ENERGY SCIENCE AND ENGINEERING, I I T BOMBAY

Dual Degree (B.Tech.-M.Tech.) Curriculum

COURSE CURRICULUM												
SEMESTER – I							**SEMESTER - II**					
Course Code	Course name	Credit structure					Course Code	Course name	Credit structure			
		L	T	P	C				L	T	P	C
MA 105	Calculus	3	1	0	8		MA 106	Linear Algebra	2	0	0	4
PH 107	Quantum Physics and application	2	1	0	6		MA 108	Ordinary Differential Equations I	2	0	0	4
CH 105	Organic/Inorganic Chemistry	2	0	0	4		PH 108	Electricity & Magnetism	2	1	0	6
CH 107	Physical Chemistry	2	0	0	4		CS101/ BB 101	Computer Programming & Utlization Biology	2	0	2	6
CS101/ BB 101	Computer Programming & Utlization Biology	2	0	2	6		ME 119	Engineering Graphics & Drawing	0	1	3	5
ME 113	Workshop Practice	0	0	4	4		PH 117/ CH 117 Lab	Physics Lab Chemistry Lab	0	0	3	3
PH 117/ CH 117 Lab	Physics Lab Chemistry Lab	0	0	3	3		EN 102	Energy Engineering Fundamentals (DIC)	2	1	0	6
NC 101/ NO 101/ NS 101	National Cadet Corps (NCC) National Sports Organization (NSS) National Service Scheme (NSS)	0	0	0	P/ NP		NC 101/ NO 101/ NS 101	National Cadet Corps (NCC) National Sports Organization (NSS) National Service Scheme (NSS)	0	0	0	P/NP
					35							**34**

COURSE CURRICULUM													
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 200/ES 200	Environmental Studies	2	1	0	6			MA 214	Introduction to Numerical Analysis	2	1	0	6
HS 101	Economics	2	1	0	6			EN 212	Electrical Machines	3	0	0	6
EN 207	Data Analysis and Interpretations	2	1	0	6			EN 204	Material Science for Energy Applications	3	1	0	8
EN 209	Basic Electrical & Electronics Engineering	3	1	0	8			EN 214	Transport Phenomena	3	1	0	8
EN 203	Thermodynamics and Energy Conversion	2	1	0	6			EN 216	Renewable Energy Technologies	2	1	0	6
EN 211	Mechanics of Materials	2	1	0	6			EN 218	Energy Resources, Economics & Environment	2	1	0	6
EN 205	Lab 1- Basic Electrical & Electronics Engineering	0	0	3	3								
					41								**40**

COURSE CURRICULUM													
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 313	Power Electronics	3	0	0	6			EN 314	Electrochemistry	3	0	0	6
EN 315	Reaction Engineering & Combustion	2	1	0	6			EN 302	Power Generation & System Planning	2	1	0	6
EN 317	Thermo-Fluid Devices	3	1	0	8			EN 304	Electrical Energy Systems	2	1	0	6
	Departmental Elective – 1	2	1	0	6			EN 312	Control & Instrumentation	3	1	0	8
HS 203, HS 205, HS 202 and HS 204	Psychology/Sociology/Philosophy/literature	3	0	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 319	Electrical Machines & Power Electronics Lab	0	0	3	3			EN 310	IC Engine and Combustion Lab	0	0.5	3	4
					38								**40**

COURSE CURRICULUM													
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 Modelling & Analysis	2	1	0	6		EN 410	Energy management	2	1	0	6	
EN 405	Energy Innovation Lab	0	0	0	6		EN408	Energy Design Project	0	0	0	6	
	Department elective 3	3	0	0	6			Institute Elective – 2	3	0	0	6	
	Department elective 4	3	0	0	6			Department elective-6	2	1	0	6	
	Department elective – 5	3	0	0	6			Department elective-7	2	1	0	6	
								Department Elective -8	3	0	0	6	
	Institute elective -1	3	0	0	6			Open Elective -1	3	0	0	6	
EN 406	Seminar	0	0	0	3								
					39							**42**	

COURSE CURRICULUM												
SEMESTER – IX							**SEMESTER – X**					
Course Code	Course name	Credit structure					Course Code	Course name	Credit structure			
		L	T	P	C				L	T	P	C
	Department Elective -9	3	0	0	6		EN 594	DD project stage - II	0	0	0	42
	Open Elective -2	3	0	0	6							
EN 593	DD project stage – I	0	0	0	30							
					42							**42**

List of Department Electives

CE 639	Green Building Design
CH 550	Interfacial electrochemistry and applications
CH 586	Structures and properties of materials
CL 260	Mol. And Stat. Thermodynamics
CL 465	Stochastic Processes
CL 601	Advance Transport Phenomena
CL 602	Mathematical and Statistical Methods in Chemical Engineering
CL 603	Optimization
CL 607	Advanced Thermodynamics
CL 618	Catalysis and Surface Chemistry
CL 625	Process Modelling and Identification
CL 647	Advanced Process Optimization
CL 649	Reaction Engineering in Dispersed Phase Systems
CL 653	State Estimation: Theory and Applications
CL 669	Product Research And Development
CL 672	Applied Multivariate Statistics in Chemical Engg.
CL 686	Advanced Process Control
CL 688	Artificial Intelligence in Process Engineering
CL 692	Digital Control
CL 710	Aerosol Technology
CL 714	Nonlinear Systems Analysis
EE 603	Digital Signal Processing and Applications
EE 610	Image Processing
EE 613	Nonlinear Dynamical Systems
EE 622	Optimal Control Systems
EE 630	Digital Measurement Techniques
EE 634	Simulation of Circuits and Devices

EE 636	Matrix Computations
EE 640	Multivariable Control Systems
EE 651	Digital Protection of Power Systems
EE 653	Power Electronics -I
EE 654	Power Electronics - II
EE 655	Computer Aided Power System Analysis
EE 656	Electrical Machine Analysis & Control
EE 657	Electric Drives I
EE 658	Power System Dynamics and Control
EE 659	A First Course in Optimization
EE 660	Application of Power Electronics to Power Systems
EE 666	High Power Semiconductor Devices
EE 675	Microprocessor Applications in Power Electronics
EE 685	Power System Protection
EE 686	HVDC Transmission
EE 701	Introduction to MEMS
EE 704	Artificial Neural Networks
EE 710	Large Sparse Matrix Computations
EE 712	Embedded Systems Design
EE 713	Circuit Simulation in Power Electronics
EE 722	Restructured Power Systems
EE 723	Physics of Nanoelectronic Devices I
EE 724	Nanoelectronics
EE 725	Computational Electromagnetics
EE 727	Physics of Nanoelectronic Devices II
EE 728	Growth and Characterization of Nano-electronic Materials
EE 731	Design of Experiment /Taguchi Method for Experimental Research
EE 732	Combinatorial Optimization
EE 734	Advanced Probability and Random Processes for Engineers

EE 736	Introduction to Stochastic Optimization
EE 737	Introduction to Stochastic Control
EN 604	Fuel Cells
EN 610	Hydrogen Energy
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	Conservation 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 634	Nuclear Reactor Thermal-Hydraulics and Safety
EN 640	Solar photovoltaics: fundamentals, technology and applications
EN 645	Process integration
EN 646	Energy and climate
EN 647	Distributed Generation and Microgrids
EN 649	Introduction to particulate flow
ES 616	Energy conversion and environment
ME 462	Appropriate Technology
ME 477	Introduction to Optimization
ME 613	Nuclear Reactor Theory
ME 618	Pressure Vessel Design
ME 623	Cryogenic Engineering II
ME 651	Fluid Dynamics
ME 655	Theory and Design of Fluid Machinery
ME 661	Advanced Thermodynamics & Combustion
ME 662	Convective Heat and Mass Transfer

ME 663	Advanced Heat Transfer
ME 665	Conduction and Radiation
ME 666	Design of Heat Exchange Equipment
ME 673	Mathematical Methods in Engineering
ME 678	Fundamentals of Gas Dynamics
ME 680	Two Phase Flow
ME 681	Thermal Environmental Engineering
ME 683	Cryogenic Engineering-I
ME 684	Air Conditioning System Design
ME 704	Computational Methods in Thermal and Fluids Engineering
ME 724	Essentials of Turbulence
ME 758	Micro Fluidics
PH 205	Physics III (Quantum physics and applications)
PH 409	Introduction to condensed matter physics
SC 605	Optimization Based Control of Stochastic Systems
SC 620	Automation and Feedback Control

Detailed Course Contents

New Courses

Name of Academic Unit (Department) : Energy Science and Engineering

Level : 200

Programme : Dual Degree

I.	Title of Course	Data Analysis and Interpretations
II.	Credit Structure (L-T-P-C)	2-1-0-6
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Autumn
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	NIL
VII	Course Content*	The role of statistics. Graphical and numerical methods for describing and summarizing data. The mean, variance and its computation. The variance as a measure of random-ness and its implication. 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. Estimations of various energy resources.
VIII	Text/Reference**	"Introduction to Probability and Statistics to Engineers and Scientists", by Sheldon M. Ross, 3rd edition (Indian). Douglas C. Montgomery, G. C. Runger, Applied Statistics and Probability for Engineers, JohnWiley and Sons, 2003. A. M. Mood and F. A. Graybill, An Introduction to the Theory of statistics, Prentice Hall of India, 1963 P. G. Hoel, S. C. Port and C. J. Stone, Introduction to Statistical Theory, Houghton Miffin, 1971 John A. Rice, Mathematical Statistics and Data Analysis, Cengage Learning. 2007 Probability and Statistics for Engineering and the Sciences, Jay L. Devore, Cengage Learning. 2012 P.J. Lee, Statistical Methods for Estimating Petroleum Resources, Oxford University Press, 2008 T. Agami Reddy, Applied Data Analysis and Modeling for Energy Engineers and Scientists, Springer, 2011
IX	Name(S) of Instructor(S)***	Pratibha Sharma, Santanu Bandyopadhay, Rangan Banarjee, Suneet Singh, J.K.Nayak
X	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	This course aims to provide basic foundation for data analysis and their interpretation with special applications related to the field of energy resources. This is a core course.

Name of Academic Unit (Department) : Energy Science and Engineering

Level : 200
Programme : Dual Degree

I.	Title of Course	Basic Electrical and Electronics Engineering
II.	Credit Structure (L-T-P-C)	3 1 0 8
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Autumn
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII	Course Content*	Network theorems: Thevenin's and Norton's theorems, superposition theorem and maximum power transfer theorem. Time domain analysis of first and second order liner circuits. Sinusoidal steady state analysis, series and parallel resonance, power calculation, reactive power, power factor and significance of power factor correction, three phase balanced and unbalanced circuits. Semiconductor diode characteristics, transistor characteristics. Low frequency transistor, amplifiers; RC-coupled amplifiers and oscillators. Op-amps: parameters and characteristics, inverting and non-inverting mode of its operation, linear application including the use of op-amps in analog computations and active filters. Timer circuits (555). Introduction to digital circuits, Boolean algebra and switching functions, elementary combinational and sequential digital circuits: adders, comparators, shift registers, counters, modulation and demodulation.
VIII	Text/Reference**	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 K.A.Krishnamurthy and M.R.Raghuveer, `Electrical and Electronics Engineering for Scientists', Wiley Eastern Ltd., 1993 Ramakant A. Gayakwad, Op-Amps and Linear Integrated Circuits, Prentice Hall of India, 2000 Allen Mottershed, Electronic Devices and Circuits, An Introduction, EEE Publication, 12th Indian Reprint, 1989.
IX	Name(S) of Instructor(S)***	S. Doolla, Rajesh Gupta, S. Bandyopadhyay
X	Name(s) of other Departments/ Academic Units to whom the course isrelevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	This course aims to provide basic foundation for basic electrical and electronics engineering. This is a core course.

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Name of Academic Unit (Department) : Energy Science and Engineering

Level : 200

Programme : Dual Degree

I.	Title of Course	Mechanics of Materials
II.	Credit Structure (L-T-P-C)	2 1 0 6
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Autumn
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII	Course Content*	Fundamentals of deformable solids, concepts of stress and strain, material properties, patterns of failure, analysis of normal stresses thermal stresses torsional members, bending in beams and columns; design approach, introduction to machine elements and selection, consideration for bearing, gears, chains, belts, pulley key, riveters, nut-bolts, pins, transmission machinery, 4-bar linkages, flywheel; typical design approach for machine or equipment.
VIII	Text/Reference**	Mechanics of materials (in SI Units); F. P. Beer, E. R. Johnston, J. T. DeWolf; Tata Mc Graw Hill Education Pvt. Ltd. Elements of Strength of Materials, S. P. Timoshenko and D. H. Young; East-West Press Pvt. Ltd.
IX	Name(S) of Instructor(S)***	Santanu Bandyopadhay, Rangan Banerjee, S.B.Kedare
X	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	This course aims to provide basic foundation for mechanics of materials that are important in mechanical design of various equipments. This is a core course.

Name of Academic Unit (Department) : Energy Science and Engineering

Level : 200

Programme : Dual Degree

I.	Title of Course	Transport Phenomena
II.	Credit Structure (L-T-P-C)	3 1 0 8
II.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
V.	Semester in which normally to be offered (Autumn/Spring)	Spring
V.	Whether Full or Half Semester Course	Full
/I.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
II.	Course Content*	Vectors and Tensors – an Introduction; Viscosity and the mechanism of momentum transport, Velocity profile in laminar flow; The equations of change for isothermal systems; Thermal conductivity and the mechanism of energy transport; Temperature distribution in solids and laminar flow; Equations of change for non-isothermal systems; Diffusivity and the mechanism of mass transport; Concentration distribution in solids and in laminar flow, Equations of change for multi-component Systems
II.	Text/Reference**	Transport Phenomena; R. B. Bird, W. E. Stewart and E. N. Lightfoot; John Wiley & Sons; 1960 Introduction to Fluid Mechanics; R. W. Fox and A. T. McDonald; 7th Edition, Wiley Student Edition Fundamentals of Heat and Mass Transfer; F. P. Incropera, D. P. Dewitt, T. L. Berhman and A. S. Lavine; 6th Edition, Wiley India Heat and Mass Transfer: A Transport Phenomena Approch; K S Gandhi; New Age International Publishers
X.	Name(S) of Instructor(S)***	Manaswita Bose, Suneet Singh, Pratibha Sharma, J K Nayak
X.	Name(s) of other Departments/ Academic Units to whom the course is relevant	Chemical Engineering, Mechanical Engineering
XI.	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	Yes, CL203 and CL336
II.	Justification/ Need for introducing the course	This course aims to provide basic foundation for different transport process, viz. heat, mass and momentum transport which are extremely important for Energy Engineering. This is a core course.

Name of Academic Unit (Department) : Energy Science and Engineering

Level : 200

Programme : Dual Degree

I.	Title of Course	Electrical Machines
II.	Credit Structure (L-T-P-C)	3 0 0 6
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Spring
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII	Course Content	Magnetic circuits, mutually coupled circuits, Transformers: Principle of operation, equivalent circuit, phasor diagrams, testing , parallel operation and analysis of single phase, three phase transformers and auto transformers. Principle of operation characteristics and control of DC, single phase and three phase induction machines and synchronous machines. Starting techniques of induction motors. Introduction to stepper motors, brushless DC machines, permanent magnetic machines, energy efficient machines.
VIII	Text/ Reference**	P.C Sen , Principle of electric machines, John Wiley & Sons, New Delhi, 2007. A. E. Fitzgerald, Charles Kingsley, S. D. Umans, Electric Machinery, TMH, New Delhi, 2009.
IX	Name(S) of Instructor(S)***	Suryanarayana Doolla, Santanu Bandyopadhyay
X	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	This course aims to provide basic foundation of electrical machines. This is a core course.

Name of Academic Unit (Department) : Energy Science and Engineering

Level : 300

Programme : Dual Degree

I.	Title of Course	Thermo-Fluid Devices
II.	Credit Structure (L-T-P-C)	3 1 0 8
III	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Autumn
V	Whether Full or Half Semester Course	Full
VI	Pre-requisite(s), if any (For the student) – Specify Course number(s)	Transport Phenomena
VII	Course Content*	Fluid motive devices: working principle, selection criteria, and characteristic curve; example to include centrifugal and reciprocal pumps, blower, fan, compressor, turbines: water, steam and gas; Heat exchangers; types of heat exchanger, selection criteria, basic design principles Combustion equipments such as different types of boilers, design principle of refrigeration and air-conditioning systems.
VIII	Text/Reference**	Fluid Mechanics and Its Applications; Vijay Gupta and Santosh K Gupta, New Age International Publishers Principles of Unit Operations; A. S. Foust, L. A. Wenzel, C. W. Clump, L. Maus and L. B. Anderson; John Wiley & Sons Unit Operations of Chemical Engineering; W. L. McCabe, J. C. Smith, and P Harriott; 7th Edition, McGraw Hill International Edition Process Heat Transfer; D. Q. Kern; Tata McGraw Hill
IX	Name(S) of Instructor(S)***	Manaswita Bose, Suneet Singh, J K Nayak, Anuradda Ganesh
X	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	No
XII	Justification/ Need for introducing the course	This course aims to enhance the applications of devices that use the fundamentals of heat transfer and fluid mechanics. This is a core course.

Name of Academic Unit (Department) : Energy Science and Engineering

Level : 300

Programme : Dual Degree

I.	Title of Course	Reaction Engineering and Combustion
II.	Credit Structure (L-T-P-C)	2 1 0 6
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV.	Semester in which normally to be offered(Autumn/Spring)	Autumn
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII.	Course Content *	Fuels: Characteristics and Properties, Combustion Thermodynamics and Thermo-chemisty, Heat of Reaction, Calorific Value, Adiabatic Flame Temp, Combustion Kinetics, Reaction Mechanism and Pathways, Rate constants, Activation Energy, Introduction to Flame, Formation of pollutants: CO, Soot, NOX and SOX, Combustion Modelling: Gas, Liquid and Solid Combustion, Formation of Ash.
VIII.	Text/Reference**	Fuels and Combustion; Samir Sarkar; 3rd Edition; Universities Press, Fundamentals of Combustion; D. P. Mishra; Prentice-Hall of India Pvt Ltd, An Introduction to Combustion: Concepts and Applications; Stephen Turns; McGraw-Hill, Elements of Chemical Reaction Engineering; H. S. Fogler; 3rd Edition; Prentice-Hall of India
IX.	Name(S) of Instructor(S)***	Manoj Neergat, Manaswita Bose, Anuradda Ganesh
X.	Name(s) of other Departments/ Academic Units to whom the course is relevant	Mechanical Engineering, Chemical Engineering, Aerospace Engineering
XI.	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	No
XII.	Justification/ Need for introducing the course	This course aims to provide basic foundation for reaction engineering with special emphasis on combustion process. This is a core course.

Name of Academic Unit (Department) : Energy Science and Engineering

Level : 300

Programme : Dual Degree

I.	Title of Course	Power Electronics
II.	Credit Structure (L-T-P-C)	3 0 0 6
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Autumn
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	Basic Electrical and Electronics Engineering
VII	Course Content*	Characteristics and protection of power semiconductor devices. AC to DC converters: Single and three phases phase controlled rectifiers, dual converters and pulse width modulated rectifiers. 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 (sine triangular space vector PWM). AC to AC conversion: AC voltage controllers, cycloconverter. Methods of dc motor control, performance and stability of variable speed dc drives. Induction motor control systems, recovery of slip energy, variable frequency control of ac motors, current source inverter fed induction motor drive, forced commutated inverter fed drives, traction drives.
VIII	Text/Reference**	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
IX	Name(S) of Instructor(S)***	Suryanarayana Doolla, Suneet Singh, Rajesh Gupta
X	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	This course aims to provide basic foundation of power electronics for electrical energy conversion and control. This is a core course.

Name of Academic Unit (Department) : Energy Science and Engineering

Level : 300

Programme : Dual Degree

I.	Title of Course	Control and Instrumentation
II.	Credit Structure (L-T-P-C)	3 1 0 8
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Spring
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII	Course Content*	Dynamics of physical systems, notion of feed-back; open- and closed-loop systems. Laplace transforms and Z-transforms; application of transforms to discrete and continuous systems-analysis; industrial control examples. Transfer function models of mechanical, electrical, thermal and hydraulic systems, closed-loop systems. Block diagram and signal flow graph analysis. Basic modes of feedback control: proportional, integral and derivative. Stability concept, stability criterion. Root locus method of design lead and leg compensation. Relationship between time & frequency response, polar plots, Bode's plots. Stability in frequency domain, Nyquist plots and criterion. Frequency-domain methods of design, Compensation and their realization in time and frequency domain. Lead and Lag compensation. Instrumentation systems for physical measurements: Measurement and control of displacement, strain, force, torque acceleration, temperature and flow. Acquisition systems: data loggers, pc based data acquisition systems, interfacing and bus standards. Introduction to distributed control systems (DCS): programmable logic controller and their industrial applications.
VIII	Text/ Reference**	M. Gopal, I.J. Nagrath, Control Systems Engineering 5th Edition, New Age International, 2011. Benjamin C Kuo, Automatic Control Systems 7th Edition, PHI Learning, 1995. William C. Dunn, Fundamentals of Industrial Instrumentation and Process Control 1st Edition, Tata Mcgraw Hill Education, 2009 Norman A. Anderson, Instrumentation for Process Measurement and Control 3rd Edition, Publisher: CRC Press, 1997
IX	Name(S) of Instructor(S)***	S Bandyopadhyay, A Ganesh, Manaswita Bose, Suneet Singh, Suryanarayana Doolla
X	Name(s) of other DepartmentsAcademic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	This course aims to provide basic foundation for control of various equipments and systems with fundamental understanding of instrumentation. This is a core course.

Detailed Course Contents

Existing Courses

Name of Academic Unit (Department) : Energy Science and Engineering

Programme : Dual Degree

I	Title of Course	**EN 102 (DIC) - Energy Engineering Fundamentals**
II	Credit Structure (L-T-P-C)	2 1 0 6
III	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered (Autumn/Spring)	Spring
V	Whether Full or Half Semester Course	Full
VI	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII	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 (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
VIII	Text/Reference**	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.
IX	Name(S) of Instructor(S)***	Rangan Banerjee, Santanu Bandyopadhyay, Suneet SIngh
X	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	None
XII	Justification/ Need for introducing the course	This course aims to provide perspective of energy engineering. This is a core course.

Name of Academic Unit (Department) : Energy Science and Engineering

Programme : Dual Degree

I.	Title of Course	**EN 203 Thermodynamics and Energy Conversion**
II.	Credit Structure (L-T-P-C)	2 1 0 6
III	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Autumn
V	Whether Full or Half Semester Course	Full
VI	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII	Course Content*	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
VIII	Text/Reference**	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
IX	Name(S) of Instructor(S)***	Santanu Bandyopadhyay, K Balasubramaniam, Manaswita Bose
X	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	

Name of Academic Unit (Department) : Energy Science and Engineering

**Programme : ** Dual Degree

I.	Title of Course	**EN 205 Basic Electrical Engineering Lab**
II.	Credit Structure (L-T-P-C)	0 0 3 3
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Autumn
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII	Course Content*	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.
VIII	Text/Reference**	-
IX	Name(S) of Instructor(S)***	
X	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	

Name of Academic Unit (Department) : Energy Science and Engineering

Programme : Dual Degree

I.	Title of Course	**EN 204 Material Science for Energy Applications**
II.	Credit Structure (L-T-P-C)	3 1 0 8
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV.	Semester in which normally to be offered(Autumn/Spring)	Spring
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII.	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.
VIII.	Text/Reference**	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.
IX.	Name(S) of Instructor(S)***	Sagar Mitra, K Balasubramaniam, Shaibal Sarkar
X.	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI.	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII.	Justification/ Need for introducing the course	

Name of Academic Unit (Department) : Energy Science and Engineering

Programme : Dual Degree

I.	Title of Course	**EN 301 Introduction to Renewable Energy Technologies**
II.	Credit Structure (L-T-P-C)	2 1 0 6
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Spring
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII	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-λ 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
VIII	Text/Reference**	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.
IX	Name(S) of Instructor(S)***	Chetan Singh Solanki, P C Ghosh, J K Nayak
X	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	

Name of Academic Unit (Department) : Energy Science and Engineering

Programme : Dual Degree

I.	Title of Course	**EN 403 Energy Resources, Economics and Environment**
II.	Credit Structure (L-T-P-C)	2 1 0 6
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Spring
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII	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.
VIII	Text/ Reference**	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
IX	Name(S) of Instructor(S)***	
X	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	

Name of Academic Unit (Department) : Energy Science and Engineering

Programme : Dual Degree

I.	Title of Course	**EN 309 Thermal & Fluid Engineering Lab**
II.	Credit Structure (L-T-P-C)	0 0 3 3
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Autumn
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII	Course Content	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.
VIII	Text/ Reference**	-
IX	Name(S) of Instructor(S)***	
X	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	

Name of Academic Unit (Department) : Energy Science and Engineering

Programme : Dual Degree

I.	Title of Course	**EN 210 Electrical Machines and Power Electronics Lab**
II.	Credit Structure (L-T-P-C)	0 0 3 3
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Autumn
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII	Course Content	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
VIII	Text/ Reference**	-
IX	Name(S) of Instructor(S)***	
X	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	

Name of Academic Unit (Department) : Energy Science and Engineering

Programme : Dual Degree

I.	Title of Course	**EN 302 Power Generation & Systems Planning**
II.	Credit Structure (L-T-P-C)	2 1 0 6
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Spring
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII	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.
VIII	Text/Reference**	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
IX	Name(S) of Instructor(S)***	Suneet Singh, Santanu Bandyopadhyay
X	Name(s) of other Departments/ Academic Units to whom the course isrelevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	

Name of Academic Unit (Department) : Energy Science and Engineering

Programme : Dual Degree

I.	Title of Course	**EN 308 Solar Energy Lab**
II.	Credit Structure (L-T-P-C)	0 0.5 3 4
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Spring
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII	Course Content*	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.
VIII	Text/Reference**	-
IX	Name(S) of Instructor(S)***	
X	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	

Name of Academic Unit (Department) : Energy Science and Engineering

Programme : Dual Degree

I.	Title of Course	**EN 404 Electrochemistry**
II.	Credit Structure (L-T-P-C)	3 0 0 6
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Spring
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII	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
VIII	Text/ Reference**	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
IX	Name(S) of Instructor(S)***	Manoj Neergat, Sagar Mitra
X	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	

Name of Academic Unit (Department) : Energy Science and Engineering

Programme : Dual Degree

I.	Title of Course	**EN 304 Electrical Energy Systems**
II.	Credit Structure (L-T-P-C)	2 1 0 6
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Spring
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII	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.
VIII	Text/ Reference**	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.
IX	Name(S) of Instructor(S)***	Surayanarayan Doolla, Suneet Singh, S. Bandyopadhyay
X	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	

Name of Academic Unit (Department) : Energy Science and Engineering

Programme : Dual Degree

I.	Title of Course	**EN 310 IC Engine and Combustion Laboratory**
II.	Credit Structure (L-T-P-C)	0 0.5 3 4
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Spring
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII	Course Content*	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
VIII	Text/Reference**	-
IX	Name(S) of Instructor(S)***	
X	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	

Name of Academic Unit (Department) : Energy Science and Engineering

Programme : Dual Degree

I.	Title of Course	**EN 401 Energy Systems Modeling and Analysis**
II.	Credit Structure (L-T-P-C)	2 1 0 6
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Autumn
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII	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 Optimisationlagrange 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.
VIII	Text/Reference**	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.
IX	Name(S) of Instructor(S)***	R Banerjee, S. Bandyopadhyay
X	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	

Name of Academic Unit (Department) : Energy Science and Engineering

Programme : Dual Degree

I.	Title of Course	**EN 405 Energy Innovation Lab**
II.	Credit Structure (L-T-P-C)	0 0 0 6
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Autumn
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII	Course Content*	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 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
VIII	Text/ Reference**	
IX	Name(S) of Instructor(S)***	DESE Faculty
X	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	

Name of Academic Unit (Department) : Energy Science and Engineering

Programme : Dual Degree

I.	Title of Course	**EN 402 Energy Management**
II.	Credit Structure (L-T-P-C)	2 1 0 6
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Spring
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII	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
VIII	Text/ Reference**	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.
IX	Name(S) of Instructor(S)***	Rangan Banerjee
X	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	

Name of Academic Unit (Department) : Energy Science and Engineering

Programme : Dual Degree

I.	Title of Course	**EN 408 Energy Design Project**
II.	Credit Structure (L-T-P-C)	0 0 0 6
III.	Type of Course (Institute/Departmental) + (Core/Elective/…)	Departmental / Core
IV	Semester in which normally to be offered(Autumn/Spring)	Spring
V.	Whether Full or Half Semester Course	Full
VI.	Pre-requisite(s), if any (For the student) – Specify Course number(s)	None
VII	Course Content*	Students are expected to do an energy system design project. This will illustrate the tradeoffs 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.
VIII	Text/ Reference**	
IX	Name(S) of Instructor(S)***	DESE faculty
X	Name(s) of other Departments/ Academic Units to whom the course is relevant	
XI	Is/Are there any course(s) in the same/other academic unit(s) which is/are equivalent to this course? If so, please give details.	
XII	Justification/ Need for introducing the course	