thin films, Fuch-Sondhemir theory, TCR and its effects. Mechanical properties: Adhesion & its measurement with mechanical and nucleation methods, stress measurement by using optical method. Optical properties: Absorption and transmission.

Unit 4: Applications of Thin Films **(15L)**

Resistors, capacitors, Junction devices (Metal semiconductor junction) Solar cells, ICs, Optical coating, Thin film sensors (gas and humidity), Thin films for information storage, electro acoustics and telecommunication.

Reference books:

1. Hand book of Thin Film Technology: Maissel and Glang, (Mc Graw Hill)
2. Thin Film Phenomena: K. L. Chopra, (Mc Graw Hill)
3. Material Science of Thin Films: M. Ohring, (Academic Press)
4. Thin Film Process: J. L. Vossen and Kern, (Academic Press)
5. Vacuum Technology (2 nd revised edition), A. Roth, (North Hollad)

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Programme Outcomes								
	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**
CO 1	3			2					
CO 2	3					2			
CO 3	3					2	3	2	
CO 4									
CO 5		2							
CO 6									
CO7			2		2				
CO8		3		2					2
CO9		3							

Justification

PO1: Disciplinary Knowledge

CO1: To understand the principle, differences and similarities, advantages, and disadvantages of different thin film deposition Techniques. Weightage: 3

Acquiring technical skills in a laboratory setting is fundamental to building disciplinary knowledge.

CO2: To understand and evaluate and use models for understanding nucleation and growth of thin films. CO3: To understand about different instrumentation techniques and to analyze thin film properties to apply for various applications. Weightage: 3

Creating experimental models for better understanding involves disciplinary knowledge and direct application, indicating a strong relationship. Weightage: 3

Visualizing and experiencing abstract concepts directly contribute to disciplinary knowledge.

PO2: Critical Thinking and Problem Solving

CO8: Evaluate and use models for nucleating and growth of thin films: 3

CO9: Asses the relation between deposition technique, film structure, and film properties. Weightage3

Critical thinking is essential in use models for nucleating and growth of thin films and interpreting Assess the relation between deposition technique, film structure, and film properties

CO4: To improve problems solving skills related to evaluation of different properties of thin films.

CO5: Problem solving ability Weightage: 2

Applying knowledge in project work involves problem-solving skills, but the link may not be as direct as in other cases.

PO3: Social Competence

CO7: Discuss the differences and similarities between different vacuum based deposition techniques. Weightage: 3

Collaborative learning and teamwork in a laboratory setting directly contribute to social competence.

PO4: Research-related Skills and Scientific Temper

CO1: To understand the principle, differences and similarities, advantages, and disadvantages of different thin film deposition Techniques. Weightage: 2

Acquiring technical skills can be part of research-related skills, but the link may not be as direct.

CO8: Evaluate and use models for nucleating and growth of thin films. Weightage: 2

Evaluate and use models can be part of developing a scientific temper, but the link may not be as strong.

PO5: Trans-disciplinary Knowledge

CO7: Discuss the differences and similarities between different vacuum based deposition techniques. Weightage: 2

Collaborative learning and teamwork contribute to trans-disciplinary knowledge, but the link may not be as strong.

PO6: Personal and Professional Competence

CO2: To understand and evaluate and use models for understanding nucleation and growth of thin film Weightage: 2

Collaborative learning and teamwork contribute to personal and professional competence, though the link may not be as direct.

CO3: To understand about different instrumentation techniques and to analyze thin film properties to apply for various applications.

Collaborative learning and teamwork contribute to personal and professional competence, though the link may not be as direct.

PO7: Effective Citizenship and Ethics

CO2: To understand and evaluate and use models for understanding nucleation and growth of thin films. Weightage: 3

Understanding laboratory procedures, especially safety and scientific methods, directly contributes to effective citizenship and ethics.

PO8: Environment and Sustainability

CO3: To understand about different instrumentation techniques and to analyze thin film properties to apply for various applications. Weightage: 2

Adhering to laboratory safety procedures can indirectly contribute to considerations of environment and sustainability.

PO9: Self-directed and Life-long Learning

CO8: Evaluate and use models for nucleating and growth of thin film. Weightage: 2

Applying knowledge in project work is relevant to self-directed and life-long learning, though the link may not be as direct.

M. Sc-II (Physics) Semester-III

CB Group –I: 2. PHY 5303: NANO TECHNOLOGY-I

Credit: 04 **Total No. of Lectures: 60**

After successful completing this course, the student will able to

CO1: To understand the nature and properties of nanomaterials.

CO2: To provide scientific understanding of application of nanomaterials and nanotechnology in agriculture, health and environmental conservation.

CO3: To foundational knowledge of the Nanoscience and related fields.

CO4: To make the students acquire an understanding the Nanoscience and Applications

CO5: To help them understand in broad outline of Nanoscience and Nanotechnology

CO6: Build models to understand the physical properties of different nano materials

CO7: Critically evaluate the approximations needed to build models to understand the solid state.

Unit 1: Science at Nano scale **(15L)**

Nano and Nature: Nanoscopic colours (Butterfly wings), Bioluminescence (fireflies), Tribology (Gecko's Sticky Feet, Nasturtium Leaf-Lotus effect etc) in nature.

Classification of nano materials:

0D, 1D, 2D and 3D and types of nano materials (QDs, QW, CNT's, Bucky Balls, Nano composites etc)

Nano science:

Quantum mechanics, Brownian motion, surface forces, surface to volume ratio

Making of nanostructures:

Top down Overview of top down nano fabrication processes. Mechanical grinding (ball milling)

Making of nano structures:

Bottom up, overview of bottom up nanofabrication processes Solid state phase synthesis

Unit 2: Physical Properties of Nano materials **(15L)**

Surface Properties:

Surface energy – chemical potential as a function of surface curvature-Electrostatic stabilization- surface charge density-electric potential at the proximity of solid surface-Van der Waals attraction potential

Mechanical properties

Melting point and lattice constants, Electrical conductivity (Surface scattering, Change of electronic structure, quantum transport).

Magnetic properties of Nano materials

Origin of magnetism in materials, Classification into Dia-, Para- and Ferro-magnetic materials, Hysteresis in ferromagnetic materials, domains, soft and hard magnetic materials, Coercivity vs particle size

Unit 3: Nano structured materials **(15L)**

Nano ceramics:

Dielectrics, ferroelectrics and magneto ceramics, Magnetic properties

Nano polymers:

Preparation and characterization of di block Copolymer based Nano composites, Nanoparticles polymer ensembles; Applications of Nano polymers

Nano composites:

Metal-Metal nano composites, Polymer-Metal nano composites, Ceramic nano composites

Special Nano materials:

Graphene, Carbon nano tubes and Types (CNT), Fullerenes, Aerogels, Core Shell Nanostructures

Unit 4: Synthesis techniques of Nano materials **(15L)**

Physical methods:

Vacuum Techniques (i) Thermal evaporation methods: Resistive heating, Electron Beam Evaporation, (ii) Sputtering system: Glow discharge, DC sputtering, Radio frequency sputtering, Magnetron sputtering, Ion beam sputtering.

Chemical Methods:

Chemical bath deposition: Ionic and solubility products, Preparation of binary semiconductors, Electrochemical deposition: Deposition mechanism and Preparation of compound thin films, Spray pyrolysis: Deposition mechanism and preparation of compound thin films.

Reference books:

1 Nanotechnology principle and practices by Sulabha K. Kulkarni (2007).

2 Klabunde, K.J. (Ed.), “Nanoscale Materials in Chemistry”, John Wiley & Sons Inc. 2001

3 Nalwa, H.S. (Ed.), “Encyclopedia of Nanoscience and Nanotechnology” 2004

4 Sergeev, G.B. Nanochemistry, Elsevier, B.V. 2010

5 Schmid, G. (Ed.), “Nanoparticles”, Wiley-VCH Verlag GmbH & Co. KgaA.2004

6 Rao, C.N.R., Müller, A. and Cheentham, A.K. (Eds.),“Chemistry of Nanomaterials”, Wiley – VCH. 2005

7 Carbon Nanotubes: Properties and Applications- Michael J. O'Connell.

8 Carbon Nanotechnology- Liming Dai.

9 Nanotubes and Nanowires- CNR Rao and A Govindaraj RCS Publishing.

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Programme Outcomes								
	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO8**	**PO9**
CO 1	3								
CO 2					2				
CO 3	3								
CO 4	3								
CO 5	3								
CO 6		3							
CO7		3							

Justification

PO1: Disciplinary Knowledge
CO1: To understand the nature and properties of nanomaterials.
CO3: To foundational knowledge of Nanoscience and related fields.
CO4: To make the students acquire an understanding of Nanoscience and Applications.
CO5: To help them understand the broad outline of Nanoscience and Nanotechnology.
Weightage: 3
All these course outcomes directly contribute to acquiring disciplinary knowledge in the field of Nanoscience.
PO2: Critical Thinking and Problem Solving
CO6: Build models to understand the physical properties of different nanomaterials.
CO7: Critically evaluate the approximations needed to build models to understand the solid state.
Weightage: 3
Building models and critically evaluating approximations involve critical thinking and problem-solving skills, especially in the context of nanomaterials and solid-state physics.
PO5: Trans-disciplinary Knowledge
CO2: To provide a scientific understanding of the application of nanomaterials and nanotechnology in agriculture, health, and environmental conservation.
Weightage: 2
Understanding the application of nanomaterials in diverse fields contributes to trans-disciplinary knowledge.

M. Sc-II (Physics) Semester-III

CB Group –I: 3. PHY 5303: BIOMEDICAL INSTRUMENTATION-I

Credit: 04 **Total No. of Lectures: 60**

Learning Outcomes:

After completion of the course, the student should be able to:

CO1: Explain the different medical imaging systems, compare advantages and disadvantages, understand the limitations and find the best suitable method for different pathological diagnoses.

CO2: Explain and describe different diagnostic measurement methods for identification of human biopotentials and their necessary instrumentation.

CO3: Explain the principles behind the operation of common biomedical instruments.

CO4: Identify and describe the components of biomedical instruments.

CO5: Understand basic signal processing techniques applied in biomedical instrumentation.

CO6: Analyze and process signals from biological systems.

CO7: Identify different types of sensors and transducers used in biomedical applications.

Unit 1: Fundamentals to Biomedical Instrumentation and patient safety **(15L)**

1.1 Basic medical instrumentation system.

1.2 System configuration

1.3 basic characteristics of measuring system

1.4 Problems faced when measuring a human body

1.5 Essentials of biomedical instrumentation.

1.6 Electric shock hazards-Gross shock-Micro current shock

1.7 Precautions to minimize electric shock hazards

Unit 2: Electrodes and physiological transducers: **(15L)**

3.1 Electrode Theory

3.2 Biopotential Electrodes

3.3 Electrodes for ECG, EEG, EMG.

3.4 Introduction to physiological transducers

3.5 Classification of Transducer

3.6 Performance characteristic of transducer.

3.7 Displacement, position and motion transducer.

3.8 Pressure transducer

3.9 Transducer for Body temperature measurement

3.10 Biosensors

Unit 3: Recording Systems and Signal Analysis: **(15L)**

3.1 Basic recording system.

3.2 General consideration for signal conditioners

3.3 Preamplifiers, Differential, Instrumentation, Isolation amplifier.

3.4 Source of noise in low level measurement.

3.5 Biomedical signal analysis techniques

3.6 Fourier Transform, FFT and Wavelet Transform

3.7 Signal processing techniques.

Unit 4: Cardiovascular System and Measurements: **(15L)**

4.1 The Heart.

4.2 The Heart and Cardiovascular system

4.3 Blood Pressure

4.4 Heart Sounds.

4.5 Block diagram of electrocardiograph

4.6 The ECG leads

4.7 Effect of Artifacts on ECG recording

4.8Introduction to pacemakers

4.9 Types of pacemakers

4.10 Need for pacemakers

4.11Pacemaker system and its functioning

Reference Books:

1. Biomedical Instrumentation and Measurements (Second edition)
   By Leslie Cromwell, Fred J. Weibell, Erich A. Pfeiffer Pearson education.
2. Handbook of Biomedical Instrumentation (Second Edition) by R. S. Khandpur (Tata McGraw Hill).
3. Biomedical Instrumentation and Measurement by Carr and Brown-Pearson.

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Programme Outcomes								
	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO8**	**PO9**
CO 1	3	3	2						
CO 2	3	3			1				
CO 3	3								
CO 4	3								
CO 5	3	2							
CO 6	3	3							
CO7	3								

Justification

CO1: Explain the different medical imaging systems, compare advantages and disadvantages, understand the limitations and find the best suitable method for different pathological diagnoses.

PO1: Disciplinary Knowledge: 3 (strong or direct relation)

Justification: This course outcome directly aligns with the development of disciplinary knowledge in the field of biomedical instrumentation, particularly in understanding medical imaging systems and their applications.

PO2: Critical Thinking and Problem Solving: 3 (strong or direct relation)

Justification: Analyzing advantages, disadvantages, and limitations of medical imaging systems requires critical thinking and problem-solving skills.

PO5: Trans-disciplinary Knowledge: 2 (moderate or partial relation)

Justification: While primarily focused on biomedical instrumentation, understanding medical imaging systems may involve knowledge from other disciplines, but to a lesser extent.

CO2: Explain and describe different diagnostic measurement methods for identification of human biopotentials and their necessary instrumentation.

PO1: Disciplinary Knowledge: 3 (strong or direct relation)

Justification: Understanding diagnostic measurement methods for biopotentials is a direct application of disciplinary knowledge in biomedical instrumentation.

PO2: Critical Thinking and Problem Solving: 3 (strong or direct relation)

Justification: Describing and explaining diagnostic measurement methods involves critical thinking and problem-solving skills.

PO5: Trans-disciplinary Knowledge: 1 (weak or low relation)

Justification: This outcome is more discipline-specific and doesn't involve significant trans-disciplinary knowledge.

CO3: Explain the principles behind the operation of common biomedical instruments.
PO1: Disciplinary Knowledge: 3 (strong or direct relation)
Justification: Understanding the principles of common biomedical instruments is foundational disciplinary knowledge.

CO4: Identify and describe the components of biomedical instruments.
PO1: Disciplinary Knowledge: 3 (strong or direct relation)
Justification: Recognizing and describing components directly contributes to disciplinary knowledge in biomedical instrumentation.

CO5: Understand basic signal processing techniques applied in biomedical instrumentation.
PO1: Disciplinary Knowledge: 3 (strong or direct relation)
Justification: Signal processing is a core aspect of biomedical instrumentation knowledge.
PO2: Critical Thinking and Problem Solving: 2 (moderate or partial relation)
Justification: Understanding signal processing involves some level of critical thinking and problem-solving skills.

CO6: Analyze and process signals from biological systems.
PO1: Disciplinary Knowledge: 3 (strong or direct relation)
Justification: Signal analysis from biological systems directly falls within the domain of disciplinary knowledge in biomedical instrumentation.
PO2: Critical Thinking and Problem Solving: 3 (strong or direct relation)
Justification: Analyzing and processing signals requires critical thinking and problem-solving skills.

CO7: Identify different types of sensors and transducers used in biomedical applications.
PO1: Disciplinary Knowledge: 3 (strong or direct relation)
Justification: Recognizing sensors and transducers is fundamental to disciplinary knowledge in biomedical instrumentation.

M. Sc-II (Physics) Semester-III

CB Group –II: 1. PHY 5304: ELECTRONIC INSTRUMENTATION-I

Credit: 04 **Total No. of Lectures: 60**

Course Outcomes: After successful completion of this course the students will be able to-

CO1: Understand the principles and functions of different instruments.
CO2: Use different instruments for measurement of various parameters.
CO3: Design experiments using sensors.
CO4: Recognize the importance of instrumentation in various engineering and scientific applications.
CO5: Study various types of sensors and transducers.
CO6: Understand the working principles and characteristics of different sensor.
CO7: Learn techniques for conditioning and processing electrical signals from sensors.

Unit 1: General Background and Measurements **(15L)**

1.1 General configuration and functional description of measuring instruments with examples of instruments and their functional description. (Ref.1: #2.1 to 2.4).

1.2 Input output configuration of measuring instruments, and methods of correction of unwanted inputs.(Ref.1: #2.5)

1.3 1.2 Qualities of measurements (Ref.9 Ch# 1)
I] Static characteristics II] Dynamic characteristics: Generalized mathematical model of measurement System, III] Order of instruments: zero, first and second order. (Ref.1: #3.3 94 to 115 & 123 to131)

1.4 Errors in measurement, Types of errors, sources of errors (Ref.9)

References: 1, 3, 9

Unit 2: Transducers **(15L)**

2.1 Displacement Measurement: a) Resistive Transducers (variable resistance, Strain gauges, Electrical strain gauges), b) Inductive transducers (LVDT, variable reluctance), c) Capacitive transducers

2.2 Pressure Measurement: a) Non-Elastic pressure transducers (Barometer, Manometer)
b) Elastic pressure transducers (Diaphragm, Bellows, Bourdon gauge), c) Electrical pressure transducers (Piezoelectric transducer)

2.3 Temperature Measurement: a) Electrical Method (RTD, Platinum resistance thermometer, Thermistor), b) Thermocouple EMF measuring Circuit, c) Non-contact Type (Semiconductor temperature sensors, Radiation pyrometers

References: 9

Unit 3: Signal Conditioners, Data acquisition and conversion **(15L)**

3.1 Signal conditioners: Op-amps, instrument amplifier, bridge, phase sensitive detector

3.2 Data Acquisition System (DAS): DAS, hardware, Single channel DAS, Multi channel DAS

3.3 Data Converters: D to A and A to D converters, Data loggers,

References: 9

Unit 4: Indicators, Display system and Oscilloscope **(15L)**

4.1 Digital display system and Indicators

4.2 Classification of Displays

4.3 Light Emitting Diodes (LED)

4.4 Liquid Crystal Display (LCD).

4.5 Printers: principle of Laser printers

4.6 Cathode Ray Oscilloscope (CRO)

4.7 Cathode Ray Tube (CRT)

4.8 Digital Storage Oscilloscope (DSO)

References: 9

Reference Books:

1. Measurement systems- applications and design. 4th edn E.O. Doeblin.
2. Measurement system – applications and design by E.O. Doblin and Manik .
3. Instrumentation, measurement and systems. Nakra and Chaudhary.
4. Electronic Instrumentation and measurement techniques by A. D. Helfrick and W. D. Cooper. (Pearson.)
5. Instrumentation, devices and systems. Rangan, Mani and Sarma Prentice Hall of India. 18 6. Process controlled instrumentation by C. D. Johnson.
7. Elements of Electronic Instrumentation and measurement. 3rd edn. Joseph Carr. (Pearson).
8. Sensors and transducers. Patranabis.
9. Electronics Instrumentation. Kalsi (Tata McGraw-Hill)

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Programme Outcomes								
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9
CO 1	3								
CO 2	3								
CO 3		3	2						
CO 4	3			3					
CO 5				3					
CO 6		3		3					
CO7	3								

Justification

PO1: Disciplinary Knowledge

CO1: Understand the principles and functions of different instruments.

CO2: Use different instruments for measurement of various parameters.

CO4: Develop the knowledge of theoretical and mathematical principles of electrical measuring instruments.

CO7: Develop the knowledge of theoretical and mathematical principles of electrical measuring instruments.

Weightage: 3

These outcomes directly contribute to acquiring disciplinary knowledge in the field of instrumentation and electrical measurements.

PO2: Critical Thinking and Problem Solving

CO3: Design experiments using sensors.

CO6: Set up testing strategies to evaluate performance characteristics of different types of sensors and transducers and develop professional skills in acquiring and applying the knowledge outside the classroom through the design of a real-life instrumentation system.

Weightage: 3

Designing experiments and setting up testing strategies involve critical thinking and problem-solving skills in the context of instrumentation and sensor applications.

PO3: Social Competence

CO3: Design experiments using sensors.

Weightage: 2 (moderate or partial relation)

Justification: While CO3 primarily focuses on the technical aspect of designing experiments using sensors, it indirectly contributes to social competence by fostering collaborative and communicative skills when working in a team setting.

PO4: Research-related Skills and Scientific Temper

CO4: Recognize the importance of instrumentation in various engineering and scientific applications.

CO5: Study various types of sensors and transducers.

CO6: Understand the working principles and characteristics of different sensors.

Weightage: 3 (strong or direct relation)

Justification: CO4 emphasizes the recognition of instrumentation's significance in scientific applications, while CO5 and CO6 delve into research-related skills by studying various types of sensors and understanding their working principles.

M. Sc-II (Physics) Semester-III

CB Group –II: 2. PHY 5304: LASER-I

Credit: 04 **Total No. of Lectures: 60**

Course Outcomes: After successful completion of this course the students will be able to-

CO1: Explain the fundamental principles of laser operation, including population inversion, stimulated emission, and amplification of light.

CO2: Describe different types of lasers, such as solid-state lasers, gas lasers, semiconductor lasers, and fiber lasers, and understand their applications.

CO3: Demonstrate knowledge of laser safety protocols, including the hazards associated with laser use and appropriate safety measures.

CO4: Identify and describe the components of a laser system, including gain medium, pump source, cavity, and optical elements.

CO5: Explain the principles of optical resonators and laser cavities and their role in laser emission.

CO6: Explore how lasers interact with different materials, including absorption, reflection, and transmission, and their applications in cutting, welding, and ablation.

CO7: Discuss various applications of lasers in science, technology, medicine, communication, and industry.

Unit 1: Basic of Lasers **(15L)**

Introduction, Historical background of laser, Einstein coefficients and stimulated light amplification, population inversion, Creation of population inversion in three level & four level lasers, Problem Solving.

Unit 2: Types of Lasers Systems **(15L)**

Introduction, Gas Laser: (CO_2 laser), Solid State Laser, Host material and its characteristics, doped ions: (Nd: YAG laser), Liquid laser: (Dye laser), Semiconductor laser.

Unit 3: Laser Beam Propagation **(15L)**

Introduction, Laser beam propagation, properties of Gaussian beam, resonator, stability, various types of resonators, resonator for high gain and high energy lasers, Gaussian beam focusing.

Unit 4: Detection and some applications of laser **(15L)**

Detection of optical radiation: Human eye, thermal detector (bolometer, pyro-electric), photon detector (photoconductive detector, photo voltaic detector and photoemissive detector), p-i-n photodiode, APD photodiode

Holography: Importance of coherence, Principle of holography and characteristics, Recording and reconstruction, classification of hologram and application, non-destructive testing, injection laser diode (double heterostructure , distributed feedback)

Reference Book:

1. Principles of lasers- O Svelto
2. Solid State Laser Engineering- W Koechner
3. Laser- B A Labgyel
4. Gas laser- A J Boom
5. Methods of Experimental Physics Vol. 15B ed. By C L Tang
6. Industrial Application of Lasers – J F Ready
7. Handbook of Nonlinear Optics- R L Sautherland
8. Laser and electro optics- C C Davis
9. Fibre optic communication- Joseph C Palais
10. Fundamentals of light sources and lasers – Mark csele

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Programme Outcomes								
	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**
CO 1	3	2							
CO 2	3	2							
CO 3							3		
CO 4	3								
CO 5	3								
CO 6	3	2							
CO7					3				

Justification

CO1: Explain the fundamental principles of laser operation, including population inversion, stimulated emission, and amplification of light.

PO1: Disciplinary Knowledge: 3 (strong or direct relation)

Justification: Understanding the fundamental principles of laser operation directly contributes to disciplinary knowledge in laser technology.

PO2: Critical Thinking and Problem Solving: 2 (moderate or partial relation)

Justification: Explaining these principles involves critical thinking, but it may not be as extensive as in some other topics.

CO2: Describe different types of lasers, such as solid-state lasers, gas lasers, semiconductor lasers, and fiber lasers, and understand their applications.

PO1: Disciplinary Knowledge: 3 (strong or direct relation)

Justification: Describing different types of lasers and their applications contributes significantly to disciplinary knowledge in laser technology.

PO2: Critical Thinking and Problem Solving: 2 (moderate or partial relation)

Justification: Understanding the applications of different types of lasers requires critical thinking.

CO3: Demonstrate knowledge of laser safety protocols, including the hazards associated with laser use and appropriate safety measures.

PO7: Effective Citizenship and Ethics: 3 (strong or direct relation)

Justification: Demonstrating knowledge of laser safety protocols aligns with ethical considerations and responsible citizenship.

CO4: Identify and describe the components of a laser system, including gain medium, pump source, cavity, and optical elements.

PO1: Disciplinary Knowledge: 3 (strong or direct relation)

Justification: Identifying and describing components directly contributes to disciplinary knowledge in laser technology.

CO5: Explain the principles of optical resonators and laser cavities and their role in laser emission.

PO1: Disciplinary Knowledge: 3 (strong or direct relation)

Justification: Explaining the principles of optical resonators directly contributes to disciplinary knowledge in laser technology.

CO6: Explore how lasers interact with different materials, including absorption, reflection, and transmission, and their applications in cutting, welding, and ablation.

PO1: Disciplinary Knowledge: 3 (strong or direct relation)

Justification: Exploring laser-material interactions directly contributes to disciplinary knowledge in laser technology.

PO2: Critical Thinking and Problem Solving: 2 (moderate or partial relation)

Justification: Understanding the applications of laser-material interactions involves critical thinking.

CO7: Discuss various applications of lasers in science, technology, medicine, communication, and industry.

PO5: Trans-disciplinary Knowledge: 3 (strong or direct relation)

Justification: Discussing various applications of lasers involves knowledge beyond the discipline, contributing to trans-disciplinary knowledge.

M. Sc-II (Physics) Semester-III

CB Group –II: 3. PHY 5304: ENERGY STUDIES-I

Credit: 04 **Total No. of Lectures: 60**

Course Outcomes:

After completion of the course, the student should be able to:

CO1: Describe environmental impacts of renewable sources of energy.

CO2: Describe hydrogen as clean sources of energy.

CO3: Understand the concept of superconductors and fuel cell energy resources.

CO4: Understand the batteries and super capacitors.

CO5: Understand the challenges and solutions for integrating renewable energy sources into existing energy grids.

CO6: Explore the role of energy storage and grid management in facilitating renewable energy integration.

CO7: Explore methods for promoting energy literacy and awareness.

Unit 1: Energy and Thermodynamics **(15L)**

Different forms of Energy, Conservation of Energy, Entropy, Enthalpy, Heat capacity, Specific heat capacity, Thermodynamic cycles: Brayton, Carnot Diesel, Otto and Rankin cycle; Fossil fuels, time scale of fossil fuels and solar energy as an option.

Unit 2: Solar Energy for Clean Environment **(15L)**

Sun as Source of Energy, Availability of Solar Energy, Nature of Solar Energy, Solar Energy & Environment, Various Methods of using solar energy –Photothermal, Photovoltaic, Photosynthesis, Present & Future Scope of Solar energy, Hybrid wind energy systems - wind + diesel power, wind + conventional grid, wind +Photovoltaic system etc.

Unit 3: Wind Energy **(15L)**

Origin and classification of winds, Aerodynamics of windmill: Maximum power, and Forces on the Blades and thrust on turbines; Wind data collection and field estimation of wind energy, Site selection, Basic components of wind mill, Types of wind mill, Wind energy farm, Hybrid wind energy systems: wind + PV; The present Indian Scenario. Concept of wind form & project cycle, Cost economics & viability of wind farm

Unit 4: Biomass Energy and Biogas Technology (15L)

Importance of biogas technology, Different Types of Biogas Plants, Aerobic and anaerobic bioconversion processes, various substrates used to produce Biogas (cow dung, human and other agricultural waste, municipal waste etc.) Individual and community biogas operated engines and their use. Removal of CO_2 and H_2O, Application of Biogas in domestic, industry and vehicles, Bio-hydrogen production, Isolation of methane from Biogas and packing and its utilization

Reference Books

1. Biomass, Energy and Environment- N.H. Ravindranath and D.O Hall, Oxford University Press.
2. Solar Energy and Rural development- S.H. Pawar, C.D. Lokhande and R.N. Patil.
3. Biomass Energy- S.H. Pawar, L.J. Bhosale, A.B. Sabale and S.K. Goel.
4. Solid State Energy Conversion-S.H. Pawar, C.H. Bhosale, and R.N. Patil
5. Solar Energy Conversion-A.E. Dixon and J.D. Leslie.
6. Advances in Energy systems and technology- Peter Auer.

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Programme Outcomes								
	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO8**	**PO9**
CO 1	3								
CO 2	3								
CO 3	3								
CO 4	3								
CO 5		3							
CO 6		3							
CO7	3								

Justification

PO1: Disciplinary Knowledge
CO1: Describe environmental impacts of renewable sources of energy.
CO2: Describe hydrogen as clean sources of energy.
CO3: Understand the concept of superconductors and fuel cell energy resources.
CO4: Understand the batteries and supercapacitors.
CO7: Explain the field applications of solar energy.
Weightage: 3
All these course outcomes directly contribute to acquiring disciplinary knowledge in the field of renewable energy.
PO2: Critical Thinking and Problem Solving
CO5: Perform an initial design of a renewable energy system.
CO6: Use laboratories and emulators of renewable energy systems to analyze relevant issues.
Weightage: 3
Performing a design and analysing issues related to renewable energy systems involve critical thinking and problem-solving skills.
PO8: Environment and Sustainability
CO1: Describe environmental impacts of renewable sources of energy.
Weightage: 2
Describing environmental impacts aligns with the environmental and sustainability aspect of PO8.

M. Sc-II (Physics) Semester-III

CB Group –II: 4. PHY 5304: MICROCONTROLLER– I

Credit: 04 **Total No. of Lectures: 60**

Course Outcomes: After successful completion of this course the students will be able to-

CO1: Explain the architecture of microcontrollers, including the CPU, memory, input/output ports, and peripherals.

CO2: Write and debug programs for microcontrollers using a high-level programming language.

CO3: Interface microcontrollers with various peripherals such as sensors, actuators, displays, and communication modules.

CO4: Design and implement real-time systems using microcontrollers for applications with time-critical requirements.

CO5: Develop embedded systems using microcontrollers for specific applications, considering constraints such as power, memory, and processing speed.

CO6: Utilize debugging tools and techniques to identify and rectify errors in microcontroller programs.

CO7: Implement interrupt-driven programming for handling events and improving system responsiveness.

Unit 1: ARCHITECTURE OF 8051 **[10L]**

Comparison of Microprocessor and Microcontroller, Overview of the 8051 family, Block diagram of Microcontroller, Functions of each block, Pin details of 8051, A and B CPU registers, Flags and Program status word (PSW), Program Counter and Data Pointer, PSW register, Memory Organization of 8051, Internal RAM, Stack and Stack Pointer, Special function registers, Internal ROM, I/O Ports, Oscillator and Clock

Unit 2: 8051 ASSEMBLY LANGUAGE PROGRAMMING **[10L]**

Introduction to 8051 Assembly programming, Assembling and running an 8051 program, 8051 data types and directives, Intel hex file, Jump, loop, and call instructions, 8051 I/O Programming, Addressing modes

Unit 3: ARITHMETIC & LOGIC INSTRUCTIONS AND PROGRAMS [10L]

Arithmetic instructions, Signed number concepts and arithmetic operations, Logic And Compare instructions, Rotate instruction, BCD, ASCII, and other application programs.

Unit 4: TIMER AND INTERRUPTS PROGRAMMING IN ASSEMBLY/C: [10L]

Timers. Programming 8051 timers, counter programming, Programming timers 0 and 1 in 8051, 8051 interrupts, Interrupt priority in the 8051

Unit 5: SERIAL COMMUNICATION: [10L]

Basics of Serial programming, RS 232 Standards, 8051 connection to RS 232, 8051 Serial Communication Programming,

Unit 6: INTERFACING TECHNIQUES [10L]

LCD and Keyboard interfacing, ADC, DAC, and sensor interfacing (LM35)

Reference Books:

1. 8051 Microcontroller by Kenneth J.Ayala.
2. 8051 Microcontroller and Embedded Systems using Assembly and C by Mazidi, Mazidi and D MacKinlay, 2006 Pearson Education Low Price Edition.
3. Microprocessor and Microcontroller by R.Theagarajan, Sci Tech Publication, Chennai
4. Programming customizing the 8051 Microcontroller by MykePredko, Tata McGraw Hill

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Programme Outcomes								
	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO8**	**PO9**
CO 1	3								
CO 2	3	3							
CO 3	3								
CO 4	3	3							
CO 5	3	3							
CO 6		3							
CO7		3							

Justification

CO1: Explain the architecture of microcontrollers, including the CPU, memory, input/output ports, and peripherals.

PO1: Disciplinary Knowledge: 3 (strong or direct relation)

Justification: Understanding microcontroller architecture is fundamental to disciplinary knowledge in microcontroller systems.

CO2: Write and debug programs for microcontrollers using a high-level programming language.

PO1: Disciplinary Knowledge: 3 (strong or direct relation)

Justification: Writing and debugging programs contribute directly to disciplinary knowledge in microcontroller programming.

PO2: Critical Thinking and Problem Solving: 3 (strong or direct relation)

Justification: Writing and debugging programs require critical thinking and problem-solving skills.

CO3: Interface microcontrollers with various peripherals such as sensors, actuators, displays, and communication modules.

PO1: Disciplinary Knowledge: 3 (strong or direct relation)

Justification: Interfacing microcontrollers with peripherals is a core aspect of disciplinary knowledge in microcontroller systems.

CO4: Design and implement real-time systems using microcontrollers for applications with time-critical requirements.

PO1: Disciplinary Knowledge: 3 (strong or direct relation)

Justification: Designing and implementing real-time systems directly contribute to disciplinary knowledge in microcontroller applications.

PO2: Critical Thinking and Problem Solving: 3 (strong or direct relation)

Justification: Designing real-time systems involves critical thinking and problem-solving skills.

CO5: Develop embedded systems using microcontrollers for specific applications, considering constraints such as power, memory, and processing speed.

PO1: Disciplinary Knowledge: 3 (strong or direct relation)

Justification: Developing embedded systems aligns with disciplinary knowledge in microcontroller applications.

PO2: Critical Thinking and Problem Solving: 3 (strong or direct relation)

Justification: Considering constraints and designing embedded systems require critical thinking and problem-solving skills.

CO6: Utilize debugging tools and techniques to identify and rectify errors in microcontroller programs.

PO2: Critical Thinking and Problem Solving: 3 (strong or direct relation)

Justification: Debugging programs involves critical thinking and problem-solving skills.

CO7: Implement interrupt-driven programming for handling events and improving system responsiveness.

PO2: Critical Thinking and Problem Solving: 3 (strong or direct relation)

Justification: Implementing interrupt-driven programming requires critical thinking and problem-solving skills.