DEPARTMENT OF PHYSICS

M.Sc. Physics

P.G. PROGRAMME

SYLLABUS

Effective from the Academic Year 2012-2013

Loyola College (Autonomous)

Chennai- 600 034

Sem	Cate	Code	Title	Hrs	Crs

I	MC	PH 1817	CLASSICAL MECHANICS	5	4
I	MC	PH 1818	ELECTRODYNAMICS	6	4
I	MC	PH 1819	ELECTRONICS AND PROGRAMMING	6	4
I	MC	PH 1820	MATHEMATICAL PHYSIVS - I	5	4
I	MC	PH 1821	PRACTICAL I	8	4
II	MC	PH 2814	EMBEDDED SYSTEMS	6	5
II	MC	PH 2815	MATHEMATICAL PHYSICS II	5	5
II	MC	PH 2816	QUANTUM MECHANICS - I	5	5
II	MC	PH 2817	PRACTICAL II	8	5
II	ES	PH 2956	GEOPHYSICS	4	3
II	ES	PH 2957	GRAVITATION AND COSMOLOGY	4	3
II	ES	PH 2958	PARTICLE PHYSICS	4	3
III	MC	PH 3914	STATISTICAL MECHANICS	6	5
III	MC	PH 3815	SPECTROSCOPY	6	5
III	MC	PH 3816	PRACTICAL III	8	5
III	ID	PH 3875	NANO SCIENCE	6	5
III	ES	PH 3953	CRYSTAL PHYSICS	4	3
III	ES	PH 3954	DATA COMMUNICATION AND COMPUTER NETWORKS	4	3
III	ES	PH 3955	REACTOR PHYSICS	4	3
IV	MC	PH 4810	QUANTUM MECHANICS II	6	5
IV	MC	PH 4811	NUCLEAR PHYSICS	6	5
IV	MC	PH 4812	SOLID STATE PHYSICS	6	5
IV	MC	PH 4813	PROJECT	12	9

LOYOLA COLLEGE (AUTONOMOUS)
CHENNAI - 600 034.

PH 1817 CLASSICAL MECHANICS

SEMESTER	: I	CATEGORY	: MC
HRS/WEEK	: 5	CREDITS	: 4

Objectives: To introduce the classical formulation approaches like Lagrangian and Hamiltonian dynamics in understanding mechanical systems and solving of problems.

Unit 1: LAGRANGIAN FORMULATION - Mechanics of a system of particles - Constraints - D'Alembert' s principle - Lagrange equations - velocity dependent potentials - applications - Variational principle - Hamilton's principle - Non - holonomic systems - Conservation theorems and symmetry properties. Two - body central force problem - equations of motion - first integrals - classification of orbits - conditions for closed orbits - Kepler's problem - scattering in a central force field -Lab frame - center of mass frame transformation.

Unit 2: RIGID BODY DYNAMICS - Kinematics - degrees of freedom - Euler angles - Euler's theorem on the motion of a rigid body - Rotations - finite and infinitesimal. Angular momentum and kinetic energy - Inertia tensor - Principal axes - Euler's equations - Torque free motion of a rigid body - Symmetric top - Precession and nutation - applications – Motion in rotational frames – centrifugal and coriolis force.

Unit 3: HAMILTONIAN FORMULATION - Legendre transformation and Hamiltonian equations - Cyclic coordinates and conservation theorems - Hamiltonian equations from Variational principle - Canonical transformations- - Poisson brackets - equations of motion - conservation theorems in Poisson bracket formulation - angular momentum Poisson brackets - generation of canonical transformations.

Unit 4: Canonical Transformations: Hamilton-Jacobi theory **-** Hamilton - Jacobi equation - Hamilton's principal function - free particle in Cartesian coordinates - central force in spherical polar coordinates - application to harmonic oscillator problem - Action-

angles - Kepler's problem - action angle variables - simple harmonic oscillator.

Unit 5: SMALL OSCILLATIONS - the eigenvalue equation - the principal axis transformation - free vibration - normal coordinates - linear triatomic molecule – double pendulum – triple pendulum – triple parallel pendulum.

BOOKS FOR STUDY:

1. Classical Mechanics by H.Goldstein, Charles Poole and John Sabko, 3rd edition, Pearson Education India, (2002)
2. Lagrangian and Hamiltonian mechanics, by M.G.Calkin, 1st Indian Reprint, Allied Publishers (2000)

BOOKS FOR REFERENCE:

1. Classical Mechanics by P.V.Panat, 5th Edition, Alpha Science International, (2005)
2. Classical Mechanics by K.N.Srinivasa Rao, Universities Press(India) Private Limited (2003)
3. Lagrangian dynamics, Schaum S Outline Series by Dare A. Wells, McGraw - Hill Education (India) Pvt Ltd, (2005)
4. Problems and solutions on Mechanics, Edited by Yung - Kuo Lim, Sarat Book House, (2001)
5. Classical Mechanics by Rana & Joag, Rana,24th Reprint, Tata McGraw-Hill Education, (2001)
6. Classical Dynamics of Particles and Systems by Stephen T. Thornton, Jerry B. Marion,5th Edition, Brooks/Cole, (2004)
7. Classical Mechanics: An Undergraduate Text by R. Douglas Gregory , Cambridge University Press, (2006)

PH 1818 ELECTRODYNAMICS

SEMESTER	: I	CATEGORY	: MC
HRS/WEEK	: 6	CREDITS	: 4

Objective: To study the laws governing the distribution and propagation

of electromagnetic fields created by static and dynamic charge distributions and their interaction with matter.

UNIT 1: Electric and Magnetic potential : Divergence and curl of **E** - Electric scalar potential - Poison's and Laplace's equations - uniqueness theorems - potential of a localised charge distribution - electric potential - energy of a continuous charge distribution - multi pole expansion: approximate potentials at large distances - - monopole and dipole terms - electric dipole moment - electric field of a dipole.

Divergence and curl of **B** - Energy in the magnetic fields due to current carrying elements - Magnetic vector potential - magnetic potential at any point due to current carrying elements - multi pole expansion of the vector potential - magnetic dipole moment - magnetic field of a dipole.

UNIT 2: Electrodynamics: Maxwell's equation in free space and in matter, displacement current, boundary conditions, Gauge transformations - Coulomb and Lorentz gauge - momentum - Poynting's theorem - Polarisation - monochromatic plane waves - energy and momentum in electromagnetic waves.

Propagation in linear media - reflection and transmission at (i) normal incidence (ii) oblique incidence - laws of geometrical optics - Fresnel's equation - Brewster's angle - boundary conditions - absorption and dispersion in conductors - skin depth - reflection at a conducting surface - dispersion and anomalous dispersion - Cauchy's formula

UNIT 3: Relativistic electrodynamics: Four vectors - tensor algebra, Lorentz transformation - invariance of Maxwell's equations under Lorentz transformation - transformation of electromagnetic field intensities - electromagnetic field tensor - electromagnetic field invariants - covariant form of Maxwell's equations - electromagnetic energy - momentum tensor, conservation laws of vacuum electrodynamics.

Relativistic Lagrangian for a free particle - energy - momentum of a free particle - Lagrangian and Hamiltoninan for a charged particle in an electromagnetic field.

UNIT 4: Electromagnetic radiation: Retarded scalar and vector potentials - Lienard - Wiechert potentials for a moving point charge

- electric and magnetic fields of a moving point charge, velocity and acceleration fields.

Electric dipole radiation - magnetic dipole radiation - radiation from an arbitrary source - power radiated by a point charge - Larmor formula - Lienard's generalization of the Larmor formula - radiation reaction - Abraham Lorentz formula.

UNIT 5: Guided waves and magneto hydrodynamics (MHD):

Essential conditions for guided waves - TEM waves in coaxial cables - TE waves - rectangular wave guide - electric and magnetic fields on the surface and inside rectangular wave guide - TE and TM waves in rectangular wave guide - cut off frequency and wavelength - circular waveguides - energy flow and attenuation in wave guides - cavity resonators - phase and group velocity

MHD - Definitions - magneto hydrodynamic equations - magnetic diffusion - viscosity and pressure

BOOKS FOR STUDY:

1. Introduction to electrodynamics by David Jeffery Griffiths, 3rd edition, Prentice Hall (1999)
2. Classical electrodynamics by John David Jackson, 3rd edition, Wiley Eastern Ltd. (1999)
3. Electrodynamics by Gupta Sl, Kumar V, Singh Sp 2nd edition, Pragati Prakashan (2001)
4. Introduction to Electrodynamics by Anton Z. Capri, P. V. Panat Narosa publishing house, New Delhi (2002)
5. Electromagnetic fields and waves by V. V. Sarwate, Reprint 2006, New Age International (P) Publishers (formerly Wiley Eastern limited) (1993)

LOYOLA COLLEGE (AUTONOMOUS)
CHENNAI - 600 034.

PH 1819 ELECTRONICS AND PROGRAMMING

SEMESTER : I | CATEGORY : MC
HRS/WEEK : 6 | CREDITS : 4

Objective : The students are exposed to the wide applications of Operational amplifiers and focuses on in depth understanding of the architecture and working of microprocessor Intel 8086. This paper also introduces the learner to the basics of C++ programming with emphasis on using C++ to solve physics related problems.

UNIT I : Operational Amplifiers and A/D & D/A Converters

Ideal Op - Amp - inverting, non - inverting, logarithmic, summing and difference amplifiers - integrator and differentiator - OP- AMP as a comparator - CMRR – differential amplifier – A/D and D/A converters.

Applications: Solving simultaneous and differential equations - weighted resistor and R - 2R D/A converters - parallel, binary counter and successive approximation AID converters. -

UNIT II : Intel 8086 Architecture, Instruction set and Introduction to Macro Assembler (ASM86)

CPU architecture - addressing modes - instruction formats - instruction set - execution timing - Assembler directives – assembler operators - assembling process - translation of assembler instructions - simple programs.

UNIT III : Modular Programming and Multiprogramming

Linking and relocation - access to external identifiers – procedures - interrupts and their routines –macros - process management and IRMX86 - semaphore operations - common procedure sharing.

UNIT IV : I/O consideration, Interrupts and System bus structure

Programmed I/O - Interrupt I/O - block transfer and DMA - basic 8086 bus configuration - minimum and maximum modes - system bus timings - interrupt priority management - single and multiple

8259.

Applications (Units II to IV): Assembly language programs involving arithmetic and logical operations - use of subroutines - manipulating arrays - solving equations - keys and LEDs interface –- delays - interfacing D/A and D/A converters - generation of waveforms - simulation of counter and successive approximation AID converters.

UNIT V : Programming in C++

Basic program structure - Simple data types, variables, constants, operators, comments - Control Flow; if, while, for, do - while, switch – Functions, Types, parameters, prototypes, recursion - Array usage Pointers, addresses and types, call by reference Pointer - array duality, Strings - Arrays of pointers - Structures - Member accessing - pointers to structures - Arrays of structures, linked lists

BOOKS FOR STUDY:

1. Electronic fundamentals and applications by John Douglas Ryder, 5th edition, Prentice - Hall (1976)
2. Digital principles and applications by Donald P. Leach, Albert Paul Malvino, 4th edition, McGraw - Hill (1986)
3. Microcomputer systems: the 8086/8088 family: architecture, programming, and design by Yu - cheng Liu, Glenn A. Gibson, 2nd Edition, Prentice - Hall (2006)
4. Microprocessors and Interfacing: Programming and Hardware, Intel Version by Douglas V. Hall, Tata McGraw - Hill, 2005.
5. Fundamentals of Microprocessor - 8086 by V Vijayendran, 3rd Edition, Viswanathan, S., Printers & Publishers Pvt Ltd (2009)
6. Teach yourself C++ by Herbert Schildt, 3rd edition, Tata McGraw Hill (2008).

BOOKS FOR REFERENCE:

1. Electronic Devices & Circuits by Millman Jacob , Christos Halkias, Satyabrata Jit, McGraw - Hill (2010)

2. Microprocessor architecture, programming, and applications with

the 8085/8080A by Ramesh S. Gaonkar, 2nd Edition, Merrill Pub. Co.(1989)

3. The Intel microprocessors: 8086/8088, 80186/80188, 80286, 80386, 80486, Pentium, and Pentium Pro processor by Barry B. Brey, 4th edition, Prentice - Hall of India, New Delhi (1997)

4. The 8086/8088 Family - Design, Programming and Interfacing, Software, Hardware and Applications by Uffrenbeck J, Prentice - Hall of India, New Delhi (1987)

5. The 8086/8088 Microprocessors: Programming, Interfacing, Software, Hardware and Applications by Tribel W.A., Avtar Singh, 3rd Edition Prentice - Hall of India, New Delhi (2000).

PH 1820 MATHEMATICAL PHYSICS - I

SEMESTER	: I	CATEGORY	: MC
HRS/WEEK	: 5	CREDITS	: 4

OBJECTIVE: The foundations to various mathematical techniques and tools like numerical methods, transform techniques and special functions which forms the back bone of all higher physics is introduced.

UNIT 1: NUMERICAL METHODS:

Solution of Nonlinear equations: Newton - Raphson method – Regula Falsi method

Solutions of system of linear equations: Gauss elimination method with and without pivoting - Gauss - Siedel iterative method

Solution of ordinary differential equations: Euler method - Euler modified method – Runge - Kutta method(2nd order)

UNIT 2: COMPLEX ANALYSIS:

Analytic function - Cauchy - Riemann equations - Laplace equation and harmonic function - Line integral in complex plane - Cauchy's theorem - multiply connected regions - Cauchy integral formula -

Derivatives of analytic function - Taylor and Laurent series - Singularities - Residue theorem - Evaluation of real integrals

Application: Potential theory - (1) Electrostatic fields and complex potentials - Parallel plates, coaxial cylinders and an annular region (2) Heat problems - Parallel plates and coaxial cylinders

UNIT 3: LINEAR VECTOR SPACE:

Basic concepts – examples of vector spaces – scalar product: orthogonality – Schmidt orthogonalization procedure – linear operators – Dual space: ket and bra notation – basis – orthogonal basis – change of basis – Isomorphism of vector spaces – projection operator – Eigen values and eigen functions – Direct sum and invariant subspaces – orthogonal transformations and rotations

UNIT 4 : TENSOR ANALYSIS:

Tensors in Physics - Notation and conventions - Contra and covariant tensors of rank one and two - Transformation from Cartesian to polar coordinates - Algebra of tensors - outer and inner products - Contraction - Symmetric and anti symmetric tensors - Quotient law - Conjugate tensors - Metric tensor - Raising and lowering of indices

Cartesian tensors - Rotation and translation - Orthogonal transformations - Transformation of divergence and curl of vectors - Stress, strain and Hooke's law - Piezoelectricity and dielectric susceptibility - Moment of inertia tensor

UNIT 5 : SPECIAL FUNCTIONS - I

Series solution with simple examples - Gamma and Beta functions - Properties - Legendre polynomial and function - Generating function - Rodrigue formula – Orthogonality property - Associated Legendre function - Recurrence relations - spherical harmonics - Graphs of Legendre functions - Bessel function - Generating function - Hankel function - Recurrence relations - Spherical Bessel function - Graphs - Orthonormality relation

BOOKS FOR STUDY:

1) Mathematical Physics by H.K.Dass, S. Chand & Company Limited (2010) (Unit 1)

2) Advanced Engineering Mathematics by Erwin Kreyszig, 10th Edition, John Wiley & Sons (2011) (Unit 2)

3) Mathematical methods in Classical and Quantum Physics – Tulsi Dass, Sathish K Sharma – University Press – 1998 – (Unit – 3)

4) Matrices and tensors in physics by A. W. Joshi, 3rd Edition, New Age International (1995) (unit 4)

5) Special functions for scientists and engineers by W. W. Bell, Reprint, Courier Dover Publications (2004) (Unit 5)

BOOKS FOR REFERENCE

1) Applied mathematics for engineers and physicists by Louis Albert Pipes, Lawrence R. Harvill, 3rd Edition, McGraw - Hill (1970)

2) Advanced Engineering Mathematics by Greenberg, 2nd Edition, Pearson Education India (1998)

3) Engineering mathematics by **Isaac A. Thangapandi Somasundaram A. Arumugam S.**, Vol I - III, 1st edition - Scitech Publications (India) Pvt. Ltd

4) Mathematical Methods for Physicists by George Arfken, Hans-Jurgen Weber,6th Edition, Academic Press, (2003)

5) Mathematical Methods for Physics and Engineering: A Comprehensive Guide by K. F. Riley , M. P. Hobson , S. J. Bence , 3rd Edition, Cambridge University Press(2006)

6) Mathematical Methods in the Physical Sciences by Mary L. Boas,3rd Edition, Wiley, (2006)

7) Special Functions and Their Applications by Nikola- Nikolaevich Lebedev, Courier Dover Publications, (1972)

PH 1821 PRACTICAL I

SEMESTER : I **CATEGORY : MC**
HRS/WEEK : 8 **CREDITS : 4**

Objectives: The course aims at exposing the students to the intricacies of handling sophisticated equipments, designing electronic circuits, trouble shooting and analysis of results.

In each Semester, the laboratory sessions must expose the students to a minimum of eighteen experiments conducted in two cycles of nine experiments each.

1. Transistorised Amplifier - RC coupled
2. Power Amplifier - IC
3. Design of Gates - transistor (NOT, AND, OR, NAND)
4. A/D converter - Parallel conversion using LM339
5. 7 segment display - 2 digit optically controlled counter
6. 555 Timer - Astable Multivibrator
7. 555 Timer - Temperature control (thermistor)
8. Op - Amp 741 - Introduction (basic functionality)
9. Op - Amp 741 - Solving Simultaneous Equations
10. Op - Amp 741 - Second order filters
11. Op - Amp 741 - Astable Multivibrator
12. Op - Amp 741 - D/A converter (R - 2R & Weighted)
13. Microprocessor 8086 - Introduction I (arithmetic - immediate mode)
14. Microprocessor 8086 - Introduction II (arithmetic and logical - all modes)
15. Microprocessor 8086 - Introduction III (code conversions and arrays)
16. Microprocessor 8086 - Solving equations
17. Microprocessor 8086 - Subroutines
18. “C++” - Language - Introduction I (simple programs)
19. “C++” - Language - Introduction II (arrays & matrices)
20. Elastic constants of glass - Cornu’s method
21. Iodine absorption spectrum - Spectroscopic constants
22. Arc Spectra - Hartman’s Interpolation

23. Susceptibility - Quinke’s method
24. Stefan’s Constant - determination

The staff in - charge shall select any 15 from this list. The remaining 3 experiments can be chosen from this list or can be new experiments included by the staff in - charge with prior approval of the department.

BOOKS FOR REFERENCE:

1. Introduction To Microprocessors For Engineers And Scientists by P. K. Ghosh, P. R. Sridhar, 2nd Edition, Prentice - Hall of India, New Delhi (2001).
2. Microcomputer systems: the 8086/8088 family: architecture, programming, and design by Yu - cheng Liu, Glenn A. Gibson, 2nd Edition, Prentice - Hall (2006)
3. The Intel microprocessors: 8086/8088, 80186/80188, 80286, 80386, 80486, Pentium, and Pentium Pro processor by Barry B. Brey, 4th edition, Prentice - Hall of India, New Delhi (1997)
4. The C programming language by Brian W. Kernighan, Dennis M. Ritchie, 2nd Edition, Prentice Hall (1988)
5. Teach yourself C++ by Herbert Schildt, 3rd edition, Tata McGraw Hill (2008).

PH 2814 EMBEDDED SYSTEMS

SEMESTER : II **CATEGORY :**
HRS/WEEK : 6 **CREDITS : 5**

Objective : This paper aims at introducing the learner to the very popular Intel 8051, the PIC24 family and the widely used ARM7 embedded processors.

UNIT 1 : 8051 ARCHITECTURE AND PROGRAMMING

Architecture – memory organization – addressing modes – instruction set – Timers - Interrupts - I/O ports, Interfacing I/O Devices – Serial Communication - Assembly language programming – Arithmetic Instructions – Logical Instructions –

Single bit Instructions

Applications: Timer Counter Programming – Serial

Communication Programming – Interrupt Programming – LCD digital clock / thermometer.

UNIT 2 : PIC18/24 ARCHITECTURE

Architecture – memory organization – addressing modes – instruction set – PIC programming in Assembly & C–I/O port, Data Conversion, RAM & ROM Allocation, Timer programming, MP - LAB.

UNIT 3 : PIC18/24 PERIPHERALS

Peripherals - Timers – Interrupts - I/O ports - I^2C bus - A/D converter – UART - CCP modules.

Applications: Interfacing ADC, DAC, Sensor, LCD Display and Keypad - Generation of Gate signals for converters and Inverters - Motor Control – Controlling AC appliances – Measurement of frequency - Stand alone Data Acquisition System.

UNIT 4 : ARM ARCHITECTURE

Advanced RISC Machine – Core & Architectures - Registers – Pipeline - Interrupts – ARM organization - ARM processor family – Co - processors. Instruction set – Thumb instruction set – Instruction cycle timings -

UNIT 5 : ARM PROGRAMMING

The ARM Programmer's model – ARM Development tools – ARM Assembly Language Programming and 'C' compiler programming – simple programs – debugging.

BOOKS FOR STUDY:

1. Programming and customizing the 8051 microcontroller by Michael Predko, McGraw - Hill(1999)
2. PIC microcontroller and embedded systems: using Assembly and C for PIC18 by Muhammad Ali Mazidi, Rolin D. McKinlay, Danny Causey, Pearson Prentice Hall (2008)
3. Arm System Developer's Guide: Designing and Optimizing System

Software by Andrew N. Sloss, Dominic Symes, Chris Wright, Morgan Kaufmann, Elsevier (2004)

REFERENCE:

1. PIC microcontroller project book by John Lovine, McGraw Hill (2000)
2. Arm System - On - Chip Architecture, 2/E by Steve Furber, Pearson Education India (2001)
3. ARM Architecture Reference Manual
4. www.arm.com

PH 2815 MATHEMATICAL PHYSICS II

SEMESTER : II	CATEGORY : MC
HRS/WEEK : 5	CREDITS : 5

OBJECTIVE: Advanced mathematical tools essential for various theoretical models in all branches of physics are introduced with aim to enable students solve problems.

UNIT 1 : INTEGRAL TRANSFORM:

Laplace transform and its inverse - Transforms of derivatives and integrals - Differentiation and integration of transforms - Transforms of Heavyside and Dirac delta functions.

Application: (1) Response of an RC circuit to a single square wave (2) Response of a damped vibrating system to a single square wave and to a unit impulse (3) Systems of two differential equations - two masses connected by a spring

Fourier transform and its inverse - Fourier transform of elementary functions - Transform of Gaussian function and Dirac delta function - Fourier transform of derivatives - Cosine and sine transforms - Convolution theorem.

Application: Diffusion equation: Flow of heat in an infinite and in an semi - infinite medium - Wave equation : Vibration of an infinite string and of a semi - infinite string - Laplace equation: Potential problem in a semi - infinite strip

UNIT 2 : PARTIAL DIFFERENTIAL EQUATIONS:

Solution of partial differential equations of first order - Solution of initial and boundary value problem by Laplace transform method: Diffusion equation, wave equation - Finite Fourier sine and cosine transform methods -

UNIT 3: SPECIAL FUNCTION - II

Hermite polynomials - Generating function - Orthogonality properties - Recurrence relations - Laguerre polynomials - Generating function - Orthogonality properties - Recurrence relation - Associated Laguerre polynomial - Properties - The error function and related functions

UNIT 4 : GROUP THEORY:

Groups - Symmetry transformation of a square - Conjugate element and classes - multiplication of classes - Subgroups - cyclic group - Normal subgroups and factor groups - Direct product of groups - Isomorphism and homomorphism - Permutation groups - Distinct groups - representation theory of finite groups - Molecular point groups - irreducible representation of point groups - reducible representation - Schur's lemma and the orthogonality theorem - character of the representation - the example of C_{4V} – irreducible representation and regular representation - Continuous groups and their representations - Lie groups - Axial rotation group SO (2) - Three dimensional rotation groups SO (3) and SU(2)

UNIT 5: PROBABILITY :

Definitions - Laws of probability - - Mean, Standard deviation – Poisson distribution - Binomial distribution - Normal distribution - Moments of distribution - Recurrence relations - Sampling of variables - Variance - The t - distribution - The Chi - Square distribution

BOOKS FOR STUDY:

1. Introduction to Partial Differential Equations by Rao Sankara 2nd

edition, Prentice - Hall of India (2005) (Unit 1 and 2)

2. Advanced Engineering Mathematics by Erwin Kreyszig, 10th Edition, John Wiley & Sons (2011)(partly for unit 1)

3. Special functions for scientists and engineers by W. W. Bell, Courier Dover Publications (2004)(Unit 3)

4. Elements of group theory for physicists by A.W. Joshi, 4th Edition, New Age International (2007) (Unit 4)

5. Mathematical Physics by H.K.Dass, S. Chand & Company Limited (2010) (Unit 5)

BOOKS FOR REFERENCE

1. Applied mathematics for engineers and physicists by Louis Albert Pipes, Lawrence R. Harvill, 3rd Edition, McGraw - Hill (1970)

2. Advanced Engineering Mathematics by Greenberg, 2nd Edition, Pearson Education India (1998)

3. Engineering mathematics by **Isaac A. Thangapandi Somasundaram A. Arumugam S.**, Vol I - III, 1st edition - Scitech Publications (India) Pvt. Ltd

4. Group theory and quantum mechanics by Michael Tinkham, Courier Dover Publications, Tata McGraw - Hill(2003)

5. Mathematical Methods for Physicists by George Arfken, Hans-Jurgen Weber,6th Edition, Academic Press, (2003)

6. Mathematical Methods for Physics and Engineering: A Comprehensive Guide by K. F. Riley , M. P. Hobson , S. J. Bence , 3rd Edition, Cambridge University Press(2006)

7. Mathematical Methods in the Physical Sciences by Mary L. Boas,3rd Edition, Wiley, (2006)

8. Special Functions and Their Applications by Nikola- Nikolaevich Lebedev, Courier Dover Publications, (1972)

9. Mathematical Methods In Classical And Quantum Physics by Tulsi Dass, S.K. Sharma, Universities Press, (1998)

LOYOLA COLLEGE (AUTONOMOUS)
CHENNAI - 600 034.

PH 2816 QUANTUM MECHANICS - I

SEMESTER	: II	CATEGORY	: MC
HRS/WEEK	: 5	CREDITS	: 5

Object: To introduce the fundamental concepts of quantum mechanics like representations theory, approximation methods angular momentum, scattering etc.

Unit – 1: General Formalism

Linear vector space – linear operators – postulates – uncertainty principle – Dirac's notation – equations of motion – momentum representation.

Free particle – finite potential well – potential barrier – linear harmonic oscillator (operator method alone) – Hydrogen atom.

Unit – 2: Matrix Formalism (Representation theory)

Matrix representation of state vectors – operators – continuous case –change of representation – eigen value problems – different representations – unitary transformations involving time – Heisenberg method – Harmonic oscillator – matrix representation of spin – spinors- expectation values – magnetic moment of an electron – precision of electron in magnetic field.

Unit – 3: Approximation methods

Time independent perturbation theory – non-degenerate energy levels – anharmonic oscillator – ground state of Helium atom – degenerate levels – Stark effect – spin-orbit interaction – variational method – Hydrogen molecule.

Unit – 4: Angular momentum

Angular momentum operator – commutation relation – eigen values and eigen functions of L^2 and L_z – general angular momentum – eigen states and eigen values of J^2 and J_z – angular momentum matrices – spin angular momentum – spin - $\frac{1}{2}$ systems – addition of angular momentum - Clebsch - Gorden Coefficients.

Unit – 5: Scattering theory and applications

Scattering cross section – scattering amplitude – partial waves – scattering by a central potential – partial wave analysis – scattering by a square well potential – Breit – Wigner formula – scattering length – phase shifts – Born approximation – scattering by screened Coulomb potential – validity of Born approximation – laboratory and centre of mass coordinate systems.

BOOKS FOR STUDY:

1. Quantum Mechanics by G Aruldhas, Prentice Hall India Learning Pvt. Ltd., 2004
2. Quantum Mechanics by B. K. Agarwal, Hari Prakash, Prentice Hall India Learning Pvt. Ltd., 2004
3. Quantum Mechanics: For M.phil, M.Sc., B.Sc. Students of Indian and Foreign Universities NET, SLET, UGC - CSIR & Other Entrance Examination by S L Kakani, H M Chandalia, Sultan Chand (2007)
4. Quantum Mechanics by V. K. Thankappan, 2nd Edition, New Age International (1993)

BOOKS FOR REFERENCE:

1. A text book of Quantum Mechanics by Piravonu Mathews Mathews, K. Venkatesan, 36th Edition Tata McGraw - Hill Education, (1978)
2. Quantum Mechanics: Concepts and Applications by Nouredine Zettili, 2nd Edition, John Wiley & Sons, (2009)
3. Quantum mechanics Vol. 1 by Claude Cohen - Tannoudji, Bernard Diu, Franck Laloë, Wiley, (1977)
4. Quantum mechanics: an introduction by Walter Greiner, 4th Edition, Elsevier Springer, (2001)
5. Introduction to Quantum Mechanics by David J. Griffith, 2nd Edition, Pearson Education India, (2005)
6. Principles of Quantum Mechanics by Ramamurti Shankar, 2nd

Edition, Springer, (1994)

7. Modern Quantum Mechanics by J.J. Sakurai, Pearson Education India

PH2817 - PRACTICAL II

SEMESTER : II	CATEGORY :
HRS/WEEK : 8	CREDITS : 5

Objectives: The course aims at exposing the students to the intricacies of handling sophisticated equipments, designing electronic circuits, trouble shooting and analysis of results.

In each Semester, the laboratory sessions must expose the students to a minimum of eighteen experiments conducted in two cycles of nine experiments each.

1. 7 segment display - 2 digit optically controlled counter
2. Op - Amp 741 - Solving Simultaneous Equations
3. Op - Amp 741 - Second order filters
4. Microprocessor 8086 - Subroutines
5. Microprocessor 8086 - Interface I (LEDs)
6. Microprocessor 8086 - Interface II (LEDs & switches)
7. Microprocessor 8086 - Interface III (Freq. generation)
8. Microprocessor 8086 - Interface IV (Waveform generation)
9. Microprocessor 8086 - Interface V (Traffic lights simulation)
10. Microprocessor 8086 - Introduction I (simple programs - all modes of addr.)
11. Microprocessor 8086 - Introduction II (equations and arrays)
12. “C++” - Language - Introduction III (use of library functions)
13. “C++” - Language - Introduction IV (Numerical methods)
14. MASM - Introduction I (using DOS interrupt 21h)
15. Turbo Debugger - Introduction I (simple programs - Trace mode)
16. Elastic constants of glass - Cornu’s method

17. Dielectric studies
18. Electrical conductivity studies - Four Probe Method
19. GM counter – Feather Analysis.

The staff in - charge shall select any 15 from this list. The remaining 3 experiments can be chosen from this list or can be new experiments included by the staff in - charge with prior approval of the department.

BOOKS FOR REFERENCE:

1. Introduction To Microprocessors For Engineers And Scientists by P. K. Ghosh, P. R. Sridhar, 2nd Edition, Prentice - Hall of India, New Delhi (2001).
2. Microcomputer systems: the 8086/8088 family: architecture, programming, and design by Yu - cheng Liu, Glenn A. Gibson, 2nd Edition, Prentice - Hall (2006)
3. The Intel microprocessors: 8086/8088, 80186/80188, 80286, 80386, 80486, Pentium, and Pentium Pro processor by Barry B. Brey, 4th edition, Prentice - Hall of India, New Delhi (1997)
4. The C programming language by Brian W. Kernighan, Dennis M. Ritchie, 2nd Edition, Prentice Hall (1988)
5. Teach yourself C++ by Herbert Schildt, 3rd edition, Tata McGraw Hill (2008).

PH 2955 ASTROPHYSICS

SEMESTER : II	CATEGORY : ES
HRS/WEEK : 4	CREDITS : 3

Objects: To provide basic understanding about Astronomy, Stellar evolution, structure of stars and energy production mechanism in a star

Unit 1: General Astronomy

System of Coordinates - Altazimuth, Equatorial (local and Universal), Ecliptic and Galactic systems. Magnitude scale and magnitude systems - correction for observed magnitudes. The proper motion - stellar parallax - Trignometric, cluster and secular

parallaxes. Method of Luminosity distance.

Unit 2: Stellar temperatures and sizes

Colour and effective temperatures - defining stellar temperatures by matter laws - HR diagram - Spectral and luminosity classification of stars. Measurement of stellar radii - Relation of luminosity with mass, radii and surface temperature. Binary stars -visual, spectroscopic and eclipsing binaries.

Unit 3: Stellar structure

Equations of stellar structure - Russel - Vogt theorem - Ideas of polytropic model - stellar opacity - Free - Free transitions, Bound - Free transitions and electron scattering. Eddington's standard model. Homologous model for main sequence stars - Schwarzchild's model for real stars.

Unit 4: Stellar evolution

The virial theorem - application to an isothermal gas sphere - -evolution of stars near the main sequence - effect of hydrogen depletion - Schoenberg - Chandrasekhar limit of an isothermal core - -nuclear time scale - ages of clusters - Star formation - Jean's criterion.

Unit 5: Stellar energy sources

Thermonuclear fusion - CN cycle - pp chain - simple formulae for the energy generation rates - abundances for the elements in the stars- structure of the sun from helioseismology - problems of nucleosynthesis.

BOOKS FOR STUDY:

1. Astrophysics: Stars and Galaxies by Abhyankar K D, Tata Mac Graw Hill (1992)
2. Text Book of Astronomy and Astrophysics with elements of Cosmology by V.B.Bhatia, Narosa Publishing House.
3. An Introduction to Astrophysics by Baidyanath Basu, Prentice Hall India Learning Pvt. Ltd.(2003)

BOOKS FOR REFERENCES:

1. An Introduction to the Sun and Stars by Simon F. Green, Mark H. Jones, S. Jocelyn Burnell, Cambridge University Press(2004)

2. Compendium of practical astronomy, Volume 1 by Günter Dietmar Roth, Springer (1994)

3. The physics of stars by A. C. Phillips, 2nd Edition, John Wiley (1999)

PH 2956 GEOPHYSICS

SEMESTER : II CATEGORY : ES
HRS/WEEK : 4 CREDITS : 3

Objective: To provide brief introduction to seismology and to have a look at the experimental data supporting electric and magnetic properties of earth.

Unit 1: seismology:

Introduction - Seismology - P - waves - S waves, their velocities - Time distance curves and the location of epicenters - Effect of Boundaries - Major discontinuities - Properties of rocks and minerals and factors that control them - .Seismic energy sources - Detectors. Reflection and refraction field surveys and interpretation of time and distance curves.

Unit 2: internal structure of earth

Introduction - Seismic waves - Rayleigh waves and Love waves - Study of earth by seismic waves - Earthquake seismology - Horizontal and vertical seismograph - Seismograph equation - Internal structure of earth.

Unit 3: Earth's age and electrical properties:

Geochronology - Radioactivity of the earth - Radioactive dating of rocks and minerals - Geological time scale - Geoelectricity - AC and DC type resistivity meters. Factors affecting resistivity. Field data collection and interpretation - Application of resistivity method and engineering.

Unit 4:Geomagnetism :

Geomagnetism - Definitions, magnetic field, main field, external

field and local anomalies, rock susceptibility - - Method of Gauss - Saturation induction magnetometers - Proton precession

magnetometer - - Dynamo theory of earth magnetism - Magnetic surveying - application.

Unit 5:Geodynamics:

Plate dynamics - Earth's size and shape - Earth's rotation - absolute and relative methods of Measurement of gravity - Gravity measurements - reduction of gravity data - separation of regional and residual. Interpretation of gravity data obtained over spherical and cylindrical objects - Application of gravity methods.

BOOKS FOR STUDY:

1. Outlines of geophysical prospecting: a manual for geologists by M. B. Ramachandra Rao, University of Mysore(1975)
2. Applied Geophysics by William Murray Telford, W. M. Telford, L. P. Geldart, Robert E. Sheriff, R. E. Sheriff, 2nd Edition, Cambridge University Press (1990)
3. Gravity and magnetic methods of prospecting by B. S. Rama Rao, I V R Murthy, 4th Edition, Arnold - Heinemann, (1978)
4. Lectures on exploration geophysics for geologists and engineers by V. L. S. Bhimasankaram, Vinod Kumar Gaur, Association of Exploration Geophysicists, Association of Exploration Geophysicists, (1977)

BOOKS FOR REFERENCE:

1. Introduction to geophysics: mantle, core, and crust by George David Garland, 2nd Edition, Saunders, (1979)
2. Physics of the earth and planets by Alan H. Cook, Macmillan, (1973)
3. Fundamentals of Geophysics by William Lowrie, 2nd Edition, Cambridge University Press, (2007)

PH 2957 GRAVITATION AND COSMOLOGY

SEMESTER : II | CATEGORY : ES
HRS/WEEK : 4 | CREDITS : 3

OBJECTIVES: -

1. To introduce the students to the general theory of relativity with an emphasis on the physical aspects.
2. To discuss the observational inputs from astrophysics and cosmology.

Unit 1: Theories of Gravitation - Conflict between Newtonian gravitation and special relativity - general theory of relativity - Mach's principle - Space - Time and co-ordinate systems - Tensors - Parallel transport - Covariant differentiation - The Riemannian Affine connection - The Lie derivative - Space - Time curvature.

Unit 2: Geodesics - Geodesic deviation - Curvature Tensor - Scalar curvature - Energy Momentum Tensors - The action principle - Einstein equations of gravitation - a heuristic derivation - Newtonian approximation - the Schwarzschild solution - particle orbits - photon orbits.

Unit 3: The experimental tests of the general theory of relativity - the gravitational red shift - Planetary motion - the bending of light - the radar echo delay - the precession of a gyroscope - Gravitational radiation.

Unit 4: Strong Gravitational Fields - equilibrium of massive spherical objects - binding energy - gravitational collapse of a homogeneous dust ball - Black holes - external Schwarzschild solution - the Kerr - Newmann solution - Black hole physics - Detection of Black holes.

Unit 5 : Cosmology - the observational background - the cosmological postulates - cosmological red shift - the Hubble law - the Olber's paradox - red shift - magnitude relation - counting of radio sources - angular diameters - age of the universe - the abundance of

elements - the microwave background.

BOOKS FOR STUDY:

1. Lectures on Gravitation and cosmology by J.V.Narlikar, Macmillan co. (1978).
2. An introduction to general relativity by Samir Kumar Bose, Wiley, (1980).

BOOKS FOR REFERENCE:

1. General Relativity by J.L.Martin, Prentice Hall, (1996).
2. Relativity and Gravitation by Philippe Tourrence, Cambridge University Press, (1997).
3. Introduction to the Theory of Relativity by Peter Gabriel Bergmann, 2nd Edition, Prentice Hall, Courier Dover Publications, (1976).

PH 2958 PARTICLE PHYSICS

SEMESTER : II CATEGORY : ES

HRS/WEEK : 4 CREDITS : 3

OBJECTIVES: -

1) To provide a concise but accessible introduction to the standard model of particle physics.
2) To develop the theoretical concepts from the electromagnetic and weak interactions of leptons and quarks to the strong interactions of quarks.
3) To look at the experimental data supporting the model.

Unit 1: The particle physicist's view of Nature: The construction of the standard model - leptons - quarks and systems of quarks - spectroscopy of systems of light quarks - more quarks - quark colour - electron scattering from nucleons - particle accelerators.

Lagrangian formulation of Lorentz covariant field theory - the Klein - Gordon equation - the energy –momentum tensor - complex scalar fields - A Lagrangian density for electromagnetism - the

energy density of the electromagnetic field - massive vector fields.

Unit 2: The Dirac equation and the Dirac field - spinors - free space solutions of the Dirac equation - the energy and momentum of the Dirac field - Dirac equation with an electromagnetic field – charge conjugation - electrodynamics of a charged scalar field - Boson and Fermion field quantization.

Unit 3: SU(2), SU(3) symmetry – U(1) gauge symmetry – Non - Abelian (SU(2), SU(3)) gauge symmetry – Spontaneous symmetry breaking - Higgs - Kibble mechanism.

Unit 4: A theory of weak interactions - Weinberg - Salam model for electro - weak theory - Lepton and quark doublets and their couplings to W, Z and ã – Experimental tests – Search for W^+, W^- and Z bosons.

Unit 5: Quantum chromodynamics - The theory of strong interactions - A local SU(3) gauge theory - colour gauge transformations on quarks and gluons - asymptotic freedom - the quark - anti-quark interaction at short distances.

BOOKS FOR STUDY:

1. An introduction to the Standard model of particle physics by W.N.Cottingham and D.A.Greenwood, 2nd Edition, Cambridge University Press, (2007).
2. Introduction to High Energy Physics by Donald H Perkins, 4th Edition, Cambridge University Press, (2000)
3. Introduction to elementary particles by David Jeffery Griffiths, 2nd Edition, Wiley - VCH Verlag GmbH Co., (2008)
4. Gauge Theories in Particle Physics, Volume 2, by Ian Johnston Rhind Aitchison, Anthony J. G. Hey, 3rd Edition, Taylor and Francis, (2004)

BOOKS FOR REFERENCE

1. The Ideas of Particle Physics: An Introduction for Scientists by G.D.Goughlan, James Edmund Dodd, Ben Gipaios, 3rd edition, Cambridge University Press, (2006).

2. Experimental techniques in high - energy nuclear and particle physics by Thomas Ferbel, 2nd Edition, World Scientific, (1991).

3. Particle physics: the quest for the substance of substance by Lev Borisovich Okun, Harwood Academic Publishers, (1985).

4. Elementary particle physics by I.R.Kenyon, Springer, 1987

5. Facts and mysteries in Elementary Particle Physics by Martinus Veltman, World Scientific, 2007.

6. Introduction to Nuclear and Particle Physics by Ashok Das, Thomas Ferbel, 2nd Edition, World Scientific, (2007).

7. Techniques for Nuclear and Particle Physics Experiments: A How - To Approach by William R. Leo, 2nd Edition, Springer, (1994)

PH 3914 STATISTICAL MECHANICS

SEMESTER	: II	CATEGORY	: MC
HRS/WEEK	: 6	CREDITS	: 5

Objective: To create a thorough understanding of how a real system should be understood by the linking of thermodynamics with kinetic theory using statistical methods – the importance of entropy in this linking – learn the concept of ensembles – tackle the simplest case of ideal gas in different ensembles – invoke the quantum picture, density matrix and quantum gases.

Unit 1: Ensemble Theory

Foundation of statistical Mechanics – connection between statistical mechanics and thermodynamics – classical ideal gas – Gibb's paradox – phase space – Liouville's theorem, microcanonical ensemble – classical gas in microcanonical ensemble – linear harmonic oscillator – coarse graining of phase space

Unit 2: Canonical Ensembles

Classical Canonical ensembles –partition function – connection with thermodynamics – energy fluctuation – classical ideal gas in canonical ensembles - calculation of statistical quantities – equipartition theorem – classical harmonic oscillator – two level

system – concept of negative temperature – particle in a box –

linear harmonic oscillator – system with internal degrees of freedom – rigid rotator – Einstein's theory of specific heat capacity

Unit 3: Grand Canonical ensemble

Particle reservoir – grand canonical partition function – connection with thermodynamics – classical gas in grand canonical ensemble – symmetry aspect of many particle wave function – photons – number fluctuation – parametric equation of states – virial expansion – critical fluctuation – pair production – elements of quantum statistics – density matrix – pure and mixed states – properties of density matrix – density operators for quantum statistics.

Unit 4: Bose – Einstein statistics

Ideal Bose gas – its thermal properties – statistics of ensembles – black body radiation – phonons – Debye's theory of specific heat – BE condensation – Liquid helium – super fluidity

Unit 5: Ideal Fermi gas

Ideal Fermi gas – Fermi Dirac distribution –thermodynamic properties of Fermi gas – electrons in metals – electronic heat capacity – paramagnetic susceptibility – white dwarf – Chandrasekhar limit – nuclear matter.

BOOKS FOR STUDY

1. Thermodynamics and Statistical Mechanics – Walter Greiner – Springer – 1995
2. Statistical Mechanics – R K Pathria – Elsevier – second edition – 1996
3. Introduction to statistical mechanics – Kerson Huang – CRC press – 2001

BOOKS FOR REFERENCE

1. Fundamentals of Statistical and thermal Physics – F Reif – McGraw Hill – 1965

2. Statistical Physics – Laundu and Lifshitz – Butterworth –

Heinemann – 3rd Edition – 1980

3. Statistical Mechanics, Principles and selected applications – Terrell Hill – Courier Dover Publications, 1987

4. Introduction to modern statistical mechanics – David Chandler – Oxford University Press – 1987

5. Statistical Mechanics – Agarwal and Eisner – New Age International Press – 2011

PH 3815 SPECTROSCOPY

SEMESTER	: III	CATEGORY	: MC
HRS/WEEK	: 6	CREDITS	: 5

Objectives: To have in depth understanding of various techniques of spectroscopy and to study its applications to modern science.

UNIT 1: MICROWAVE SPECTROSCOPY: Rotation of molecules-Rotational spectroscopy-Rigid and non-rigid diatomic rotator-Intensity of spectral lines-Isotopic substitution-Polyatomic molecules (Linear and symmetric top)-Hyperfine structure and quadrupole effects-Inversion spectrum of ammonia-Chemical analysis by microwave spectroscopy-Techniques and instrumentation-microwave oven

UNIT 2: VIBRATIONAL SPECTROSCOPY: Infrared spectroscopy-Vibration of molecules-Diatomic vibrating rotator-Vibrational rotational spectrum-Interactions of rotations and vibrations-Influence of rotation on the Vibrational spectrum of linear and symmetric top and polyatomic molecules-Analysis by infrared techniques-Instrumentation-FTIR spectroscopy

Raman spectroscopy: Classical and quantum mechanical picture of Raman effect-Polarizability –Pure rotational Raman spectrum-Vibrational Raman Spectrum-Raman activity of vibrations of CO_2 and H_2O-Rule of mutual exclusion-Overtones and combination-Rotational fine structure-Depolarization ratio-Vibrations of spherical top molecule-structural determination from IR and Raman spectroscopy-techniques and instrumentation-FT Raman

spectrosopy

UNIT 3: ELECTRONIC SPECTROSCCOPY: Electronic spectra-Frank-Condon principle-Dissociation energy and dissociation products-Fortrat diagram-predissociation-shapes of some molecular orbits-Chemical analysis by electronic spectroscopy-Techniques and instrumentation-Mass spectroscopy-ESR spectroscopy-Introduction-techniques and instrumentation- Electronic angular momentum in diatomic molecules

UNIT 4: NUCLEAR SPECTROSOPY: Nuclear magnetic resonance spectroscopy-Introduction-Interaction of spin and magnetic field-population of energy levels-Larmor precession-Relaxation times-Double resonance- Chemical shift and its measurement-Coupling constant-Coupling between several nuclei- Quadrupole effects-C^{13} NMR spectroscopy- Interpretation of simple spectrum - Mossbauer spectroscopy: Principle-instrumentation- Isomer shift-Effect of electric and magnetic fields- Magnetic hyperfine interaction.

UNIT 5: SURFACE SPECTROCOPY AND DEVICES: Electron energy loss spectroscopy (EELS)-Reflection absorption spectroscopy (RAIRS)-Photoelectron spectroscopy (PES) – Instrumentation – interpretation of spectrum; XPES, UPES-Auger electron spectroscopy (AES) - X-ray Flourescence spectroscopy (XRF)-SIMS - Surfaces for SERS study-SERS Microbes-Surface selection rules- SEM- TEM - AFM

BOOKS FOR STUDY:

1. G. Aruldhas Molecular and Structure and Spectroscopy:, PHI Learning Private Limited 2 edition, 2007

2. Colin Banwell and Mc Cash, Fundamentals of molecular spectroscopy:, TMH publishers-5th edition, 2004

BOOKS FOR REFERENCE:

1. Rajat K. Chaudhuri, M.V. Mekkaden, A. V. Raveendran, A. Satya Narayanan Recent Advances in Spectroscopy: Theoretical, Astrophysical and Experimental Perspectives.

2. Berman Paul R., Malinovski Vladimir S. Principles of Laser Spectroscopy and Quantum Optics Princeton University Press

2011

3. Tuniz C., Kutschera W., Fink D., Herzog G.F Accelerator Mass Spectrometry
4. CRC press 2011
5. Thomas Engel Quantum Chemistry and Spectroscopy International Edition 3rd Edition Pearson Publications 2012
6. Wozniak Bogdian, Dera Jerzy Light Absorption in Sea Water Springer Publications 2011
7. www.ups.edu/faculty/hanson/chemwebsites/organicwebsites.htm
8. www.**rsc.org**/.../InterestGroups/ESRSpectroscopy/index.asp

PH3816 - PRACTICAL III

SEMESTER	**: III**	**CATEGORY**	**: MC**
HRS/WEEK	**: 8**	**CREDITS**	**: 5**

Objectives: The course aims at exposing the students to the intricacies of handling sophisticated equipments, designing electronic interface circuits, trouble shooting, programming and analysis of results.

1. Microprocessor 8086 - Interface (A/D - Counter)
2. Microprocessor 8086 - Interface (A/D - Successive approx.)
3. Microprocessor 8086 - Interface (Calculator - 16 switches)
4. Microprocessor 8086 - Interface (Stepper motor control)
5. Microprocessor 8086 - Interface (7 segment display multiplexing)
6. Microprocessor 8086 - Interface (Stop clock - light operated)
7. Microprocessor 8086 - Interface (7x5 LED dot matrix display)
8. Microprocessor 8086 - Interface (Rolling display)
9. Microprocessor 8086 - Interface (LCD display)
10. Micro controller 8051 - Introduction I

11. Micro controller 8051 - Introduction II
12. Micro controller 8051 - Interface (LCD display)

13. Embedded ARM7 – Introduction I
14. Embedded ARM7 – Introduction II
15. Embedded ARM7 – Introduction III
16. Embedded PIC – Introduction I
17. Embedded PIC – Introduction II
18. Embedded PIC – Introduction III
19. Inverter - Low D.C. to High A.C. converter
20. A/D - Binary counter - IC 7493
21. PLL - remote control applications
22. MASM - 2 digits arithmetic operations
23. Turbo Debugger - Arrays manipulations
24. "C++" - Language - Introduction to graphics
25. "C++" - Language - Interface (Stepper motor control)

The staff in - charge shall select any 10 from this list. The remaining 8 experiments can be chosen from this list or can be new experiments included by the staff in - charge with prior approval of the department.

BOOKS FOR REFERENCE:

1. Introduction To Microprocessors For Engineers And Scientists by P. K. Ghosh, P. R. Sridhar, 2nd Edition, Prentice - Hall of India, New Delhi (2001).
2. Microcomputer systems: the 8086/8088 family: architecture, programming, and design by Yu - cheng Liu, Glenn A. Gibson, 2nd Edition, Prentice - Hall (2006)
3. The Intel microprocessors: 8086/8088, 80186/80188, 80286, 80386, 80486, Pentium, and Pentium Pro processor by Barry B. Brey, 4th edition, Prentice - Hall of India, New Delhi (1997)
4. The C programming language by Brian W. Kernighan, Dennis M. Ritchie, 2nd Edition, Prentice Hall (1988)

5. Teach yourself C++ by Herbert Schildt, 3rd edition, Tata McGraw Hill (2008).

LOYOLA COLLEGE (AUTONOMOUS)
CHENNAI - 600 034.

PH 3875 NANO SCIENCE

(With the Department of Chemistry)

SEMESTER	: III	CATEGORY	: ID
HRS/WEEK	: 6	CREDITS	: 5

Objectives: The course will introduce the students to the rapidly developing field of nanoscience and technology with special focus on the methods of synthesis, characterization techniques and applications of nanomaterials with interdisciplinary approach involving Physics and Chemistry. The course is expected to provide the necessary understanding in nanotechnology and the students must be able to perform their project works related to the synthesis and characterization of nanomaterials by direct experience.

Unit 1: Fundamentals of Nanoscale Science

1.1. Introduction - nano and nature - background to nanotechnology - scientific revolutions opportunities at the nanoscale - time and length scale in structures - surfaces and dimensional space - evolution of band structures and Fermi surfaces - electronic structure of nanocrystals - bulk to nano transition - size and shapes - dimensionality and size dependent phenomena.

1.2. Energy landscapes basic intermolecular forces - interdynamic aspects of intermolecular forces.

Unit 2: Classification of nanoparticles and its properties

2.1. Metal Nanoparticles: Size control of metal nanoparticles, Structural, Surface, electronic and optical properties.

Semiconductor Nanoparticles: solid state phase transformation, Excitons, Quantum confinement effect, Semiconductor quantum dots (SQDs), Correlation of properties with size, Quantum Well, Quantum Wires, Super lattices band and Band offsets, Quantum dot lasers.

Magnetic nanomaterials: Fundamentals of magnetic materials, Dia, Para, Ferro, Ferric, and Superpara magnetic materials,

Nanostructured Magnetism.

2.2. Semiconductor Nanocomposites: Types of Nanocomposites (Metal oxides, ceramic and Glass), Core - Shell nanoparticles - Types of systems - properties of nanocomposites.

Carbon Nanostructures: Introduction, Fullerenes, C60, CNT, mechanical, optical and properties.

Unit 3: Synthesis of Nanomaterials

3.1. Physical methods: Thermal evaporation, Spray pyrolysis, Molecular beam epitaxy (MBE), Physical vapour deposition (PVD), Microwave heating, Electric arc deposition, Ion implantation.

B. Chemical methods: Chemical and co - precipitation, Sol fundamentals - sol - gel synthesis of metal oxides, Micro emulsions or reverse micelles, Solvothermal, Sonochemical synthesis, Electrochemical synthesis, Photochemical synthesis, Langmuir - blodgett (LB) technique, Chemical vapour deposition (CVD)

Unit 4: Characterization Techniques

4.1. Powder X - Ray Diffraction, Scanning electron microscope (SEM), Transmission electron microscope (TEM), Scanning tunnelling microscope (STM), Atomic force microscope (AFM), Scanning probe microscopy (SPM), UV - Visible absorption, Impedance measurement, V - I characteristics, Vibrating sample magnetometer (VSM).

4.2. Brunauer - Emmett - Teller (BET) Surface Area Analysis, Energy dispersive X - ray (EDX), X - ray photoelectron spectroscopy (XPS) and Photoluminescence.

Unit 5: Applications of Nanomaterials and Nanocomposites

5.1. Nanophotonics and Devices: ID, 2D, 3D Photonic crystals, Couplers, Waveguides, Photonic crystal fibres, Optical data storage systems and Quantum computing

Medical applications: Imaging of cancer cells, Biological tags and Targeted nano drug delivery system.

5.2. Nanosensors: Sensors based on physical properties -

Electrochemical sensors, Sensors for aerospace, defence and Biosensors.

Energy: Solar cells, LEDs and Photovoltaic device applications.

Photocatalytic applications: Air purification, Water purifications and Volatile organic pollution degradation.

Carbon nanotubes: Field emission, Fuel cells and Display devices.

BOOKS FOR STUDY:

1. Structure and properties of solid state materials by B. Viswanathan, 2nd Edition, Alpha Science International, (2006).
2. Nano - The essentials by T.Pradeep, Tata McGraw - Hill publishing company limited (2007).

BOOKS FOR REFERENCE:

1. Nanocomposite Science and Technology by Pulickel M. Ajayan, Linda S. Schadler, Paul V. Braun, John Wiley & Sons, (2006)
2. Nanoparticles: From Theory to Application by Günter Schmid, 2nd Edition, John Wiley & Sons, (2011)
3. Nanotechnology: Principles And Practices by Sulabha K.Kulkarni, Capital publishing company (2007).
4. Nanomaterials by B. Viswanathan, , Narosa Publishing House Pvt. Ltd., New Delhi, (2009)
5. Nano Materials by A. K. Bandyopadhyay, 2nd Edition, New Age International Publishers Ltd., New Delhi, (2007).
6. Encyclopedia of Materials Characterization: Surfaces, Interfaces, Thin Films by C. R. Brundle, Charles A. Evans, Shaun Wilson, Butterworth - Heinemann publishers (1992).
7. Introduction to nanotechnology by Charles P.Poole, Frank J. Owens, John Wiley & Sons publication (2003).
8. Synthesis of inorganic materials by Ulrich Schubert, Nicola Husing, 3rd Edition, John Wiley & Sons, (2012)
9. Cluster beam synthesis of nanostructured materials by Paolo Milani, Salvatore Iannotta, Springer, (1999)

Note: The first part of all sections will be handled by the Physics faculty and the second part will be handled by Chemistry faculty.

LOYOLA COLLEGE (AUTONOMOUS)
CHENNAI - 600 034.

PH 3953 CRYSTAL PHYSICS

SEMESTER : III **CATEGORY : ES**
HRS/WEEK : 4 **CREDITS : 3**

Objectives: To provide a qualitative idea on the fundamentals of growing crystals and characterizing the grown samples. This paper will serve as an eye opener for students keen in research activities particularly in experimental physics.

UNIT 1 : NUCLEATION - Different kinds of nucleation – equilibrium stability and metastable state – classical theory of nucleation – effect of soluble impurities on nucleation – determination of solubility – methods of induction period measurements – desupersaturation – steady state nucleation rate – nucleation parameters.

UNIT 2 : LOW TEMPERATURE GROWTH TECHNIQUES - Low temperature solution growth - slow cooling and slow evaporation methods - temperature gradient method - criteria for optimizing solution growth parameters - basic apparatus for solution growth. Gel growth - structure of silica gel and gelling mechanism - nucleation control - merits of gel method - experimental methods - chemical reaction method - chemical reduction method - complex de - complex method - solubility reduction method - sol gel method.

UNIT 3 : MELT AND VAPOUR TECHNIQUES - Growth from melt – Bridgman, Czochralski, zone melting, Verneuil techniques - physical vapour deposition - flux growth - chemical vapour deposition - chemical vapour transport - hydrothermal growth - epitaxial growth.

UNIT 4 : OPTICAL STUDIES - Atomic absorption spectroscopy - UV - Visible - NIR spectroscopy - Experimental set ups for Fourier Transform Infrared analysis, FT - Raman vibrational spectroscopy - Illustrations with selected crystals - Nonlinear optical phenomenon (qualitative) - Kurtz powder SHG method - photoconductivity and

schematic set up for measurements - negative photoconductivity.

UNIT 5 : CRYSTAL CHARACTERIZATION - Thermal analysis - methods of thermal analysis - thermogravimetric analysis (TGA) - Differential thermal analysis (DTA) - Differential Scanning Calorimetry (DSC) - Mechanical studies - methods of hardness testing (qualitative) - Vickers hardness testing - correlation of microhardness with other properties - estimation of hardness number and work hardening coefficient (n) - dielectric studies - dielectric constant and dielectric loss measurements.

BOOKS FOR STUDY AND REFERENCE:

1. Crystal growth processes by James Coble Brice, John Wiley and Sons, New York.(1986)
2. The growth of crystals from liquids by John Chadwick Brice North - Holland Pub. Co., (1973)
3. Crystal growth by Harold Eugene Buckley, John Wiley and Sons, New York(1951)
4. Crystal growth by Brian R. Pamplin, 2nd Edition, Pergamon, (1980)
5. Crystals in Gels and Liesegang Rings by Heinz K. Henisch, Cambridge University Press(2005)
6. Thermal Analysis: Theory and Applications by R. T. Sane, Jagdish K. Ghadge, Quest Publications, (1997)
7. Handbook of Nonlinear Optical Crystals by Valentin G. Dmitriev, Gagik G. Gurzadyan, David N. Nikogosyan, 3rd Edition, Springer, (2010)
8. Photoconductivity: Art, Science, and Technology by N. V. Joshi, Marcel Dekker, (1990)
9. Crystal growth Process and Methods by Santhanaraghavan P. and Ramasamy P., KRU Publications, Kumbakonam. (2000)
10. Springer Handbook of Crystal Growth by Govindhan Dhanaraj, Kullaiah Byrappa, Vishwanath Prasad, Springer, (2010)
11. Advances in technologically important crystals by Binay Kumar, R. P. Tandon, University of Delhi. Dept. of Physics and

Astrophysics, Macmillan, (2007)

LOYOLA COLLEGE (AUTONOMOUS)
CHENNAI - 600 034.

PH 3954 DATA COMMUNICATION AND COMPUTER NETWORKS

SEMESTER : III | CATEGORY : ES
HRS/WEEK : 4 | CREDITS : 3

Objective : The advances in the information and communication technology during the last decade have left an indelible mark in all walks of life. This paper is aimed at exposing the students to the latest techniques in data communication and computer networks.

UNIT 1 : DATA TRANSMISSION AND ENCODING - Concepts: Analog and Digital transmission, Transmission impairments - Transmission media - Synchronous / Asynchronous transmission - Line configurations - interfacing.

Digital data digital signals - Variations of NRZ and bi - phase - Digital data Analog signals - ASK, FSK, PSK, QPSK - Analog data digital signals - PCM, DM.

UNIT 2 : DATA LINK CONTROL

Flow control, Error control - HDLC, Multiplexing.

UNIT 3 : INTRODUCTION TO COMPUTER NETWORKS AND THE PHYSICAL LAYER - Introduction: The uses of computer networks - Network hardware - Network software - Reference models - Example of networks - Network standardization.

The physical layer: The theoretical basis for data communication - Guided Transmission media - Wireless transmission.

UNIT 4 : THE DATA LINK AND THE NETWORK LAYERS - The Data Link Layer: Data link layer design issues - Error detection and correction - Elementary data link protocols - Sliding window protocols - Example of data link protocols - ETHERNET.

The network layer: Network layer design issues - Routing algorithms - Congestion control algorithms.

UNIT 5 : THE TRANSPORT AND THE APPLICATION LAYERS - The transport layer: Transport layer design issues - Transport protocols - Simple transport protocol - Internet transport protocols UDP, TCP.

The application layer: Domain name system - Electronic mail - World Wide Web.

BOOKS FOR STUDY:

1. Data and Computer Communications by William Stallings, 8th Edition, Prentice - Hall of India, (2008)
2. Computer Networks by Andrew S. Tanenbaum, 4th edition, Prentice - Hall of India, New Delhi, (2005).
3. Introduction to Data Communication and Networking by Behrouz Forouzan, Tata McGraw - Hill, (2000).

BOOKS FOR REFERENCE:

1. Volume 1 of Internetworking with TCP/IP by Douglas Comer, 5th Edition, Prentice - Hall of India, (2006).
2. Principles Of Communication Systems by Taub and Schilling, McGraw Hill, (1986).
3. Computer Networking: A Top - Down Approach Featuring the Internet by James F. Kurose, Keith W. Ross, Julie C. Meloni, 3rd Edition, Pearson Education, Asia, (2006).

PH 3955 REACTOR PHYSICS

SEMESTER : III	CATEGORY : ES
HRS/WEEK : 4	CREDITS : 3

OBJECTIVES: - To expose the students to the physics of neutrons and fuel inside a reactor. Also the construction of a nuclear reactor and precautions to be taken in its operation will be dealt in this paper.

Unit 1 : Nuclear energy

Nuclear mass - Binding energy-Radioactivity - Nuclear reactions -

Nuclear fission **-** Mechanism of fission - Fuels - Products of fission

- Energy release from fission - Reactor power - Fuel burn up - Consumption.

Unit 2 : Neutron diffusion

Multiplication factor **- n**eutron balance and conditions for criticality - Conversion and breeding - Classification of reactors.

Diffusion of neutrons**:** Flux and current density - Equation of continuity - Fick's law - Diffusion equation - Boundary conditions and solutions - Diffusion length - Reciprocity theorem.

Unit 3 : Neutron moderation

Energy loss in elastic collision - moderation of neutrons in Hydrogen - lethargy - Space dependent slowing down - Fermi's age theory - Moderation with absorption.

Fermi theory of Bare thermal reactor **:** Criticality of an infinite reactor - One region finite thermal reactor - Critical equation - Optimum reactor shape.

Unit 4 : Reactor kinetics

Infinite reactor with and without delayed neutrons - Stable period - Prompt jump - Prompt criticality - Negative reactivity - Changes in reactivity - Temperature coefficient - Burn up and conversion.

Unit 5 : Control and shielding

Reactor control : Road worth - One control rod - modified one group, two group theory - ring of rods.

Radiation shielding : Reactor safeguards - Reactor properties over life - core life estimation.

BOOKS / WEBSITES FOR STUDY AND REFERENCE:

1. John R. Lamarsh, Introduction to Nuclear Reactor Theory , American Nuclear Society (2002)
2. Samuel Glasstone, Milton C. Edlund, The Elements of Nuclear Reactor Theory, Van Nostrand, (1965)

3. H. S. Isbin, Introductory Nuclear Reactor Theory, **Reinhold,** New

York (1963)

4. www.ans.org/PowerPlants
5. npcil.nic.in/main/AllProjectOperationDisplay.aspx
6. www.world-**nuclear**.org/info/inf53.html

PH 4810 QUANTUM MECHANICS II

SEMESTER	: IV	CATEGORY	: MC
HRS/WEEK	: 6	CREDITS	: 5

Objective: To introduce time dependent perturbation theory, its applications, the concepts of relativity and relativity in quantum mechanics, symmetries in QM and to introduce the concepts of quantum field theory.

Unit – 1: Time dependent perturbation theory

Introduction – first order perturbation – constant perturbation – harmonic perturbation – interaction of atom with electro-magnetic field – dipole approximation – selection rules – Einstein coefficients and spontaneous emission

Unit – 2: Relativistic Mechanics

Relativistic addition of velocities – structure of space-time – metric tensor – contra & covariant vectors – proper time and proper velocity – relativistic energy and momentum – momentum 4-vector – momentum transformation – Compton scattering – work energy theorem – Minkowski force

Unit – 3: Relativistic Quantum Mechanics

K – G equation – interpretation – particles in a Coulomb field – Dirac's equation for a free particle – Dirac's matrices – covariant form of Dirac's equation – negative energy states – probability density – plane wave solution – spin of Dirac's particle – magnetic moment of electron – spin-orbit interaction – radial equation for electron in a central potential – Hydrogen atom – Lamb shift

Unit – 4: Identical particles, Symmetries and conservation laws

Identical particles in quantum mechanics – exchange degeneracy – permutation operators - two- particle system – symmetric and

antisymmetric kets – system with arbitrary number of particles – parity

Symmetry transformations – conservation laws and degeneracy – discrete symmetries – parity or space inversion – parity conservation – time reversal

Unit – 5: Elements of field quantization

Introduction – quantization of free electromagnetic field – creation and annihilation operators – Lagrangian field theory – non-relativistic fields – relativistic fields – Klein-Gorden field – Dirac's field – electromagnetic field – interacting fields – Feynmann diagrams – electron-photon interaction (optional – scattering – Coulomb scattering – Moller scattering – Bhabha scattering – Bremstrauhlung and pair production

BOOKS FOR STUDY:

1. Quantum Mechanics by G Aruldhas, Prentice Hall India Learning Pvt. Ltd., 2004
2. Quantum Mechanics by B. K. Agarwal, Hari Prakash, Prentice Hall India Learning Pvt. Ltd., 2004
3. Quantum Mechanics: For M.Phil, M.Sc., B.Sc. Students of Indian and Foreign Universities NET, SLET, UGC - CSIR & Other Entrance Examination by S L Kakani, H M Chandalia, Sultan Chand (2007)
4. Quantum Mechanics by V. K. Thankappan, 2nd Edition, New Age International (1993)

BOOKS FOR REFERENCE:

1. A text book of Quantum Mechanics by Piravonu Mathews Mathews, K. Venkatesan, 6th Edition Tata McGraw - Hill Education, (1978)
2. Quantum Mechanics: Concepts and Applications by Nouredine Zettili, 2nd Edition, John Wiley & Sons, (2009)
3. Quantum mechanics Vol. 2 by Claude Cohen - Tannoudji, Bernard Diu, Franck Laloë, Wiley, (1977)

4. Quantum mechanics: an introduction by Walter Greiner, 4th Edition, Elsevier Springer, (2001)

PH 4811 NUCLEAR PHYSICS

SEMESTER : IV | CATEGORY : MC
HRS/WEEK : 6 | CREDITS : 5

Objective: This paper aims to explore the understanding of nuclear models and various physical properties of nucleus.

UNIT 1: Nuclear size, shapes and forces: Nuclear size determination by different methods - Electron scattering method - Electric - moments - magnetic moments. Nuclear forces: Two - nucleon potentials - Tensor forces - Ground state of the deuteron - Neutron Proton scattering at low energies - Singlet state - magnetic moment - Charge independence of nuclear forces - Iso - spin formalism - Meson theory of nuclear forces.

UNIT 2: Nuclear Models: Liquid drop model - Semi - empirical mass formulas and nuclear fission - Binding energy - Weizsacker mass formula - Levy's formula - Atomic masses and its significance - Shell model - Magic numbers - Optical model - Unified model - Barrier penetration - Basic ideas of reactors.

UNIT 3: Nuclear reactions: Nuclear reactions and cross - sections - Breit - Weigner single - level formula - Resonance scattering - The compound nucleus - Continuum theory - Optical model - Absorption cross - section at high energies. - Stability of heavy nuclei - Relativistic heavy ion collision – Controlled chain reaction – basic ideas of reactors.

UNIT 4: Radioactivity: Introduction - Gamow theory of alpha decay - Beta decay - Energy spectrum - Fermi theory - Fermi and Gamow - Teller selection rules - Non - conservation of parity - Pion condensation - Neutron stars.

UNIT 5: Elementary particles – classification – types of interaction – hadrons and leptons – symmetries and conservation laws – CP and CPT invariance – CPT theorem – classification of hadrons – Lie algebra – SU(2) and SU(3) multiplets – quark model – Gellman - Okubo mass formula for octets and decuplet hadrons – charm,

bottom, top quarks.

BOOKS FOR STUDY:

1. Nuclear physics: theory and experiment by Radha Raman Roy, B. P. Nigam, 1st Edition, New Age International, Chennai, (2008).
2. Nuclear Physics (VI and VII), Mermier, Shelton.
3. Introduction to elementary particles by David Jeffery Griffiths, 2nd Edition, Wiley - VCH, (2008)
4. Nuclear and Particle Physics: An Introduction by B R Martin, 2nd Edition, John Wiley & Sons, (2011)
5. Elementary Particle Physics in a Nutshell by Christopher G Tully, Princeton University Press, (2011)

BOOK FOR REFERENCE:

1. Principles of nuclear reactor engineering by Samuel Glasstone, Van Nostrand, (1956)

PH 4812 SOLID STATE PHYSICS

SEMESTER : IV **CATEGORY : MC**
HRS/WEEK : 6 **CREDITS : 5**

Objective: This paper aims to give an understanding of the basic theoretical models to study the properties of matter from a microscopic point of view.

UNIT 1: Crystal structure and lattice dynamics:

Lattice— translation symmetry- 3D crystal systems - Bravias lattices - Reciprocal lattice - Miller indices; X Ray Diffraction — Bragg's law(Vector form) - atomic scattering factor- structure factor- extinction rules for BCC, FCC, ZnS and diamond structure.

Lattice vibrations for a linear mono atomic lattice - linear diatomic lattice - acoustical and optical modes - extinctions and optical branch in ionic crystals- quantisation of lattice vibrations- - lattice dynamics of a BCC three dimensional solid - inelastic scattering of phonons.

UNIT 2: **Theory of metals and semiconductor:**

Brillouin zones - electrons in periodic potential- Bloch's theorem - Kronig- Penney model - nearly free electron model- effective mass - zone schemes- band model of metal, semiconductor and insulator.

Intrinsic semiconductor- carrier concentration- impurity semiconductors (n and p type) - carrier concentration- steady state diffusion- pn junction - homogeneous semiconductors.

UNIT 3: Transport phenomena and dielectric properties:

Thermal conductivity: of lattice - of free electrons - Fermi surface - effect of electric field on Fermi surface - effect of magnetic field on Fermi surface - mobility of charge carriers in semiconductors: intrinsic region and impurity range - Hall effect.

Dipole moment - atomic polarisability - Classius - Mossotti equation - theory of electronic polarisation - frequency dependent polarisability - ferro electricity

UNIT 4: Magnetism:

Larmor diamagnetism - Langevin's theory of para magnetism - Hund's rules- origin of magnetic interaction - molecular field theory of ferromagnetism - failure of independent electron approximation

Spin Hamiltonian and Heisenberg model - Magnons and thermal excitation of magnons - domain theory of hysteresis and anti ferromagnetic magnons- types of magnetic structure.

UNIT 5: **Superconductivity**:

Historical survey of superconductivity - critical parameters - Isotope effect- Meissner effect- type I and II superconductors- thermodynamics of superconducting transition - other properties.

London's theory - elements of BCS theory - flux quantisation - Dc and Ac Josephson effect - SQUID - High temperature superconductivity.

BOOKS FOR STUDY:

1. Solid state Physics, Mircea S. Rogalski, Stuart B.Palmer, Gordan & Breach (2000)
2. Solid state Physics : Structure and properties of materials, Mohammad Abdul Wahab, 2nd edition , Alpha science International (2005)
3. Introduction to Solid state Physics, Charles Kittel, 7th edition , John Wiley & sons (2007)
4. Solid state Physics, Neil. W. Ashcroft, N. David Mermin, Harcourt Asia PTE Ltd, first reprint (2001)
5. Solid state Physics, H.C.Gupta, 2nd edition, Vikas publishing house Pvt Ltd (2009)

BOOKS FOR REFERENCE:

1. Solid state Physics, R.K.Puri and V.K.Babber, 3rd edition, S.Chand and company Ltd (2005)
2. Solid state Physics, P.K. Palanisamy, Scitech Publication Pvt Ltd (2003)
3. Solid state Physics, John Sydney Blakemore, 2nd edition, Cambridge University press(1985)
4. Principles of the solid state H.V.Keer, New age International (1993)
5. Solid state Physics, Dr.Ajay Kumar Saxena, MacMillan India Ltd (2005)

PH 4813 PROJECT

SEMESTER : IV **CATEGORY : MC**
HRS/WEEK : 12 **CREDITS : 9**