DEPARTMENT OF RENEWABLE ENERGY SCIENCE

MANONMANIAM SUNDARANAR UNIVERSITY, TIRUNELVELI – 12

M. Sc. Energy Science (CBCS)

Course Structure and Syllabus

(From the academic year 2018-2019 onwards)

1.0 Preamble of the Programme:

M.Sc. in Energy science built up the understanding on the energy sector and to develop the research and development skills in the energy fields. The objective of the course is to motivate, encourage and develop scientific manpower through innovative academic training and endeavors for national growth and global needs in Energy Science.

To provide training of post-graduate level in the field of energy, so that the students after successfully completing the programme may take research work in the development of renewable energy system, which are technological and economical viable.

The students after successfully completing the programme may find placements in the Industry with many companies now seeking to exploit the benefits of Green Technology products and processes.

2.0 Eligibility for Admission

A candidate for being eligible for admission to the M.Sc. in Energy Science programme must have passed the B.Sc degree examination with Physics / Chemistry / Applied physics/Chemistry/Material Science / Energy Science / Electronic sciences (with mathematics as one of the subjects) or its equivalent.

2.1 Student strength: Twelve (12)

3.0 Course Structure for the M.Sc Energy Science Programme in University Departments (with effect from the academic year 2018-19 onwards)

Sem	Sub. No.	Subject Status	Subject Title	Credits	Contact Hours/ Week
I	1	**Core - 1**	Classical Mechanics	04	04
	2	**Core - 2**	Advanced Electronics	04	04
	3	**Core - 3**	Mathematical Physics – I	04	04
	4	**Core - 4**	Renewable Energy Sources – I	04	04
	5	**Core - 5**	Physics of Energy	04	04
	6	**Practical - I**	General Electronics Experiments	02	04
	7	**Practical - II**	General Optics Experiments	02	04
			Subtotal	**24**	**28**
II	8	**Core - 6**	Quantum Mechanics	04	04
	9	**Core - 7**	Mathematical Physics – II	04	04
	10	**Core - 8**	Thermodynamics and Statistical Physics	04	04
	11	**Core - 9**	Solid State Physics	04	04
	12	**Supportive Course -I**	Basics of Renewable Energy Source	03	03
	13	**Practical - III**	General Energy Experiments	02	04
	14	**Practical - IV**	General solar Experiments	02	04
			Subtotal	**23**	**27**
III	15	**Core - 10**	Renewable Energy Sources – II	04	04
	16	**Core - 11**	Nuclear Science	04	04
	17	**Core - 12**	Spectroscopy	04	04
	18	**Core - 13**	Materials Science	04	04
	19	**Core - 14**	Electromagnetic Theory	04	04
	20	**Supportive Course - II**	Solar Energy Conversion Technologies	03	03
	21	**Practical - V**	Solid State Physics – Experiments	02	04
			Subtotal	**25**	**27**
IV	22	**Elective Course - I**	a) Solar Thermal Energy Utilization b) Renewable Energy: Conversion, Storage And Environmental Aspects	03	03
	23	**Elective Course - II**	c) Materials Characterization Technique d) Hydrogen Production, Storage and Fuel Cells	03	03
	24	**Project**		12	12
			Subtotal	**18**	**18**
			Total	**90**	

4.0 Scheme of Evaluation:

For evaluation of theory papers the Continuous Internal Assessment (CIA) will be of 25 marks and External Examination for 75 marks. Practical's and Major project carry a maximum of 100 marks with 50 % internal and 50 % external.

4.1 Core, Elective, and Supportive papers :

(a) Continuous Internal Assessment (CIA) :

The marks for the continuous internal assessment of 25 is split into three components, viz., 15 marks for the internal test, 5 for the Seminar and 5 for the Assignment activities. There is no passing minimum for the CIA components and for the CIA in total. There shall be no provision for improvement of CIA components. There shall be three compulsory periodical tests in a semester. Each test carries a maximum of 25 marks and shall be converted for a maximum of 15 marks. The question paper pattern for each test of each of the theory papers is given below:

Section	Type of Questions	Max. Marks
Part A	Objective Type -5 Qns.	5 X 1 = 05
Part B	2 out of 3 problems /Qns.	2 X 5 = 10
Part C	1 out of 2 Descriptive or Analytical Qns.	1 X 10 = 10
	Total Marks	25

(b) External Examinations :

The duration of the University examination for each theory course is 3 hours. The question paper pattern for the end-semester examination of each theory paper is given below:

Section	Type of Questions	Max. Marks
Part A	Objective Type -10 Qns. (2 from each units)	10 X 1 = 10
Part B	Unit-wise choice – Either (a) or (b) type – 5 Qns. Problems	5 X 5 = 25
Part C	Unit-wise choice-Either (a) or (b) type – 5 Descriptive or analytical Qns.	5 X 8 = 40
	Total Marks	75

There is a passing minimum of 50% in the University examinations in each theory course and there is a passing minimum of 50% in the overall component, i.e. out of the total marks in the CIA component and the University examination for each theory course.

4.2 Practical:

The CIA and the University Examination marks will be awarded as per the table given below:

Phase of Examinations	Marks	Methodology
Phase I - Continuous Assessment	**Continuous Assessment** : 25 marks	"N" number of practical's be conducted based on the practical's prescribed in the syllabus and the marks should be distributed equally for each practical's. There is no passing minimum in the Internal Continuous Assessment.
	Test : 25 marks	Two tests should be conducted and average of tests will be taken
	Total : 50 marks	**Calculation of marks:** Sum of marks awarded to number of practical's (25 marks) + the Average Marks of two tests (25 marks).
Phase II - End semester assessment – Practical Examinations	**Course teacher** : 25 marks **External Examiner** : 25 marks **Total : 50 marks** { for Practical's : 20 marks Records : 5 marks }	Only one practical examination be conducted at the end of semester for the students on lot basis by appointing TWO examiners from the same Department / one from the other institution. 1. Course Teacher 2. External Examiner (From Other Institution / from the same Department) Passing minimum: 50% (25 marks) in the External

3.3 Major Project work:

The major project work shall be an individual project. After completion of the project work at the end of semester II, each student should submit two copies of the project report / thesis to the Department on or before a date as notified for the same. The project viva-voce examination for the students will be conducted individually.

Examinations	**Marks**	**Assessment**
Phase I - Internal	**Total – 50 marks**	By the Course Teacher There is no passing minimum for Assessment

Phase II - External	**Total – 50 marks** **Course teacher** – 25 marks **External Examiner** – 25 marks {For Project – 20 marks Viva – 5 marks}	By 1. Course Teacher 2. External Examiner (From Other Institution / from the same Department)

There is no passing minimum for the CIA components and for the CIA in total. There is passing minimum of 50% in the University examinations in Project course and there is a passing minimum of 50% in the overall component, i.e. out of the total marks in the CIA component and the University examination for each Project course.

CLASSICAL MECHANICS

L	T	P	C
4	0	0	4

Preamble:

- This course helps the student to understand the concepts of mechanics of a system of particles, conservation laws, constraints, generalized coordinates, Lagrange equations, Hamilton's principle, Rigid bodies, Euler's equations, Lorentz transformation, relativistic law .
- Student will acquire enough knowledge about the mechanics of the macroscopic objects and their laws.

UNIT I: Motion of a system of particles

Mechanics of a system of particles – Conservation laws – Motion in a central force field: Equivalent one body problem – Equation of motion and first intergrals. Differential equation of the orbit – Kepler's problem – Viral theorem – Scattering in central force field – Rutherford scattering. **(10L)**

UNIT II: Generalised coordinates

Constraints – Generalised coordinates, generalised velocity, force – Virtual work – D'Alembert's principle – Lagrange's equations – applications: Simple pendulum and Atwood's machine – Hamilton's equation of motion – Cyclic coordinates – Routh procedure – Liouville's theorem. **(13L)**

UNIT III: Hamilton's formulation

Calculus of variations – Euler's Lagrange equations – Hamilton's principles – Deduction of Hamilton's principle – Lagrange's equation from Hamilton's principle – Hamiltonian equation from variational principle – Principle of least action – Symmetries and laws of conservation – Canonical transformations – Problems – Poisson bracket: Equation of motion in Poisson bracket form – Hamilton Jacobi theory – Harmonic oscillator problem. **(14L)**

UNIT IV: Rigid body dynamics

Rigid bodies – moments and products of inertia – Euler's angles – Euler's equation of motion of a rigid body – Motion of a symmetric top in a gravitational field – Theory of small oscillations – Normal coordinates and normal modes – Linear triatomic molecules. **(11L)**

UNIT V: Relativistic mechanics

Lorentz transformation – relativistic law of addition of velocities – kinematics of Lorentz transformation. Relativistic generalisation of Newton's law – Lagrangian and Hamiltonian formulation of relativistic mechanics – A covariant Lagrangian and Hamiltonian formulation. **(12L)**

(Total: 60L)

Text Books:

1. H. Goldstein, Classical Mechanics, Addition Wesley, New York, 3rd Edition, 2000.
2. R. G. Takwale and P. S. Puranik, Introduction to Classical Mechanics, Tata McGraw – Hill Publishing Company Ltd., New Delhi, 1989.
3. N.C. Rana and P.S. Joag, Classical Mechanics, Tata McGraw-Hill, New Delhi, Ist Edition, 1991.

References:

1. I. Perceival and D. Richards, Introduction to Dynamics, Cambridge Univ. Press, UK, 1991.
2. V.B. Bhatia, Classical Mechanics, Narosa Publishing house, New Delhi, 1997.
3. Chinmoy Taraphdar, The Classical Mechanics, Asian Books Private Ltd., New Delhi, 2007.
4. A. Sommerfeld, Mechanics, Academic Press, USA, 1952
4. V. Devanathan, The Special Theory of Relativity – Narosa Publishing House, New Delhi, 2015.
5. V.B. Bhatia, Classical Mechanics – Narosa Publishing house, New Delhi, 1997.

ADVANCED ELECTRONICS

Preamble:

- This course helps the student to understand the concepts of forward bias, reverse bias of the diode, LED, OP AMP applications, D/A and A/D conversion, counters: asynchronous, synchronous, transducers with their types.
- Student will acquire enough knowledge about the basic electronic principles.

L	T	P	C
4	0	0	4

UNIT I: OP AMP Applications

Operational Amplifier: Characteristics, Virtual ground, Inverting, Non-inverting OP AMP – Differential amplifier – Common mode rejection ratio. OP AMP adder, subtractor – Analog integration and differentiation – Analog computations, solution of various equations – Comparators, Window comparator – Phase meters – Logarithmic amplifiers – Schmitt trigger – R Capacitive filters – Voltage to Current and Current to Voltage converter. **(11L)**

UNIT II: D/A and A/D conversion

Variable – resistor network – Binary ladder – D/A converter – D/A accuracy and resolution – A/D converter – Simultaneous conversion – Counter method – continuous A/D conversion – A/D techniques – Dual-slope A/D conversion – A/D accuracy and resolution. **(10L)**

UNIT III: Counters and Registers

Counters – Asynchronous counters – Synchronous counters – Changing the counter modulus – Decade counter – Shift counters – Types of registers – Serial in - Serial out – Serial in – Parallel out – Parallel in – Serial out – Parallel in – Parallel out – Shift registers – Shift Counter. **(11L)**

UNIT IV: Microprocessor

Introduction to INTEL 8086, Pins and signals of INTEL 8086- Instruction and Data flow in 8086 – Instruction format – Addressing modes of 8086 – Instruction affecting flags – Data transfer – arithmetic - Logical – String manipulation - control transfer instructions. – Levels of Programming – Flowchart Assembly language program development tools.

Microcontroller: Overview of the 8051 family – 8051 Assembly language programming, structure of assembly language – Assembling and running an 8051 program – Program counter and ROM space in 8051 – 8051 Data types and directives – 8051 flag bits and PSW register – 8051 Register Banks and Stack. **(14L)**

UNIT V: Transducers

Light Emitting Diodes – Photo detectors, Classification, Photo resistors, Photo diodes – Solar cells, Photo transistors – Photo-field effect transistor. Primary and Secondary Transducers – Classification of Detector – Mechanical devices as primary detectors – Pressure sensitive primary devices – Active and Passive transducers – Analogue and Digital Transducers – Electrical phenomena used in Transducers – Resistive Transducers – Potentiometers – Strain Gauges – Resistance wires train gauges – Resistance thermometers – Thermistors – Capacitive detectors – Piezoelectric detectors – Optical Transducers. **(14L)**

(Total: 60L)

Text Books:

1. Jacob Milman and Christos C. Halkias, Integrated Electronics, Tata Mc Graw Hill Edition, New Delhi, 1991
2. A.B.Bhattacharya – Electronic Principles and Applications – New Central Book Agency (P) Ltd., Kolkatta, 2006.
3. V. Hall, Microprocessor and Interfacing, Tata Mcgraw Hill Private Limited, New Delhi, 2005.
4. A. Nagoor Kani, Microprocessor 8086 programming & Interfacing , RBA Publication, Chennai, Ist Edition, 2009.
5. Muhammed Ali Mazidi, Janice Gillispie and Rolin D.McKinlay – The 8051 Microcontroller and Embedded systems – Pearson Education, New York, 2nd Edition, 2008.

References:

1. Donald P. Leach, Albert Paul Malvino and Goutam Saha – Digital Principles and Applications, Tata Mcgraw - Hill Publishing Company Ltd., New Delhi, 6th edition, 2008.
2. A. K. Sawhney – Electrical and Electronic Measurements and Instrumentation – Dhanpat Rai & Sons, Educational and Technical Publishers, Delhi., 4th edition, 2013.
3. H.S. Kalsi, Electronic Instumentation, Tata Mcgraw - Hill Publishing Company Ltd., New Delhi, 3rd edition, 2008.

MATHEMATICAL PHYSICS – I

Preamble:

- This course helps the student to understand the concepts of vector calculus, linear algebra, Gamma, Beta, and special functions, probability and statistics, integral transform: Fourier transform, Fourier integral.
- Student will acquire enough knowledge about the problem solving.

L	T	P	C
4	0	0	4

UNIT- I: Vector Calculus

Vector differential calculus: Limits, continuity and derivatives of vector function – scalar and vector field – ∇ operator - gradient, divergence and curl – Laplacian – identities of successive ∇ operation. Vector Integral Calculus: Vector integration – line integral – path independence – surface and volume integrals – Gauss, Greens and Stokes theorem – verification and problems – applications. Transformation of coordinates – orthogonal curvilinear coordinates. **(14L)**

UNIT-II: Linear Algebra

Matrices: Matrix algebra – Gauss elimination – rank of matrix – determinants – Cramers rule –inverse of matrix – Gauss-Jordan elimination – eigen values and eigenvectors of matrix – diagonalisation – Cayley Hamilton theorem – Definition of symmetric, orthogonal, Hermitian and Unitary matrices. Linear Vector Space: Basis – dimension – linear dependence and independence – Gram-Schmidt orthogonalisation – Hilbert space.

(10L)

UNIT-III: Gamma, Beta and Special Functions

Gamma and Beta function: Gamma function – it's graph – Beta function – simple problems. Special functions: Bessel function; Bessel function of the first kind – generating function – recurrence relation - differential equation – orthogonality. Legendre function; generating function – Legendre polynomials – recurrence relation – differential equation – orthogonality – Rodrigues' formula – spherical harmonics. Hermite functions; generating function – Hermite polynomials – recurrence relation. Laguerre function; differential equation – Laguerre polynomials.

(12L)

UNIT-IV: Curve Fitting

Error analysis - Empirical laws and curve fitting – graphical method – Group average method – Equation involving three constants – Least square method – Fitting straight line, parabola, exponential curve method of moments – Chi Square test - Newton's forward and backward Interpolation – Newton's Divided Difference method – Lagrange interpolation. Solutions of Algebraic and Transcendental Equations – Iteration method – Bisection method – Regular Falsi method – Newton Raphson method. **(11L)**

UNIT-V: Integral Transforms

Fourier Transform: periodic functions – Fourier integrals – Fourier cosine and sine transform – Fourier Transform – physical interpretation of a spectrum – convolution. Laplace transform: Linearity – first and second shifting theorems – Laplace and inverse Laplace transform of simple functions – transforms of derivative and integral – differential equations - initial value problems - UNIT step function – Dirac delta function - inverse Laplace transform – partial fractions. **(13L)**

(Total: 60L)

Text Books:

1. George B. Arfken and Hans J. Weber, Mathematical Methods for Physicists, Academic Press, New York, 6th Edition, 2005.
2. K.F. Riley, M.P. Hobson and S.J. Bence, Mathematical Methods for Physics and Engineering, Cambridge University Press, UK, 2nd Edition, 2002.
3. B.S. Grewal, Numerical Methods in Engineering and Science, Khanna Publications, New Delhi, 10th Edition, 2014.
4. H. K. Dass, Mathematical Physics, S. Chand Publication, New Delhi, Revised Edition, 2016.
5. M.P. Boas, Mathematical Methods in the Physical Sciences, Wiley, New Jersy, 3rd Edition, 2005.
6. Dr. M.K.Venkatraman, Numerical methods in Science and Engineering, The National Publishing Co., Chennai, 5th Edition, 2000.

References:

1. Murray R. Spiegel, Seymour Lipschutz and Dennis Spellman, Schaum's outline Vector Analysis, Tata McGraw-Hill, New Delhi, 2nd Edition, 2009.
2. Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley and sons, New Jersy, 8th Edition, 2005.

RENEWABLE ENERGY SOURCES - I

L	T	P	C
4	0	0	4

Preamble:

- To understand the different kinds of Energy sources. To study the basis of solar energy and solar radiation measurement. To learn the fundamental principles and theory of wind energy conversion system.
- Student will acquire enough knowledge enough knowledge about the renewable energy resources

UNIT I: Introduction to Energy Sources

Conventional energy sources: coal – oil – agricultural and organic waste – water power – nuclear power – new energy technologies. Non conversional energy sources: solar – wind – bio mass and bio gas – ocean thermal energy - tidal energy – wave energy – hydrogen energy – fuel cells. **(10L)**

UNIT II: Solar energy

Basis of solar energy – Solar radiation analysis: The structure of the sun - Solar constant – solar radiation outside the Earth's atmospheres – Solar radiation at the Earth's surface - solar radiation geometry – Determination of solar time- Derived solar angle – Sunrise, Sunset and Day length.

Solar Radiation measurement: Pyrheliometers – Pyranometers – Sunshine recorder. Solar radiation data – estimation of average solar radiation – estimation of direct and diffuse radiation – Solar radiation on tilted surface. **(13L)**

UNIT III: Solar thermal energy

Conduction – Radiation – Reflectivity – Transmissivity – Convection – Heat exchangers – Heat transfer through an insulated wall or pipe – Physical principles of the conversion of solar radiation into heat – Flat-plate collectors – Thermal losses and efficiency – Characteristics – Evaluation of overall loss coefficient – Thermal analysis of Flat – Plate Collector and useful heat gained by the fluid.

(14L)

UNIT IV: Physics of Photovoltaic's

Introduction –Photovoltaic principle – power output and conversion efficiency limitations of Photovoltaic cell efficiency – Photovoltaic System for power generation – solar cell modules – advantages and disadvantages of photovoltaic solar energy conversion. Crystalline Silicon solar cells: basic principles – the p-n junction and PV effect – Mono-crystalline silicon cells – polycrystalline silicon cell. Thin film solar cell: Amorphous silicon solar cell– Multi junction PV cells – Concentrating PV cells – Photochemical cells - Organic and dye sensitised solar cells. **(10L)**

UNIT V: Photovoltaic system

Ratings of PV Module – standard PV Module parameters: I-V and P-V characteristic of SPV module – Estimating or designing wattage of a PV module – factors affecting electricity generated by a solar PV module: effect of conversion efficiency – change in the amount of input light – effect of change in PV module temperature – change in PV module area – change in angle of light falling on PV module. Measuring module parameters: Measuring V_{oc} and I_{sc} – higher wattage modules. Connection of modules in series: estimating no. of PV modules required in series and their total power – mismatch in voltage in series connected PV modules – mismatch in current in series connected PV modules. Connection of modules in parallel combination: power generated by parallel connected PV modules – estimating the no. of PV modules to be connected in parallel and their total power **.**

(13L)

(Total: 60L)

Text Books:

1. G. D. Rai, Non - Conventional Energy Sources, Khanna Publishers, New Delhi, 5th Edition, 2012.
2. Godfrey Boyle, Renewable Energy: Power for a sustainable Future, Alden Oess Limited - Oxford, 1996.
3. G. D. Rai, Solar Energy Utilisation, Khanna Publishers, Delhi, 13th Reprint, 2018.
4. Chetan Singh Solanki, Solar photovoltaic technology and systems, PHI learning private limited, Delhi, Recent edition, 2013.

References:

1. G.D. Rai. Solar Energy Utilisation, Khanna Publishers, New Delhi, 5th Edition, 2009.
2. D. P. Kothari, K. C. Singal & Rakesh Ranjan, Renewable energy sources and emerging Technologies, Prentice Hall of India pvt. Ltd., New Delhi, 2nd Edition, 2008.
3. Domkundwar, Solar energy and non-conventional energy resources, Dhanpat Rai & Co. (P) Ltd, New Delhi, 1st Edition, 2010.

PHYSICS OF ENERGY

L	T	P	C
4	0	0	4

Preamble:

- This course helps the student to understand the concepts of energy sources and their technologies. To learn the environmental pollution and climate change. To understand the basic need of carbon free energy.
- Student will acquire enough knowledge about the renewable energy sources.

UNIT I: An Introduction to Energy Sources

General - Energy Consumption as a Measure of Prosperity - World Energy Futures - Energy Sources and their Availability – Introduction - Commercial or Conventional Energy Sources - New Energy Technologies - Renewable Energy Sources - Prospects of Renewable Energy Sources. **(11L)**

UNIT II: Environment Energy

Introduction – Environmental Studies – A Multidisciplinary Approach – Environment – Biogeochemical Cycles – Ecological Pyramids – Ecosystem – Food chain – Food Web – Ten Per Cent Law – Terrestrial Ecosystems - Pollution – Air Pollution – Water Pollution. **(8L)**

UNIT III: Global Climate Change

Ground Water Depletion – Soil Pollution – Global Climate Change- Climate Change – Adverse Effects of global Warming – Sensitivity, Adaptability and Vulnerability – Prominent Climate Change, Vulnerability and Impacts in India – Global Warming Potential – Forest Resources of India – Water Management in India – Ecological Succession – Biodiversity – Population Growth – Important Days w.r.t Environment. **(13L)**

UNIT IV: Clean Energy

Less efficient - energy use and waste today – Personal energy needs: Domestic electricity – Heat surviving the winter with almost no heating – Transport using less energy – Industry – The sale of Ecological indulgence – carbon free energy – option for carbon free energy – carbon di oxide sequestrations – Nuclear energy squeaky clean – option for protecting the climate – Reliable supply using renewable energies. **(14L)**

UNIT V: Environmental aspects

Introduction – Atmospheric pollution from conventional thermal plants – Atmospheric pollution from nuclear power plants – Green house effect – impact of green house effect – methods to reduce green house effect – Global environment awareness – Non conventional generation and environment – India's future energy policies – Economics of non – conventional energy system – life cycle costing – present worth factor – a present worth of capital and maintenance cost. **(14L)**

(Total: 60L)

Text Books:

1. G. D. Rai, Non - Conventional Energy Sources, Khanna Publishers, New Delhi, 5th Edition, 2012.
2. D. P. Kothari, K. C. Singal & Rakesh Ranjan, Renewable energy sources and emerging Technologies, Prentice Hall of India pvt. Ltd., New Delhi, 2nd Edition, 2008.
3. Volker Quaschning, Renewable Energy and Climate Change, Willy India Pvt Ltd, 1st Edition, 2010.
4. Domkundwar, Solar energy and non-conventional energy resources, Dhanpat Rai & Co. (P) Ltd, New Delhi, 1st Edition, 2010.

References:

1. Godfrey Boyle, Renewable Energy: Power for a sustainable Future, Alden Oess Limited - Oxford, 1996.
2. G. D. Rai, Solar Energy Utilisation, Khanna Publishers, New Delhi, 13th Reprint, 2018.
3. Chetan Singh Solanki, Solar photovoltaic technology and systems, PHI learning private limited, New Delhi, Recent edition, 2013.

PRACTICAL – I : GENERAL ELECTRONICS EXPERIMENTS

Preamble:

- This course helps the student to impart the practical knowledge of Electronics experiments which includes Voltage controlled oscillator, Differentiator, Integrator, Wien Bridge Oscillator, characteristics of photo diode, photo transistor, LDR,LED and the practical knowledge of handling 8086 Microprocessor.
- Students will acquire enough practical skills by hands on experience and able to handle Electrical & Electronic circuits.

L	T	P	C
0	0	4	2

List of Experiments (Any 8):

1. Voltage Controlled Oscillator
2. IC 555 timer – Schmitt Trigger Hysteresis loop
3. Wien's Bridge oscillator using operational amplifier
4. Astable and monostable Multivibrator using IC555
5. Phase Shift Oscillator
6. Characteristics of Photo Diode, Photo Transistor, LDR, LED
7. 8 bit and 16 bit Addition in 8086 microprocessor
8. 8 bit and 16 bit Subtraction in 8086 microprocessor
9. Multiplication in 8086 microprocessor
10. Division in 8086 microprocessor
11. Sum of n numbers in 8086 microprocessor
12. Square of a number in 8086 microprocessor
13. Sorting a series of data in 8086 microprocessor
14. Square root of a number in 8086 microprocessor

GENERAL OPTICS EXPERIMENTS

L	T	P	C
0	0	4	2

Preamble:

- This course helps the students to impart the practical knowledge of experiments such as Michelson interferometer, Air wedge and Laser beam parameters etc.
- Student will acquire sufficient knowledge of concepts through instruments by hands on experience.

List of Experiments (Any 8):

1. Michelson Interferometer
2. Cauchy's constant by curve fitting method
3. Hartmann's dispersion relation
4. Elliptic fringes - q, n, σ determination
5. Hyperbolic fringes - q, n, σ determination
6. Air wedge
7. Cleavage step height of crystal by multiple Fizeaue fringes
8. Study of Laser beam parameters (Coherent)
9. Fraunhofer diffraction using Laser
10. Determination of wavelength of Laser
11. Haidinger's fringes in a wedge plate
12. Faraday's rotation using Laser
13. Fabry - Perot Etalon

QUANTUM MECHANICS

L	T	P	C
4	0	0	4

Preamble:

- This course helps the student to understand the concepts of particle duality, uncertainty principle, Angular momentum operators, time independent perturbation theory, WKB approximation, elementary theory of scattering.
- Student will acquire enough knowledge about microscopic objects and their laws.

UNIT I: Introduction

Heisenberg uncertainty principle – Particle duality – Schrodinger Time dependent and Time independent equation – Eigen values problems: Particle in a box – Square well potential – Quantum mechanical tunneling – Harmonic oscillator – Hydrogen atom – Rigid Rotator – Wave functions in momentum space. **(12L)**

UNIT II: Linear vector space

Linear and Hermitian Operator – Dirac's notation for state vectors – Equation of motion – Energy raising and lowering operators – Symmetry transformations – Parity conservation – Semi-classical theory of radiation. **(11L)**

UNIT III: Angular momentum techniques

Angular momentum operators – Angular momentum – Commutation relations – eigen value and eigen functions of L^2 and L_z – Eigen values J^2 and J_z – Spin Angular Momentum – Spin vectors for Spin – Addition of angular momentum. **(12L)**

UNIT IV: Perturbation theory

Time independent perturbation theory: Non-degenerate and degenerate energy levels – Applications. Variation method: Principle and Applications – WKB Approximation method – Validity of WKB method – Time dependent perturbation theory – Fermi's Golden rule – Selection rules. **(13L)**

UNIT V: Scattering

Elementary theory of Scattering – Partial waves – Born Approximation. Relativistic wave equations: Klein-Gordon equation – Dirac's equation. Pauli's exclusion principle – Spin-statistic connection – Identical particles. **(12L)**

(Total: 60L)

Text Books:

1. L.I. Shiff, Quantum Mechanics, Mc Graw Hill Book Company, New York, 4th Edition, 2017.
2. P. M. Mathews and Venkatesan, A Text book of Quantum Mechanics, Tata Mc Graw Hill, New Delhi, 2nd Edition, 2010.
3. J.L. Powell and B. Crasemann, Quantum Mechanics, Addison-Wesley Mass, New York, 1st Edition, 1998.

References:

1. V. Devanathan, Quantum Mechanics, Narosa Publishing House Pvt.Ltd., New Delhi, 2nd revised edition, 2011.
2. G. Aruldhas, Quantum Mechanics, Prentice Hall India Learning Private Limited; New Delhi, 2nd Edition, 2008.
3. V. Devanathan, Angular momentum techniques in Quantum Mechanics, Kluwer academic publishers, Dordrecht/Boston/London, 1999.
4. B.S. Rajput, Advanced Quantum Mechanics, Pragati Prakashan, Meerut, 2016.

MATHEMATICAL PHYSICS – II

Preamble:

This course helps the student to understand the concepts of complex analysis, group theory, partial differential equations and tensors. Student will acquire enough knowledge about the problem solving skills.

L	T	P	C
4	0	0	4

UNIT I: Complex Analysis

Complex functions – limits and continuity – derivatives – Cauchy-Riemann equations – integrals – Cauchy theorem – Cauchy integral formula – Taylor's theorem – singular points – poles – Laurent series – residues – residue theorem – evaluation of definite integrals – conformal mapping. **(12L)**

UNIT II: Group Theory

Discrete Groups: Axioms of group – examples – multiplication table – rearrangement lemma – class – invariant subgroup – factor group – homomorphism and isomorphism – representation – examples – reducible and irreducible representation – Schur's lemmas – great orthogonality theorem – character table – symmetry elements and operations - character table of C_{2v}, C_{3v}, C_4 and D_3 point groups. Continuous Groups: Lie groups and lie algebra – SO(3) group – SU(2) and SU(3) unitary groups. Applications: Vibrational modes of H_2O, Zeeman splitting of energy levels – classification of elementary particles. **(15L)**

UNIT III: Partial Differential Equations

Some examples of partial differential equations – method of separation of variables – Laplace equation – one-dimensional wave equation – two-dimensional wave equation – heat equation – Schrodinger equation – classification of partial differential equations. **(10L)**

UNIT IV: Interpolation, Numerical Integration and differential equations

Differences – Newton's forward interpolation formula – Newton's backward interpolation formula central differences – Gauss forward and backward formula – Interpolation with unequal intervals – Newton's Divided Difference – Lagrange's Interpolation. Numerical Integration: Trapezoidal rule, Simpson's rule – Gauss quadrature formula – Solution for differential equation – Taylor's series method - Euler's methods – Second and Fourth order Runge-Kutta methods – RK4 method for second order differential equation. **(11L)**

UNIT V: Tensors

Notations and conventions – tensors of second rank – general definition – equality and null tensor – addition and substraction – outer product of tensors – inner product of tensors – symmetric and antisymmetric tensor – Kronecker delta – quotient law – metric tensor – Cartesian tensor – isotropic tensor – stress, strain and Hooke's law – piezoelectricity and dielectric susceptibility – moment of inertia tensor. **(12L)**

(Total: 60L)

Text Books:

1. George B. Arfken and Hans J. Weber, Mathematical Methods for Physicists, Academic Press, New York, 6th Edition, 2005.
2. K.F. Riley, M.P. Hobson and S.J. Bence, Mathematical Methods for Physics and Engineering, Cambridge University Press, United Kingdom, 2nd Edition, 2002.
3. B.S. Grewal, Numerical Methods in Engineering and Science, Khanna Publications, New Delhi, 10th Edition, 2014.
4. H. K. Dass, Mathematical Physics, S. Chand Publication, New Delhi, Revised Edition, 2016.
5. M.P. Boas, Mathematical Methods in the Physical Sciences, Wiley, New Jersy, 3rd Edition, 2005.
6. Dr. M.K.Venkatraman, Numerical methods in Science and Engineering, The National Publishing Co., Chennai, 5th Edition, 2000.

References:

1. Murray R. Spiegel, Seymour Lipschutz and Dennis Spellman, Schaum's outline Vector Analysis, Tata McGraw-Hill, New Delhi, 2nd Edition, 2009.
2. Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley and sons, New Jersy, 8th Edition, 2005.

THERMODYNAMICS AND STATISTICAL PHYSICS

L	T	P	C
4	0	0	4

Preamble:

- This course helps the student to understand the concepts of thermo dynamical laws and their consequences, quantum statistics of identical particles, Fermi dirac distribution law, Relation between statistical and thermodynamical quantities.
- Student will acquire enough knowledge about the thermodynamical and statistical physics.

UNIT I: Thermodynamics for Energy

First law of Thermodynamics- Consequences-Carnot cycle- heat engine and refrigerator - Second law of thermodynamics- clausius –kelvin planck statement – Helmoltz function and gibbs function – phase transition – clausius clapeyron equation –third law of thermodynamics . **(14L)**

UNIT II: Thermodynamical system of particles

Review of thermodynamics – thermodynamical laws and consequences – Gibb's free energy and Helmholtz' free energy – Thermodynamical potential – Phase-space – Micro canonical, canonical and grand canonical ensembles – Chemical potential – Density of states – Liouville's theorem – Probability consideration of tossing of distinguishable and indistinguishable coins – General expression for probability of distribution – Stirling's formula – Most probable distribution – Maxwell-Boltzmann's distribution law – Law of equipartition of energy. **(13L)**

UNIT III: Statistical thermodynamics - I

Quantum statistics of identical particles – Density matrix and limitations – Bose-Einstein distribution law – Black body radiation – Planck's radiation law – Specific heat of solids – Einstein theory – Debye's theory – Ideal Bose-Einstein gas – Degeneracy of Bose- Einstein gas – Bose-Einstein Condensation. **(10L)**

UNIT IV: Statistical thermodynamics - II

Fermi-Dirac distribution law – Ideal Fermi-Dirac gas – Fermi energy – degeneracy – Weak degeneracy, strong degeneracy – Electron gas in metals – Thermionic emission of electrons – Specific heat of gases – monoatomic, diatomic and polyatomic gases – variation with temperature. **(13L)**

UNIT V: Thermodynamical quantities

Relation between statistical and thermodynamical quantities – Partition function and thermodynamical quantities – Entropy mixing and Gibbs' paradox – Saucker-tetrode equation for entropy – Molecular partition function – Translational partition function – rotational and vibrational partition functions and applications. **(10L)**

(Total: 60L)

Text Books:

1. F.W. Sears and G. L. Salinger, Thermodynamics Kinetic Theory and Statistical Thermodynamics, Narosa Publishing House, 3rd Edition, New Delhi, 1998.
2. Kerson Huang, Statistical Mechanics, John Wiley & Sons, Inc., New York, 2nd Edition, 1987.
3. A.K.Dasgupta, Fundamentals of Statistical Mechanics, New Central Book Agency (P) Ltd., Calcutta, 2nd revised edition, 2007.

References:

1. Sears and Zymanski, Statistical Mechanics, McGraw Hill Book Company, New York, 1961.
2. A.K. Agarwal and Melvin Eisner, Statistical Mechanics, New Age International (P) Limited, New Delhi, 1998.
3. Federick Reif, Fundamentals of Statistical and thermal Physics, McGraw Hill International Editions, Singapore, 1985.
4. F. Mandl, Statistical Physics, ELBS & Wiley, USA, 2nd edition, 1988.
5. R. K. Pathria and Paul D. Beale, Statistical Mechanics, Academic Press, New York, 3rd Edition, 2011.

SOLID STATE PHYSICS

L	T	P	C
4	0	0	4

Preamble:

- This course helps the student to understand the concepts the classification of condensed matter, Lattice vibrations, Defects and their dislocations, quantum theory of Para magnetism, diamagnetism, ferromagnetic materials and superconductivity.
- Student will acquire enough knowledge about vibration defects, dislocations, classification of condensed matter.

UNIT I: Classification of Solids

Crystalline, noncrystalline, nanocyrstalline, quasicrystalline solids, liquids; Crystalline solids : Bravais lattices, crystal systems, crystal symmetry, point groups, space groups, common crystal structures and types of binding in crystals; Reciprocal lattice, Brillouin zones, diffraction of waves by crystals: X-rays, neutrons, electrons; Bragg's law in direct and reciprocal lattice and structure factor – Defects and dislocations.

(13L)

UNIT II:Lattice vibrations

Phonons, monatomic lattice, lattice with two atoms per primitive cell, lattice heat capacity, Debye law, anharmonic crystal interactions; Free electron Fermi gas : Drude Model - electrical conductivity, electronic heat capacity, Hall effect and thermoelectric power ; Electron motion in periodic potential : energy bands in solids, metals, semiconductors and insulators; nearly free electron model, Bloch functions, Kronig – Penny model, Construction of Fermi surfaces. **(13L)**

UNIT III:Dielectrics

Internal electric field, polarizability, ferroelectric crystals and their types, polarization catastrophe, Landau theory of phase transitions – first and second order – antiferro, pyro and piezoelectric crystals.

(9L)

UNIT IV: Magnetism

Quantum theory of paramagnetism, paramagnetism in transition metal ions and rare earth ions in solids, crystal field effect and orbital quenching, paramagnetic susceptibility of metals, Ferromagnetic, ferrimagnetic and antiferromagnetic ordering, Curie-Weiss law and Heisenberg theory, Curie and Neel temperatures, ferromagnetic domains, Spin waves and Magnon dispersion. **(11L)**

UNIT V: Superconductivity

Meissner effect, Thermodynamics of superconducting transitions and Critical fields, Isotopic effect; Electrodynamics: London equations and penetration depth, Flux quantization. Microscopic BCS theory : Cooper pairs, BCS ground state, energy gap and its temperature dependence, Coherence length, Type I & II superconductors; Tunneling: d.c. and a.c. Josephson effects and macroscopic quantum interference.

(14L)

(Total: 60L)

Text Books:

1. A. J. Dekker, Solid State Physics, Macmillan India Ltd., New Delhi, 1st Edition, 2000.
2. A.R.Verma and O. N. Srivastava, Crystallography Applied to Solid State Physics, Wiley –Eastern Ltd., Noida, 1982.
3. Richard Christman, Fundamentals of Solid State Physics, John – Wiley & Sons, New York, 1st Edition, 1988.
4. Charles Kittel, Introduction to Solid State Physics, Wiley, New York, 7th Edition, 2011.
5. M. A. Wahab, Solid State Physics, Narosa Publishing House, New Delhi, 1999.
6. L. V. Azaroff, Introduction to Solids, McGraw Hill, USA, 1977.

References:

1. Herald Iback and Hans Luth, Solid State Physics, Narosa Publishing House, New Delhi, 1991.
2. J. S. Blakemore, Solid State Physics, Cambridge University Press, USA, 2nd edition, 1974.
3. M.Tinkham, Introduction to Superconductivity, McGraw-Hill, USA, 1975.
4. N. W. Ashcroft and N.D. Mermin, Solid State Physics, Saunders College Publishing House, US, 1976.

BASICS OF RENEWABLE ENERGY SOURCE

Preamble:

L	T	P	C
3	0	0	3

- To understand the different kinds of Energy sources.
- To study the basis of solar energy, solar radiation measurement and applications of solar energy.
- To learn the fundamental principles and theory of wind energy conversion system.
- To understand the biogas production from biomass.
- To study the additional alternate energy sources.

UNIT I: Introduction to Energy Sources

Conventional energy sources: coal – oil – agricultural and organic waste – water power – Nuclear power – new energy technologies. Non conversional energy sources: solar – wind – bio Mass and bio gas – ocean thermal energy- tidal energy – hydrogen energy- fuel cells. **(11L)**

UNIT II: Solar energy

Basis of solar energy – solar radiation and its measurement – solar thermal collector – principles of Solar PV – Solar energy storage – applications of solar energy. **(7L)**

UNIT III: Wind energy

Basic principles of wind energy conversion- the nature of the wind – the power of the wind – maximum power – wind energy conversion – basic components of wind energy conversion systems. **(9L)**

UNIT IV: Bio mass energy

Bio resources – bio mass conversion – technologies – wet process – dry process – photosynthesis. Bio gas plants – classification –plants in India- methods of obtaining energy from bio mass. **(10L)**

UNIT V: Other energy sources

Geothermal energy sources – energy from ocean – chemical energy sources- hydrogen energy – magneto hydrodynamic – thermo electric power. **(8L)**

(Total: 45L)

Text Books:

1. G. D. Rai, Non - Conventional Energy Sources, Khanna Publishers, New Delhi, 5th Edition, 2012.

References:

1. Godfrey Boyle, Renewable Energy: Power for a sustainable Future, Alden Oess Limited, Oxford, 1996.
2. D. P. Kothari, K. C. Singal & Rakesh Ranjan, Renewable energy sources and emerging Technologies, Prentice Hall of India pvt. Ltd., New Delhi, 2nd edition, 2008

GENERAL ENERGY EXPERIMENTS

(8 Experiments)

L	T	P	C
0	0	4	2

1. Estimation of Power Configuration of Various Loads
2. Measurement of power of wind mill
3. Energy Content in Wind. (Prototype Wind Mill of 100W)
4. Determine aerodynamic characteristics of wind turbine blades
5. Energy Audit of residential/institutional building
6. Efficiency of the fuel cell stack
7. Bio-gas Production from Kitchen waste.
8. Efficiency of electrical motors.

GENERAL SOLAR EXPERIMENTS
(Any 8 Experiments)

L	T	P	C
0	0	4	2

1. Measurement of Intensity of solar radiation
2. To study the I-V Characteristics of a solar cell with varying temperature at constant irradiation.
3. To study of the application of solar cell of providing electrical energy to the domestic appliance such as lamp etc.
4. Solar cells in series and parallel- effect of series and shunt resistance.
5. To study the voltage and current of the solar cell in series and parallel combination.
6. Determination of thermal efficiency of Solar Water Heater
7. Performance Evaluation of Solar Still
8. Thermal testing of a Box-type Solar Cooker and determination of first and second figure of merit.
9. Performance of Solar Air Heater (Forced Dryer) and Solar Air Dryer (Natural Dryer)
10. To study the thermal performance of parabolic solar cooker
11. Determination of time constant of a flat plate solar collector
12. Performance evaluation of concentrating solar collector

RENEWABLE ENERGY SOURCES – II

Preamble:

L	T	P	C
4	0	0	4

- This course helps the student to understand the concepts of hydropower system, biomass, bio gasification and liquefaction, biogas plants, power generation system using biofuels, ocean thermal energy, wave energy conversion, geothermal energy.
- Student will acquire enough knowledge about the renewable energy resources.

UNIT I: Wind energy

Basic principles of wind energy conversion: The nature of the wind – the power of the wind – maximum power – forces on the blades - wind energy conversion. Basic components of wind energy conversion systems – classification of WEC systems – advantages and disadvantages of WEC system. Applications of wind energy: Pumping - Direct heat - electric generation. **(10L)**

UNIT II: Wind Energy Conversion System & Wind energy farms

Basic components of wind energy conversion system – classification of WEC system – advantage and disadvantage of wind energy system – performance of wind machines. Generating systems – energy storage – applications of wind energy.

Wind energy farms: Grid interfacing of a wind farm – methods of grid connection – grid system and properties – capacity of wind farms for penetration into grid – Microprocessor-based control system for wind farms – economics of wind farms**.** **(13L)**

UNIT III: Biomass

Introduction – usable forms of biomass, their composition and fuel properties – biomass resources – Biomass as a source of energy: Introduction – energy plantation – advantages of energy plantation – plants proposed for energy plantation. Biomass conversion technologies: physical method – incineration – thermo chemical – biochemical. Urban waste to energy conversion – Biogas production from waste biomass.

Power generation system using biofuels: power generation from solid waste wood – power generation from biogas – power generation using landfill gas – power generation liquid waste. Thermodynamic cycle for power generation using biogas: I.C engines – gas turbine – steam turbine plant. **(13L)**

UNIT IV: Small Hydropower system

Introduction – general layout of small hydro-plant (SHP) – low head small hydro-plants – classification of water turbines: Reaction turbines, axial flow turbines, tube turbine, bulb turbine, straflo turbine. Impulse turbines: pelton turbine, turgo impulse turbine, Ossberger crossflow turbine. Electric generators – advantages and limitations of SHP – types of SHP in India. (**10L)**

UNIT V: Other Sources

Ocean Thermal Energy Conversion: Introduction - Historical review of OTEC - Principle of OTEC – Open cycle OTEC system – closed cycle OTEC system – Hybrid cycle OTEC system – selection of working fluid – different OTEC system: land based system – floating system – mounted system – plantship – status of OTEC in India.

Ocean Wave Energy Conversion: Different methods to convert wave energy into mechanical energy – some special wave energy conversion devices: Hydrolic accumulator wave machine – high level reservoir wave convertor – dolphin type wave power system. Advantage and disadvantage of wave energy – wave energy in India.

Geothermal Energy: Different parts of Internal structure of earth – Geothermal energy – thermal gradient – resources of geothermal energy – vapour dominated power plant – liquid dominated systems – liquid dominated binary cycle – total flow geothermal power unit – merits and demerits of geothermal power generation – applications of geothermal energy. (**15L)**

(Total: 60L)

Text Books:

1. D.P. Kothari, K.C.Singal, Rakesh Ranjan, Renewable energy sources and emerging technologies, PHI learning pvt. Ltd., New Delhi, 2nd edition, 2014
2. B H Khan, Non – conventional energy resources, McGraw Hill Education Pvt. Ltd, New Delhi, 2009.
3. G. D. Rai, Non - Conventional Energy Sources, Khanna Publishers, New Delhi, 5th Edition, 2012.

Books for reference:

1. S.Rao, B.B.Parulekar, Energy Technology-Nonconventional, Renewable & Conventional, Khanna Publishers, New Delhi, 3rd edition, 1994 .
2. Domkundwar, Solar energy and non-conventional energy resources, Dhanpat Rai & Co. (P) Ltd, New Delhi, 1st edition, 2010.

Nuclear Science

L	T	P	C
4	0	0	4

Preamble:

- This course helps the student to understand the concepts of nuclear forces, nuclear reaction with their types and models, radioactive decay like α-decay, β-decay, nuclear fission, fusion reactors.
- Student will acquire enough knowledge about the nuclear forces and the nuclear reaction.

UNIT I: Nuclear Energy

Types of fission – Distribution of fission products – mass and energy – Bohr Wheeler theory – Barrier penetration - theory of spontaneous fission - Nuclear chain reaction four factor formula - critical size – neutron emission. Diffusion equation – reactor design – classification of reactors – Nuclear power production in India – Nuclear fusion – thermo nuclear energy. Controlled thermo nuclear reactions.

(13L)

UNIT II: Nuclear forces and Deuteron problems

Nuclear forces – Binding energy – Weizsacker semi empirical mass formula – ground and excited state of deuteron. Meson theory of nuclear forces. Neutron – proton scattering of low energies – phase shift analysis scattering length – phase shift. Effective range theory in n-p scattering – spin dependence of nuclear forces and charge independence of nuclear forces. **(11L)**

UNIT III: Nuclear reactions and models

Kinds of nuclear reactions. Nuclear cross-section – partial wave analysis of reaction cross section – compound nucleus – inverse process (reciprocity theorem) – cross section of nuclear reaction – Resonance – Briet Wigner one level formula – Liquid drop model – Shell model – Extreme single particle model - Predictions of shell model. **(11L)**

UNIT IV: Radioactive decay

α-decay – Gamow's theory. β-decay – Fermi's theory – Pauli's neutrino hypothesis angular momentum and parity selection rules – violation of parity conservation in β decay. Gamma decay – Electric and magnetic multipole radiation – selection rules – internal conversion – nuclear isomers.

(12L)

UNIT V: Nuclear Reactors

Nuclear reactors: Self sustained chain reaction and reactor criticality. Neutron diffusion – classification of reactors. General features – Efficiency – critical mass and size of a reactor – conditions – four factor formula – Homogeneous and Heterogeneous reactors –Constructional and operational details of Pressurized Water Reactor (PWR), Boiling Water Reactor (BWR) – Pressurized Heavy Water Reactor (PHWR) – Constructional details of Fast Breeder Test Reactor (FBTR), Light Water Breeder Reactor (LWBR) and Molten Salt Breeder Reactor (MSBR).

(13L)

(Total: 60L)

Text Books:

1. V. Devanathan, Nuclear Physics, Narosa Publication, New Delhi, 2nd Edition, 2006.
2. D. K. Jha, Elements of Nuclear reactors, Discovery Publishing house, New Delhi, 2nd Edition, 2004.
3. J.M.Blatt, V.F.Weisskopf, Theoretical Nuclear Physics Interscience, New York, 2nd Edition, 1952.
4. Roy and Nigam, Nuclear Physics, Wiley Eastern Ltd, New Delhi, 3rd Edition, 1980.
5. Y.R.Waghmare, Introduction to Nuclear Physics, OXFORD STBH, New Delhi, 2nd Edition, 1981.
6. B.L.Cohen, Concepts of Nuclear Physics, McGraw Hill Book Company, New Delhi, 3rd Edition, 1971.

References:

1. M.K.Pal, Theory of Nuclear Structure, Affiliated East-West Press, New Delhi, 3rd Edition, 1982.
2. A.Bohr and B.R.Mottelson, Nuclear Structure Vol. I & II, Benjamin, 2nd Edition 1975.
3. J.M.Eisenberg and W.Greiner, Nuclear Theory Vol. I & II, North Holland Publishing Co., Amsterdam, 3rd Edition, 1972.
4. M. L. Pandiya and R.P.S. Yadav, Elements of Nuclear Physics, Kedar Nath Ram Nath, New Delhi, 2006.

SPECTROSCOPY

Preamble:

- This course helps the students to understand the basic concepts of electronic, rotational, vibrational, spectra of atoms with their selection rules.
- It also gave an insight about the electronic transition with their application.

L	T	P	C
4	0	0	4

UNIT – I: Atomic & Electronic Spectroscopy

Quantum states of electron in atoms – hydrogen spectrum – electron spin – Stern-Gerlach Experiment – spin-orbit interaction – Lande interval rule – two electron systems – LS & JJ coupling – fine structure –hyperfine structure – exchange symmetry of wave function – Pauli's exclusion principle – alkali type spectra. Electronic spectra of diatomic molecules – Frank-Condon principle – dissociation energy and dissociation products – rotational fine structure of electronic vibration transitions – Fortrat Diagram – predissociation. **(12L)**

UNIT – II: Rotational Spectroscopy

Rotational spectra of diatomic molecules – rigid and non-rigid rotator – effect of isotropic substitution of polyatomic molecules – linear, symmetric top and asymmetric top molecules – experimental techniques – diatomic vibrating rotator – linear, symmetric top molecule – characteristic and group frequencies. Theory and Experimental methods of Rotational Raman Spectroscopy – Diatomic and Linear polyatomic molecules – Symmetric and Asymmetric Rotor molecules – Structure determination from rotational constants. **(12L)**

UNIT – III: Vibrational Spectroscopy - I

Theory of IR spectroscopy - Linear molecules - Symmetric top molecules - Asymmetric molecules - Instrumentation-Modes of vibrations of atoms in polyatomic molecules - Factors which influences vibrational frequencies - Selection rules - Position and intensity of Bands - Applications of IR spectroscopy to Organic and Inorganic compounds - Attenuated total reflectance - Quantitative analysis. **(12L)**

UNIT – IV: Vibrational Spectroscopy - II

Introduction – Pure rotational Raman spectra – Vibrational Raman Spectra – Polarization of Light and the Raman effect – Structure determination from Raman and Infra – red spectroscopy – Techniques and Instrumentation – Near Infra – red FT – Raman Spectroscopy. **(12L)**

UNIT –V: NMR & ESR Spectroscopy

NMR Spectroscopy: Nuclear spin states - Mechanism of absorption - Population densities of nuclear spin states - Chemical shift and shielding - NMR spectrometer - Chemical equivalence - Chemical environment - Magnetic anisotropy - Spin-Spin splitting rule - Pascal triangle - The COSY and HETCOR - Magnetic Resonance Imaging. ESR Spectroscopy: Theory and Instrumentation -Hyperfine splitting - determination of g value - line width – Applications – ENDOR - ELDOR. **(12L)**

(Total 60 L)

Textbooks:

1. C.N. Banwell, Fundamentals of Molecular Spectroscopy, McGraw-Hill, New York, 2004.
2. G. Aruldhas, Molecular Structure and Spectroscopy, PHI Learning Private Limited, New Delhi, 2nd Edition, 2011.

References:

1. John A. Weil, James R.Boilton, Electron Paramagnetic Resonance: Elementary theory and Practical Applications, Wiley-Interscience, USA, 3rd Edition 2006.
2. J. Michael Hollas, Modern Spectroscopy, John Wiley & Sons, Singapore, 1995.
3. Jag Mohan, Organic Spectroscopy: Principles and Applications, Alpha Science Intl. Ltd, United Kingdom, 3rd Edition 2004.
4. Pavia, Lampman, Kriz and Vyvyan, Spectroscopy, Cengage Learning India Pvt. Ltd, New Delhi, 2nd Edition 2007.
5. Roger S. Macomber, A Complete Introduction to Modern NMR Spectroscopy-Wiley, Singapore, 2nd Edition 1998.
6. Manas chanda, Atomic Structure and Chemical Bond, Tata McGraw-Hill, New Delhi, 2003.
7. B.P. Straughan & S. Walker, Spectroscopy,Vol. I, Chapmen and Hall, London, 3rd Edition 1976.
8. G.M Barrow, Introduction to Molecular Spectroscopy, McGraw Hill Ltd., Singapore 1986.
9. Gurdeep R. Chatwal and Sham K. Anand, Spectroscopy, Himalaya Publishing house, Bangalore, 2008.

PHYSICS OF MATERIALS

L	T	P	C
4	0	0	4

Preamble:

- This course helps the student to understand the concepts of crystal and amorphous structure in materials about solidification and crystalline imperfections, Thermal and Mechanical properties of solids their phase diagrams and also give introduction about ceramics, glasses their composites.
- Student will acquire enough knowledge about the structure of materials and their properties.

UNIT I: Crystal and Amorphous Structure in materials

Space lattice and unit cells – Crystal Systems and Bravais lattices – Principal Metallic Crystal Structures – Atom positions in Cubic unit cells – Directions in Cubic unit cells – Miller indices for crystallographic planes in cubic unit cells – Crystallographic plane and directions in hexagonal crystal structure – comparison of FCC, HCP and BCC crystal structures – Volume, Planar and Linear density unit cell calculations – Polymorphism or Allotropy – Crystal Structure analysis – Amorphous materials. **(13L)**

UNIT II: Solidification and Crystalline Imperfections

Solidification of metals , single crystals – Metallic solid solutions – Crystalline imperfections – Point , line , planar and volume defects – Experimental techniques for identification of microstructure and defects – Optical metallographic, ASTM Grain Size and diameter determinations – Scanning Electron microscopy (SEM), Transmission Electron microscopy (TEM), High resolution Transmission Electron microscopy (HRTEM), Scanning Probe Microscopes and Atomic Resolution. **(11L)**

UNIT III: Thermal and Mechanical properties

Rate processes in solids – Atomic diffusion in solids – Industrial applications of diffusion processes – Effect of temperature on diffusion in solids – Processing of metals and alloys – Stress and Strain in metals – Tensile test and the engineering stress – strain diagram – Hardness and Hardness testing – Fracture of metals – Ductile and Brittle fracture – Toughness and Impact testing – Ductile or Brittle transition temperature. **(11L)**

UNIT IV: Phase diagrams and Polymeric materials

Phase diagrams of pure substances – Gibbs Phase rule – Cooling curves – Binary Isomorphous alloy systems – The Lever rule – Nonequilibrium solidification of alloys – Binary Eutectuic , Peritectic, monotectic alloy systems – Invariant reactions – Phase diagrams with intermediate Phases and compounds – Ternary Phase diagrams – Introduction to Polymer materials – Polymerization reactions – Industrial Polymerization methods – Crystallinity and Stereoisomerism in some thermoplastics – Processing of plastic materials.

(12L)

UNIT V: Ceramics, Glasses and Composites

Introduction to ceramics – Simple ceramic crystal structures – Silicate structures – Processing of Ceramics – Traditional and Engineering Ceramics – Mechanical properties of ceramics – Thermal properties of ceramics – Glasses – Ceramic coatings and surface engineering – Ceramics in biomedical applications – Nanotechnology and ceramics. Introduction to composite materials – Fibers for reinforced – plastic composite materials – Fiber reinforced plastic composite materials – Open - mold processes for fiber – reinforced plastic composite materials – Closed – mold processes for fiber – reinforced plastic composite materials.

(13L)
(Total: 60L)

Text Books:

1. William F Smith, Javad Hashemi, Materials Science and Engineering in SI units, Tata McGraw Hill Education Private Limited, New Delhi, 4th Edition, 2011.

References:

1. V. Raghavan, Materials Science and Engineering, PHI Learning Private Limited, New Delhi, 6th edition, 2015.
2. James F. Shackleford, Madhanapalli K.Muralidhara, Introduction to Materials Science for Engineers, Pearson Publications, Chennai, Second impression, 2009.
3. M. Arumugam, Materials Science, Anuradha Publications, Chennai, 2002.
4. Yip-Wah-Chung, Introduction to Materials Science and Engineering, CRC Press, USA, 2007.
5. J.C.Anderson, Keith D. Leaver, Rees D. Rawlings, Patrick S. Leevers, Materials Science for Engineers, CRC Press, USA, 2004.

ELECTROMAGNETIC THEORY

Preamble:

L	T	P	C
4	0	0	4

- This course helps the student to understand the concepts of basic laws in electronic: laplace and Poisson's equations, Electromotive forces: Faraday's law, Maxwell's equations, Potential formulation: Coulomb and Lorentz gauge, Magneto hydrodynamic equations.
- Student will acquire sufficient knowledge about the basic laws in electrostatics.

UNIT I: Electrostatics

Basic laws in Electrostatics – Laplace and Poisson's equations – Work and Energy in Electrostatics – Boundary value problems – Method of images – Multipole expansion of Potential due to a localized charge distribution – Polarisation – Basic laws in Magnetostatics – Vector Potentials – Multipole expansion of vector Potential – Magnetisation. **(13L)**

UNIT II: Electrodynamics

Electromotive force – Faraday's law – Maxwell's equations – in free space and in linear isotropic media – conservation Energy and momentum in electrodynamics – Maxwell's stress tensor. **(10L)**

UNIT III: Electromagnetic waves

The wave equation – Electromagnetic waves in nonconducting media – Electromagnetic waves in conductors – Reflection, refraction, interference, coherence, diffraction, polarization – Dispersion – Wave guides. **(10L)**

UNIT IV: Magnetostatics

Potential formulation – Coulomb and Lorentz gauge – Retarded potential – Jefimenko equation - Lienard-Wiechart potentials - fields of a moving point charge – Electric and Magnetic dipole radiation - Power radiated by a point charge – Physical basis of radiation reaction. **(12L)**

UNIT V: Magnetohydrodynamic

Introduction and definitions – Magneto hydrodynamic equations – Magnetic diffusion – Viscosity and pressure – Magneto hydrodynamic flow between boundaries with crossed electric and magnetic fields – Pinch effect – Instabilities in a pinched plasma column – Magneto hydrodynamic waves – Plasma oscillations – Short-wavelength limit on plasma oscillations and the Debye shielding. **(15L)**

(Total: 60L)

Text Books:

1. David J.Griffiths, Introduction to Electrodynamics, Printice - Hall India, New Delhi, 3rd Edition, 2006.
2. J. A.Bittencourt, Fundamentals of Plasma Physics, Springer International Edition, New Delhi, 3rd Edition, 2004.

References:

1. J.D. Jackson, Third Edition, Classical Electrodynamics John Wiley & Sons Inc., Singapore, 1998.
2. Zoya Popnic and Branko D.Popovic, Introductory Electromagnetics,Prentice Hall, New Jersey, 1999.
3. Paul Lorrain & Dale R.Corson, Electromagnetic fields and waves, W.H.Freeman and Co., New York, 1988.

SOLAR ENERGY CONVERSION TECHNOLOGIES

Preamble:

L	T	P	C
3	0	0	3

- This course helps the student understand the basic concepts of energy sources, solar energy conversion devices with their operation and maintenance.
- Solar measuring devices like Multi detectual meter, contactless Thermometer by hands on experience with theoretical aspects.

UNIT-I: Different forms of Energy

Introduction: Energy - Form of Energy - Natural Energy Sources - Non Conventional and Conventional Energy Sources. **(5L)**

UNIT-II: Solar energy conversion

Solar Energy Conversion: Solar Energy Conversion Devices - Solar Hot Water System -Solar Cooker - Solar Still - Solar dryer - Solar panels - Operation and Maintenance. **(8L)**

UNIT-III: Measuring devices

Measuring Devices: Solar radiation - Sun meter - Solar insolation and Power - Solar Time - Reflectivity of Surfaces - Use of Multi detectual meter - Power estimation - Contactless Thermometer - Temperature measurement - Efficiency of the thermal electrical system. **(10L)**

Practical: 50 marks **Duration: 3 hours**

1. Measurement of Efficiency of a Box Type Solar Cooker.
2. Solar Still and Estimation of Efficiency.
3. Estimation of Efficiency of Solar Hot Water System.
4. Estimation of I-V curve for a Solar Cell and Estimation of Cell Efficiency.
5. Estimation of Power Configuration of Various Loads. **(22L)**

(Total: 45L)

Text Books:

1. G. D. Rai, Non - Conventional Energy Sources, Khanna Publishers, New Delhi, Fifth Edition, 2012.

References:

1. D. P. Kothari, K. C. Singal & Rakesh Ranjan, Renewable energy sources and emerging Technologies, Prentice Hall of India pvt. Ltd, New Delhi, 2008.
2. Chetan Singh Solanki, Solar Photovoltaic technology and Systems, PHI learning Pvt. Ltd, New Delhi, 2013.

SOLID STATE PHYSICS

Preamble:

- This course helps the students to calculate physical constants like dielectric constant, band gap, hall effect and ionic conductivity etc.,
- Student will gain sufficient knowledge to apply these parameters in their project work.

L	T	P	C
0	0	4	2

List of Experiments (Any 8) :

1. Dielectric Constant of liquid
2. Hysteris Loop
3. Four Probe Method
4. Determination of Band gap
5. Hall effect
6. Guoy Balance
7. Quincke's method
8. Ferroelectric Phase transition
9. Ultrasonic Interferometer
10. Ionic conductivity measurement
11. Etching process: Specimen preparation
12. Determination of Specific heat of a material
13. Any other related experiments

a) SOLAR THERMAL ENERGY UTILIZATION

L	T	P	C
3	0	0	3

Preamble:

- This course helps the student to understand the concepts of solar air heaters, concentrators, solar distillation, solar house, energy storage, Principles of solar cell operation with their types, solar PV module arrays.
- Student will acquire enough knowledge about the solar thermal utilization.

UNIT I:

Heat Transfer: Concepts and Definitions: introduction – Conduction -Boundary Conditions, - Overall Heat Transfer Dimensionless Heat-conduction Parameters - Convection - Radiation Heat and Mass Transfer.

Flat-plate Collectors: Introduction, Flat-plate Collector - Classification - Testing of Collector - Heat Transfer Coefficients - Optimization of Heat Losses - Determination of Fin Efficiency - Thermal Analysis of Flat-plate Collectors - Configuration of FPC Connection - Effect of Heat Capacity in Flat-plate Collector - Optimum Inclination of Flat-plate Collector - Effect of Dust in Flat-plate Collector. **(12L)**

UNIT II:

Solar Water Heating System: Introduction - Heat Exchanger - Choice of Fluid - Analysis of Heat Exchanger - Heat Exchanger Factor - Natural Convection Heat Exchanger - Heat Collection in a Storage Tank - Heat Collection with Stratified Storage Tank - Heat Collection with Well-mixed Storage Tank - Effect of Heat Load.

Solar Air Heaters: Introduction, Description and Classification :Non-porous Type - Porous Type - Conventional Heater - Double Exposure Heaters - Air Heater with Flow above the Absorber - Air Heater with Flow on Both Sides of the Absorber - Two Pass Solar Air Heater - Comparison with Experimental Results - Heater with Finned Absorber - Heater with Vee-corrugated Absorber - Reverse Absorber Heater - Air Heaters with Porous Absorbers - Testing of Solar Air Collector - Parametric Studies - Comparison of Performance of Liquid and Air Collector - Applications of Air Heater. **(12L)**

UNIT III:

Solar Concentrators: Introduction - Characteristic Parameters - Classification - Types of Concentrators - Geometrical Optics in Concentrators - Theoretical Solar Image - Thermal Analysis - Tracking Methods - Materials for Concentrators.

Solar Distillation: Introduction - Working Principle - Thermal Efficiency - Heat Transfer, External Heat Transfer - Internal Heat Transfer - Overall Heat Transfer - Determination of Distillate Output - Passive Solar Stills - Effect of Various Parameters - Other Design of Solar Still - Modified Internal Heat Transfer. **(12L)**

UNIT IV:

Solar House: Introduction - Solair Temperature and Heat Flux - Thermal Gain - Various Thermal Cooling Concepts - Time Constant - Approximate Methods - Solar-load Ratio Method.

Energy Storage: Introduction - Sensible Heat Storage - Liquid Media Storage - Solid Media Storage - Dual Media Storage - Basics of Latent Heat Storage - Chemical Storage. **(12L)**

UNIT V:

Other Applications: Collection-cum-storage Water Heater - Non-convective Solar Pond - Solar water heating system - Heating of Swimming Pool by Solar Energy - Passive Heating of Swimming Pools - Controlled Environment Greenhouse - Heating of Biogas Plant by Solar Energy - Solar Cooker - Design Method - Solar Fraction - Solar Cooling. **(12L)**

(**Total 60L**)

Textbooks:

1. G.N. Tiwari, Solar Energy: Fundamentals, Design, Modelling and Applications, Narosa Publishing House, New Delhi, 2013.
2. G. D. Rai, Non - Conventional Energy Sources, Khanna Publishers, New Delhi, 5th Edition, 2012.

(b) RENEWABLE ENERGY: CONVERSION, STORAGE AND ENVIRONMENTAL ASPECTS

L	T	P	C
3	0	0	3

Preamble:

- This course helps the student to understand the concepts Renewable energy conversion technologies, electrical storage and their distribution, environmental aspects of energy and pollution control .
- Student will acquire enough knowledge about renewable energy.

UNIT I: Energy Conversion Technologies

Introduction, Energy Conversion process and devices, Summary of energy and Conversion devises, Electrical energy route, UNIT of energy and power in electrical form, Electrical energy supply system (power system), Basic objectives of electrical energy supply undertaking, Difficulties in electrical energy route, Electrical load curves and peak load. **(10L)**

UNIT I: Electrical Power Plants

Energy conversion plant for base load intermediate load peak load and energy displacement, Suitable type of energy conversion plant for various primary energy sources, Coal fired steam thermal power plant, Gas turbine power plant, Combined coal gasification combined cycle power plant (ICGCC), Diesel electric power plant, Plant factors and reserves, Magneto hydro dynamics (MHD), Nuclear fusion energy Conversion, Fuel cells and chemical to electrical energy Conversion, Thermionic Converters, Heat pumps, Energy densities in primary resources, Net energy analysis of electrical route /plant. **(10L)**

UNIT III: Energy Storage and Distribution-I

Introduction, Energy storage systems, Mechanical Energy storage, pumped hydroelectric storage, compressed air storage, Energy storage via flywheels Electric storage :The lead acid battery, Chemical storage- Introduction, Energy storage via hydrogen, ammonia, reversible chemical reactions. **(9L)**

UNIT IV: Energy Storage and Distribution-II

Electromagnetic Electric storage, Thermal Energy storage, Sensible heat storage, latent heat storage, Biological storage, Distribution of energy- Introduction, gas pipelines, electricity transmission, batch transport, Heat, chemical heat pipe. **(6L)**

UNIT V: Environmental Aspects of Energy and Pollution Control

Introduction, Terms and definitions, Pollution from use of energy, Combustion products of fossil fuels, Particulate matter, Fabric filter and bag house, Electro-statics precipitator, Carbon dioxide, Greenhouse effect and global warming, Emission of carbon monoxide, Pollution by sulphur dioxide and hydrogen sulphide, Emission of nitrogen oxides, Acid rains, acid snow, acidic fog and dry acidic deposits, Acid fog, Dry acidic deposition, FGD and SCR systems for cleaning flue gases. **(10L)**

(Total: 45L)

Text Books:

1. S. Rao and Dr. B. B. Parulekar, Energy Technology-Nonconventional, Renewable & Conventional, Khanna Publishers, New Delhi, ISBN No. 81-7409-040-1.
2. G. D. Rai, Non - Conventional Energy Sources, Khanna Publishers, New Delhi, 5th Edition, 2012.
3. G. D. Rai, Non-Conventional Energy Sources, Khanna Publishers, New Delhi, ISBN No. 81-7409-073-8.
4. D. P. Kothari, K. C. Singal, Rakesh Ranjan, PHI Learning Private Limited, New Delhi, ISBN No.-978-81-203-4470-9.

References :

1. Ibrahim Dincer, Marc A. Rosen, Thermal Energy Storage: Systems and Applications, John Wiley & Sons, New Jersy, 2002 .
2. Huggins & Robert, Energy Storage, 1st Edition, ISBN 978-1-4419-1024-0 17.
3. Paul Kruger, Alternative Energy Resources: The Quest for Sustainable Energy, Wiley, New Jersy, 1st Edition, 2006
4. Domkundwar, Nonconventional energy sources, Dhanpat rai & Co, Khanna Publishers, New Delhi, 41 Edition, 2009.
5. S. Hasan Saeed, D.K. Sharma, Non conventional Energy Source, S.K. Kataria & Sons, New Delhi, 3rd Editon, 2009.

L	T	P	C
3	0	0	3

c) MATERIALS CHARACTERIZATION TECHNIQUES

Preamble:

- This course helps the student understand the basic concepts of structural, thermal, microscopy, Electrical, Spectroscopy Characterization with their principle, Instrumentation and their application.
- Student will acquire enough knowledge about characterization techniques to determine the structural, thermal, microscopy, Electrical, spectroscopic properties.

UNIT I: Structural characterization

X-ray powder diffraction: Bragg's law – x-ray diffractometer essentials – estimation of x-ray diffraction intensity – structure, polarization, multiplicity, Lorentz, absorption and temperature factors – intensity formula – crystal structure determination of cubic systems – determination of lattice parameter, crystallite size and lattice strain – problems. **(9L)**

UNIT II: Thermal characterization

Differential Thermal Analysis: instrument design – introduction to DTA applications - Thermodynamic data from DTA – calibration – melting, boiling, decomposition and phase equilibiria. Thermogravimetric analysis: TG design and experimental concerns – decomposition kinetics using TG. Introduction and application of Differential scanning calorimetry. **(9L)**

UNIT III: Microscopy characterization

Magnetic lens – Scanning Electron Microscope: working method – detection of secondary and backscattered electrons – optics of SEM – EDAX. Transmission Electron Microscope: electron gun – projection of image – specimen preparation. Chemical analysis through EDAX: generation of x-rays within a specimen – detection and counting of x-rays – energy and wavelength dispersive analyses. **(8L)**

UNIT IV: Electrical characterization

Impedance spectroscopy: importance of interface – impedance related functions – physical models for equivalent circuit – single RC circuit – single impedance arcs – dielectric relaxation – conductivity and diffusion in electrolytes – mixed electronic-ionic conductors. Automated impedance analyzer: impedance measurement - audio frequency bridge – automated frequency response and impedance analyzer – measurements using 2, 3 or 4 terminals. Applications: microstructure and impedance – layer models – Bauerle's equivalent circuit – impedance spectra of composite electrodes. **(10L)**

UNIT V: Spectroscopy characterization

UV-Vis spectrophotometer: Introduction – principle – qualitative analysis – quantitative analysis – instrumentation – experimental parameters – application. Infrared spectroscopy: introduction – principle – instrumentation – sample preparation and accessories - qualitative analysis – quantitative analysis – application. Raman spectroscopy: introduction – Raman Effect – experimental consideration – analysis of bulk materials.

(9L)

(Total: 45L)

Textbooks:

1. Yoshio Waseda, Eiichiro Matsubara and Kozo Shinoda, Spinger-Verlag, X-ray diffraction crystallography, , Berlin Heidelberg, Germany, 2011.
2. Erich H. Kisi and Christopher J. Howard, Applications of Neutron Powder Diffraction, Oxford University Press, New Delhi, 2008.
3. Robert F. Speyer, Marcel Dekker, Thermal analysis of Materials, r Inc., New York, 1994.
4. Peter J. Goodhew, John Humphreys and Richard Beanland, Electron Microscopy and Analysis, Taylor & Francis, London, 2001.
5. Evgenij Barsoukov and J. Ross Macdonald, Impedance Spectroscopy Theory, Experiment and Applications, , John-Wiley & Sons, New Jersey, 2005.

References:

1. B.D.Cullity, Elements of X-ray diffraction, Pearson, Chennai, 3rd Edition, 1998
2. Ruth E. Whan, Materials Characterization, ASM Handbook, Volume 10, 1998.

L	T	P	C
3	0	0	3

D) HYDROGEN PRODUCTION, STORAGE AND FUEL CELLS

Preamble:

- This course helps the student understand the basic concepts of hydrogen energy from various sources like fossil fuels, biomass, water, and its distribution, storage, Fuel cells with their types.
- Student will acquire enough knowledge about hydrogen energy sources & understood the basic need of energy sources and it storage with their distribution.

UNIT I: Introduction

Security of Energy Supplies, Climate Change (Global Warming), Atmospheric Pollution, Electricity Generation, Hydrogen as a Fuel, A Note of Caution.

Hydrogen from Fossil Fuels: Present and Projected Uses for Hydrogen, Natural Gas, Reforming of Natural Gas (Gas Separation Processes, Characteristics of Steam Reforming of Methane, Solar-Thermal Reforming), Partial Oxidation of Hydrocarbons, Other Processes (Autothermal Reforming, Sorbent-enhanced Reforming, Plasma Reforming), Membrane Developments for Gas Separation (Membrane Types, Membrane Reactors), Coal and Other Fuels (Gasification Technology, Entrained-flow Gasifier, Moving-bed Gasifier, Fluidized-bed Gasifier, Combined-cycle Processes, FutureGen Project). **(10L)**

UNIT II:

Hydrogen from Biomass Photobiological hydrogen production potential, hydrogen production by fermentation, Overview, Energetics, Thermotogales, Biochemical pathway for fermentative hydrogen production, thermotoga, hydrogen production by other bacteria, Co-product formation, Batch fermentation, hydrogen inhibition, role of sulpher, Sulphedogenesis, use of other carbon sources obtained from agricultural residues, process and culture parameters, hydrogen detection, quantification and reporting, total gas pressure, water vapour pressure, hydrogen partial pressure, hydrogen gas concentration expressed as "mole H2/L-media", hydrogen production rate, dissolved H2 concentration in liquid, fermentation bioreactor sizing for PEM fuel cell use. **(7L)**

UNIT III:

Hydrogen from Water: Electrolysis, Electrolyzers, Water Splitting with Solar Energy (Photovoltaic Cells, Solar-Thermal Process, Photo-electrochemical Cells, Dye-sensitized Solar Cells, Direct Hydrogen Production, Tandem Cells, Photo-biochemical CellS), Thermochemical Hydrogen Production (Sulfur_Iodine Cycle, Westinghouse Cycle, Sulfur-Ammonia Cycle, Metal Oxide Cycles, Concluding Remarks,

Hydrogen Distribution and Storage: Strategic Considerations, Distribution and Bulk Storage of Gaseous Hydrogen (Gas Cylinders, Pipelines, Large-scale Storage), Liquid Hydrogen, Metal Hydrides, Chemical and Related Storage (Simple Hydrogen-bearing Chemicals, Complex Chemical Hydrides, Nanostructured Materials), Hydrogen Storage on Road Vehicles. **(9L)**

UNIT IV:

Fuel Cells: Fuel Cell History, Fuel Cell Operation, Types of Fuel Cell: Low-to-Medium Temperature (Phosphoric Acid Fuel Cell (PAFC), Alkaline Fuel Cell (AFC), Direct Borohydride Fuel Cell (DBFC), Proton-exchange Membrane Fuel Cell (PEMFC), Direct Methanol Fuel Cell (DMFC), Miniature Fuel Cells), Types of Fuel Cell: High Temperature (Molten Carbonate Fuel Cell (MCFC), Internal Reforming, Direct Carbon Fuel Cell (DCFC), Solid Oxide Fuel Cell (SOFC)), Fuel Cell Efficiencies, Applications for Fuel Cells (Large Stationary Power Generation, Small Stationary Power Generation, Mobile Power, Portable Power), Prognosis for Fuel Cells.

Microbial fuel cells: biochemical basis, Fuel cell design, Anode compartment, Microbial cultures, Redox mediators, Cathode compartment, Exchange membrane, Power density as function of circuit resistance. MFC performance methods, Substrate and biomass measurements, basic power calculations, MFC performance, power density as function of substrate, Single chamber vs two chamber designs, Single chamber design, Waste water treatment effectiveness, Fabrication examples. **(10L)**

UNIT V:

Hydrogen-fuelled Transportation: Conventional Vehicles and Fuels, Hybrid Electric Vehicles (HEVs) (Classification of Hybrid Electric Vehicles, Cars, Buses, Batteries, Conventional versus Hybrid Vehicles), 'Green' Fuels for Internal Combustion Engines, Hydrogen-fuelled Internal Combustion Engines (Road Vehicles, Aircraft), Fuel Cell Vehicles (FCVs) (Buses, Delivery Vehicles, Cars (Automobiles), Other Vehicles, Submarines), Hydrogen Highways, Efficiency Calculations and Fuel Consumption.

Hydrogen Energy: World-wide Energy Problems (Security of Energy Supply, Climate Change), Hydrogen Energy: The Challenges (Production, Distribution and Storage, Fuel Cells), The Role of Government

(Energy Conservation Policies, Energy Diversification, Electricity, Transportation, Carbon Emissions, Renewable Energy), Hydrogen Energy: The Prospects**.** **(9L)**

(Total: 45L)

Text Books:

1. D.A.J. Rand and R.M. Dell, Hydrogen Energy: Challenges and Prospects, Royal Society of Chemistry Publication, London.

References:

1. Caye M. Drapcho, Nghiem Phu Nhuan, Terry H. Walker, Bio fuels Engineering Process Technology, The McGraw-Hill Companies, New Delhi, 2008.
2. K. J. Gross, K. Russell Carrington, Recommended Best- Practices for the characterization

2018-19/MSU/46th SCAA/Univ. Depts./PG./M.Sc.(Energy Science)/Sem – IV/Project/Ppr.-24/

PROJECT WORK

M.Sc. in Energy Science Programme for Semester-IV consists of one elective course and full time project of 12 credits. The project report shall be in the form of Thesis and should be hard bound. Viva voce examination will be conducted.