Appendix-38
Resolution No. 38-24

Department of Electrical Engineering
Faculty of Technology
University of Delhi
Detailed Course Structure and Curriculum of B.Tech. (EE) Third Year

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Department of Electrical Engineering
Faculty of Technology
University of Delhi

Course Structure of B. Tech. (EE) Third Year

Semester V						
S. No.	**Course Domain**	**Course Title**	**Credits***			**Total Credits**
			L	**T**	**P**	
1	DSC-13	Power System Analysis	3	0	1	4
2	DSC-14	Control System	3	0	1	4
3	DSC-15	Electromagnetic Field Theory	3	0	1	4
4	DSE-03	Select a course from the specified list of DSE-3				4
5	GE-05	Select a course from the specified list of GE-5				4
6	SEC / IAPC	Choose one SEC or Internship / Apprenticeship / Project / Community Outreach (IAPC)				2
Total Credits						**22**

Semester VI						
S. No.	**Course Domain**	**Course Title**	**Credits***			**Total Credits**
			L	**T**	**P**	
1	DSC-16	Switchgear and Protection	3	0	1	4
2	DSC-17	Embedded System Technologies	3	0	1	4
3	DSC 18	Power Electronics	3	0	1	4
4	DSE-04	Select a course from the specified list of DSE-4				4
5	GE-06	Select a course from the specified list of GE-6				4
6	SEC / IAPC	Choose one SEC or Internship / Apprenticeship / Project / Community Outreach (IAPC)				2
Total Credits						**22**

**Credits*
L (01 Credit) is equivalent to 01 contact hour per week.
T (01 Credit) is equivalent to 01 contact hour per week.
P (01 Credit) is equivalent to 02 contact hours per week.

Department of Electrical Engineering
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Pool of DSEs offered by the Department of Electrical Engineering in Third Year

S. No.	Semester	DSE	Course Title
1.	V	DSE-3	Utilization of Electric Power
2.			Economic Operations of Power System
3.	VI	DSE-4	Digital Control System
4.			Digital Signal Processing

List of SECs offered by the Department of Electrical Engineering in Third Year

S. No.	Semester	Course Title
1.	V	IAPC
2.	VI	Advanced Electrical Workshop-II

Department of Electrical Engineering
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Specializations and Minor offered by the Department of Electrical Engineering

S. No.	Sem	DSE/ GE	Minor in EE (Open only for CSE/ ECE)	Specializations for EE / Minors for ECE and CSE		
				Robotics and Automation	**Sustainable Energy Engineering**	**Electric and Hybrid Vehicle**
1	V	DES-3/ GE-5	Electrical Measurement Technique	Introduction to Robotics and Mechatronics	Energy Conservation and Audit	Electrical Storage and Management System
2	VI	DSE-4/ GE-6	Power Converters and Applications	Industrial Automation	Energy Policies for Sustainable Development	Power Electronics Converters and Drives for Electric Vehicles

Detailed Syllabus of Discipline Specific Core (DSC) Courses of B. Tech. (EE) – SEMESTER V

Power System Analysis (DSC-13)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Power System Analysis	4	3	0	1	Power Transmission and Distribution

Course Hours: L-03, T-00, P-02

Course Objectives:

1. Understand Power System Components.
2. Analyze Power Flow.
3. To identify the impact of short circuits, line faults, and other disturbances on the system..
4. Explore Stability and Control.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. To model power system components for simulation in an integrated manner.
2. Analyzing and estimating power flow through the network to meet load demand from generation.
3. To evaluate short circuit levels at different buses for adequate protection against damage.
4. To keep the power system running in synchronism under any small or large disturbance.
5. To avoid disintegrating the power system due to voltage instability.

UNIT-I

Power System Components and Modeling: Transmission lines, one line diagram, impedance and reactance diagram, per unit system.

Load Flow Analysis: Introduction, nodal admittance matrix analysis (Y-bus), the concept of bus impedance matrix (Z-bus) and its building procedure, bus classifications, development of load flow equations, load flow solution using Gauss-Siedel, and Newton-Raphson, Jacobian Matrix, fast decoupled methods.

UNIT-II

Faults and Short Circuit Analysis: Symmetrical three-phase fault analysis, use of Z-bus in computation of short circuit currents, short circuit capacity at a bus, selection of circuit breaker, use of current limiting reactors.

Significance of positive, negative and zero sequence components, sequence impedances and sequence networks equations, unsymmetrical short circuit analysis - single line to ground fault, line to line fault, double line to ground fault on power systems, faults with fault impedance, open circuit faults.

UNIT-III

Power System Stability: Swing equation, power angle equation, synchronizing power coefficient, basic concepts of steady state, dynamic and transient stability, equal area criterion, solution of the swing equation, multi-machine transient stability studies with classical machine representation.

UNIT-IV

Voltage Stability: Introduction, comparison of angle and voltage stability, reactive power flow and voltage collapse, mathematical formulation of voltage stability problem, voltage stability analysis, prevention of voltage collapse, trends and challenges.

Suggestive Readings:

1. G. W. Stagg, and A. H. El-Abiad, "Computer Methods in Power System Analysis", McGraw Hill Kogakusha, 1968.
2. John Grainger, William Stevenson, "Power System Analysis," McGraw Hill, 2017.
3. Abhijit Chakraborty, and Sunita Halder, "Power System Analysis, Operation and Control", PHI, New Delhi, 2011.
4. M. A. Pai, "Computer Techniques in Power System Analysis", Tata McGraw Hill, New Delhi, 2006.
5. Carson W. Taylor, "Power System Voltage Stability", McGraw-Hill, 1994.

List of Experiments:

1. To study and test a typical Radial DC Distribution system supplied from one and both ends.
2. To study and test a typical Ring main DC Distribution system.
3. Ferranti Effect of Single-Phase Transmission Line.
4. Study of Short Transmission Line for calculation of various parameters.
5. P-V Characteristics of Single-Phase Transmission Line.
6. Measurement of Capacitance of Three-Core Cable.
7. Determination of Voltage Drop in a Cable.
8. To locate the fault in a cable using the Murray Loop Test.
9. Simulation of the string of insulation with and without a guard ring and evaluation of its efficiency.
10. To determine the dielectric strength of the given transformer oil using an oil testing Kit.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Control System (DSC-14)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Control Systems	4	3	0	1	Introduction to Electrical and Electronics Engineering, Mathematics-I, Electrical Network Analysis

Course Hours: L-03, T-00, P-02

Course Objectives:

1. To acquire the knowledge of control systems.
2. To model and analyze the physical systems for controlling their responses.
3. To design and analyze the stability and performance of control systems.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Acquire and demonstrate knowledge of various types of control systems.
2. Model the physical system using the transfer function and state space method and analyze the time domain responses of first and second-order systems.
3. Analyze the stability of control systems.
4. Design PID control and various types of compensators.

UNIT-I

Introduction: Open loop and closed loop control systems, feedback, effects of feedback, linear and non-linear control systems, block diagrams, some examples.

Modelling: Modeling of physical system: electrical, mechanical, translational, rotational, electrical, mechanical analogies, Laplace transform, transfer function, characteristic equation, block diagram algebra, signal flow graphs, error detectors potentiometer, synchros, stepper motor, AC and DC tacho-generators.

UNIT-II

Time Domain Analysis: Importance of time response in transient and steady-state analysis, typical test input signals, transient response of the first order and second order system, time response specifications, dominant closed-loop poles of higher order systems, steady-state error and error coefficients.

Stability: Concepts of absolute and relative stability, pole-zero location, Routh Hurwitz criteria.

UNIT-III

Root Locus Technique: Introduction, root locus concept, construction of root loci, stability analysis.

Transient behaviour and initial conditions: Behavior of circuit elements under switching condition and their representation, evaluation of initial and final conditions in RL, RC and RLC circuits for AC and DC excitations.

UNIT-IV

Frequency Response: Introduction and importance of frequency response, bode diagram, polar plots, Nyquist stability criterion, stability analysis, relative stability, gain margin & phase margin, closed-loop frequency response.

Introduction to Design: Necessity of compensation, lag and lead compensation, PID controller.

State Space Analysis: Concept of state, state variable and state vector, state transition matrix, controllability and observability, solution of state equation.

Suggestive Readings:

1. Control Systems Engineering by I J Nagrath and M Gopal, Wiley Eastern.
2. Linear Control Systems by B S Manke.
3. Raymond A. DeCarlo, Pen-Min Lin, Linear Circuit Analysis, OUP USA; 2nd edition.
4. Automatic Control systems by B C Kuo.
5. Modern Control Engineering by K Ogata, PHI.

List of Experiments:

1. To obtain the time responses of first-order and second-order RLC circuits.
2. To simulate the various responses of the linear system using a linear system simulator.
3. To study and implement the temperature-controlled system.
4. To study the performances of open-loop and closed-loop systems.
5. To implement the characteristics of the stepper motor interfaced with a microprocessor.
6. To study the closed loop performances with P, PI and PID controllers.
7. To implement lag, lead and lag-lead compensators.
8. To study and implement the various characteristics of DC motor position control system.
9. To study synchro-transmitter and receiver and obtain output versus input characteristics.
10. To study the AC position trainer kit and analyze its performance.
11. To draw Nyquist plot of open loop transfer functions and examine the stability of the closed loop system.
12. To obtain the Bode frequency response for first and second-order systems.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Electromagnetic Field Theory (DSC-15)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Electromagnetic Field Theory	4	3	0	1	Introduction to Electrical and Electronics Engineering, Physics, Mathematics-I

Course Hours: L-03, T-00, P-02

Course Objectives:
1. To understand Maxwell's Equation and apply it to the basic electromagnetic problem.
2. To interpret the given problem and solve it using Maxwell's equations.
3. To analyze time varying electric and magnetic fields, wave propagation in different media.
4. To understand transmission line fundamentals and apply them to the basic problem.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:
1. Recognize and classify the basic Electrostatic theorems and laws and derive them.
2. Discuss the behavior of Electric fields in matter and Polarization concepts.
3. Classify the basic Magneto static theorems and laws and infer the magnetic properties of matter.
4. Summarize the concepts of electrodynamics and derive and discuss Maxwell's equations.
5. Students are expected to be familiar with Electromagnetic wave propagation.

UNIT-I

Preliminaries: Physical interpretation of gradient, divergence and curl. The Laplacian operator, vector relationship in rectangular, cylindrical and spherical polar coordinate systems, divergence and curl equations and its Integral forms, Stoke's Theorem, Green's Theorem, Dirac delta distribution. Field as derivative of potential, Helmholtz Theorems.

UNIT-II

Electrostatic Field: Coulomb's Law, electrostatic field, Laplace and Poisson's equation, divergence and curl of electrostatic field, scalar potential, Field equations in different coordinate systems, boundary conditions, Continuity equation and relaxation time, Energy stored due to accumulation of charges.

Magnetostatic Field: Lorentz force, Biot-Savart's law, Scalar and vector potentials. Divergence and curl of magnetic field, Ampere's law, Force and Torque equations, field equations in different coordinate systems. Boundary conditions, magnetic vector potential and flux, energy stored in a magneto static field.

UNIT-III

Dynamic electric and magnetic fields: Time varying fields and Faraday's law. Displacement current, Maxwell's correction to Ampere's law, relation between electric and Magnetic fields.

Poynting's Theorem and flow of power: Poynting's theorem and its equivalence to energy conservation law, Poynting's vector, power flow and relevance to power transmission.

UNIT-IV

Wave Equation: Maxwell's equations, Wave equations in free space and in conducting medium, Wave impedance. Wave propagation in Dielectrics, Propagation in Good Conductors, Skin Effect, Reflection of uniform Plane Waves at normal incidence, Plane Wave reflection at Oblique Incidence, Wave propagation in dispersive media.

Transmission Lines: Typical Transmission lines- Co-axial, Two Wire, Microstrip, Coplanar and Slot Lines, Transmission Line Parameters, Transmission Line Equations, Wave propagation in Transmission lines, low loss, lossless line, Distortionless line.

Suggestive Readings:

1. Matthew N.O. Sadiku, "Principles of electromagnetics" 4th edition, Oxford university Press, 2014.
2. Hayt Jr, William H., John A. Buck, and M. Jaleel Akhtar, "Engineering Electromagnetics (SIE)", McGraw-Hill Education, 2020.
3. Karl E. Longren, Sava V. Savov, Randy J. Jost., "Fundamentals of Electromagnetics with MATLAB", PHI (For MATLAB experiments)
4. D. C. Cheng, "Field and Wave Electromagnetics," Pearson Education (2001)

List of Experiments:

Hardware based experiments:

1. To study electric field patterns between two circular electrodes.
2. To study the electric field between parallel conductors.
3. To study Electric Field and Potential Inside the Parallel Plate Capacitor.
4. To study Capacitance and Inductance of Transmission Lines.
5. To study Magnetic Field Outside a Straight Conductor.
6. To study Magnetic Field of Coils.
7. To study Magnetic Inductions.

Simulation based experiments:

Write a program to:

1. Find gradient of a scalar field.
2. Find divergence of a vector field.
3. Find the curl of a vector field.
4. Transform
    a. spherical coordinates to cartesian coordinates.
    b. cylindrical coordinates to cartesian coordinates.
    c. cartesian coordinates to cylindrical coordinates.
    d. cartesian coordinates to spherical coordinates.
5. Represent electric field lines due to a point charge at origin.
6. Plot equipotential contours and electric field due to dipole.
7. Plot magnetic flux density due to current carrying wire.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Detailed Syllabus of Discipline Specific Elective (DSE) courses for B.Tech. (EE) – SEMESTER V

Utilization of Electric Power (DSE-03)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Utilization of Electric Power	4	3	1	0	Introduction to Electrical and Electronics Engineering, Power Transmission and Distribution

Course Hours: L-03, T-01, P-00

Course Objectives:

1. To introduce various electric drives and their applications.
2. To explain various techniques for designing indoor &outdoor lighting schemes.
3. To discuss different methods of electrical heating and electric welding.
4. To illustrate the fundamentals of electrolytic and electrometallurgical processes.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Recognize and classify the basic electric traction system.
2. Discuss the behavior of different lighting systems and their illuminance.
3. Classify the basic heating system used for industrial purposes.
4. Students are expected to be familiar with the different uses of electric systems in the industry.

UNIT-I

Electric Traction Drives: Advantages of electric drives, Characteristics of different mechanical loads, Parts of electric drives electric motors, close loop of electric drive system, Types of motors used in electric drive pulley drives etc., Examples of selection of motors for different types of domestic loads, Selection of drive for applications such as general workshop, textile mill, paper mill, steel mill, printing press, crane and lift etc.

UNIT-II

Illumination: Nature of light, visibility spectrum curve of relative sensitivity of human eye and wave length of light, Definition: Luminous flux, solid angle, luminous intensity, illumination, luminous efficiency, depreciation factor, coefficient of utilization, space to height ratio, reflection factor, glare, shadow, lux, Laws of illumination, Different type of lamps, construction and working of incandescent and discharge lamps – their characteristics, fittings required for filament lamp, mercury vapor lamp, fluorescent lamp, metal halide lamp, neon lamp, Main requirements of proper lighting; absence of glare, contrast and shadow, General ideas bout street lighting, flood lighting, monument lighting and decorative lighting, light characteristics etc.

UNIT- III

Electric Heating: Advantages of electrical heating, Heating methods: Resistance heating – direct and indirect resistance heating, electric ovens, their temperature range, properties of resistance heating elements, domestic water heaters and other heating appliances and thermostat control circuit, Induction heating; principle of core type and coreless induction furnace, Electric arc heating; direct and indirect arc heating, construction, working and applications of arc furnace.

UNIT -IV

Electric Welding: Advantages of electric welding, Welding method, Principles of resistance welding, types, Principle of arc production, electric arc welding, characteristics of arc; carbon arc, metal arc, hydrogen arc welding method of and their applications.

Electrical Circuits used in Refrigeration and Air Conditioning and Water Coolers: Principle of air conditioning, vapor pressure, refrigeration cycle, eco-friendly Refrigerants, Electrolytic Processes, Laws of electrolysis, process of electro-deposition clearing, operation, deposition of metals, polishing, buffing.

Suggestive Readings:

1. "Utilization of electrical energy" by E. O. Taylor and V. V. L. Rao, English Universities Press.
2. "Electrical Drives: Concept and applications" by Vedam Subrahmanyam" Tata McGraw Hill.
3. "Art and Science of Utilization of Electrical Energy" by H. Pratab, Dhanpat Rai & Co.

Economic Operations of Power System (DSE-3)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Power System Economics	4	3	1	0	Power Transmission and Distribution

Course Hours: L-03, T-01, P-00

Course Objectives:

5. To understand the fundamentals of power system economics.
6. To ensure cost-effective power generation while meeting system demands.
7. To develop skills in coordinating hydro and thermal power plants for optimal power generation.
8. To explore and apply various methods for optimal power flow (OPF) analysis, ensuring economic and secure operation of power systems.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

6. Demonstrate an understanding of power system economics, including the key principles of economic operation and optimization.
7. Analyze and solve the economic dispatch and unit commitment problems.
8. Apply hydro-thermal coordination techniques.
9. Solve optimal power flow (OPF) problems using various optimization techniques, ensuring economic, reliable, and secure operation of power systems.

UNIT-I

Introduction: Introduction to power system economics, Introduction to microeconomics, Introduction to economic operations, Evolution of Indian Power System, Control in Power Systems, Optimization Preliminaries.

UNIT-II

Economic Operation: Economic dispatch problem and methods of solutions, economic importance, characteristics of steam units, economic dispatch of thermal units and methods of solutions, problem considering and neglecting transmission losses, and iterative and non-iterative methods of solutions.
Unit Commitment: Definition, Constraints in Unit Commitment, Unit Commitment solution methods, Priority, List Methods, Dynamic Programming Solution, Economic dispatch versus Unit Commitment.

UNIT-III

Hydro-thermal coordination: Hydroelectric plant models, short-term hydrothermal scheduling problem, gradient approach, Hydro units in series, pumped storage hydro plants, hydro-scheduling using Dynamic programming and linear programming.

UNIT-IV

Optimal Power Flow: Introduction, Solution of OPF, gradient method, Newton’s method, Linear Sensitivity analysis, linear programming method, Security Constrained OPF, Interior Point OPF, Bus Incremental Coats.

Suggestive Readings:

1. Allen J. Wood and Bruce F. Wollenberg, “Power Generation Operation and Control,” John Wiley & Sons, New York, 2016.
2. Elgerd O. I, “Electric Energy System Theory – an Introduction,” Tata McGraw Hill, New Delhi, 2013.
3. Robert H. Miller, James H. Malinowski, “Power System Operation,” Tata McGraw Hill, 2009.
4. J. C. Das, “Load Flow Optimization and Optimal Power Flow,” CRC press, 2017.
5. Abhijit Chakrabarti and Suita Halder, “Power System Analysis, Operation and Control,” PHI, 2010.

Detailed Syllabus of Discipline Specific Core (DSC) courses for B.Tech. (EE) – SEMESTER VI

Switchgear and Protection (DSC-16)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Switchgear and Protection	4	3	0	1	Power Transmission and Distribution, Power System Analysis

Course Hours: L-03, T-00, P-02

Course Objectives:

1. To get introduced to protective relays for power systems.
2. To be familiar with the protection schemes of generators and motors.
3. To know about how to protect transformers.
4. To design protection of transmission lines.
5. To be aware of the phenomenon of arcing and its interruption by circuit breakers.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Understanding Protective Relays and Instrument Transformers.
2. Knowledge of Protection Schemes for Electrical Equipment.
3. Transmission Line Protection and Safety Practices.
4. Circuit Breakers and Switchgear Selection and Application.

UNIT-I

Protective Relays, CTs and PTs: Classification - electromechanical, static, and numerical relays; construction, operating characteristic and their applications with limitations; over and under current, directional, differential, distance and other types of relay; constructions and characteristics of CTs and PTs, capacitance-voltage transformer.

UNIT-II

Protection of Generators and Motors: Differential Protection, protection of stator windings against short circuits, turn-to-turn faults and ground faults; rotor earth fault protection; protection against unbalanced loading, loss of excitation, loss of synchronism and prime mover failure; protection of motors (induction and synchronous) and bus bars.

Protection of Transformers: Protection against internal faults such as short circuits and turn-to-turn faults using differential and overcurrent relays, as well as protection for other abnormal conditions.

UNIT-III

Protection of Transmission lines: Over current protection, grading of overcurrent relays, distance protection, types of distance relays and their characteristics, carrier current protection; protection against surges, surge diverters, surge absorbers; use of ground wires on transmission lines; necessity of grounding system neutral and substation equipment, methods of grounding.

UNIT-IV

Switchgear: Types and applications of fuse and MCB; physics of arcing phenomenon and arc interruption, DC and AC circuit breaking, re-striking voltage and recovery voltage, rate of rise of recovery voltage, resistance switching, current chopping, interruption of capacitive current; circuit breakers and types – air-blast, air-break, oil, SF6 and vacuum circuit breaker, comparison of different circuit breakers, ratings and selection of circuit breakers.

Suggestive Readings:

1. J. J. Grainger, and W.D. Stevenson, "Power System Analysis", Tata McGraw-Hill, 2003.
2. Paul M. Anderson "Power System Protection" IEEE Press.
3. C L Wadhva, "Electrical Power System" Wiley Eastern Ltd., 3rd edition, 2000.
4. D.P. Kothari, and I.J. Nagrath "Modern Power System Analysis," Tata McGraw-Hill, 4th Edition.

List of Experiments:

1. Measure the high value of AC Voltage by a low-range AC Voltmeter and Potential Transformer.
2. Draw and study the operating characteristics of Miniature Circuit Breaker Type-B and Type-C.
3. Study the operating characteristics of the HRC fuse.
4. To study the IDMT Over the Current Relay & its applications.
5. To study and verify the operating characteristics of over current relay at various plug & time settings.
6. To study the performance of over voltage relay.
7. To study the performance of under voltage relay.
8. To study and verify the operating Characteristics of Earth Fault Relay with different plug settings.
9. Study and verify the operating characteristics of three phases over current and earth fault numeric relays with different time multiplier settings (TMS) and current Settings.
10. Unsymmetrical fault analysis of a single and three-phase transmission line.
11. Symmetrical fault analysis of three-phase transmission line.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Embedded System Technologies (DSC-17)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Embedded System Technologies	4	3	0	1	Fundamentals of Computer Programming, Analog and Digital Electronic Circuits

Course Hours: L-03, T-00, P-02

Course Objectives:

1. To understand the concepts of the Architecture of the 8085 microprocessors.
2. To understand the concepts of the Architecture of the 8051 microcontrollers.
3. To understand the design aspects of I/O and Memory Interfacing circuits.
4. To understand the architecture and programming of ARM processors.

Course Outcomes:

At the end of this course, students will have the ability to:

1. To design and implement programs on the 8085 microprocessor.
2. To design and implement programs on the 8051 microcontroller.
3. To design I/O circuits and Memory Interfacing circuits.
4. To design and develop components of the ARM processor.

UNIT-I

Microprocessors: 8085-architecture, operation, pin configuration and functions, bus organization, control signal generation for external operations- fetch, IO/M, read/write, machine cycles and bus timings. Addressing mode, instruction set, Overview/concept of peripheral interfacing devices- 8251, 8253, 8255 and 8279.

UNIT-II

Microcontrollers: 8051-architecture, operation, pin configuration and functions, memory organization, register, I/O ports, addressing modes, instruction sets, instruction classification. Assembly language programming, Interrupts in 8051. Timer/Counter programming for time delay generation and waveform generation. Interfacing with ADC, DAC, LEDs and seven-segment display.

UNIT-III

Introduction to Embedded Systems: Complex systems and microprocessors, Embedded system design process, Instruction sets preliminaries of ARM Processor, CPU: programming input and output supervisor mode, exceptions and traps, Co-processors, Memory system mechanisms, CPU performance.

UNIT-IV

Embedded Computing Platform Design and Optimization of CPU: Bus-Memory devices and systems, designing with computing platforms, platform level performance analysis, Components for embedded programs, Models of programs Assembly, linking and loading, compilation techniques-Program level performance analysis, Software performance optimization, Analysis and optimization of program size, Program validation and testing.

Suggestive Readings:

1. Ramesh S. Goankar, "8085 Microprocessors Architecture Application and Programming", Penram International, 5th Edition.
2. Mohamed Ali Mazidi, Janice Gillispie Mazidi, Rolin McKinlay, "The 8051 Microcontroller and Embedded Systems: Using Assembly and C", 2nd Edition, Pearson Education, 2011
3. Marilyn Wolf, "Computers as Components - Principles of Embedded Computing System Design", 3rd Edition "Morgan Kaufmann Publisher (An imprint from Elsevier), 2012

List of Experiments:

1. To develop and execute a program on the 8085 microprocessor for arithmetic and logical operations relevant to electrical signal processing.
2. To implement data transfer and sorting algorithms on the 8086 microprocessor for efficient electrical system management.
3. To design and simulate a traffic light controller using the 8051 microcontroller and LED interfacing.
4. To program the 8051 microcontroller for generating pulse width modulation (PWM) signals for motor speed control.
5. To interface an ADC with the 8051 microcontroller to digitize an analog electrical signal and display the result.
6. To design and implement a real-time clock using timers on the 8051 microcontroller for power system monitoring.
7. To configure an ARM-based microcontroller for temperature monitoring using ADC and an LED-based alarm system.
8. To implement an ARM-based system for serial communication between electrical devices using UART.
9. To develop a program on the ARM processor for controlling a DC motor using timers and PWM signals.
10. To design an embedded system for energy measurement using an ARM microcontroller and interfacing it with an ADC and LED display.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Power Electronics (DSC-18)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Power Electronics	4	3	0	1	Introduction to Electrical and Electronics Engineering, Electrical Network Analysis, Mathematics-1

Course Hours: L-03, T-00, P-02

Course Objectives:

1. To outline the working of uncontrolled devices.
2. To introduce the basic theory of power semiconductor devices and passive components,
3. their practical application in power electronics.
4. To familiarize the operation principle of AC-DC, DC-DC, and DC-AC conversion circuits and their applications.
5. Analyzing power electronics circuits and understanding circuit operation by drawing output waveforms.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Explain the characteristics, functions, and applications of various power electronic devices such as SCR, Power Transistor, MOSFET, GTO, IGBT, and MCT.
2. Design and analyze single-phase and three-phase controlled rectifiers with different types of loads (R, R-L, R-L-E).
3. Understand the principles of chopper operation and design chopper circuits for various applications, including step-up and step-down choppers.
4. Analyze the operation of single-phase and three-phase inverters, and implement voltage control and harmonics reduction techniques.
5. Explain the principles and applications of AC voltage controllers and cycloconverters for various load types (R and RL).

UNIT-I

Introduction and Power Semiconductor Devices: Power Electronics: Scope and applications, Introduction to power electronics devices, SCR, Power Transistor, MOSFET, GTO, IGBT, MCT etc. Thyristor V-I and Gate Characteristics, Two transistor analogy of SCR, methods of triggering and commutation (A,B,C,D,E,F), ratings and protection of device, snubber circuits and safe operating area. Firing circuit.

UNIT-II

Phase Controlled Rectifiers: Principle of phase control, single phase half wave-controlled rectifiers with R, R-L, R-L-E load, single phase full wave-controlled converters, 2-pulse mid-point converters, 2-pulse half and fully controlled bridge converters with R, R-L, R-L-E load, Three phase uncontrolled & controlled rectifier, triggering schemes, flyback diode, effect of source inductance.

UNIT-III

DC – DC Converters: Basic Principle of step-down chopper operation with R-L Loads, control strategies-time ratio control and current limit control. Types of chopper circuits, four quadrant chopper, steady state time domain analysis of type a chopper, effect of source inductance, step up and step-down Chopper, chopper circuit design.

Inverters: Forced commutated inverters, single phase voltage source inverters, Half bridge inverter, full bridge inverter (with R and RL load), steady state analysis, voltage control in single phase inverters, 3-phase bridge inverters (with R and RL load) 120, 150 and 180 mode, pulse width modulated inverters, harmonics reduction techniques, current source inverter, inverter circuit design. (Voltage & frequency control).

UNIT-IV

AC Voltage Controllers and Cycloconverters: Principle of AC voltage controllers-phase control and integral cycle control, types of AC voltage controllers, single-phase and three-phase AC controllers with R and RL loads, fan and temperature control. **Cyclo-converter:** Principles of operation, advantages, disadvantages and applications of single/three cycloconverters on R and RL load.
Applications in power electronics: UPS, SMPS and Drives.

Suggestive Readings:

1. Lander C. W., "Power Electronics", 3rd Ed., McGraw-Hill International Book Company
2. Mohan N., Undeland T. M. and Robbins W. P., "Power Electronics Converters, Applications and Design", 3rd Ed., Wiley India.
3. Rashid M. H., "Power Electronics Circuits Devices and Applications", 3rd Ed., Pearson Education.
4. Derek A. Paice "Power Electronic Converter Harmonics – Multipulse Methods for Clean Power", IEEE Press, 1996.
5. P.C.Sen, "Modern Power Electronics ", S. Chand and Co. Ltd., New Delhi, 2000.
6. Power Electronics", P.S. Bimbhra, Khanna Pub.
7. Power Electronics Circuits and MATLAB simulations", Alok Jain, Penram International Pub.(India) Pvt.Ltd.
8. Power Electronics Principles and Applications, Joseph vithayathil, McGraw Hill Education India P. Ltd
9. Power Electronics : Essentials & Applications, L. Umanand, Wiley India Pvt Ltd
10. "Power Electronics and Variable Frequency Drives", Bimal K.Bose, IEEE Press.
11. "Power Electronics Systems: Theory and Design", Jai P. Agrawal, Pearson Education Pvt.Ltd.

List of Experiments:

1. Characteristics of SCR, IGBT & Power MOSFET.
2. Analysis of Single-phase AC voltage controller with R & RL Loads.
3. Analysis of Single phase fully controlled bridge converter With R & RL Loads.
4. Analysis of Single phase IGBT inverter with R and R-L Loads.
5. Analysis of Three phase fully controlled bridge converter with R Load.
6. Analysis of Single-phase dual converter with RL load.
7. Analysis of Four quadrant operation of chopper with R-load.
8. Analysis of PWM control of Boost converter with R and R-L loads.
9. Simulation of Single-Phase ac to dc converter with LC filter in MATLAB.
10. Simulation of Single-phase inverter with current controlled PWM technique in MATLAB.
11. Analysis of single phase cyclo converter with R and R-L load.
12. Simulation of Single phase fully controlled PWM rectifier with R & RL loads using PSCAD.
13. Generation of PWM pulses using microcontroller kit.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Detailed Syllabus of Discipline Specific Elective (DSE) courses for B.Tech. (EE) – SEMESTER VI

Digital Control System (DSE-4)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Digital Control System	4	3	0	1	Introduction to Electrical and Electronics Engineering, Mathematics-I, Electrical Network Analysis/ Network Analysis and Synthesis

Course Hours: L-03, T-00, P-02

Course Objectives:

1. To acquire the knowledge of digital control systems.
2. To understand the modelling of discrete-time systems, time response analysis and stability analysis method.
3. To design digital control systems with deadbeat response.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:
1. Apply the concepts of signal processing and digital control.
2. Apply z-transformation for the digital control system.
3. Design and analyze the digital control system for various physical systems.

UNIT-I
Introduction to Digital Control Systems
Discrete-time system representation, mathematical modelling of the sampling process.

UNIT-II
Modelling Discrete-Time Systems by Pulse Transfer Function
Z-transform, mapping of s-plane to z-plane, pulse transfer function, related examples.

UNIT-III
Stability Analysis
Jury stability test, stability analysis using bi-linear transformation, related examples.
Time Response Analysis
Transient and steady-state responses, time response parameters of a second order system, related examples.

UNIT-IV
Design of Sampled Data Control Systems
Root locus method, controller design using root locus, Nyquist stability criteria, bode plot, lead compensator design, lag compensator design, lag-lead compensator design in the frequency domain.

Deadbeat Response Design

Design of digital control systems with deadbeat response, practical issues with deadbeat response design, sampled data control systems with deadbeat response.

Suggestive Readings:

1. Digital Control and State variable methods by M Gopal, Tata McGraw-Hill publishing company limited.
2. Discrete-Time Linear Systems: Theory and Design with Applications by G Gu, Springer Science & Business Media.
3. Discrete Time Control Systems by K Ogata.
4. Discrete Control Systems by Y Okuyama, Springer London.
5. Advanced Discrete-Time Control by K Abidi, J X Xu, Springer Singapore.

List of Experiments:

1. Discrete time state space modelling for the SISO system.
2. Discrete time state space modelling for MIMO system.
3. Time response analysis of the SISO discrete-time system.
4. Time response analysis of MIMO discrete-time system.
5. Stability analysis of SISO discrete-time system.
6. Stability analysis of MIMO discrete-time system.
7. Design of lead compensator for the discrete-time system.
8. Design of lag compensator for the discrete-time system.
9. Design of a Lag-lead compensator for a discrete-time system.
10. Design of digital control systems with deadbeat response.
11. Design of Root locus for the discrete-time system.
12. Implementation of Bode plot for discrete-time system.
13. Implementation of Nyquist criteria on discrete-time system.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Digital Signal Processing (DSE-4)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Digital Control Processing	4	3	1	0	Introduction to Electrical and Electronics Engineering, Mathematics-I, Electrical Network Analysis/ Network Analysis and Synthesis

Course Hours: L-03, T-01, P-00

Course Objectives:

1. To acquire knowledge of digital signal processing for various process controls, signal and signal processing.
2. To understand the time domain representation of digital signals.
3. To learn the concepts of digital filter designs.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Acquire knowledge of digital signal processing for various process controls.
2. Learn thoroughly signal and signal processing.
3. To formulate the time domain representation, transformation, filtered design etc. for their projects and research applications.

UNIT-I

Signal & Signal Processing: Classification of signals, typical signal processing operations, typical signal processing applications, why digital signal processing.

Time Domain Representation of Signals & Systems: Discrete-time signals, operations on sequences, the sampling process, discrete-time systems, time-domain characters tics of LTI discrete-time systems, state space representation of LTI discrete-time systems.

UNIT-II

Transformations: Domain representation of signals: the discrete-time Fourier transform, discrete Fourier transform, computation of the DFT of real sequences, linear convolution using the DFT, z-transform, inverse z-transform.

UNIT-III

Time Domain Representation of LTI Systems: Frequency response, transfer function. Digital two-pair stability test.

Digital Processing of Continuous Time – Signals: Sampling of continuous-time signals, analysis filter design, anti-aliasing filter design, and reconstruction filter design**.**

UNIT-IV

Digital Filter Structures

Block diagram representation, signal flow graph representation, equivalent structures, Basic FIR digital filter structures, Basic IIR filter structures, all-pass filters, and tunable structures**.**

Digital Filter Design: Preliminary conditions, impulse invariance method of IIR filter design, bilinear transform method of IIR filter design, design of filter IIR notch filters, FIR filter design based on truncated Fourier series, FIR filter design based on frequency sampling approach, computer-aided design of digital filters.

Suggestive Readings:

1. Digital Signal Processing by Sanjit K. Mitra, Tata McGraw Hill
2. Digital Filters: Analysis & Design by A. Antoniou, McGraw Hill book company
3. Digital Signal Processing by S.D. Sterms, Prentice Hall Inc

Department of Electrical Engineering
Faculty of Technology
University of Delhi

List of Discipline Specific Elective (DSE)/ Generic Elective (GE) courses offered for Minors / Specializations by the Department of Electrical Engineering in Third Year

1. **Minor in EE (Offered to ECE and CSE)**
    a. DSE-3/ GE-5: Electrical Measurement Technique
    b. DSE-4/ GE-6: Power Converters and Applications

2. **Minor/Specialization in Robotics and Automation (Offered to EE, ECE, and CSE)**
    a. DSE-3/ GE-5: Introduction to Robotics and Mechatronics
    b. DSE-4/ GE-6: Industrial Automation

3. **Minor/Specialization in Sustainable Energy Engineering (Offered to EE, ECE, and CSE)**
    a. DSE-3/ GE-5: Energy Conservation and Audit
    b. DSE-4/ GE-6: Energy Policies for Sustainable Development

4. **Minor/Specialization in Electric and Hybrid Vehicle (Offered to EE, ECE, and CSE)**
    a. DSE-3/ GE-5: Electrical Storage and Management System
    b. DSE-4/ GE-6: Power Electronics Converters and Drives for Electric Vehicles

Detailed Syllabus of Generic Elective (GE) courses offered for Minors / Specializations by Department of Electrical Engineering in SEMESTER V

Electrical Measurement Techniques (DSE-3/ GE-5)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Electrical Measurement Techniques	4	3	0	1	Introduction to Electrical and Electronics Engineering, Physics

Course Hours: L-03, T-00, P-02

Course Objectives:

1. To make students familiarize themselves with different types of error in measurements.
2. To analyze the constructions of different analog type measuring instruments.
3. To understand the working of different power, energy, resistance, inductance and capacitance measurement techniques.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Classify various measuring instruments used to measure electrical quantities.
2. Apply methods for the measurement of resistance, capacitance and inductance.
3. Choose the suitable current and potential transformers.
4. Measure and analyze the error free currents and voltages.

UNIT-I

Preliminaries: Concepts of Measurements & Measurement Systems: Introduction to measurement and instrumentation, S. I. system, methods of measurement, static and dynamic characteristics of instruments, definitions – true value, accuracy, error, precision, sensitivity, resolution etc.

Analog Instruments: Classification of analog instruments, principle of operation, operating forces, errors in ammeters and voltmeters. Permanent magnet moving coil, moving iron, dynamometer type, induction type, electrostatic type instruments.

UNIT-II

Potentiometers: Principle of D. C. potentiometer, direct reading potentiometers, accurate forms of potentiometers, A. C. potentiometer principle, polar and Co - ordinate type A. C. potentiometer, applications of A. C. and D. C. potentiometers.

Measurement of Power and Energy: Electrodynamometer type wattmeter, measurement of power in three phase circuits, three phase wattmeter, measurement of reactive power, energy meter for A.C. circuits, induction type energy meter.

UNIT-III

Measurement of Resistance: Measurement of low, medium & high resistances, insulation resistance measurement, localization of cable fault, Loop tests.

Measurement of Inductance and Capacitance: A. C. bridges for inductance measurement – Maxwell, Hays, Anderson and Owen bridges, capacitance measurement – De Sauty and Schering Bridge. Measurement of frequency by Wien's bridge.

UNIT-IV

Magnetic Measurements: Magnetic measurement using Ballistic Galvanometer, Grassot Flux meter, BH curve of magnetic material, separation of losses.

Instrument Transformers: Current and Potential transformers, ratio and phase angle errors, design considerations, numerical problem.

Suggestive Readings:

1. Introduction to Modern Electronic Instrumentation and Measurement Techniques: Helfrick and Cooper, Prentice Hall of India, 1997.
2. Instrumentation Measurement and Feedback: Jones, B. E., Tata McGraw-Hill, 1995.
3. Electrical Measurement and Measuring Instruments: Golding, E. W., Sir Issac Pitman & Sons., 3rd Edition.
4. A course in Electrical and Electronic Measurement and Instrumentation: A. K. Sawhney, Dhanpat Rai Publication.

List of Experiments:

1. Calibration of voltmeter and Ammeter.
2. Calibration of single phase A.C. Energy meter.
3. Three phase power measurement by two wattmeter method.
4. Measurement of reactive power using single wattmeter in three-phase circuit.
5. Measurement of percentage ratio error and phase angle of given C.T. by Silsbee's method.
6. Extension of instrument ranges using C.T. and P.T.
7. Measurement of resistance using Kelvin's Double Bridge.
8. Measurement of earth resistance using Meggar.
9. Measurement of self-inductance and Quality factor using Anderson Bridge.
10. Measurement of capacitance using Schering Bridge.
11. Measurement of voltage, current and resistance using DC potentiometer.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Introduction to Robotics and Mechatronics (DSE-3/ GE-5)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Introduction to Robotics and Mechatronics	4	3	0	1	Introduction to Electrical and Electronics Engineering

Course Hours: L-03, T-00, P-02

Course Objectives:

1. To acquire the knowledge of fundamentals of mechatronics.
2. Impart knowledge and information about product design.
3. Development and control of intelligent systems for all aspects of life.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. To understand the components of mechatronic system,
2. To design product and systems theoretically as well as practically with intelligence.

UNIT-I

Understanding Mechatronics : Mechatronics System, Evolution, Definitions of Mechatronics, Key Elements of Mechatronics, Mechatronics for all Civil, Metallurgical, Aerospace, Chemical, Architecture, Medical, Robotics, Defense, Agriculture, etc., Role of Mechanical, Electrical, Electronics, Computer Engineers in Intelligent Product and Process Design, Development and Control, Bio-mechatronics.

UNIT-II

Systems and Machines: System, Classification of System, Mechanistic System Classification Based on Input Energy, Mathematical Model and Function, Machine, Parts of Machine, Concepts of Machine, Classification of Machines based on Function and Size.

System Intelligence: Properties of Intelligent System, System Intelligence Levels, Human Intelligence System, Future Generation System Intelligence Level, Expressing System Intelligence.

UNIT-III

Sensor and Transducer: Sensors in Mechatronics System, Difference between Sensors and Transducers, Classification of Sensors, Based on Sensor Output Signal, Sensor Input Physical Parameters, Sensor Accuracy (Smart/Intelligent Sensor), Performance Terminology, Static Characteristics, Dynamic Characteristics.

Signal Conditioning Devices: Signal Conditioning Processes, Application of Signal Conditioning Devices in Mechatronics based on Their Characteristics such as Diode, Transistor, SCR, DIAC, TRIAC, Op-Amps, Signal Filtering, Circuit Protection, Signal Conversion, ADC and DAC, Logic Gates, Flip-Flops, Register, Counters.

Actuators: Actuators, Types of Actuators, Mechanical Actuation System (i.e. Linear-rotary, Rotary-linear Mechanism, Gear, Bearing, Pulley etc.). Electrical Actuation System (DC, AC, Stepper Motors), Pneumatic and Hydraulic Actuation System.

UNIT-IV

Controllers: Microprocessor, Microcontroller, PLC Controller & Their Architectures, Principles and Working Software Programs (Assembly/High Level), Interfacing Aspects, Application Examples.

Robotics and Automation:

Evolution of Robots, Definitions, Types of Motions, Function, Governing Laws, Classification, Features and Components of Robots, System Automation.

Suggestive Readings:

1. Mechatronics First edition by Tilak Thakur, published by Oxford University Press
2. Mechatronics, fourth edition by W Bolton. ISBN 978-81-317-3253-3
3. Dan Necsulescu Mechatronics published by Pearson Education (Singapore) Pvt. Ltd.
4. Book by H M T Limited, Mechatronics Tata McGraw Hill Publishing Company Limited, New Delhi.
5. Mechatronics Principles, Concepts & Applications by Nitaigour P Mahalik published by TMH

List of Experiments:

1. ***Experiment on Sensors & Transducers:***
   i. To study the characteristics of LVDT using linear displacement trainer Kit & compare with ideal characteristics.
   ii. To measure the strain of the metal strip using strain gauge trainer kit & compare with ideal characteristics.
   iii. To measure the angular displacement of resistive & capacitive transducer using angular displacement trainer kit & compare with ideal characteristics.
   iv. To obtain the characteristics of RTD, Thermistor, thermocouple with hot and cold junction thermal trainer kit & compare with ideal characteristics.
2. ***Experiments on Signal Conditioning***:
   i. PN Junction Diode
   ii. Zener Diode
   iii. Half wave rectifier
   iv. Full wave rectifier
3. ***Experiments on Digital devices:***
   i. Logic Gates (AND, OR, NAND, NOR etc)
   ii. Flip Flop (RS Flip Flop), D Flip Flop.
4. ***Experiments on Controller:***
   i. Study of microprocessors, microcontroller, programmable logic controller (PLC).
   ii. PLC interfacing of I/O and I/O addressing.
   iii. To perform any basic sequence programming using PLC.
5. ***Experiments on Actuators:***
   i. Study of mechanical, electrical, hydraulic/pneumatic actuators.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Energy Conservation and Audit (DSE-3/ GE-5)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Energy Conservation and Audit	4	3	1	0	Introduction to Electrical and Electronics Engineering, Mathematics-I

Course Hours: L-03, T-01, P-00

Course Objectives:

6. To understand basic principles of energy audit and management.
7. To describe lighting modification of existing systems.
8. To examine power factor improvement measures and energy instruments.
9. To analyze space conditioning systems.
10. To evaluate the energy management strategies.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

5. Ability to Conduct Energy Audits.
6. Understanding of Energy Management Principles.
7. Skill in Lighting and Power Systems Optimization.
8. Proficiency with Energy Measurement Instruments.
9. Economic and Financial Analysis of Energy Projects.

UNIT-I

Principles of Energy Audit and Management: Energy audit: Definitions, Concept, Types of audit, Energy index, Cost index, Pie charts, Sankey diagrams, Load profiles. Energy conservation schemes and energy saving potential, Principles of energy management: Initiating, planning, controlling, promoting, monitoring, reporting.

UNIT-II

Lighting Modification of existing systems, Replacement of existing systems, Priorities: Definition of terms and units, Luminous efficiency, Polar curve, Calculation of illumination level, Illumination of inclined surface to beam, Luminance or brightness, Types of lamps, Types of lighting, Electric lighting fittings (luminaries), Floodlighting, White light LED and conducting Polymers, Energy conservation measures.

UNIT-III

Power Factor and energy instruments: Power factor, Methods of improvement, Location of capacitors, Power factor with nonlinear loads, Effect of harmonics on Power factor. Energy Instruments: Watt-hour meter, Data loggers, Thermocouples, Pyrometers, Lux meters, Tong testers, Power analyzer.

Space Heating and Ventilation: Air–Conditioning (HVAC) and Water Heating: Introduction, Heating of buildings, Transfer of Heat, Space heating methods, Ventilation and air–conditioning, Cooling load, Electric water heating systems, Energy conservation methods.

UNIT-IV

Economic Aspects and Analysis Economics Analysis: Depreciation Methods, Time value of money, Rate of return, Present worth method, Replacement analysis, Life cycle costing analysis, Energy efficient motors (basic concepts).

Computation of Economic Aspects Calculation of simple payback method, Net present worth method, Power factor correction, Applications of life cycle costing analysis, Return on investment.

Suggestive Readings:

1. W.R. Murphy & G. Mckay, “Energy management,” Butter worth Elsevier publications. 2012
2. John. C. Andreas, “Energy-Efficient Electric Motors,” Taylor & Francis, 2018.
3. S C Tripathy, “Electric Energy Utilization and Conservation”, Tata McGraw hill, 1991.
4. Paul o’ Callaghan, “Energy management,” Mc–Graw Hill, 1998.
5. W.C. Turner, “Energy management handbook,” John wiley and sons.
6. K. V. Sharma, P. Venkataseshaiah, “Energy Management and Conservation,” I K International Publishing House, 2020.

Electrical Storage and Management System (DSE-3/ GE-5)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Electrical Storage and Management System	4	3	0	1	Introduction to Electrical and Electronics Engineering, Physics, Introduction to Electric and Hybrid Vehicles

Course Hours: L-03, T-00, P-02

Course Objectives:

1. To understand the different types of energy storage systems.
2. To study the battery characteristics & parameters.
3. To model the types of batteries
4. To know the concepts of the battery management system and design the battery pack.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Analyse different types of batteries.
2. Describe the battery characteristics & parameters.
3. Apply the concepts of a battery management system and design the battery pack.
4. Explain battery testing, disposal, and recycling.

UNIT-I

Energy Storage Technologies: Classification of Storage Technologies by Energy type- Thermal Energy: Heat Storage; Chemical Energy: Organic and Non- Organic; Mechanical Energy: Kinetic and Potential Energy; Electrical Energy: Electrical Potential.

Energy Storage Systems (ESS) in Modern Electrical Systems: Lead-acid batteries, Nickel-cadmium batteries, Lithium-ion batteries, Sodium-sulphur batteries, Nickel metal hydride batteries, Capacitors and Supercapacitors. Solid state Batteries. Differences amongst different ESS.

UNIT-II

Typical ESS and Battery Chemistry: Electrodes, Electrolytes, Collectors, Thermal management, Packaging of battery pack Lithium-based batteries: Lithium manganese oxide, Lithium iron phosphate, Lithium nickel manganese cobalt oxide, Lithium nickel cobalt aluminium oxide and Lithium titanate; Silicon Batteries, Sodium-sulphur Batteries, Proton Batteries, Graphite Dual-Ion Batteries, Salt-water Batteries and Potassium-Ion Batteries**.**

The development cycle of Batteries: ESS sizing, Electrical, Mechanical and Thermal Design, BMS Software and Hardware development, Prototype development, System Validation, Lab Testing, Safety test and Certification.

UNIT-III

Battery Management Systems (BMS): Introduction to BMS, Objectives of the BMS: Discharging control, Charging control, State-of-Charge Determination, State-of-Health Determination, Cell Balancing; BMS topologies: Distributed Topology, Modular Topology and Centralized Topology, Firmware development, Certification, Aging.

UNIT-IV

Batteries for the EV application: Performance criterion for EV batteries, Energy density, Amp hour density, Energy efficiency, Cost, Operating temperature, number of life cycles, recharge and self-discharge rates and commercial availability, some reference batteries and extension to nonautomotive sectors.

Chemical & structure material properties for cell safety and battery design, battery testing, limitations for transport and storage of cells and batteries, Recycling, disposal and second use of batteries. Battery Leakage: gas generation in batteries, leakage path, leakage rates. Ruptures: Mechanical stress and pressure tolerance of cells, safety vents, Explosions: Causes of battery explosions, explosive process, Thermal Runway: High discharge rates, Short circuits, charging and discharging. Environment and Human Health impact assessments of batteries, General recycling issues and drivers, methods of recycling of EV batteries.

Suggestive Readings:

1. Alfred Rufer, "Energy Storage systems and components", CRC Press 2017
2. Tom Denton, "Automotive Electrical and Electronic Systems", 5th Edition, Routledge 2018.
3. Mehard Ehsani, Yiming Gao, Stefano longo and Kambiz Ebrahimi, "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles", CRC Press, 3rd Edition. 2019.
4. Iqbal Husain, "Electric and Hybrid Vehicles: Design Fundamentals", CRC Press. 2021
5. K. T. Chau, "Energy Systems for Electric and Hybrid Vehicles," IET Transportation Series 2 2016.
6. Jiuchun Jiang and Caiping Zhang, "Fundamentals and Applications of Lithium–Ion Batteries in Electric Drive Vehicles," John Wiley & Sons 2015.
7. Pistoia, J.P. Wiaux, S.P. Wolsky, Used Battery Collection and Recycling, Elsevier, 2001.
8. Chris Mi, Abul Masrur& David Wenzhong Gao, Hybrid electric Vehicle- Principles & Applications with Practical Properties, Wiley, 2011.
9. Arno Kwade, Jan Diekmann, Recycling of Lithium-Ion Batteries: The LithoRec Way, Springer, 2018.
10. Ibrahim Dinçer, Halil S. Hamut and Nader Javani, Thermal Management of Electric Vehicle Battery Systems, JohnWiley& Sons Ltd., 2016.

List of Experiments:

1. Study the basic parameters of battery
2. Measure the charging voltage and current of a given battery.
3. Demonstrate any charging technique of lead acid battery/Lithium Ion battery.
4. Efficiency Analysis: Evaluate charge/discharge efficiency at different C-rates. State of Charge (SOC) Estimation: Perform tests to estimate SOC using voltage and current data.
5. Study of ratings of battery for e-cycle, 2W EVs, Erickshaws, E-CARsetc
6. Study the process of battery testing and measure the parameters of the battery.
7. Study and Demonstration of Battery Temperature Measurement / thermal safety issues (Thermocouple, Thermistor etc)
8. Battery pack design for given EV application (Testing Various series parallel combinations for given application)
9. Voltage and Current Ripple Testing: Study the effect of DC-DC converter integration on battery pack voltage and current quality. Fast Charging Analysis: Study the impact of fast charging on cell and pack performance.
10. Battery Recycling Efficiency: Study cell disassembly and material recovery for end-of-life batteries.
11. BMS Functional Testing and its integration with EV battery: Validate the basic functionalities of the Normal & Smart BMS, including voltage and current monitoring and how to perform its connection with EV Battery and other auxiliary systems.
12. Communication Protocol Testing (CAN Bus): Verify data communication between the BMS and external systems using CAN protocol.

13. CAN Data Analysis: Analyze and interpret CAN bus data from the BMS for insights into system performance. Data Logging and Monitoring: Record and analyze real-time data from the battery system during operation.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Detailed Syllabus of Generic Elective (GE) courses offered for Minors / Specializations by Department of Electrical Engineering in SEMESTER VI

Power Converters and Applications (DSE-4/ GE-6)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Power Converters and Applications	4	3	0	1	Introduction to Electrical and Electronics Engineering

Course Hours: L-03, T-00, P-02

Course Objectives:

1. To outline the working of uncontrolled devices.
2. To introduce the basic theory of power semiconductor devices and passive components and their practical application in power electronics.
3. To familiarize the operation principle of AC-DC, DC-DC, DC-AC conversion circuits and their applications.
4. Analyzing power electronics circuits and understanding circuit operation by drawing output waveforms.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Explain the characteristics, functions, and applications of various power electronic devices such as SCR, Power Transistor, MOSFET, GTO, IGBT, and MCT.
2. Design and analyze single-phase and three-phase controlled rectifiers with different loads (R, R-L, R-L-E).
3. Understand the principles of chopper operation and design chopper circuits for various applications, including step-up and step-down choppers.
4. Analyze the operation of single-phase and three-phase inverters and implement voltage control and harmonics reduction techniques.
5. Explain the principles and applications of AC voltage controllers and cycloconverters for various load types (R and RL).

UNIT-I

Solid State Power Devices: Principle of operation of SCR, dynamic characteristic of SCR during turn ON and turn OFF, parameters of SCR, dv/dt and di/dt protection, snubber circuit, commutation circuits, Heat sink design.

Modern Power Devices: Principle of operation of MOSFET, IGBT, GTO, MCT, SIT, SITH, IGCT, and their operating characteristics.

UNIT-II

Single-phase Converter: Half wave converter, 2-pulse midpoint converter, half-controlled and fully controlled bridge converters, input current and output voltage waveforms, the effect of load and source impedance, expressions for input power factor, displacement factor, harmonic factor and output voltage, the effect of the free-wheeling diode, triggering circuits.

UNIT-III

DC-DC Converters: Principle of operation of single quadrant chopper, continuous and discontinuous modes of operation; Voltage and current commutation, design of commutating components; Introduction to SMPS.

UNIT-IV

Inverters: Voltage source and current source inverters, Principle of operation of single-phase half bridge and full bridge voltage source inverters, voltage and current waveforms; Three-phase bridge inverter, 120^0 and 180^0 modes of operation, voltage and current waveforms with star and delta connected RL load; Voltage and frequency control of inverters.

Suggestive Readings:

1. Lander C. W., “Power Electronics”, 3rd Ed., McGraw-Hill International Book Company
2. Mohan N., Undeland T. M. and Robbins W. P., “Power Electronics Converters, Applications and Design”, 3rd Ed., Wiley India.
3. Rashid M. H., “Power Electronics Circuits Devices and Applications”, 3rd Ed., Pearson Education.
4. Derek A. Paice “Power Electronic Converter Harmonics – Multipulse Methods for Clean Power”, IEEE Press, 1996.
5. P.C.Sen, “Modern Power Electronics ”, S. Chand and Co. Ltd., New Delhi, 2000.
6. Power Electronics”, P.S. Bimbhra, Khanna Pub.
7. Power Electronics Circuits and MATLAB simulations”, Alok Jain, Penram International Pub.(India) Pvt.Ltd.
8. Power Electronics Principles and Applications, Joseph vithayathil, McGraw Hill Education India P. Ltd
9. Power Electronics : Essentials & Applications, L. Umanand, Wiley India Pvt Ltd
10. “Power Electronics and Variable Frequency Drives”, Bimal K.Bose, IEEE Press.
11. “Power Electronics Systems: Theory and Design”, Jai P. Agrawal, Pearson Education Pvt.Ltd.

List of Experiments:

1. To study various static switches (SCR, TRIAC, DIAC, IGBT and MOSFET) and their control.
2. To study R and RC-based triggering circuits for thyristors.
3. Design a relaxation oscillator circuit using a Unijunction Transistor (UJT) to be used as a firing circuit for single-phase phase-controlled rectifiers.
4. To study the phase control of TRIAC using DIAC & RC circuits.
5. To study single-phase half-controlled rectifier configurations for R and RL loads.
6. To study single-phase half-controlled rectifier configurations for RLE loads.
7. To study single-phase fully controlled rectifier configurations for R and RL loads.
8. To study three-phase fully controlled rectifier configurations for R and RL loads.
9. To study the working of step-up chopper.
10. To study the working of 180 degree inverter circuit.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Industrial Automation (DSE-4/ GE-6)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Industrial Automation	4	3	0	1	Sensors and Transducers, Introduction to Robotics and Mechatronics

Course Hours: L-03, T-00, P-02

Course Objectives:

1. To introduce the importance of automation techniques for process industries.
2. To impart the role of PLC in industry automation.
3. To expose to various control techniques employed in process automation.
4. To develop automation systems for process industries.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Familiar with various automation technologies in process industries.
2. Understand various automation tools and methods in the process industry.
3. Implement various control and automation methods in process industries.
4. Familiar with various communication technologies in manufacturing and process industries.

UNIT-I

Introduction: Physical Process, Types of Industrial Processes, Industry Classification, Process Automation System, Needs Met by automation, Advantages of Automation, Steps of Automation, Process Signals, Main Components of Industrial Automation.

Types Of Automation Systems: Localized Process, Distributed Process, Supervisory Control and Data Acquisition.

UNIT-II

Programmable Logic Controller (PLC): Block diagram of PLC, Programming languages of PLC, Basic instruction sets, Design of alarm and interlocks, Networking of PLC, Overview of safety of PLC with case studies. Process Safety Automation: Levels of process safety through use of PLCs, Integrating Process safety PLC and DCS, Application of international standards in process safety control.

Fundamental PLC wiring diagram, relays, switches, transducers, sensors, seal-in circuits. Fundamentals of logic, Program scan, Relay logic, PLC programming languages, Digital logic gates, Boolean algebra PLC programming.

UNIT-III

Introduction to Computer based Industrial Automation: Direct Digital Control (DDC), supervisory control and data acquisition (SCADA) based architectures. SCADA for process industries includes understanding of RTUs, Pumping stations, Evacuation processes, Mass Flow Meters and other flow meters, Leak-flow studies of pipelines, Transport Automation.

SCADA Systems Software and Protocols: The components of a SCADA system, SCADA software package, Specialized SCADA Protocols, Error Detection, Distributed Network Protocols, New technologies in SCADA systems.

UNIT-IV

Distributed Control System (DCS): Local Control Unit (LCU) architecture, LCU Process Interfacing Issues, Block diagram and Overview of different LCU security design approaches, Networking of DCS. Introduction to communication protocols- Profibus, Field bus, HART protocols. Data gathering, Data analytics, Real-time analysis of data stream from DCS, Historian build, Integration of business inputs with process data, Leveraging RTU (as different from PLCs and DCS).
Automation System Functionalities and Application Areas: Major Functionalities like Data Acquisition, Data Supervision or Monitoring, Process Survey, Process Control, Process Studies, Human Interaction, Data Logging and History Generation, Data Exchange, Data Availability, Application Areas of Automation System.

Suggestive Readings:

1. John W. Webb and Ronald A. Reis, "Programmable Logic Controllers: Principles and Applications", 5th Edition, Prentice Hall Inc., New Jersey, 2003.
2. Krishna Kant, "Computer - Based Industrial Control", 2nd Edition, Prentice Hall, New Delhi, 2011.
3. Frank D. Petruzella, "Programmable Logic Controllers", 5th Edition, McGraw- Hill, New York, 2016.
4. Curtis D. Johnson, "Process Control Instrumentation Technology", 8th Edition, Pearson New International, 2013.
5. Lukas M. P., "Distributed Control Systems", Van Nostrand Reinhold Co., New York, 1986.

List of Experiments:

1. Feed forward and ratio controller design for real time process trainer.
2. Development of combinational and sequential logic application using minimum PLC languages.
3. Development of Ladder logic program for control of real time processes.
4. Development of SCADA for a control of real time processes.
5. Study of HART and Field bus protocol.
6. P&I diagram development using simulation software for complex processes.
7. Study of Distributed Control System and different instruction sets.
8. Development of Cascade, ratio and feedback controller using DCS simulation software.
9. Development of HMI and annunciator circuits using DCS simulation software.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)

Energy Policies for Sustainable Development (DSE-4/ GE-6)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Energy Policies for Sustainable Development	4	3	1	0	Introduction to Electrical and Electronics Engineering

Course Hours: L-03, T-01, P-00

Course Objectives:

1. Understand the Legal and Regulatory Framework
2. Analyze India's Energy Resources and Consumption Patterns
3. Examine the Global Energy Context
4. Evaluate Energy Policies and Security
5. Address Future Energy Challenges

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. In-depth Understanding of Energy Acts
2. Comprehensive Knowledge of Indian Energy Resources
3. Global Energy Awareness
4. Energy Policy and Security Expertise
5. Problem-Solving for Future Energy Needs

UNIT-I

Energy Conservation: Energy Conservation Act-2001 and its features, Electricity Act – 2003 and its features, Framework of Central Electricity Authority (CEA), Central & States Electricity Regulatory Commissions (CERC & ERCs), Role of MoP (Ministry of Power)-BEE (Bureau of Energy Efficiency).

UNIT-II

Indian Energy Scenario: Energy resources & Consumption, Commercial and non-commercial forms of energy, Fossil fuels, Renewable sources in India, Sector-wise energy Consumption, Impact of energy on the economy, Need for use of new and renewable energy sources-present status and future of nuclear and renewable energy-Energy, Policy Issues related, Fossil Fuels-Renewable, Energy-Power sector reforms, restructuring of energy supply sector, energy strategy for future.

UNIT-III

Global Energy Scenario: Role of energy in economic development and social transformation, Energy and GDP - GNP and its dynamics, Energy sources, overall Energy demand and availability, Energy consumption in various sectors and its changing pattern, Depletion of energy sources and impact economics on international relations.

UNIT-IV

Indian Energy Policy: Global Energy Issues, National & State Level Energy Issues, National & State Energy Policy, Industrial Energy Policy, Energy Security, Energy Vision, Energy Pricing and Impact of Global Variations, Energy Productivity (National & Sector wise productivity).

Global Energy Policy: International Energy Polices of G-8 Countries, G-20 Countries, OPEC Countries, EU Countries, International Energy Treaties (Rio, Montreal and Kyoto), INDO-US Nuclear Deal, Future Energy Options, Sustainable Development, Energy Crisis, Role of International Energy Agency.

Suggestive Readings:

1. Mohan Munasinghe, Peter Meier, “Energy Policy analysis and Modelling,” Cambridge University Press1993
2. J. Goldemberg, T.B. Johansson, A.K.N. Reddy and R.H. Williams, “Energy for a Sustainable World,” Wiley Eastern, 1990.
3. P. Meier and M. Munasinghe, “Energy Policy Analysis & Modeling,” Cambridge University Press, 1993.
4. Charles E. Brown, “World Energy Resources,” Springer 2002.
5. Resources, Charles E. Brown, “International Energy Outlook” EIA Annual Publication.
6. A.W. Culp, “Principles of Energy Conversion,” McGraw Hill International edition, BEE Reference book: no. 1/2/3/4.
7. S Rao, “Energy Technology,” Khanna Publishers.

Power Electronics Converters and Drives for Electric Vehicles (DSE-4/ GE-6)

(Credit Distribution and Pre-Requisites of the Course)

Course title	Credits	Credit distribution of the course			Prerequisite of the course (if any)
		Lecture	Tutorial	Practical	
Power Electronics Converters and Drives for Electric Vehicles	4	3	0	1	Introduction to Electrical and Electronics Engineering, Electric Vehicle Motor

Course Hours: L-03, T-00, P-02

Course Objectives:

1. To provide a comprehensive understanding of semiconductor devices and their application in power electronics for electric vehicle (EV).
2. To understand the fundamentals of DC-DC converters, grid-connected converters, and their role in bidirectional energy flow and V2X (Vehicle-to-Everything) applications.
3. To introduce the principles and modelling of advanced motor drives such as SRM, BLDC, and PMSM, with emphasis on field-oriented and direct torque control.
4. To explore the applications of high-power and high-speed motor drives in EVs, including power converter design, special PWM techniques, and field-oriented control.

Course Outcomes:

At the end of this course, students will demonstrate the ability to:

1. Design and model DC-DC converters for grid-connected and bidirectional energy flow in EV systems, including isolated and non-isolated types.
2. Classify different types of EV chargers and understand their operational principles and impact on EV charging infrastructure.
3. Demonstrate proficiency in controlling induction motor drives using open-loop V/f, vector control techniques, and slip recovery methods for various applications.
4. Model and implement control techniques for switched reluctance motors (SRM), brushless DC (BLDC) motors, and permanent magnet synchronous motors (PMSM) in EV systems.
5. Apply advanced field-oriented control and PWM techniques for high-power and high-speed motor drives in electric vehicles, ensuring efficient energy conversion and performance optimization.

UNIT-I

Review of semiconductor devices; turn-on and turn-off characteristics; loss computation in semiconductor devices; basics of nonisolated/isolated DC-DC and grid connected converters; classification of EV chargers; modelling and control of bi-directional DC-DC converters; discussions on V2X applications.

UNIT-II

Induction Motor Drives: Basics of induction motor; open-loop v/f control; basic pulse width modulation techniques; vector control of IM drives of IM drives for different applications, VSI and CSI fed IM drives, vector controlled permanent magnet induction machines, slip recovery and stator emf injection method, vector control of wound rotor Induction machines.

UNIT-III

SRM, BLDC and PMSM Drives: Basics of switched reluctance motor, BLDC motor and PMSM motors; Basics modelling of SRM, BLDC and PMSM drives, Field oriented control and direct torque control of these drives.

UNIT-IV

High-power and High-speed EVs: Applications of High-power induction motor drives; power converter design; special PWM techniques for high-power applications; field-oriented control of high-power IM drives; applications of highspeed PMSM drives; power converter design and PWM techniques; field-oriented control of high-speed PMSM drives.

Suggestive Readings:

1. Ali Emadi, Advanced Electric Drive Vehicles, CRC Press (2015)
2. Iqbal Husain, Electric and Hybrid Vehicles – Design Fundamentals, Second Edition, CRC Press (2011).
3. W. Leonard, Control of Electric Drives, Springer Press (2007).
4. R Krishnan, Permanent Magnet Synchronous and Brushless DC Motor Drives", CRC Press (2010).
5. Berker B., James W. J. & A. Emadi, Switched Reluctance Motor Drives, CRC Press (2019).
6. Bin Wu, High-Power Converters and Ac Drives, IEEE WILEY Press (2017).
7. Bimal K. Bose, Modern Power Electronics and AC Drives,Prentice Hall PTR (2001).

List of Experiments:

1. To familiarize with the basic vector control of Permanent Magnet Synchronous Motor (PMSM) and Induction Motor (IM) drives with speed/torque control operation using a two-level DC-AC voltage source converter.
2. To measure and analyze the power, torque, and efficiency of a 4-wheeler EV chassis under varying operational conditions during a complete drive cycle.
3. To understand and measure energy flow in an EV power train during modes such as charging, Vehicle-to-Grid (V2G) feeding, motoring, and braking.
4. To operate an EV in all four quadrants (forward motoring, forward braking, reverse motoring, and reverse braking) using multiple motor drives and demonstrate necessary PWM control techniques.
5. To implement and demonstrate special synchronized PWM techniques for high-power and high-speed Induction Motor (IM) drives with field weakening capabilities.
6. To compute turn-on and turn-off losses in power semiconductor devices (e.g., IGBT, MOSFET) under varying load conditions.
7. To design and implement a bidirectional DC-DC converter and analyze its operation in charging and discharging modes.
8. To design and implement a bidirectional DC-DC converter and analyze its operation in charging and discharging modes.
9. To develop models for Induction Motor (IM) drives in both forward and reverse motoring modes.
10. To design a control system for SRM drives and study its performance under varying load conditions.
11. To model and control a PMSM drive using advanced control techniques such as field-oriented control (FOC).
12. To apply and analyze special PWM techniques for high-speed PMSM drives and study their performance.
13. To implement field-oriented control on high-power IM drives and analyze its effectiveness in EV applications.

(Note: Course instructor may add/delete/update new experiments in addition to the above suggested practical exercise.)