Proposal for

# Dual Degree (B.Tech. + M.Tech.)
# in
# Energy Engineering
# B.Tech. (Energy Engineering)
# M.Tech. (Energy Systems Engineering)

Department of Energy Science and Engineering,
Indian Institute of Technology Bombay

## Preamble for Dual Degree programme (B.Tech.-M.Tech.) in Energy Systems Engineering

The energy sector is critical for socio-economic development. In the Indian context, the challenge is to provide affordable energy services to the population. At present official statistics indicate that 50% of Indian households do not have access to electricity. The development of energy systems is also constrained by the depletion of fossil fuel, local environmental impacts (for example adverse health impacts) and the problem of global warming and associated climate change. Energy security concerns also dictate the search for alternative transport fuels to reduce the dependence on imported oil.

The energy sector is in transition and needs analytical and design inputs. There is significant need for engineering, design, research and development inputs in building efficient conventional energy systems, cost effective renewables, new energy sources and conversion devices.

The objective of the Dual Degree programme is to provide specialist engineers (post-graduates) to meet the challenges of the energy sector with cross cutting analytical skills. The course has been designed for the energy sector with relevant inputs from mechanical engineering (e.g. thermodynamics, thermal engineering----), electrical engineering (e.g. power electronics, electrical machines) and chemical engineering (e.g. transport processes). In addition to this are the core energy courses providing the required background for analysing and designing energy systems.

## ENERGY SYSTEMS ENGINEERING

***COURSE CURRICULUM FOR THE NEW PROGRAMME (B.Tech./Dual Degree and 5yr. Int. M.Sc.) w.e.f. 2008 BATCH***

### Semester I

| Course code | Course Name | Credit Structure | | | |
|---|---|---|---|---|---|
| | | **L** | **T** | **P** | **C** |
| CH 103+ | Chemistry | **2** | **1** | **0** | **6** |
| CS 101 | Computer Programming | **2** | **0** | **2** | **6** |
| HS 101 | Economics | **3** | **0** | **0** | **6** |
| MA 105 | Calculus | **3** | **1** | **0** | **8** |
| PH 103* | Electricity and Magnetism | **2** | **1** | **0** | **6** |
| PH 105* | Modern Physics | **2** | **1** | **0** | **6** |
| CH 117+ | Chemistry Lab | **0** | **0** | **3** | **3** |
| ME 113* | Workshop Practice | **0** | **1** | **3** | **5** |
| ME 119* | Engineering Graphics and Drawing | **1** | **0** | **3** | **5** |
| PH 117+ | Physics Lab | **0** | **0** | **3** | **3** |
| NC 101# | National Cadet Corps (NCC) | **0** | **0** | **0** | **P/NP** |
| NO 101# | National Sports Organization (NSS) | **0** | **0** | **0** | **P/NP** |
| NS 101# | National Service Scheme (NSS) | **0** | **0** | **0** | **P/NP** |

* Any one of these two courses and any one of these Lab courses only for **D3 D4**
\+ Only for D1 D2
\# Any one of these three P/NP courses

### Semester – II

| Course Code | Course Name | Credit Structure | | | |
|---|---|---|---|---|---|
| | | **L** | **T** | **P** | **C** |
| MA 106 And MA 108 | Linear Algebra and Ordinary Differential Equations I | **3** | **1** | **0** | **8** |
| CH 103+ | Chemistry | **2** | **1** | **0** | **6** |
| PH 103* | Electricity and Magnetism | **3** | **0** | **0** | **6** |
| PH 105* | Modern Physics | **3** | **1** | **0** | **8** |
| DIC | Department Introductory Course | **3** | **0** | **0** | **6** |
| XX 102 | Data Analysis and Interpretation | **2** | **1** | **0** | **6** |
| CH 117* | Chemistry Lab. | **0** | **0** | **3** | **3** |
| ME 113+ | Workshop Practice | **0** | **1** | **3** | **5** |
| ME 119+ | Engineering Graphics and Drawing | **0** | **1** | **3** | **5** |
| PH 117* | Physics Lab. | **0** | **0** | **3** | **3** |
| NC 102# | National Cadet Corps (NCC) | **0** | **0** | **0** | **P/NP** |
| NO 102# | National Sports Organization (NSS) | **0** | **0** | **0** | **P/NP** |
| NS 102# | National Service Scheme (NSS) | **0** | **0** | **0** | **P/NP** |

* Any one of these two courses and any one of these Lab courses only for **D1 D2**
\+ Only for D3 D4
\# Any one of these three P/NP courses

Note: The Department of Energy Science and Engineering is offering only DD in Energy Systems Engineering. There is no B.Tech. Degree. It will be only available as an exit option for poor students.

***ENERGY SYSTEMS ENGINEERING***

***COURSE CURRICULUM FOR THE NEW PROGRAMME (Dual Degree) w.e.f. 2008 BATCH***

| **Semester III** | | | | | | **Semester – IV** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Course code** | **Course Name** | **Credit Structure** | | | | **Course Code** | **Course Name** | **Credit Structure** | | | |
| | | **L** | **T** | **P** | **C** | | | **L** | **T** | **P** | **C** |
| HS 203, HS 205, HS 202 and HS 204 | Psychology/Sociology/Philosophy /literature | **3** | **0** | **0** | **6** | MA 214 | Introduction to numerical analysis | **2** | **1** | **0** | **6** |
| ES 403 | Environmental Studies | **2** | **1** | **0** | **6** | EN 202 | Electronics | **2** | **1** | **0** | **6** |
| EN 201 | Basic Electrical Engineering | **2** | **1** | **0** | **6** | EN 204 | Material Science for energy applications | **3** | **1** | **0** | **8** |
| EN 203 | Thermodynamics and energy conversion | **3** | **1** | **0** | **8** | EN 206 | Power electronics and machines | **2** | **1** | **0** | **6** |
| IC 215 | Experimentation and measurements Lab | **0** | **0.5** | **3** | **4** | EN 208 | Electronics Lab | **0** | **0** | **3** | **3** |
| EN 205 | Lab-1: Basic Electrical engineering Lab | **0** | **0** | **3** | **3** | EN 210 | Electrical machines & power electronics Lab | **0** | **0** | **3** | **3** |
| **Total** | | | | | **33** | **Total** | | | | | **32** |
| COURSES FOR HONOR REQUIREMENT | | | | | | COURSES FOR HONOR REQUIREMENT | | | | | |
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| COURSES FOR MINOR REQUIREMENT | | | | | | COURSES FOR MINOR REQUIREMENT | | | | | |
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***ENERGY SYSTEMS ENGINEERING***

***COURSE CURRICULUM FOR THE NEW PROGRAMME (Dual Degree ) w.e.f. 2008 BATCH***

| **Semester V** | | | | | | **Semester – VI** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Course code** | **Course Name** | **Credit Structure** | | | | **Course Code** | **Course Name** | **Credit Structure** | | | |
| | | **L** | **T** | **P** | **C** | | | **L** | **T** | **P** | **C** |
| EN 301 | Introduction to renewable energy technologies | **2** | **1** | **0** | **6** | EN 302 | Power generation and system planning | **2** | **1** | **0** | **6** |
| EN 303 | Heat and mass transfer | **3** | **1** | **0** | **8** | EN 304 | Electrical energy systems | **3** | **1** | **0** | **8** |
| EN 305 | Fluid mechanics | **2** | **1** | **0** | **6** | EN 306 | Combustion engineering | **2** | **1** | **0** | **6** |
| EN 307 | Equipment design and control | **2** | **1** | **0** | **6** | | Department Elective-2 | **2** | **1** | **0** | **6** |
| EN 309 | Thermal & fluid Engineering Lab | **0** | **0** | **3** | **3** | EN 308 | Solar Energy Lab | **0** | **0.5** | **3** | **4** |
| EN 311 | Energy Systems Lab | **0** | **0.5** | **3** | **4** | EN 310 | IC Engine and Combustion Lab | **0** | **0.5** | **3** | **4** |
| | Departmental Elective-1 | **2** | **1** | **0** | **6** | | HSS Elective | **3** | **0** | **0** | **6** |
| | | | | | | | Practical Training | | | | **P/NP** |
| **Total** | | | | | **39** | **Total** | | | | | **40** |
| COURSES FOR HONOR REQUIREMENT | | | | | | COURSES FOR HONOR REQUIREMENT | | | | | |
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| COURSES FOR MINOR REQUIREMENT | | | | | | COURSES FOR MINOR REQUIREMENT | | | | | |
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***ENERGY SYSTEMS ENGINEERING***

***COURSE CURRICULUM FOR THE NEW PROGRAMME (Dual Degree ) w.e.f. 2008 BATCH***

| **Semester VII** | | | | | | **Semester – VIII** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Course code** | **Course Name** | **Credit Structure** | | | | **Course Code** | **Course Name** | **Credit Structure** | | | |
| | | **L** | **T** | **P** | **C** | | | **L** | **T** | **P** | **C** |
| EN 401 | Energy Systems modeling and analysis | **2** | **1** | **0** | **6** | EN 402 | Energy management | **2** | **1** | **0** | **6** |
| EN 403 | Energy resources, economics and environment | **2** | **1** | **0** | **6** | XXxxx | Institute elective-2 | **2** | **1** | **0** | **6** |
| XXxxx | Department elective- 3 | **2** | **1** | **0** | **6** | EN 404 | Electrochemistry | **2** | **1** | **0** | **6** |
| XXxxx | Department elective – 4[$] | **2** | **1** | **0** | **6** | XXxxx | Department elective-5[$] | **2** | **1** | **0** | **6** |
| XXxxx | Institute elective -1 | **2** | **1** | **0** | **6** | EN 406 | Seminar[$] | **0** | **0** | **0** | **3** |
| EN 405 | Energy Innovation Lab | **0** | **0.5** | **3** | **4** | EN 408 | Energy design project[$] | **0** | **0** | **0** | **12** |
| **Total** | | | | | **34** | **Total** | | | | | **39** |
| COURSES FOR HONOR REQUIREMENT | | | | | | COURSES FOR HONOR REQUIREMENT | | | | | |
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| COURSES FOR MINOR REQUIREMENT | | | | | | COURSES FOR MINOR REQUIREMENT | | | | | |
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[$] It indicates that the courses are a part of compulsory honors credits required for a DD program. This information will be useful for evaluating the exit option for a poor student. Total credits for of the courses, except the courses that are marked with [$], is 256. Total credits for DD program is 379

| *ENERGY SYSTEMS ENGINEERING*<br>*COURSE CURRICULUM FOR THE NEW PROGRAMME (Dual Degree) w.e.f. 2008 BATCH* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Semester IX** | | | | | | **Semester – X** | | | | | |
| **Course code** | **Course Name** | **Credit Structure** | | | | **Course Code** | **Course Name** | **Credit Structure** | | | |
| | | **L** | **T** | **P** | **C** | | | **L** | **T** | **P** | **C** |
| MG 696 | Engineering project management[$] | **3** | **0** | **0** | **6** | XXxxx | Open Elective 2[$] | **3** | **0** | **0** | **6** |
| XXxxx | Institute Elective-5[$] | **3** | **0** | **0** | **6** | XXxxx | DD project stage-II[$] | **0** | **0** | **0** | **42** |
| XXxxx | Open Elective I[$] | **3** | **0** | **0** | **6** | | | | | | |
| XXxxx | DD project stage-I[$] | **0** | **0** | **0** | **30** | | | | | | |
| **Total** | | | | | **48** | **Total** | | | | | **48** |
| COURSES FOR HONOR REQUIREMENT | | | | | | COURSES FOR HONOR REQUIREMENT | | | | | |
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| COURSES FOR MINOR REQUIREMENT | | | | | | COURSES FOR MINOR REQUIREMENT | | | | | |
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[$] It indicates that the courses are a part of compulsory honors credits required for a DD program. This information will be useful for evaluating the exit option for a poor student.

**List of EN Core courses**

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|---|---|
| EN-102 | Energy engineering fundamentals |
| EN 201 | Basic electrical engineering |
| EN 202 | Electronics |
| EN 203 | Thermodynamics and energy conversion |
| EN 204 | Material science for energy applications |
| EN 205 | Basic electrical engineering Lab |
| EN 206 | Power electronics and machines |
| EN 208 | Electronics lab |
| EN 210 | Electrical Machines & Power Electronics lab |
| EN 301 | Introduction to renewable energy technologies |
| EN 302 | Power generation and system planning |
| EN 303 | Heat and mass transfer |
| EN 304 | Electrical energy systems |
| EN 305 | Fluid mechanics |
| EN 306 | Combustion engineering |
| EN 307 | Equipment design and control |
| EN 308 | Solar Energy Lab |
| EN 309 | Thermal and fluid engineering lab |
| EN 310 | IC engine and combustion laboratory |
| EN 311 | Energy systems lab |
| EN 401 | Energy Systems modelling and analysis |
| EN 402 | Energy management |
| EN 403 | Energy resources, economics and environment |
| EN 404 | Electrochemistry |
| EN 405 | Energy Innovation Lab |
| EN 406 | Seminar |
| EN 408 | Energy design project |

**List of electives**

| | |
|---|---|
| EN 604 | Fuel Cells |
| EN 613 | Nuclear Reactor Theory |
| EN 615 | Wind Energy Conversion Systems |
| EN 616 | Direct Energy Conversion |
| EN 617 | Thermodynamic Analysis of Industrial Systems |
| EN 619 | Solar Energy for Industrial Process Heat |
| EN 624 | Conversion of Energy in Buildings |
| EN 628 | Materials and Devices for Energy Conversion |
| EN 630 | Utilization of Solar Thermal Energy |
| EN 632 | Waste to Energy |
| EN 634 | Nuclear Reactor Thermal Hydraulics & Safety |
| EN 640 | Solar photovoltaics: fundamentals, technology and applications |
| EN 645 | Process integration |
| EN 646 | Energy and climate |
| | |
| ME 462 | Appropriate Technology |
| ME 477 | Introduction to Optimization |
| ME 618 | Pressure Vessel Design |
| ME 655 | Theory and Design of Fluid Machinery |
| ME 661 | Advanced Thermodynamics & Combustion |
| ME 662 | Convective Heat and Mass Transfer |
| ME 666 | Design of Heat-Exchange Equipment |
| ME 681 | Thermal Environmental Engineering |
| ME 683 | Cryogenic Engineering - I |
| ME 684 | Air-conditioning System Design |
| ME 701 | Optimization Methods in Engineering Design |
| ME 704 | Computational Methods in Thermal & Fluid Engineering |
| CH 550 | Interfacial electrochemistry and applications |
| EE 655 | Computer Aided Power System Analysis |
| EE 657 | Electric Drives |

| | |
|---|---|
| EE 659 | A First Course in Optimization |
| EE 675 | Microprocessor Applications in Power Electronics |
| EE 725 | Computational Electromagnetic |
| EE 651 | Digital Protection of Power Systems |
| EE 654 | Power Electronics - II |
| EE 656 | Electrical Machine Analysis and Control |
| EE 658 | Power System Dynamics and Control |
| EE 660 | Application of Power Electronics to Power Systems |
| EE 722 | Restructured Power System |
| EE 713 | Circuit Simulation in Power Electronics |
| ES 616 | Energy conversion and environment |
| PH 205 | Physics III (Quantum physics and applications) |
| PH 409 | Introduction to condensed matter physics |
| CL 203 | Introduction to transport phenomena |
| CH 586 | Structures and properties of materials |

**List of Proposed New Theory Courses and possible instructor**

| Name | Year-Semester | Possible Instructors |
|---|---|---|
| Energy Engineering fundamentals | 1st year 2nd Sem | Prof. J. K. Nayak<br>Prof. Rangan Banerjee<br>Prof. S. Bandyopadhyay |
| Basic Electrical Engineering | 2nd year 1st Sem | Prof. P. C. Ghosh<br>Prof. P. Sharma |
| Thermodynamics & Energy conversion | 2nd year 1st Sem | Prof. P. Sharma<br>Prof. S. Bandyopadhyay<br>Prof. P. C. Ghosh |
| Electronics | 2nd year 2nd Sem | Prof. P. Sharma<br>Prof. P. C. Ghosh |
| Material Science for Energy Applications | 2nd year 2nd Sem | Prof. C. S. Solanki<br>Prof. P. Sharma |
| Power Electronics and Machines | 2nd year 2nd Sem | Prof. B. G. Fernandes*<br>Prof. S. Bandyopadhyay |
| Fluid Mechanics | 3rd year 1st Sem | Prof. S. Bandyopadhyay<br>Prof. S. B. Kedare<br>Prof. S. V. Prabhu* |
| Introduction to Renewable Energy Technologies | 3rd year 1st Sem | Prof. J. K. Nayak,<br>Prof. S. B. Kedare<br>Prof. C. S. Solanki<br>Prof. Rangan Banerjee |
| Heat & Mass Transfer | 3rd year 1st Sem | Prof. S. Bandyopadhyay<br>Prof. U. N. Gaitonde* |
| Equipment design and control | 3rd year 1st Sem | Prof. S. B. Kedare, Prof. S. Bandyopadhyay,<br>Prof. Rangan Banerjee,<br>Prof. C. S. Solanki |
| Power Generation and Systems Planning | 3rd year 2nd Sem | Prof. S. |
| Combustion Engineering | 3rd year 2nd Sem | Prof. A. Ganesh<br>Prof. P Aghalayam |
| Electrical Energy Systems | 3rd year 2nd Sem | A. M. Kulkarni* |
| Energy Systems Modelling & Analysis | 4th year 1st Sem | Prof. S. Bandyopadhyay<br>Prof. Rangan Banerjee |
| Energy resource Economics & Environment | 4th year 1st Sem | Prof. A. Ganesh<br>Prof. Rangan Banerjee |
| Energy Management | 4th year 2nd Sem | Prof. A. Ganesh<br>Prof. Rangan Banerjee<br>Prof. S. Bandyopadhyay |
| Electrochemistry | 4th year 2nd Sem | Prof. Manoj Nirgat |

# Course contents

## 1st year courses

CH 103 Chemistry-1 2 1 0 6

### Course Content:

Schrödinger equation, origin of quantization, applications of particle in a box problem; hydrogen atom, properties of atomic orbitals; many electron atoms; molecular orbital theory, bonding and energy levels of diatomic molecules N2, O2, CO and HF; polyatomics; intermolecular forces; bonding in solids.

Hückel treatment of ethylene, butadiene and benzene, concept of aromaticity; configuration, molecular chirality and isomerism; conformation of alkanes and cycloalkanes; reactivity of carbonyl group (additions, addition-eliminations, reactions due to acidic proton, reactivity of acid halide, ester and amide); functional group interconversions involving oxidation and reduction.

Periodic properties: trends in size, electron affinity, ionization potential and electronegativity; Use of Ellingham diagram and thermodynamics in extraction of elements; transition metal chemistry: inorganic complexes, bonding theories, magnetism, bonding aspects and structural distortion; bioinorganic chemistry: storage and transport of proteins; introduction to organometallic reagents.

### Texts/References :

P. W. Atkins, Physical Chemistry, ELBS/Oxford, 5th Edition, 1995.
R. A. Alberty and R. J. Silbey, Physical Chemistry, 1st Edition, John Wiley & Sons (ASIA), Singapore, 1995.
G. M. Barrow, Physical Chemistry, 5th Edition, Tata McGraw-Hill, New Delhi, 1992.
D. K. Chakrabarty, Physical Chemistry, Narosa, New Delhi, 1997.
B. H. Mahan and R. J. Myers, University Chemistry, 4th edition, Benjamin, California, 1987.
S. H. Maron and C. F. Prutton, Principles of Physical Chemistry, 4th Edition, Oxford & IBH, New Delhi, 1972.
H. V. Keer, A. Q. Contractor, B.L.Tembe (Editor), R. S. Singh, P. Mathur, G. K. Trivedi, M. Sharan, N. S. Punekar, ET-105 Part B, Chemistry (5 Blocks/booklets): Atoms and Molecules, Energetics and Kinetics, Equilibria and Electrochemistry,

Inorganic Chemistry and Organic Chemistry. Written for the First Year B. Tech. Course of the Indira Gandhi National Open University, 1995
D. A. McQuarrie and J. D. Simon, Physical Chemistry - a molecular approach, Viva Books Pvt. Ltd., 1998 .

## HS 101 Economics 3 0 0 6

### Course Content:

Basic economic problems. Resource Constraints and Welfare maximization. Nature of Economics: Positive and normative economics; Micro and macroeconomics, Basic concepts in economics. The role of the State in economic activity; market and government failures; New Economic Policy in India.

Theory of utility and consumer's choice. Theories of demand, supply and market equilibrium. Theories of firm, production and costs. Market structures. Perfect and imperfect competition, oligopoly, monopoly.
An overview of macroeconomics, measurement and determination of national income. Consumption, saving, and investment. Commercial and central banking. Relationship between money, output and prices. Inflation - causes, consequences and remedies. International trade, foreign exchange and balance payments, stabilization policies: Monetary, Fiscal and Exchange rate policies.

### Texts/References:

P. A. Samuelson & W. D. Nordhaus, Economics, McGraw Hill, New York, 1995.
A. Koutsoyiannis, Modern Microeconomics, Macmillan, 1975.
R. Pindyck and D. L. Rubinfeld, Microeconomics, Macmillan Publishing Company, New York, 1989.
R. J. Gordon, Macroeconomics 4th Edition, Little Brown & Co., Boston, 1987.
William F. Shughart II, The Organization of Industry, Richard D. Irwin, Illinois, 1990. (Chapter 3).

## CS 101 Computer programming 2 0 2 6

### Course Content:

Functional organisation of computers, algorithms, basic programming concepts, FOR-TRAN language programming. Program testing and debugging. Modular programming subroutines: Selected examples from Numerical Analysis, Game playing, sorting/searching methods, etc.

**Texts/References:**

N. N. Biswas, FORTRAN IV Computer Programming, Radiant Books, 1979.
K. D. Sharma, Programming in Fortran IV, Affiliated EAST WEST, 1976.

## *MA 105 Calculus* **3 1 0 8**

**Course Content:**

Review of limits, continuity, differentiability. Mean value theorem, Taylors Theorem, Maxima and Minima. Riemann integrals, Fundamental theorem of Calculus, Improper integrals, applications to area, volume. Convergence of sequences and series, power series. Partial Derivatives, gradient and directional derivatives, chain rule, maxima and minima, Lagrange multipliers. Double and Triple integration, Jacobians and change of variables formula. Parametrization of curves and surfaces, vector Fields, line and surface integrals. Divergence and curl, Theorems of Green, Gauss, and Stokes.

Texts/References

1. D. Hughes-Hallett, Calculus - Single variable and Multivariable, 3rd Edition, John-Wiley and Sons, 2003.
2. James Stewart, Calculus, 5th Edition, Thomson, 2003.
3. T. M. Apostol, Calculus, Volumes 1 and 2, 2nd Edition, Wiley Eastern, 1980.
4. G. B. Thomas and R. L. Finney, Calculus and Analytic Geometry 9th Edition, ISE Reprint, Addison-Wesley, 1998.

## PH 103 Electricity & Magnetism 2 1 0 6

**Course Content:**

## PH 105 Modern Physics 2 1 0 6

**Course Content:**

## CH 117 Chemistry Labs 0 0 3 3

**Course Content:**

**CH 115 Chemistry Lab** **0 0 3 3**

Experiments illustrating the concepts of galvanic cells, thermochemistry, chemical kinetics, equilibrium constant, analysis by oxidation reduction titration. Experiments pertaining to volumetric analysis by complexometry, analysis by ion exchange resins, analysis of drug, organic/inorganic synthesis, instrumental methods of analysis

**ME 113 Workshop Practice** 0 0.5 3 4

**Course Content:**

Introduction to safety measures, introduction to the principles of working, construction, operation, types of cutting tools, selection of cutting speeds and feeds etc. regarding basic machine tools e.g. lathe, shaping, slotting, milling and grinding machines, etc. Introduction to gas and arc welding processes, soldering and brazing. Exercise; simple jobs on centre lathe and shaping machines and welding. emonstrations; Slotting, milling and grinding machines.

**Texts/References:**

S. K. Hajra Choudhury, Elements of Workshop Technology, Vol. II Asia Publishing House,1986.

**ME 119 Engineering Graphics and Drawing** **1 0 3 5**

**Course Content**

**PH 117 Physics Lab** **0 0 3 3**

**Course Content**

**MA 106 Linear Algebra** 3 1 0 4

**Course Content:**

Vectors in Rn, notion of linear independence and dependence, linear span of a set of vectors, vector subspaces of Rn, basis of a vector subspace. Systems of linear equations, matrices and Gauss elimination, row space, null space, and column space, rank of a matrix. Determinants and rank of a matrix in terms of determinants. Abstract vector spaces, linear transformations, matrix of a linear transformation, change of basis and similarity, rank-nullity theorem. Inner product spaces, Gram-Schmidt process, orthonormal bases, projections and least squares approximation. Eigenvalues and eigenvectors, characteristic polynomials, eigenvalues of special matrices ( orthogonal, unitary, hermitian, symmetric, skew symmetric, normal). algebraic and geometric multiplicity, diagonalization by similarity transformations, spectral theorem for real symmetric matrices, application to quadratic forms.

### Texts/References:

H. Anton, Elementary linear algebra with applications, 8th Edition, John Wiley, 1995.
G. Strang, Linear algebra and its applications, 4th Edition, Thomson, 2006.
S. Kumaresan, Linear algebra - A Geometric approach, Prentice Hall of India, 2000.
E. Kreyszig, Advanced engineering mathematics, 8th Edition, John Wiley, 1999.

## MA 108 Differential Equation – 1 3 1 0 4

### Course Content:

Exact equations, integrating factors and Bernoulli equations. Orthogonal trajectories. Lipschitz condition, Picard's theorem, examples on nonuniqueness. Linear differential equations generalities. Linear dependence and Wronskians. Dimensionality of space of solutions, Abel-Liouville formula. Linear ODE's with constant coefficients, the characteristic equations. Cauchy-Euler equations. Method of undetermined coefficients. Method of variation of parameters. Laplace transform generalities. Shifting theorems. Convolution theorem.

### Texts/References:

E. Kreyszig, Advanced engineering mathematics, 8th Edition, John Wiley,1999.
W. E. Boyce and R. DiPrima, Elementary Differential Equations, 8th Edition, John Wiley, 2005.
T. M. Apostol, Calculus, Volume 2, 2nd Edition, Wiley Eastern, 1980.

## PH 104 Modern Physics 2 1 0 6

### Course Content:

(Quantum Physics and Applications) Review of quantum concepts : particle nature of light, photoelectric effect, Compton effect, matter waves, wave packets, phase and group velocity, Davisson Germer experiment, Heisenberg uncertainty principle. Schrodinger equation : probabilistic interpretation of wave function, one dimensional problems

particle in a box, harmonic oscillator, potential barrier and tunneling. Hydrogen atom, electrons in a magnetic field, Landau levels. Elements of statistical physics: density of states, Fermi energy, Bose condensation. Solid state physics : Free electron model of metals, classical and quantum Hall effect, superconductivity, London equation, coherence and penetration depth, flux quantization, applications of superconductivity, SQUIDS. Nuclear physics : binding energy, nuclear reactions, elements of nuclear reactors, fission and fusion, fundamental forces, elementary particles, quarks and leptons.

### Texts/References:

S. H. Patil, Elements of Modern Physics, Tata McGraw Hill, 1989.
H. S. Mani and G. K. Mehta, Introduction to Modern Physics, Affiliated East West, 1988.
A. Beiser, Perspectives in Modern Physics, McGraw Hill, 1969. K. Krane, Modern Physics, 2nd ed., John Wiley, 1998.

## EN 102 (DIC) Energy Engineering Fundamentals 2 1 0 6

### Course content:

Objective: To provide an idea of the challenges in the field of energy engineering, to provide a perspective on energy technology, systems
Dimensions of the energy problem, Historical perspective on energy technology and system development. This will be illustrated by examples of technology development for power generation, transportation and a few application sectors (lighting).

Power generation – Wind mills, water wheels for shaft work, Industrial revolution – steam engine and coal fired boilers, Edison’s invention of electricity, Thermal power plant, Electricity generator, electric motor, Economics of scale, super-critical power plants, Distributed generation. Measures of performance and comparison of efficiency and costs for these technologies.

Transportation – Bullock car, bicycle, IC engine, Ford T, modern efficient IC engine, electric vehicle, fuel cell vehicle future car concepts – solar car, ethanol cars, lighting – candle kerosene lamp, incandescescent lamp, fluorescent lamps, solid state lighting, Design criteria, Material selection, Reasons for emergence of new technology, Identification of features propelling new developments, constraints imposed by fundamental basis, scarcity of energy resources and materials, Environmental constraints Identification of trends
Use of sensors and instrumentation to quantify performance of energy devices (Laboratory sessions).

Apart from the technologies analysed, students will be encouraged to identify the challenges in a different energy application (e.g. cooling, heating, powering laptops, …..) and proposing innovative solutions or developing small prototypes in the course project. The course will revise basic laws of thermodynamics and economics and use them in the analysis.

### Text/references:

A. Bejan, Advanced Engineering Thermodynamics , John Wiley, New York, 1988.
J. M. Fowler, Energy and the Environment, McGraw Hill, 2nd Edn, New York,1984.
T. B. Johannson, H. Kelly, A. K. N. Reddy and R. H. Williams (Ed), Renewable Energy: sources for fuel and electricity, Island Press, Washington DC, 1993.

## XX 102 Data Analysis and Interpretation 2 1 0 6

The role of statistics. Graphical and numerical methods for describing and summarising data. Probability. Population distributions. Sampling variability and sampling distributions. Estimation using a single sample. Hypothesis testing a single sample. Comparing two populations or treatments. Simple linear regression and correlation. Case studies.

## ME 113 Workshop practice 0 1 3 5

## ME 118 Engineering Drawing & Graphics 0 0 4 4

### Course Content:

Introduction of drawing instruments, lettering, lines and dimensioning. Construction of simple geometrical figures. Simple orthographic projections, first and third angle. Missing views and lines. Isometric views. Free hand sketching. Projection of points and lines. Projection of planes and solids. Section of solids. Orthographic projections of simple machine elements like couplings, tools post, I.C. engine components etc. using half, full sections. Simple assembly and part drawings. Introduction to AutoCAD.

### Texts/References:

K. Venugopal, Engineering Drawing and Graphics, New Age International (P) Ltd., 1995.
N. D. Bhat and V.M. Panchal, Engineering Drawing, Charotar Publishing House, Anand, 1996.

**PH 116 Physics Laboratory 0 0 3 3**

## Course contents:

Error analysis and accuracy of measurement. Selected experiments from the following : current and voltage sensitivities of a moving coil galvanometer, measurement of self inductance using Anderson's bridge, resistivity of a thermistor, Helmholtz coil. Fresnel biprism, Newton's rings. Young's modulus using Koenig's method, physical pendulum, Kundts Tube, Laser Diffraction, Grating Spectrometer, G.M. Counter.

## Texts and References:

B.L. Worsnop and H.T. Flint, Advanced Practical Physics for students, Asia Publishing House, 1971.

G.L. Squires, Practical Physics, University Press, Cambridge, 1999

## 2rd year courses

## MA 214 Introduction to Numerical Analysis 2 1 0 6

### Course contents:

Interpolation by polynomials, divided differences, error of the interpolating polynomial, piecewise linear and cubic spline interpolation. Numerical integration, composite rules, error formulae. Solution of a system of linear equations, implementation of Gaussian elimination and Gauss-seidel methods, partial pivoting, row echelon form, LU factorization Cholesky's method, ill-conditioning, norms. Solution of a nonlinear equation, bisection and secant methods. Newton's method, rate of convergence, solution of a system of nonlinear equations, numerical solution of ordinary differential equations, Euler and Runge-Kutta methods, multi-step methods, predictor-corrector methods, order of convergence, finite difference methods, numerical solutions of elliptic, parabolic, and hyperbolic partial differential equations. Eigenvalue problem, power method, QR method, Gershgorin's theorem. Exposure to software packages like IMSL subroutines, MATLAB.

### Texts/References:

S. D. Conte and Carl de Boor, Elementary Numerical Analysis- An Algorithmic Approach, 3rd Edition, McGraw-Hill, 1980.
C. E. Froberg, Introduction to Numerical Analysis, 2nd Edition, Addison-Wesley, 1981.
E. Kreyszig, Advanced engineering mathematics, 8th Edition, John Wiley, 1999.

## ES 203 Environmental studies 2 1 0 6

### Course contents:

Multidisciplinary nature of environmental studies; Natural Resources: Forest, Water, Mineral, Energy, Land; Sustainable development; Ecosystems; Biodiversity and its conservation.

Environmental Pollution: Air, Water, Soil, Marine, Noise, Thermal, Nuclear hazards; Solid and Hazardous Waste Management; Environment and human health; environmental Legislation.
Global Issues: Climate change, global warming, acid rain, ozone layer depletion.

Social Issues and the Environment : Environmental ethics and economics; Resettlement and rehabilitation of people; Public awareness and Human Rights, Women and Child Welfare.

### Text and References:

W. P. Cunningham and M. A. Cunningham, Principles of Environmental Science, Tata McGraw-Hill Publishing Company, New Delhi, 2002.
P. Dasgupta and G. Maler (Eds.), The Environment and Emerging Development Issues, Vol. I, OUP, 1997.
A.R.W. Jackson and J. M. Jackson, Environmental Sciences: The Environment and Human Impact, Longman Publishers, 1996.
J.A. Nathanson, Basic Environmental Technology, Prentice Hall of India, New Delhi, 2002.
M. Redclift and G. Woodgate (Eds.), International Handbook of Environmental Sociology, Edward Edgar, 1997.
K.P. Srivastava, An Introduction to Environmental Study, Kalyani Publishers, Ludhiana, 2002.

## EN 201 Basic electrical engineering 2 1 0 6

### Course contents:

Fundamental physical laws used frequently in electrical engineering, circuit parameters. Elementary techniques for analyzing simple electrical circuits. Network theorems: Thevenin's and Norton's theorems, superposition theorem and maximum power transfer theorem. Time domain analysis of first and second order linear circuits. Sinusoidal steady state analysis, series and parallel resonance, power calculations, reactive power, power factor and significance of power factor correction, balanced three phase circuits. Analysis of magnetic circuits, basic principles of operation of transformers, dc and ac machines.

**Texts/References:**

T. K. Nagsarkar and M. S. Sukhija, Basic Electrical Engineering, Oxford University Press, 2005.
Vincent Del Toro, Electrical Engineering Fundamentals, Prentice Hall of India, 2004.
P. C. Sen, Principles of Electrical Machines and Power Electronics, John Wiley and Sons, 1997.
I. J. Nagrath and D. P. Kothari, Electrical Machines, Tata McGraw Hill, 1990.

## EN 203 Thermodynamics and Energy Conversion 3 1 0 8

### Course contents:

Basic concepts, Zeroth law and temperature, Energy interaction, First Law, Flow processes, Second Law, Entropy and availability, Combined First and Second Laws, Gas Power cycles: Carnot, Stirling, Brayton, Otto, Diesel and Duel cycles, Vapour power cycles: Rankine cycle and improvements, Refrigeration, Psychrometry, Role of thermodynamics in Energy conversion.

## Texts/References:

P.K.Nag, Engineering Thermodynamics, Tata Mc-Graw Hill, New Delhi, 1991.
H.B. Callen, Thermodynamics and an Introduction to thermostatistics, John Wiley, Toronto, 1985
A. Bejan, Advanced Engineering thermodynamics, John Wiley, Toronto, 1988

## XX Experimentation and measurements: Lab 0 0.5 3 4

(New lab course as per Biswas committee)

- How to design experiments to generate data cogently
- About the measurement and measuring systems
- How to interface equipment and sensors for modern day computational devices

**EN 205 Basic electrical engineering lab** **0 0 3 3**

(Lab to follow with EN201)

Introduction to Basic Laboratory Equipment and Measurements, Simple Circuit Measurements and Ohm's Law, Introduction to Digital Circuits Using TTL(Transistor-Transistor Logic), Resistors: Simplification of Series and Parallel Networks, Nodal Analysis of Simple Networks, Loop Analysis of Simple Networks, Operational Amplifiers, Design and Circuit Simulation using SPICE, Thevenin and Norton Equivalent Circuits, Superposition Theorem, Power Relationships in Simple Circuits RL and RC Circuits.

**Psychology/Philosophy/Sociology/Literature**

## HS 203 Introduction to Psychology 3 0 0 6

### Course Content:

Understanding human experience and behavior: Definition, schools, methods, branches and application of psychology for engineers; Measuring human abilities: Intelligence, Personnel testing; The individual working life: Personality - definition, approaches and theories; Psychological problems of everyday life: Stress and coping; Psychological disorders, work and mental health; Human learning; Motivation : the concept and theoretical framework, motivating people at work; Attitude and work behavior; Group dynamics Intergroup relations, conflict resolutions; Leadership and management.

### Texts/References:

J.V. McConnell, Psychology, New York: Holt., Rinehart & Wiaton, 1986.
C.T. Morgan, R.A. King, J.R. Weiss and J. Schopler, Introduction to Psychology (VIIth Ed.), New York: McGraw-Hill, 1986.
D.G. Myers, Psychology (IVth Ed.), New York: Worth, 1995.
S.E. Asch, Social Psychology, OUP Oxford, 1987.

## HS 205 Introduction to Sociology 3 0 0 6

### Course Content:

What is sociology, some sociological concepts: social structure, status, role, norms, values etc. Socialization, and culture and change. Social stratification - various approaches and concept of social mobility. Population and society - Trends of demographic change in India and the world, Human Ecology, Trends of Urbanization in the developing countries and the world. Major social institutions - Family and marriage, caste and tribe and organizations: (i) formal organization (bureaucracy) (ii) informal organization. Processes of social change - Modernization (including Sanskritization), industrialization, environmental/ecological changes and Development. Social movements - protest movements, reformist movement and radical movements in India.

### Texts/References:

L. Broom, P. Selznick and D. Dorrock, Sociology, 11th Edn. Harper International, 1990.
M. Haralambos, Sociology: Themes and Perspectives, Oxford University Press, 1980.
M.S.A. Rao (Ed) Social movements in India, vols. 1-2, Manohar, 1984.

David Mandelbaum, Society in India, Popular, 1990.
M.N. Srinivas, Social Change in Modern India, Orient Longman, 1991.
Guy Rocher, A. General Introduction to Sociology, MacMillan, 1982.

## HS 202 Introduction to Philosophy 3 0 0 6

### Course Content:

The course will acquaint the students of science and engineering with the some issues on the nature and methods of science and mathematics, and the ethical issues arising out of the application of science and technology. The objective is to develop a critical, reflective and historical awareness on the issues relating to the following topics:

Philosophy and History of Science: Growth of scientific knowledge: factors leading to the emergence of modern science. Conceptual evolution: internal and external history. Methodology of science: induction, falsificationism, confirmation and probability. Nature of scientific laws and theories: realism, instrumentalism and under determination. Relationship between scientific observation, experient and scientific theory. Nature of scientific explanation: teleological explanations and the covering law model. Selected case studies on scientific theories.

Logic and the nature of mathematical reasoning: Inductive and deductive forms of reasoning. Nature of axioms: formal axiomatic systems. Concept of consistency, independence and completeness. Nature of rules of inference and proof. Selected examples of axiomatic systems and proof procedures.

Cognition: Current approaches to the understanding of mind and mental processes: empiricist, rationalist, behaviorists and cognitivist.

Ethics: Impact of science and technology on man and society: elements of environmental and professional ethics.

### Texts/References:

A.C. Grayling (Ed.), Philosophy: A Guide through the subject, Oxford Univ. Press, London, 1995. Marx W. Wartofsky, Conceptual Foundations of Scientific Thought: An Introduction to the Philosophy of Science, Macmillan, London, 1968. I.B. Cohen, The Birth of a New Physics, Vakils, Feffer and Simons Pvt. Ltd., Bombay, 1968. H. Eves and C.V. Newsom, Foundations and Fundamental Concepts of athematics, Boston, PWS-Kart Pub. Co., 1990. K.E. Goodpaster and K.M. Sayre (Ed.), Ethics and Problems of 21st Century, Univ. of Notre Dame Press, London, 1979. S.D. Agashe, A. Gupta and K. Valicha, (Ed.), Scientific Method, Science, Technology and Society: A Book of Readings, Univ. of Bombay Press, 1963.

## HS 204 Introduction to Literature 3 0 0 6

**Course Content:**

Nature of literature: Literature as a Humanistic Experience. Definitions: (i) Humanities : concern with culture, values, ideologies; (ii) Literature: concepts of imitation, expression, intuition & imagination. Major themes of literature : Nature, Science, Selfhood, Love, Rebellion. The language of literature : Modes of literary and non-literary expression. The concepts of Figurative language, Imagery, Symbolism, Style. 4. The forms of literature : Prose Narratives (short stories & novels) Poetry, Drama
Essays. [NOTE: 1. Suitable texts are to be chosen by the instructor from the Texts and References listed below as well as from other sources. 2. Use of a Learner Dictionary (e.g.Oxford Advanced Learner's Dictionary is prescribed for language work.]

**Texts/References:**

David Murdoch (Ed.), The Siren's Song: An Anthology of British and American Verse, Orient Longman, 1988. S. Alter & W. Dissanayake (Ed.), The Penguin Book of Modern Indian Short Stories. Penguin Books (India), 1989. Bertrand Russell, Impact of Science on Society. Allen & Unwin, 1952. Henrik Ibsen, A Doll's House, Macmillan India, 1982. George Orwell, Animal Farm, Penguin, 1951. J. Bronowski, The Ascent of Man, BBC, 1973.

## ES XXX Environmental Studies 2 1 0 6

Course Content:

## EN 202 Electronics 2 1 0 6

**Course Content:**

Semiconductor diode characteristics, transistor characteristics. Biasing Circuit small signal low frequency h-parameter model. Low frequency transistors, amplifiers; FET biasing and low frequency amplifier circuits; RC-coupled amplifiers and oscillators.
Rectifiers and power supplies, Elements of IC regulated power supply.
Op-amps: Parameters and characteristics, inverting and non-inverting mode of its operation, linear applications including the use of op-amps in analog computations and active filters.
Introduction to digital circuits, modulation and demodulation.

**Texts/References:**

Allen Mottershed, Electronic Devices and Circuits, An Introduction, EEE Publication, 12th Indian Reprint, 1989.
Y.N. Bapat, Electronic Devices and Circuits, Tata McGraw Hill, 9th Reprint, 1989.
A.P. Malvino, Electronic Principles, 3rd TMH Edition, Tata McGraw Hill, 12th Printing, 1989.

## EN 204 Material Science for Energy Applications 3 1 0 8

### Course Content:

Review of quantum concepts: particle nature of light. Atomic Structure, Solid state physics: Free electron model of metals, Energy Bands, Bonding, superconductivity, Crystal Structure & Defects, Diffusion, Non Crystalline Materials, Phase Equilibria and Phase Diagrams, Phase Transformation, Microstructural Development. Conductivity, Electron Mobility, Energy levels, Electrical Resistivity of Metals & Alloys, Semiconductors, Hall Effect, Carrier Concentration. Dielectric Properties, Capacitance, Types of polarisations, Piezoelectricity & Ferroelectricity. Optical properties, Interaction of solids with radiation, Luminescence, Photoconductivity, Lasers.

### Texts/References:

L.H. Van Vlack, Elements of Materials Science and Engineering, Addison-Wesley, New York, 1989.
W.D. Callister, Jr., Materials Science and Engineering: An Introduction, John Wiley, New York, 1997.
Z.D. Jastrzebski, the Nature and Properties of Engineering Materials, John Wiley, New York, 1987
Ben G. Streetman, Solid State electronic devices, Prentice-Hall of India Pvt. Ltd., New Delhi, 1995.

## EN 206 Power Electronics and Machines 2 1 0 6

### Course Content:

Magnetic circuits, mutually coupled circuits, 3.Single phase and three phase transformers, Auto transformers. Basic concepts of Electromechanical energy conversion leading to rotating machines. Principle of operation characteristics and control of DC, three phase and single phase asynchronous machines and synchronous machines. Special machines, e.g. Stepper motors, brushless DC machines.

Characteristics of Power diodes, Thyristors, GTOs , BJTs , MOSFETs , IGBTs. Phase controlled AC to DC converters: Single and three phase, dual converters, unity power factor AC to Dc converters: PWM current source converter, PWM voltage source

converters. DC to DC converters: Operations of buck, boost, buck b boost, Cuk, fly back, and forward converters. DC to AC converters: Single phase and three phase topologies, PWM techniques including Space vector pulse with modulation. Brief introduction to AC to AC conversion: AC voltage controllers. Application of power electronic systems: HVDC, active power filters, motor control.

## Texts/References:

P.C Sen , Principle of electric machines ,John Wily & Sons.
Nagarath & Kothari, Electric machines, Tata Mc Graw hill.
N. Mohan, T.M. Undeland & W.P.Robbins, Power Electronics: converter, Applications & design, John Wiley & Sons,1989
M.H.Rashid, Power electronics, Prentice Hall of India, 2004 B.K. Bose Power Electronics & A. C. Drives, prentice Hall, 1986

## EN 208 Electronics Lab 0 0 3 3

(Lab to follow with EN 202)

Band Gap of a semiconductor, Forward and reverse characteristics of a diode; Half wave, Full wave and Bridge rectifier with different filter circuits; Study of Zener regulated power supply; Input and Output characteristics of a PNP/NPN transistor in CB/CE/CC configurations and determination of h-parameters, Transistor bias Stability; Characteristic curves for a FET; Fabrication of RC coupled transistor amplifier and its study; Study of Hartley, Colpitt and RC phase shift oscillators; Inverting and non-inverting OPAMP, Applications of OPAMP like adder, substractor, unity gain buffer, integration and differentiation; Flip Flops.

## EN 210 Electrical Machines & Power Electronics Lab 0 0 3 3

(Lab to follow EN 206)

A study of the characteristics and working of the power devices such as SCR, Power MOSFET and IGBT, controlled rectifies (SCR) – voltage control of DC motor, inverter performance (DC-AC, harmonics, V-f performance), power factor correction, Power measurement in balanced 3 phase circuits and power factor improvement, Open circuit short circuit test on single phase transfer, Characteristics of DC generators, Charactesrtics of separately excited DC generator, speed control of 3 phase induction generator,

## 3rd year courses

### EN 301 Introduction to Renewable Energy Technologies 2 1 0 6

### Course Content:

Introduction to world energy scenario, Renewable energy resources, Radiation, Solar Geometry, radiation models; Solar Thermal, Optical efficiency, thermal efficiency, concentrators, testing procedures, introduction to thermal systems (flat plate collector), solar architecture, solar still, air heater, panel systems; Photovoltaic; Introduction to semiconductor physics, doping, P_N junction, Solar cell and its I_V characteristics, PV systems components, design of a solar PV systems. Biomass, Biomass resources, wood composition, pyrolysis, gasifies, biogas, biodisel, ethanol; Wind, Introduction, types of wind machines, Cp-$\lambda$ curve & betz limits, wind recourse analysis; Systems, stand alone, grid connected, hybrid, system design; Hydro systems**,** Hydro resources, types of hydro turbine, small hydro systems; Other systems, Geothermal, wave energy, ocean energy

### Texts/References:


S. P. Sukhatme, Solar Energy - Principles of thermal collection and storage, second edition, Tata McGraw-Hill, New Delhi, 1996

J. A. Duffie and W. A. Beckman, Solar Engineering of Thermal Processes, second edition, John Wiley, New York, 1991

D. Y. Goswami, F. Kreith and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis, Philadelphia, 2000

D. D. Hall and R. P. Grover, Biomass Regenerable Energy, John Wiley, New York, 1987.

J. Twidell and T. Weir, Renewable Energy Resources, E & F N Spon Ltd, London, 1986.

M. A. Green, Solar Cells, Prentice-Hall, Englewood Cliffs, 1982.


### EN 303 Heat and mass transfer 3 1 0 8

### Course content:

Introduction; General Equation of Heat Conduction; 1-D and 2-D steady conduction – analytical approach; Unsteady conduction; Numerical approach to conduction problems; Introduction to convection; Conservation equations for mass, momentum and energy; Internal and external laminar forced convection; Natural convection; Effect of turbulence on convective heat transfer; Heat Exchangers – basic principles and design; Introduction to Radiation; Spectral and directional nature of surface radiation; Kirchhoff's law and gray surface approximation; View factor; Radiation exchange between black and diffuse gray surfaces in an enclosure; Introduction to radiation in participating media; Introduction to Boiling and Condensation; Introduction to Mass Transfer; Conservation of species equations; Mass diffusion with/without homogeneous chemical reactions

## Texts/References:

S. P. Sukhatme, Heat Transfer, 4th Edition, University Press, 2005.
F. P. Incropera and D. P. Dewitt, Fundamentals of Heat and Mass Transfer, 5th Edition, John Wiley and Sons, 2004.
P. S. Ghoshdastidar, Heat Transfer, Oxford, 2004.

## EN 305 Fluid Mechanics 2 1 0 6

## Course content:

Introduction; Fluid Statics; Flow Kinematics; Reynolds transport theorem; Integral equations for mass, momentum and energy; Differential equations for mass, momentum and energy; Dimensional Analysis; Introduction to Turbulence; Analysis of laminar and turbulent flows in pipes and channels; Boundary Layer theory – laminar and turbulent boundary layers; Inviscid irrotational flow (Potential flow) and introduction to aerodynamics**;** Introduction to compressible flows (optional); Fluid Machinery – principles and design considerations

## Texts/ References:

F. M. White, Fluid Mechanics, 5th Edition, McGraw-Hill, 2004.
R. W. Fox, A. T. McDonald and P. J. Pritchard, Introduction to Fluid Mechanics, 6th Edition, John Wiley and Sons, 2004.
S. K. Som and C. Biswas, Introduction to Fluid Mechanics and Fluid Machines, 2nd Edition, Tata McGraw-Hill, 2004.

## EN 307 Equipment Design and Control 3 0 0 6

## Course content:

Philosophy of equipment design, Fundamentals of mechanics of deformable solids. Concepts of stress and strain and their relationships, Fatigue, thermal stresses, and creep. Equilibrium equations, strain displacement relation, Combined stresses. Mohr's circle diagram, bending moments, shear forces and stresses, Torsion Theories of failure, Other material properties influencing design, Corrosion and its protection, Materials and Fabrication Selection, Safety issues in equipment design, Dynamic models of equipments. Relief Systems, Different types of sensors: Sensors for important process variables, Feedback control. Controller modes, Relay control: Stability and Performance Analysis using root locus, frequency response methods, Introduction to Controller design based on different criteria

**Texts/ References:**

W.L.Luyben. Process Modelling Simulation and Control for Chemical Engineers, McGraw Hill, 1990.
B. Liptak, Instrumentation Engineer's handbook, 1995
R.W. King and J. Magid, Industrial Hazards and Safety Handbook, Butterworth, 1982.
S.Walas, Chemical Process Equipment Selection and Design, Butterworth, 1988.
S.H. Crandall, N.C. Dahl and S. J. Lardner, An Introduction to Mechanics of Solids, Tata McGraw Hill, 1978.
E.P. Popov, Introduction to Mechanics of Solids, Prentice Hall, 1973.
H.H. Uhlig, R.W. Revie, Corrosion and Its Control, Wiley, Singapore, 1991

## EN 309 Thermal & Fluid Engineering Lab 0 0 3 3

Calibration of Pitot-static tube for gas (air) flow, orifice meter and ventury meter for liquid (water) flow through pipe Laminar and turbulent flow through pipes, pressure drop, heat transfer coefficient Flow over a cylinder – study of wake, drag coefficient and heat transfer coefficient Flow through converging and diverging nozzles Heat transfer by radiation and natural convection Drying of material by hot air Shell and tube heat exchangers – LMTD, pressure drop, heat transfer coefficient Plate heat exchangers – LMTD, pressure drop, heat transfer coefficient Pump and turbine efficiencies
CoP of refrigeration cycles – VCR and VAR Efficiency and BHP of SI and CI engines
Efficiency of Rankine cycle and Stirling cycle.

## EN 311 Energy Systems Lab 0 0.5 3 4

Energy consumption measurements of lights and ballast, light efficacy, fuel cell and its performance, Study of various speed control methods and calculating their efficiencies, Perform an experiment for efficiency testing of 3-phase squirrel cage induction motor and study the characteristics, Testing of Propeller type of wind turbine, testing gasifier, boiler efficiency testing, measurement of the calorific value of different Bio-mass fuels

## Department Elective-1 3 0 0 6

## EN 302 Power Generation & Systems Planning 2 1 0 6

### Course Content:

Overview of the Indian power sector, Thermodynamic analysis of Conventional Power Plants. Advanced Power Cycles, Kalina (Cheng) Cycle, IGCC, AFBC/PFBC.

Overview of Nuclear power plant, Radio activity, Cross sections, Fission process, reaction rates, diffusion theory, elastic scattering and slowing down, criticality calculations, critical heat flux, power reactors, nuclear safety.

Steam Turbine - Superheater, reheater and partial condenser vacuum.Combined Feed heating and Reheating. Regenerative Heat Exchangers, Reheaters and Intercoolers in Gas Turbine power plants. Hydro power plants - turbine characteristics. Auxiliaries - Water Treatment Systems, Electrostatic Precipitator / Flue gas Desulphurisation, Coal crushing / Preparation - Ball mills / Pulverisers, ID/FD Fans, Chimney, Cooling Towers.

Power plant control systems- Review of control principles, Combustion control, pulveriser control, control of air flow, Furnace pressure and feed water, steam temperature control, Safety provisions / Interlocks

Analysis of System load curve -plant load factor, availability, Loss of load Probability calculations for a power system, Maintenance Scheduling Pricing of Power - Project cost components, Analysis of Power Purchase Agreements (PPA), Debt/Equity Ratio and effect on Return on Investment, Environmental Legislations/Government Policies Optimal Dispatch - Scheduling of Hydro-Thermal plants. Load Forecasting - Time series, Econometric, end use techniques. Least Cost Power Planning - Integration of DSM, Renewables into supply.

### Texts/References:


R. W. Haywood, Analysis of Engineering Cycles, 4th Edition, Pergamon Press, Oxford, 1991.

D. Lindsay, Boiler Control Systems, Mcgraw Hill International, London, 1992.

H. G. Stoll, Least Cost Electrical Utility / Planning, John Wiley & Sons, 1989.

T. M. O` Donovan, Short Term Forecasting : An introduction to the Box Jenkins Approach, Wiley, Chichester, 1983.

A. B. Gill, Power Plant Performance, Butterworths, 1984.

A. J. Wood and B. F. Wollenberg, Power Generation, operation & control, John Wiley, New York, 1984.

J. R. Lamarsh, Introduction to Nuclear Engineering, 2nd edition, Addison-Wesley, 1983

## EE 304 Electrical Energy Systems 3 1 0 8

### Course Content:

Introduction Evolution of Power Systems, Energy Sources Structure of Bulk Power Systems Basic three phase system concepts Power System Components Generators, Loads, Transformers, Transmission Lines etc. Modelling, Performance and Constraints of these components Formulation/Solution of steady state equations for interconnected systems: Balanced and Unbalanced systems: Positive Sequence Network Per Unit System, Ybus formation Simple example of a load flow solution Introduction to generator swing equations and stability issues Simple Example of Loss of Synchronism Interconnected System Operation and Control Operational Objectives Frequency Control, Voltage Control Power Flow Control: Introduction to HVDC transmission and FACTS Economic Issues in Power Systems Analysis of Faulted Power Systems and Protection Unbalanced System Analysis using Sequence Components Equipment Protection Schemes: Over current, Differential and Distance Protection Relay coordination Preventive Control and Emergency Control (System Protection Schemes) Blackouts and Restoration.

### Texts/References

O. I. Elgerd, Electric energy systems theory-An Introduction, 2nd edition, Tata McGraw Hill, 1982.

A. R. Bergen and V. Vittal, Power Systems Analysis, Pearson Education Asia, New Delhi, 2002.

P. Kundur, Power System Stability and Control, MGraw Hill, 1993.

## EN 306 Combustion Engineering 2 1 0 6

### Course Content:

Fuels - Characteristics and Properties. Combustion Thermodynamics and Thermo-chemistry - Heat of Reaction, Calorific Value, Adiabatic Flame Temp. etc. Combustion Kinetics – Reaction Mechanism / Pathways, Rate Constants, Activation Energy. Flame – Diffusion Flame, Mixed Flame, Flame Velocity. Formation of Pollutants – CO, Soot, NOX and SOX. Combustion Modelling – Solid Combustion, Gas Combustion and Liquid Combustion. Combustion Equipment: Combustion in Boilers (including Fluidised Bed Combustion), Liquid Combustion – Atomiser, Spray Combustion etc., Gas Combustion – Gas Burners, Interchangibility of Fuels, Special Equipment. Engines, Combustion

Phenomenon in Engines, Performance of Engine and Emissions. Stoves. Catalysis – Catalytic Combustion and Control of Emissions.

## Texts/References:

F. A. Williams, Combustion Theory – the fundamental theory of chemically reacting flow systems, 2nd Edition, Addison-Wesley, Reading, 1965.
W. C. Gardiner (Ed), Combustion Chemistry, Springer-Verlag, New York, 1984.
D. Kunii and O. Levenspiel, Fluidisation Engineering, Wley, 1969.
S. R. Turns, Introduction to Combustion:-Concepts and Applications, 2nd Edition, McGraw-Hill, New York, 2000.
C. R. Ferguson and A. T. Kirkpatrick, Internal Combustion Engines – Applied Thermosciences, John Wiley, New York,, 2000.
V. Ganesan, Internal Combustion Engines, Tata McGraw-Hill, New Delhi, 1996.
J. J. Priestley, Industrial Gas Heating Design and Application, Benn, !973.
R. Flagan and J. H. Seinfeld, Fundamentals of Air Pollution Engineering, Prentice Hall, 1988.

**Department Elective – 2** **2 1 0 6**

## EN 308 Solar Energy Lab 0 0.5 3 4

Measurement of solar radiation and sunshine hours, Measurement of albedo, UV & IR radiation, Measurement of emissivity, reflectivity, transmittivity, Performance testing of solar flat plate water heater, forced flow & thermosyphon systems, Performance testing solar air heater & dryer & desalination unit, Performance testing of solar thermal concentrators, Characteristics of photovoltaic devices & testing of solar PV operated pump, Energy consumption & lumen measurement of lights & ballasts.

## EN 310 IC Engine and Combustion Laboratory 0 0.5 3 4

The laboratory exercise will mainly aim at introducing the determination of fuel properties relevant to their combustion and design of combustion equipments. This will include the properties like calorific value, proximate analysis, viscosity, surface tension, density, flash point, carbon residue (for liquid fuels) and determination of Flame velocity

for gaseous fuels. The basic understanding of IC engines, their parts and its working will be shown. The testing and performance evaluation of engine will also be included

**HSS Elective** **3 0 0 6**

## 4th year courses

### EN 401 Energy Systems Modelling & Analysis 2 1 0 6

**Course Content:**

Energy Chain, Primary energy analysis. Modelling overview- levels of analysis, steps in model development, examples of models. Quantitative Techniques : Interpolation - polynomial, lagrangian. curvefitting , regression analysis, solution of transcendental equations. Systems Simulation- information flow diagram, solution of set of nonlinear algebraic equations, successive substitution, Newton Raphson. Examples of energy systems simulation Optimisation: Objectives/constraints, problem formulation. Unconstrained problems- Necessary & Sufficiency conditions. Constrained Optimisation- lagrange multipliers, constrained variations, Kuhn-Tucker conditions. Linear Programming - Simplex tableau, pivoting, sensitivity analysis. Dynamic Programming . Search Techniques-Univariate/Multivariate. Case studies of optimisation in Energy systems problems. Dealing with uncertainty- probabilistic techniques. Trade-offs between capital & energy using Pinch Analysis. Energy- Economy Models: Scenario Generation, Input Output Model. Numerical solution of Differential equations- Overview, Convergence, Accuracy. Transient analysis- application example.

**Texts/References:**

W.F. Stoecker, Design of Thermal Systems, McGraw Hill, 1981.
S.S.Rao, Optimisation theory and applications, Wiley Eastern, 1990.
S.S. Sastry, Introductory methods of numerical analysis, Prentice Hall, 1988.
P. Meier, Energy Systems Analysis for Developing Countries, Springer Verlag, 1984.
R.de Neufville, Applied Systems Analysis , Mcgraw Hill, International Edition,1990.
S. G. Beveridge and R. S. Schechter, Optimisation Theory and Practice,McGraw Hill, 1970.

**EN 403 Energy Resources, Economics and Environment 2 1 0 6**

## Course Content:

Overview of World Energy Scenario, Dis-aggregation by end-use, by supply Fossil Fuel Reserves - Estimates, Duration Overview of India`s Energy Scenario - Dis-aggregation by end-use, by supply, reserves Country Energy Balance Construction - Examples Trends in energy use patterns, energy and development linkage. Energy Economics - Simple Payback Period, Time Value of Money, IRR, NPV, Life Cycle Costing, Cost of Saved Energy , Cost of Energy generated, Examples from energy generation and conservation, Energy Chain, Primary energy analysis Life Cycle Assessment, Net Energy Analysis Environmental Impacts of energy use - Air Pollution - SOx, NOx, CO, particulates Solid and Water Pollution, Formation of pollutants, measurement and controls; sources of emissions, effect of operating and design parameters on emission, control methods, Exhaust emission test, procedures, standards and legislation; environmental audits; Emission factors and inventories Global Warming, CO2 Emissions, Impacts, Mitigation Sustainability, Externalities, Future Energy Systems.

## Texts/References:

Energy and the Challenge of Sustainability, World energy assessment, UNDP, New York, 2000.

A.K.N. Reddy, RH Williams, TB Johansson, Energy after Rio, Prospects and challenges, UNDP, United Nations Publications, New York, 1997.

Global energy perspectives / edited by Nebojsa Nakicenovic, Arnulf Grubler and Alan McDonald, Cambridge University Press, 1998

J.M. Fowler, Energy and the environment,. 2nd Ed. ,McGraw Hill, New York, 1984

**Department Elective – 3 2 1 0 6**

**Department Elective – 4 2 1 0 6**

**Institute Elective – 1 2 1 0 6**

**Institute Elective – 2 2 1 0 6**

**EN 405 Energy Innovation Lab 0 0.5 3 4**

This laboratory will involve using different energy hardware components to build up prototype systems. This may involve power electronics devices or thermal devices. The laboratory will provide a list of projects where the students have to design and implement

a hardware solution for specified tasks. The laboratory will need a functioning solution for a completion grade.

## EN 402 Energy Management 2 1 0 6

### Course Content:

Importance of energy management. Energy auditing: methodology, analysis of past trends plant data), closing the energy balance, laws of thermodynamics, measurements, portable and on line instruments.

Energy economics - discount rate, payback period, internal rate of return, life cycle costing. Steam Systems: Boiler -efficiency testing, excess air control, Steam distribution & use- steam traps , condensate recovery , flash steam utilisation. Thermal Insulation.

Electrical Systems : Demand control, power factor correction, load scheduling/shifting, Motor drives- motor efficiency testing, energy efficient motors, motor speed control.

Lighting- lighting levels, efficient options, fixtures, daylighting, timers, Energy efficient windows.

Energy conservation in Pumps, Fans (flow control), Compressed Air Systems, Refrigeration & air conditioning systems. Waste heat recovery: recuperators, heat wheels, heat pipes, heat pumps.

Cogeneration - concept, options (steam/gas turbines/diesel engine based), selection criteria, control strategy. Heat exchanger networking- concept of pinch, target setting, problem table approach, composite curves. Demand side management. Financing energy conservation

### Texts/References:

L. C. Witte, P. S. Schmidt and D. R. Brown , Industrial Energy Management and Utilisation, Hemisphere Publ, Washington,1988.

Industrial Energy Conservation Manuals, MIT Press, Mass, 1982.

I. G. C. Dryden (Ed), The Efficient Use of Energy, Butterworths, London, 1982

W.C.Turner (Ed), Energy Management Handbook, Wiley, New York, 1982.

Technology Menu for Efficient energy use- Motor drive systems, Prepared by National Productivity Council and Center for & Environmental Studies- Princeton Univ, 1993.

## Institute Elective – 3 2 1 0 6

## EN 404 Electrochemistry 3 0 0 6

### Course content:

First law of thermodynamics, work, heat, and energy, standard enthalpy changes, temperature dependence of enthalpy changes, the second law of thermodynamics, concept of entropy, helmholtz and Gibbs energies, chemical potential and fugacity, Reaction kinetics, rate of reactions, temperature dependence of reaction rates, activated complex theory, Electrified interface, structure, and thermodynamics of electrified interface, electrochemical kinetics, Butler-Volmer equation, electrocatalysis, and some electrochemical systems of technological interest

### Texts/References:

P. W. Atkins, Physical Chemistry, Oxford University press, 1978

J. O. M. Bockris and A. K. N. Reddy, Modern Electrochemistry, Plenum Press, New York, 1970

Keith J. Laidler, Chemical Kinetics, McGraw-Hill, New York, 1950

## Open Elective 2 1 0 6

## Department Elective – 5 2 1 0 6

## EN 406 Seminar 0 0 0 3

## EN 408 Energy Design Project 0 0 0 12

### Objectives

Students are expected to do an energy system design project. This will illustrate the trade-offs and issues involved in system design and provide an opportunity to synthesis the different concepts and techniques learnt in the individual courses. Designs are expected to be detailed with engineering drawings and cost estimation. Depending on the type of project, there would be practical demonstration of the project. The topics offered by faculty guides will be of practical relevance and would be allotted in the previous semester.

## 5th year courses

## MG 696 Engineering Project Management 3 0 0 6

### Course Content:

Characteristics of Engineering projects, Definition and objectives of Project Management, Stages of Project Management, Project Planning Process, Establishing Project organization, Work definition: Defining work content, Time Estimation Method, Project Cost Estimation and budgeting, Project Risk Management, Project scheduling and Planning Tools: Work Breakdown structure, LRC, Gantt charts, CPM/PERT Networks; Developing Project Plan (Baseline), Project cash flow analysis, Project scheduling with resource Constraints: Resource Leveling and Resource Allocation. Time Cost Tradeoff: Crashing Heuristic; Project Implementation: Project Monitoring and Control with PERT/Cost, Computers applications in Project Management, Contract Management, Project Procurement Management; Post Project Analysis

### Texts/References:

N. J. Smith (Ed), Engineering Project Management, Blackwell Publishing, 2002.

Jack R Meredith and Samuel J Mantel, Project Management: A Managerial Approach, John Wiley, 4th Edition, 2000.

Horald Kerzner, Project Management: A Systemic Approach to Planning, Scheduling and Controlling, CBS Publishers, 2002.

John M Nicholas, Project Management for Business and Technology: Principles and Practice, Prentice Hall of India, 2002

Robert K. Wysocki, Robert Back Jr. and David B. Crane, Effective Project Management, John Wiley, 2002

## DD Project Stage – I 0 0 3 6

## Open Elective 3 0 0 6

## DD Project Stage – II 0 0 36