CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET402	ELECTRICAL SYSTEM DESIGN AND ESTIMATION	PCC	2	1	0	3

Preamble: Electrical System Design would provide general awareness on IS Product standards / Codes of Practice, The Electricity Act 2003, CEA Regulations and Rules, NEC etc. related to Domestic, Industrial and Commercial Installations. It will also help in the design of Main and Sub Switchboards and distribution system for a medium class domestic and industrial electrical installations. Design of lighting system and selection of luminaries. Selection of Underground cables, Standby generators, lifts and with all involved auxiliaries. Design and selection of power distribution system with power and motor loads for a medium industry. Electrical system design for High-rise buildings with rising main/ cable distribution to upper floors including fire pumps. Design of indoor and outdoor 11kV substations including selection of switching and protective devices for an HT consumer. Essential safety requirements for the electrical installations for Recreational buildings.

Prerequisite: Basics of electrical power systems, circuit analysis and fault level calculations.

Course Outcomes: After the completion of the course the student will be able to:

CO 1	Explain the rules and regulations in the design of components for medium and high voltage installations.
CO 2	Design lighting schemes for indoor and outdoor applications.
CO 3	Design low/medium voltage domestic and industrial electrical installations.
CO 4	Design, testing and commissioning of 11 kV transformer substation.
CO 5	Design electrical installations in high rise buildings.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	1	2	-	-	1	-	2	-	-	-	-
CO 2	3	2	3	-	-	1	1	1	-	-	-	1
CO 3	3	1	3	-	-	1	-	1	-	-	-	1
CO 4	3	1	3	-	-	1	-	1	-	-	1	1
CO 5	3	1	3	-	-	1	1	1	-	-	-	1

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember (K1)	10	10	20
Understand (K2)	15	15	30
Apply (K3)	25	25	50
Analyse (K4)			
Evaluate (K5)			
Create (K6)			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Case study/Course project : 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contains 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):
1. Mention the Scope of The Electricity Act 2003 (K1, K2, PO1)
2. Precautions to be followed for electric safety against loss of life and materials (K3, PO2, PO3, PO6)
3. Mention the Scope of IS 732 (K2, PO8)

Course Outcome 2 (CO2)
1. How are the luminaries selected based on the area of application? (K2, PO3, PO3, PO6)
2. What is CRI? (K1, PO1)
3. Parameters taken into consideration while designing street lighting and flood lighting (K3, PO2, PO3, PO7, PO8, PO12)

Course Outcome 3 (CO3):
1. Characteristics of MCBs (K1, PO1, PO3)
2. Grading between MCBs (K2, PO2, PO6, PO8)
3. Electrical Schematic and physical layout drawings of switch boards, DBs, lighting fittings, fans etc.(K3, PO2, PO6, PO8, P12)

Course Outcome 4 (CO4):
1. Selection of transformer substation. (K1, K2, PO1, PO3)
2. Protective switchgear selection and design of earthing. (K3, PO2, PO6, PO8, PO11)
3. Pre-commission tests to be conducted (K3, PO6, PO12)

Course Outcome 5 (CO5):
1. Selection of different electrical components/systems for multi-storeyed buildings (K1, K2, PO1)
2. Fire protection in high rise buildings (K1, K2, PO2, PO6, PO8)
3. The energy conservation techniques (K2, K3, PO2, PO6)

4. PV solar system design (K3, PO3, PO6, PO7, PO12)
5. Functioning of AMF system (K2, PO1)

Model Question Paper

PAGES: 3

QP CODE:

Reg. No:_____

Name:_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
EIGHTH SEMESTER B. TECH DEGREE EXAMINATION
MONTH & YEAR

Course Code**: EET402**

Course Name: **ELECTRICAL SYSTEM DESIGN AND ESTIMATION**

Max. Marks: 100 **Duration: 3 Hours**

PART A
Answer all Questions. Each question carries 3 Marks

1	Describe the scope of NEC with regard to electrical system design.
2	What are the 3 phase AC system voltages as per NEC and their permissible limits.
3	Explain the specific design considerations in the design of a good lighting scheme.
4	List the different types of lamps suitable for street lighting and give their merits and demerits.
5	What is load survey and explain its importance in electrical system design.
6	Explain the salient aspects considered for the selection of LV/MV cables.
7	Explain the working principle of MCB/MCCB and compare MCB and MCCB.
8	List out the pre-commissioning tests of 11kV indoor substation of an HT consumer and explain any one method.
9	Explain the terms Continuous, Prime and Standby power ratings as applied to a Diesel Generator set.
10	Explain the principle of operation of an AMF panel in an electrical system. What is its necessity in an industry?

PART B
Answer any one full question from each module. Each question carries 14 Marks

Module 1

11	a	What is standardization, how does NEC assist for the electrical system design.	(5)
	b	Explain the relevance of the following IS codes: IS 732, IS 3043.	(5)
	c	Briefly explain the electrical services in buildings.	(4)
12	a	Enumerate any five safety measures incorporated in system design.	(5)
	b)	Draw the standard graphical symbols as given in NEC for: i) circuit breaker ii) star-delta starter iii) fuse disconnector iv) autotransformer v) energy meter	(5)

c Explain the scope of the Electricity Act 2003. (4)

Module 2

13 a) What are the requirements to be satisfied for good road lighting? How are sources selected for road lighting? (7)

b) An office room of size 9X15m is to be illuminated by 2x18W LED luminaire. The lamps are being mounted at a height of 3m from the work plane. The average illumination required is 240 lux. Calculate the number of lamps required to be fitted, assuming a CU of 0.75 and a LLF of 0.8. Assume the ceiling height of the room as 5m. Draw the layout of the luminaire arrangement. The lumen output of 2x18W LED may be taken as 4000 lumens. (7)

14 a Briefly explain the working of an LED lamp with circuit diagram. (7)

b) Design a road way lighting scheme and determine the spacing between the poles using the given lamps. Which alternative you will choose, from the point of energy conservation?

Width of the road way = 12 m
Illumination required = 15lux
Mounting height of poles = 9 m
Arm length = 2m

Types of Lamps	CU	LLF
HPSV - 150 W, 16000 lumen	0.65	0.7
LPSV - 150 W, 25500 lumen	0.5	0.9

The lamps are placed on one side of the road. Assume any missing data. (7)

Module 3

15 a) List the pre-commissioning tests for domestic installation and with the help of schematic diagram explain any one test in detail. (4)

b) Determine the total connected load, number of sub circuits and type of supply for a domestic building with the following rooms: One-bedroom with attached toilet, hall and kitchen (1BHK). Draw the schematic diagram showing the ratings of MCBs and sub circuits. Design shall be based on the NEC guide lines. Assume all required data. (10)

16 a Briey explain the working of ELCB with a neat connection diagram. (4)

b) A rest house has four air-conditioned bed rooms with attached toilets, dining hall and kitchen. Prepare the room wise list of electrical materials for the installation. Draw the schematic diagram showing the ratings of MCBs and sub circuits. Design is based on the NEC guide lines. Assume all required data. (10)

Module 4

17 a Explain the criteria for the design of bus-bar system of a Motor Control Centre (MCC). (4)

b) An industry consists of the following loads:

a. 7.5 kW, 3 phase cage induction motor – 1 No.
b. 11.2 kW, 3 phase cage induction motor – 2 Nos.
c. 22.5 kW, 3 phase cage induction motor – 1 No.

d. Power sockets – 15Nos.

e. Lighting loads - 40 Nos of 2 x 18 W LED lamps

f. Exhaust fans 100 W - 4 Nos.

Design the electrical system for the industry, if the industry is located in a village, and also determine:

i. Type of industry,

ii. Transformer capacity required and type of substation, and

iii. Draw the single line schematic diagram showing the details of cable size, starters and switch gears. Use a switch board with MCCB/SFU incomer and MCCB/SFU/MCB as outgoing and MCB type distribution board for lighting. (10)

18 a) Explain the design procedures of the MSB of an industry with predominantly motor loads. (4)

b) A factory has the following connected load:

i. Large motor of 150 kW - 1 no.
ii. Machine shop with 7.5 kW motors - 6 nos.
iii. Painting booth of 22.5 kW
iv. 10 kVA welding transformers - 4 nos.
v. Water pumping station load 15 kW
vi. Lighting load 5 kW

Select the transformer rating and design an indoor substation including the schematic diagram showing the details of switchgear and cable sizes. Assume a diversity factor of 1.2. (10)

Module 5

19 a) Draw the schematic diagram of a 400 A rising main arrangement for a five-storied building also give the rating of floor wise feeders and switchgears. (6)

b) Briefly explain the sizing of solar PV system for a domestic installation with a daily usage of 5 units. (8)

20 a) Draw the electric schematic diagram of a 320 kVA standby DG set with an AMF panel. Explain the essential potential and metering arrangements required in the generator control panel. (6)

b) Briefly explain the sizing of the battery bank of an off grid solar PV system to cater 3 kWh per day for a domestic installation. (8)

Syllabus

Module 1

IS Product Standards and Codes of practice, The Electricity Act 2003 and NEC 2011 (6 hours):

General awareness of IS Codes - IS 732 - IS 3043 –IS 2026- IS 3646-part 1&2 - IS 5216 part 1&2 - Electricity supply code-2014 (Relevance of each code in electrical installation applications only).

The Electricity Act 2003- General introduction- Distribution of Electricity (Part VI)- Central Electricity Authority (Part IX)- Regulatory Commissions (Part IX).

National Electric Code (NEC 2011) - Scope – Wiring installation (Section 9)- Short circuit calculations (Section 10).

Graphical symbols and signs as per NEC for electrical installations.

Classification of voltages-standards and specifications, tolerances for voltage and frequency.

Module 2

Lighting Schemes and calculations (6 hours):

Lighting design calculations - Definitions of luminous flux, Lumen, Luminous intensity/illuminance (Lux), Illumination calculations, factors affecting Coefficients of Utilisation (CoU) - and Light Loss Factor (LLF).

Benefits of LED lamps over the yesteryear luminaires – Efficacy of present-day LED lamps- Design of illumination systems – Average lumen method - Space to mounting height ratio- Design of lighting systems for a medium area seminar hall using LED luminaires

Exterior lighting design- point to point method - road lighting and public area lighting- Space to mounting height ratio - selection of luminaires- Metal Halide- High & Low pressure Sodium– LED lamps.

Module 3

Domestic Installation (10 hours)

General aspects as per NEC and IS 732 related to the design of domestic dwellings availing single phase supply (LV) and three phase supply (MV) for a connected load less than 15kW.

Load Survey- common power ratings of domestic gadgets- connected load-diversity factor-selection of number of sub circuits (lighting and power)-selection of MCB distribution boards to provide over load, short circuit and earth leakage protection.

Principle of operation of MCB, MCB Isolator, ELCB/RCCB and RCBO. Selection of CBs for protection and grading between major and minor sections.

Selection of wiring cables, conduits as per NEC and IS 732.

Design of electrical schematic and physical layout drawings for low and medium class domestic installation. Preparation of schedule of works and bill of quantities (cost estimation excluded).

Pre-commissioning tests- Insulation resistance measurement, continuity test, polarity test, and earth resistance measurement as applicable to domestic installations.

Module 4
Industrial Power and Lighting Installations (9 hours):

Industrial installations –classifications- Design of electrical distribution systems with main switch board, sub switch boards and distribution boards with ACBs, MCCBs and MCBs as the case may be, for feeding power (mainly motors) and lighting loads of small and medium industries.

Selection of armoured power cables (AYFY, A2XFY, YWY) – calculation of ampacity, voltage drop, short circuit withstand capacity etc.

Design of MSB & SSB including Motor Control Centre (MCC) for motor controls - selection of bus bars and switchgears.

Selection of 11kV indoor and outdoor transformer substations upto 630kVA - selection of switchgears and protective devices –Preparation of schedule of works and bill of quantities (cost estimation excluded).

Short circuit calculations and earthing design for the HV and LV sides of an 11 kV substation of capacity up to 630 kVA.

Pre-commissioning tests of 11kV indoor/outdoor substation of an HT consumer.

Module 5
High Rise building, Solar PV system, Standby generators and Energy conservation (8 hours):

Electrical installations of high-rise buildings: Distribution systems – rising main, cable system - Installation of lifts, standby generators, fire pumps - electric schematic drawing.

Selection of standby Diesel Generator set (DG set) –power rating - Continuous, Prime and Standby power ratings- installation and essential protections-Introduction to Automatic Mains failure (AMF) systems.

Energy Conservation Techniques in electrical power distribution - Automatic Power Factor Correction (APFC) panel – Principle of operation and advantages.

Introduction to Solar PV Systems, off-grid and on-grid systems, Solar panel efficiencies-design of a PV system for domestic application-Selection of battery for off-grid domestic systems.

Data Book (Use for Examination Hall)

1. Data Book Published by the University

Text/Reference Books

1. National Electrical Code 2011, Bureau of Indian Standards.
2. National Lighting Code 2010, Bureau of Indian Standards.
3. National Building Code of INDIA 2016 - Bureau of Indian Standards.
4. M. K. Giridharan, Electrical Systems Design, I K International Publishers, New Delhi, 2nd edition, 2016.
5. U.A.Bakshi, V.U.Bakshi Electrical Technology, Technical publications, Pune.
6. Narang K.L., A Text Book of Electrical Engineering Drawing, Tech India Publications.
7. J. B. Gupta, A Course in Electrical Installation Estimating and Costing, S.K. Kataria & Sons; Reprint 2013 edition (2013).
8. K. B. Raina, S. K. Bhattacharya, Electrical Design Estimating Costing, NEW AGE; Reprint edition (2010).

Website

1. www.price.kerala.gov.in (Reference for module 3 and 4)

Course Contents and Lecture Schedule:

Module	Topic coverage	No. of Lectures
1	**IS Codes, Ats, Rules and NEC (6 hours):**	
1.1	General awareness of IS Codes - IS 732 - IS 3043 –IS 2026- IS 3646-part 1&2 - IS 5216 part 1&2 - Electricity supply code-2014 (Relevance of each code in electrical installation applications only). The Electricity Act 2003- General introduction- Distribution of Electricity (Part VI)- Central Electricity Authority (Part IX)- Regulatory Commissions (Part IX).	2
1.2	National Electric Code (NEC 2011) - Scope – Wiring installation (Section 9)- Short circuit calculations (Section 10).	2
1.3	Graphical symbols and signs as per NEC for electrical installations. Classification of voltages-standards and specifications, tolerances for voltage and frequency.	2
2	**Lighting Schemes and calculations (6 hours):**	
2.1	Lighting design calculations - Definitions of luminous flux, Lumen, Luminous intensity/illuminance (Lux), Illumination calculations, factors affecting Coefficients of Utilisation (CoU) - and Light Loss Factor (LLF).	2
2.2	Benefits of LED lamps over the yesteryear luminaires – Efficacy of present-	2

	day LED lamps-Design of illumination systems – Average lumen method - Space to mounting height ratio- Design of lighting systems for a medium area seminar hall using LED luminaires	
2.3	Exterior lighting design- point to point method - road lighting and public area lighting- Space to mounting height ratio - selection of luminaires- Metal Halide- High & Low pressure Sodium– LED lamps.	2
3	**Domestic Installation (10 hours):**	
3.1	General aspects as per NEC and IS 732 related to the design of domestic dwellings availing single phase supply (LV) and three phase supply (MV) for a connected load less than 15kW.	2
3.2	Load Survey- common power ratings of domestic gadgets- connected load- diversity factor-selection of number of sub circuits (lighting and power)- selection of MCB distribution boards to provide over load, short circuit and earth leakage protection.	2
3.3	Principle of operation of MCB, MCB Isolator, ELCB/RCCB and RCBO. Selection of CBs for protection and grading between major and minor sections. Selection of wiring cables, conduits as per NEC and IS 732.	2
3.4	Design of electrical schematic and physical layout drawings for low and medium class domestic installation. Preparation of schedule of works and bill of quantities (cost estimation excluded). Pre-commissioning tests- Insulation resistance measurement, continuity test, polarity test, and earth resistance measurement as applicable to domestic installations.	4
4	**Industrial installations (9 hours):**	
4.1	Industrial installations –classifications- Design of electrical distribution systems with main switch board, sub switch boards and distribution boards with ACBs, MCCBs and MCBs as the case may be, for feeding power (mainly motors) and lighting loads of small and medium industries. Selection of armoured power cables (AYFY, A2XFY, YWY) – calculation of ampacity, voltage drop, short circuit withstand capacity etc.	3
4.2	Design of MSB & SSB including Motor Control Centre (MCC) for motor controls - selection of bus bars and switchgears.	2

4.3	Selection of 11kV indoor and outdoor transformer substations upto 630kVA - selection of switchgears and protective devices –Preparation of schedule of works and bill of quantities (cost estimation excluded). Short circuit calculations and earthing design for the HV and LV sides of an 11 kV substation of capacity up to 630 kVA.	3
4.4	Pre-commissioning tests of 11kV indoor/outdoor substation of an HT consumer.	1
5	**High Rise building, Solar PV system, Standby generators and Energy conservation (8 hours):**	
5.1	Electrical installations of high-rise buildings: Distribution systems – rising main, cable system - Installation of lifts, standby generators, fire pumps - electric schematic drawing.	2
5.2	Selection of standby Diesel Generator set (DG set) –power rating - Continuous, Prime and Standby power ratings- installation and essential protections-Introduction to Automatic Mains failure (AMF) systems.	3
5.3	Energy Conservation Techniques in electrical power distribution - Automatic Power Factor Correction (APFC) panel – Principle of operation and advantages.	1
5.4	Introduction to Solar PV Systems, off-grid and on-grid systems, Solar panel efficiencies-design of a PV system for domestic application-Selection of battery for off-grid domestic systems.	2

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET424	ENERGY MANAGEMENT	PEC	2	1	0	3

Preamble: This course introduces basic knowledge about energy management and audit. Energy management opportunities in electrical and mechanical systems are discussed. Demand side management and ancillary services are explained. Economic analysis of energy conservation measures are also described.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Analyse the significance of energy management and auditing.
CO 2	Discuss the energy efficiency and management of electrical loads.
CO 3	Apply demand side management techniques.
CO 4	Explain the energy management opportunities in industries.
CO 5	Compute the economic feasibility of the energy conservation measures.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO7	PO8	PO 9	PO 10	PO 11	PO 12
CO 1	**2**					1	1		1			
CO 2	**2**		1	1		1	1					
CO 3	**2**		1	1		1	1					
CO 4	**2**		1	1		1	1					
CO 5	**2**										2	

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember (K1)	15	15	30
Understand (K2)	20	20	40
Apply (K3)	15	15	30
Analyse (K4)			
Evaluate (K5)			
Create (K6)			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contains 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have a maximum 2 subdivisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define energy management. (K1, PO1, PO6, PO7)

2. List the different phases involved in energy management planning. (K1, PO1, PO6, PO7)

3. State the need for energy audit. (K2, PO1, PO6, PO7, PO9)

Course Outcome 2 (CO2)

1. State the different methods which can be adopted to reduce energy consumption in lighting. (K2, PO1, PO3, PO4)

2. Describe how energy consumption can be reduced by energy efficient motors. (K2, PO1, PO3, PO4, PO6, PO7)

3. Discuss the maximum efficiency standards for distribution transformers. (K1, PO1, PO3, PO4, PO6, PO7)

Course Outcome 3 (CO3):

1. Discuss the different techniques of DSM. (K2, PO1, PO3, PO4)

2. Illustrate the different techniques used for peak load management. (K2, PO1, PO3, PO4, PO6, PO7)

3. Explain the different types of ancillary services. (K2, PO1, PO3, PO4)

Course Outcome 4 (CO4):

1. Define Coefficient of performance. (K1, PO1)

2. Demonstrate how waste heat recovery can be done. (K2, PO1, PO3, PO4, PO6, PO7)

3. Describe how energy consumption can be reduced by cogeneration. (K3, PO1, PO3, PO4, PO6, PO7)

Course Outcome 5 (CO5):

1. State the need for economic analysis of energy projects. (K2, PO1, PO11)

2. Define pay back period. (K2, PO1, PO11)

3. Demonstrate how life cycle costing approach can be used for comparing energy projects. (K3, PO1, PO11)

Model Question Paper
QP CODE:

PAGES: 3

Reg. No:_____
Name:_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY EIGHTH SEMESTER B.TECH DEGREE EXAMINATION,
MONTH & YEAR
Course Code: EET424

Course Name: ENERGY MANAGEMENT

Max. Marks: 100 Duration: 3 Hours

PART A (3 x 10 = 30 Marks)

Answer all questions. Each question carries 3 Marks

1. Explain what you mean by power quality audit.
2. Write notes on building management systems.
3. Compare the efficacy of different light sources.
4. Write notes on design measures for increasing efficiency in transformers.
5. Discuss the benefits of demand side management.
6. Explain the benefits of power factor improvement.

7. Discuss any two opportunities for energy savings in steam distribution.

8. Explain the working of a waste heat recovery system.

9. What are the advantages and disadvantages of the payback period method?

10. Write notes on computer aided energy management systems.

PART B (14 x 5 = 70 Marks)
Answer any one full question from each module. Each question carries 14 marks

Module 1

11. a. With the help of case studies, explain any four energy management principles. 8

b. Explain the different phases of energy management planning. 6

12. a. Explain the different steps involved in a detailed energy audit. 7

b. Discuss the different instruments used for energy audit. 7

Module 2

13. a. With the help of case studies, explain any four methods to reduce energy consumption in lighting. 8

b. Explain how energy efficient motors help in reducing energy consumption. 6

14. a. With the help of case studies, explain any four methods to reduce energy consumption in motors. 8

b. Define cascade efficiency of an electrical system. How it can be calculated? 6

Module 3

15. a. Explain the different techniques of demand side management. 6

b. The load on an installation is 800 kW, 0·8 lagging p.f. which works for 3000hours per annum. The tariff is Rs 100 per kVA plus 20 paise per kWh. If the power factor is improved to 0·9 lagging by means of loss-free capacitors costing Rs 60 per kVAR, calculate the annual saving effected. Allow 10% per annum for interest and depreciation on capacitors. 8

16. a. Discuss the importance of peak demand control. Explain the different methods used for that. 8

b. Explain the different types of ancillary services. 6

Module 4

17. a. Explain any four energy conservation opportunities in furnaces 7

b. Explain the working of different types of cogeneration systems. 7

18. a. Discuss the different energy conservation opportunities in boiler. 7

b. Explain any five energy saving opportunities in heating, ventilating and air conditioning systems. 7

Module 5

19. a. Calculate the energy saving and payback period which can be achieved by replacing a 11 kW, existing motor with an EEM. The capital investment required for EEM is Rs. 40,000/-. Cost of energy/kWh is Rs. 5. The loading is 70% of the rated value for both motors. Efficiency of the existing motor is 81% and that of EEM is 84.7%. 8

b. Compare internal rate of return method with present value method for the selection of energy projects. 6

20. a. Explain how the life cycle costing approach can be used for the selection of energy projects. 6

b. The cash flow of an energy saving project with a capital investment cost of Rs. 20,000/- is given in the table below. Find the NPV of the project at a discount rate of 10%. Also find the Internal Rate of Return of the project. 8

Year	Cash flow
1	7000
2	7000
3	7000
4	7000
5	7000
6	7000

Syllabus

Module 1 (7 hours)

Energy Management - General Principles and Planning:

General principles of energy management and energy management planning

Energy Audit: Definition, need, types and methodologies. Instruments for energy audit, Energy audit report - Power quality audit

Energy conservation in buildings: ECBC code (basic aspects), Building Management System (BMS).

Module 2 (9 hours)

Energy Efficiency in Electricity Utilization:

Electricity transmission and distribution system, cascade efficiency.

Lighting: Modern energy efficient light sources, life and efficacy comparison with older light sources, energy conservation in lighting, use of sensors and lighting automation.

Motors: Development of energy efficient motors and the present status, techniques for improving energy efficiency, necessity for load matching and selection of motors for constant and variable loads.

Transformers: Present maximum efficiency standards for power and distribution transformers, design measures for increasing efficiency in electrical system components.

Module 3 (8 hours)

Demand side Management: Introduction to DSM, benefits of DSM, different techniques of DSM –time of day pricing, multi-utility power exchange model, time of day models for planning.

Load management, load priority technique, peak clipping, peak shifting, valley filling, strategic conservation, energy efficient equipment.

Power factor improvement, numerical examples.

DSM and Environment.

Ancillary services: Introduction of ancillary services – Types of Ancillary services

Module 4 (6 hours)

Energy Management in Industries and Commercial Establishments:

Boilers: working principle - blow down, energy conservation opportunities in boiler.

Steam: properties of steam, distribution losses, steam trapping. Identifying opportunities for energy savings in steam distribution.

Furnace: General fuel economy measures, energy conservation opportunities in furnaces.

HVAC system: Performance and saving opportunities in Refrigeration and Air conditioning systems.

Heat Recovery Systems:

Waste heat recovery system - Energy saving opportunities.

Cogeneration: Types and schemes, optimal operation of cogeneration plants, combined cycle electricity generation.

Module 5 (6 hours)

Energy Economics:

Economic analysis: methods, cash flow model, time value of money, evaluation of proposals, pay-back period, average rate of return method, internal rate of return method, present value method, life cycle costing approach. Computer aided Energy Management Systems (EMS).

Text/Reference Books

1. Energy Conservation Act – 2001 and Related Rules and Standards.
2. Publications of Bureau of Energy Efficiency (BEE).
3. Albert Thumann, William J. Younger, Handbook of Energy Audits, CRC Press, 2003.
4. IEEE recommended practice for energy management in industrial and commercial facilities
5. D. Yogi Goswami, Frank Kreith, Energy Management and Conservation Handbook, CRC Press, 2007
6. Operation of restructured power systems Kankar Bhattacharya, Jaap E. Daadler, Math H.J Bollen, Kluwer Academic Pub., 2001.
7. Wayne C. Turner, Energy management Hand Book - the Fairmount Press, Inc., 1997
8. Charles M. Gottschalk, Industrial energy conservation, John Wiley & Sons, 1996.

No	Topic	No. of Lectures
1	**Energy Management - General Principles and Planning; Energy audit (7 hours)**	
1.1	Energy management; General principles of energy management	2
1.2	Energy management planning	1
1.3	**Energy audit:** Definition, need, types and methodologies.	2
1.4	Instruments for energy audit, Energy audit report. Power quality audit	1
1.5	ECBC code (basic aspects), Building Management System (BMS).	1
2	**Energy management in Electricity Utilization (8 hours)**	
2.1	Electricity transmission and distribution system, cascade efficiency.	1
2.2	Energy management opportunities in Lighting: Modern energy efficient light sources, life and efficacy comparison with older light sources, energy conservation in lighting, use of sensors and lighting automation.	2
2.3	Energy management opportunities in Motors: Development of energy efficient motors and the present status, techniques for improving energy efficiency, necessity for load matching and selection of motors for constant and variable loads.	2
2.4	Transformers: Present maximum efficiency standards for power and distribution transformers, design measures for increasing efficiency in electrical system components.	3
3	**Demand side Management and Ancillary service management:(8 hours)**	
3.1	Introduction to DSM, benefits of DSM, different techniques of DSM, DSM and Environment.	2
3.2	Time of day pricing, multi-utility power exchange model, time of day models for planning.	2

3.3	Load management, load priority technique, peak clipping, peak shifting, valley filling, strategic conservation, energy efficient equipment.	2
3.4	Power factor improvement, simple problems.	1
3.5	Introduction of ancillary services – Types of Ancillary services	1
4	**Energy Management in Industries and Commercial Establishments (6 hours):**	
4.1	Boilers: working principle - blow down, energy conservation opportunities in boiler.	1
4.2	Steam: properties of steam, distribution losses, steam trapping. identifying opportunities for energy savings in steam distribution.	1
4.3	Furnace: General fuel economy measures, energy conservation opportunities in furnaces.	1
4.4	Performance and saving opportunities in Refrigeration and Air conditioning systems.	2
4.5	Waste heat recovery system - Energy saving opportunities. Cogeneration: types and schemes, optimal operation of cogeneration plants, combined cycle electricity generation.	1
5	**Energy Economics (6 hours)**	
5.1	Economic analysis methods	1
5.2	Cash flow model, time value of money, evaluation of proposals	1
5.3	Pay-back method, average rate of return method, internal rate of return method	2
5. 4	Present value method, life cycle costing approach.	1
5.4	Computer aided Energy Management Systems (EMS).	1

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET434	SMART GRID TECHNOLOGIES	PEC	2	1	0	3

Preamble: This course introduces various advancements in the area of smart grid. It also introduces distributed energy resources and micro-grid. In addition, cloud computing, cyber security and power quality issues in smart grids are also introduced.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Explain the basic concept of distributed energy resources, micro-grid and smart grid
CO 2	Choose appropriate Information and Communication Technology (ICT) in smart grid
CO 3	Select infrastructure and technologies for consumer domain of smart grid
CO 4	Select infrastructure and technologies for smart substation and distribution automation
CO 5	Formulate cloud computing infrastructure for smart grid considering cyber security
CO 6	Categorize power quality issues and appraise it in smart grid context

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	2										
CO 2	3	3	3	3	2							
CO 3	3	3	3	3	2							
CO 4	3	3	3	3								
CO 5	3	3	3	3	3							
CO 6	3	3	3	3	3							

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember (K1)	10	10	20
Understand (K2)	30	30	60
Apply (K3)	10	10	20
Analyse (K4)			
Evaluate (K5)			
Create (K6)			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have a maximum of 2 subdivisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1)

1. Explain the drivers, functions, opportunities, barriers, challenges, technologies and standards of smart grid (K2, PO1)
2. Explain the basic concept of distributed energy resources and their grid integration. (K2, PO1, PO2)
3. Explain the basic concept of microgrid. (K1, PO1)

Course Outcome 2 (CO2)

1. Choose appropriate communication technology for smart grid. (K3, PO1, PO2, PO3, PO4, PO5)

2. Explain the communication protocols and standards in Smart grid. (K2, PO1)

Course Outcome 3 (CO3)

1. Explain the features and merits of Smart Meters, for smart grid implementation. (K2, PO1, PO2, PO3)
2. Explain the role of real time pricing in smart grid. (K3, PO1, PO2, PO3)
3. Describe the concept and role of AMR and AMI in smart grid. (K2, PO1, PO2)
4. Choose various end use devices and explain their role in Home & Building Automation. (K3, PO1, PO2, PO3, PO4, PO5)
5. Explain the various methods for energy management and role of technology for its implementation. (K3, PO1, PO2, PO3, PO4, PO5)

Course Outcome 4 (CO4)

1. Explain the concept of smart substation. (K1, PO1)
2. Describe the functionalities and applications of IED in substation and distribution automation. (K2, PO1, PO2, PO3, PO4)
3. Explain the architecture components and applications of Wide Area Monitoring Systems. (K3, PO1, PO2, PO3)
4. Explain the role of PMU in WAMS. (K2, PO1, PO2,)
5. Explain the role of various application modules in distribution automation. (K2, PO1, PO2, PO3)

Course Outcome 5 (CO5)

1. Classify cloud computing based on its deployment and services. (K2, PO1)
2. Design cloud architecture of smart grid. (K3, PO1, PO2, PO3, PO4, PO5)
3. Explain the challenges and solutions related to cyber security in smart grid. (K2, PO1, PO2, PO3, PO4, PO5)

Course Outcome 6 (CO6)

1. Explain the power quality issues in smart grid. (K2, PO1, PO2)
2. Choose technologies for the mitigation of power quality issues in the smart grid. (K3, PO1, PO2, PO3, PO4, PO5)

Model Question Paper

QP CODE: Pages:

Reg No.:_____

Name:_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY EIGHTH SEMESTER

B.TECH DEGREE EXAMINATION,

MONTH & YEAR

Course code: EET 434

Course Name: SMART GRID TECHNOLOGIES (E)

Max. Marks: 100 **Duration: 3hrs**

PART A

(Answer all questions. Each question carries 3 marks)

1. Define smart grid concept and explain its necessity.
2. Explain the concept of resilient and self-healing grid.
3. Write a note on ZIGBEE.
4. Discuss 61850 standard and its benefits.
5. Explain how automatic meter reading can make the system smarter.
6. What is meant by real time pricing?
7. Describe substation automation.
8. Explain outage management system.
9. Explain the necessity of cyber security in smart grid
10. Write a note on power quality conditioners in smart grid.

PART B

11. (a) With the help of block diagram explain the architecture of smart grid (7)

    (b) What are the challenges of smart grid technology? (7)

OR

12. (a)Explain smart grid drivers (6)

    (b)What are the functions of smart grid components (8)

13. (a) Explain the various communication protocols used in smart grid. (7)

(b) Write a note on Wi-Max based communication in smart grid. (7)

OR

14. (a) Write a note on various mobile communication technologies used in smart grid. (7)

(b) Explain the role of HAN in smart grid. (7)

15. (a) Explain plug in electric vehicles (7)

(b) Explain the role of phasor measurement unit in smart grid (7)

OR

16. (a) What are the advantages of smart meters? (5)

(b) What are IEDs? What are their application in monitoring and protection (9)

17. (a) With the help of block diagram explain the main features of smart substation (10)

(b) Explain GIS (4)

OR

18. (a) Explain demand side ancillary services. (7)

(b) Write a note on smart inverters. (7)

19. (a) Describe cloud architecture of smart grid. (7)

(b) Explain the role of EMC in the smart grid. (7)

OR

20. (a)Why is cyber security of prime importance in smart grid and how can it be achieved? (7)

(b) Describe the power quality issues of grid connected renewable energy source (7)

Syllabus

Module 1 Introduction to Smart Grid: Evolution of electric grid, Definitions, Need for smart grid, Smart grid drivers, Functions of smart grid, Opportunities and barriers of smart grid, Difference between conventional grid and smart grid, Concept of resilient and self- healing grid.

Components and architecture, Inter-operability, Impacts of smart grid on system reliability, Present development and international policies in smart grid, Smart grid standards.

Module 2 Information and Communication Technology in Smart Grid: Wired and wireless communication -radio mesh, ZIGBEE, 3G, 4G and 5G. Digital PLC, DSL, Wi-Max, LAN, NAN, HAN, Wi-Fi, Bluetooth, Bluetooth Low Energy (BLE), Li-Fi.
Communication Protocols in Smart grid, Introduction to IEC 61850 standard and benefits, IEC Generic Object-Oriented Substation Event - GOOSE, Substation model.

Module 3 Smart grid Technologies Part I: Introduction to smart meters, Electricity tariff, Real Time Pricing- Automatic Meter Reading (AMR) - System, Services and Functions, Components of AMR Systems, Advanced Metering Infrastructure (AMI).

Plug in Hybrid Electric Vehicles (PHEV), Vehicle to Grid (V2G), Grid to Vehicle (G2V), Smart Sensors, Smart energy efficient end use devices, Home & Building Automation.

Intelligent Electronic Devices (IED) and their application for monitoring & protection: Digital Fault Recorder (DFR), Digital Protective Relay (DPR), Circuit Breaker Monitor (CBM), Phasor Measurement Unit (PMU), Standards for PMU. Time synchronization techniques, Wide Area Monitoring System (WAMS), control and protection systems (Architecture, components of WAMS, and applications: Voltage stability assessment, frequency stability assessment, power oscillation assessment, communication needs of WAMS, remedial action scheme).

Module 4 Smart grid Technologies Part II: Smart substations, Substation automation, Feeder automation, Fault detection, Isolation, and Service Restoration (FDISR), Geographic Information System (GIS), Outage Management System (OMS).
Introduction to Smart distributed energy resources and their grid integration, Smart inverters, Concepts of microgrid, Need and application of microgrid – Energy Management- Role of technology in demand response- Demand side management, Demand side Ancillary Services, Dynamic line rating.

Module 5 Cloud computing in smart grid: Private, Public and hybrid cloud. Types of cloud computing services- Software as a Service (SaaS), Platform as a service (PaaS), Infrastructure as a service (IaaS), Data as a service (DaaS), Cloud architecture for smart grid.
Cyber Security - Cyber security challenges and solutions in smart grid**,** Cyber security risk assessment, Security index computation.
Power Quality Management in Smart Grid- Fundamentals, Power Quality (PQ) & Electromagnetic Compatibility (EMC) in smart grid, Power quality conditioners for smart grid.
Case study of smart grid.

Text/Reference Books

1. **Stuart Borlase** "Smart Grid Infrastructure Technology and Solutions", CRC Press; 2nd edition.
2. **James Momoh**, "Smart Grid: Fundamentals of Design and Analysis", Wiley, 2012.
3. **S. Chowdhury**, "Microgrids and Active Distribution Networks." Institution of Engineering and Technology, 2009.
4. **Janaka Ekanayake, Kythira Liyanage, Jianzhong Wu, Akihiko Yokohama, Nick Jenkins**- "Smart Grids Technology and Applications", Wiley, 2012.
5. **Clark W.Gellings,** "The Smart Grid: Enabling Energy Efficiency and Demand Response", CRC Press.
6. **Jean Claude Sabonnadière, Nouredine Hadjsaïd,** "Smart Grids", Wiley Blackwell.
7. **James Larminie, John Lowry**, Electric Vehicle Technology Explained, Wiley, 2003.
8. **Chris Mi, M. AbulMasrur, David WenzhongGao**, "Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives", 2011, Wiley publication.
9. **Danda B. Rawat; Chandra Bajracharya,** Cyber security for smart grid systems: Status, challenges and perspectives IEEE SoutheastCon 2015, DOI: 10.1109/SECON.2015.7132891.
10. **Pillitteri, V. and Brewer, T. (2014),** Guidelines for Smart Grid Cybersecurity, NIST Interagency/Internal Report (NISTIR), National Institute of Standards and Technology, Gaithersburg, MD, [online], https://doi.org/10.6028/NIST.IR.7628r1.
11. **Barker, Preston, Price, Rudy F**., "Cybersecurity for the Electric Smart Grid: Elements and Considerations", Nova Science Publishers Inc, 2012.
12. **Eric D. Knapp, Raj Samani, "**Applied Cyber Security and the Smart Grid: Implementing Security Controls into the Modern Power Infrastructure", Syngress; 1st edition (26 February 2013).
13. **Richard J. Campbell, "**The Smart Grid and Cybersecurity: Regulatory Policy and Issues", Congressional Research Service, 2011.
14. **Dariusz Kloza, Vagelis Papakonstantinou, Sanjay Goel, Yuan Hong**, "Smart grid security", Springer.
15. **Roger C. Dugan**, "Electrical Power Systems Quality", McGraw-Hill Publication, 3/e.
16. **G.T.Heydt**, "Electric Power Quality", Stars in a Circle Publications, 2/e.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Introduction to Smart Grid**:	**(7)**
1.1	Evolution of electric grid, definitions need for smart grid, smart grid drivers, functions of smart grid, opportunities and barriers of smart grid, difference between conventional grid and smart grid, concept of resilient and self- healing grid	3
1.2	Components and architecture, inter-operability, impacts of Smart Grid on system reliability	2
1.3	Present development and international policies in smart grid.	2

	smart grid standards.	
2	**Information and Communication Technology in Smart Grid**:	**(8)**
2.1	Wired and wireless communication -radio mesh, ZIGBEE, 3G, 4G and 5G, digital PLC, DSL, Wi-Max, LAN, NAN, HAN, Wi-Fi, bluetooth, Bluetooth Low Energy (BLE), Light-Fi, substation event - GOOSE, IEC 61850 substation model	4
2.2	Communication protocols in smart grid, introduction to IEC 61850 standard and benefits, IEC Generic Object-Oriented Substation Event - GOOSE.	2
2.3	IEC 61850 ,Substation model	2
3	**Smart grid Technologies Part I**	**(7)**
3.1	Introduction to smart meters, electricity tariff, real time pricing-Automatic Meter Reading (AMR) System, services and functions, components of AMR systems, Advanced Metering Infrastructure (AMI)	2
3.2	Plug in Hybrid Electric Vehicles (PHEV), Vehicle to Grid, Grid to Vehicle.	1
3.3	Smart sensors, smart energy efficient end use devices, home & building automation, Intelligent Electronic Devices (IED) and their application for monitoring & protection, DFRA, DPRA, CBMA	1
3.4	Phasor Measurement Unit (PMU), standard for PMU. time synchronization techniques, Wide Area Monitoring, control and protection systems - architecture, components of WAMS, and applications: voltage stability assessment, frequency stability assessment, power oscillation assessment, communication needs of WAMS, remedial action scheme.	3
4.	**Smart grid Technologies Part II**	**(7)**
4.1	Smart substations, substation automation, feeder automation, fault detection, isolation, and service restoration, Geographic Information System (GIS), Outage Management System (OMS).	2
4.2	Introduction to smart distributed energy resources and their grid integration, smart inverters.	2
4.3	Concepts of micro grid, need & application of micro grid – Energy Management-Role of technology in demand response-Demand Side Management, Demand Side Ancillary Services, Dynamic Line rating.	3
5	**Cloud computing in smart grid**:	**(8)**
5.1	Public and hybrid cloud, cloud architecture of smart grid, types of cloud computing services- IaaS, SaaS, PaaS, DaaS.	2
5.2	**Cyber Security -** Cyber security challenges and solutions in	2

	smart grid**,** cyber security risk assessment, security index computation .	
5.3	**Power Quality Management in Smart Grid**- Fundamentals, power quality & EMC in Smart Grid.	2
5.4	Power quality conditioners for smart grid -case study of smart grid	2

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET416	NONLINEAR SYSTEMS	PEC	2	1	0	3

Preamble: Most of the systems that we come across are nonlinear. Nonlinear systems exhibit interesting oscillatory behaviours and indeed unexpected phenomena like limit cycles, bifurcation, chaos etc. The course aims in understanding the basic phenomena of limit cycles, determine their existence and non-existence in systems using various theorems. This course also aims to investigate the behaviour of nonlinear systems, analyze their stability using the Lyapunov direct/indirect methods, frequency-domain methods and design various control schemes. For understanding the concepts, a basic mathematical foundation is also built throughout the course.The course will provide the basis for designing controllers for various applications such as aerospace, power systems, robotics, electric drives etc.

Prerequisites: EET 302 Linear Control Systems and EET 401 Advanced Control Systems

Course Outcomes: After the completion of the course the student will be able to:

CO 1	Analyse the qualitative behaviour of nonlinear systems about their equilibrium points.
CO 2	Identify the existence and uniqueness of solutions of nonlinear differential equations, the existence of periodic orbits/limit cycles for nonlinear systems.
CO 3	Analyse the stability of nonlinear systems.
CO 4	Design feedback control systems for nonlinear systems.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	2	-	-	-	-	-	-	-	-	-	1
CO 2	3	3	-	-	-	-	-	-	-	-	-	1
CO 3	3	3	-	-	-	-	-	-	-	-	-	1
CO 4	3	2	-	-	-	-	-	-	-	-	-	1

Assessment Pattern:

Total Marks	CIE marks	ESE marks	ESE Duration
150	50	100	03 Hrs

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember (K1)	10	10	20
Understand (K2)	15	15	30
Apply (K3)	25	25	50
Analyse (K4)			
Evaluate (K5)			
Create (K6)			

End Semester Examination Pattern: There will be two parts; Part A and Part B. **Part A** contains 10 questions with 2 questions from each module having 3 marks for each question. Students should answer all questions.
Part B contains 2 questions from each module of which student should answer anyone. Each question carries 14 marks and can have sub-divisions.

Course Level Assessment Questions:

Course Outcome 1 (CO1)

1. Discuss the characteristics of non-linear systems? (K1, PO1)
2. Model a given nonlinear system. (K2, PO1, PO12)
3. Identify and classify the equilibrium solutions of nonlinear systems. (K2, PO1)
4. Analyse the qualitative behaviour of a given system about its equilibrium points and plot a rough sketch of the phase portrait. (K3, PO2, PO12)
5. What are bifurcations? (K1, PO1)
6. Problems to identify the type of bifurcation. (Saddle-node and Pitchfork only) (K2, PO1)

Course Outcome 2 (CO2):

1. Identify the existence of limit cycles using the Poincare Bendixson theorem. (K3, PO2, PO12)
2. Identify the non-existence of limit cycles using Bendixson's theorem. (K3, PO2, PO12)
3. Problems to check the existence and uniqueness of initial value problems. (K2, PO2)

Course Outcome 3 (CO3):

1. Explain the concept of stability (local and global), instability in the sense of Lyapunov. (K2, PO1)
2. Apply Lyapunov direct/indirect methods to analyze the stability of nonlinear systems. (K3, PO2, PO12)
3. Analyze the stability using LaSalle's invariance theorem. (K3, PO2, PO12)
4. Construct Lyapunov functions using Variable gradient and Krasovskii's method. (K3, PO2)
5. Explain memoryless systems and passivity. (K1, PO1)
6. Examine whether a given system transfer function is positive real or not. (K2, PO1)
7. Explain sector nonlinearity and absolute stability. (K1, PO1)
8. Define KYP Lemma (without proof). (K1, PO1)
9. Examine the stability of the sector nonlinearity using Circle criterion. (K3, PO2)
10. Explain Popov criterion for stability. (K1, PO1)

Course Outcome 4 (CO5):

1. Define feedback control problem - state feedback and output feedback. (K1, PO1)
2. Use state feedback control law for stabilizing a given system. (K2, PO1)
3. Explain the concept of input-state and input-output linearization. (K1, PO1)
4. Examine whether a given system is input-output linearizable. (K3, PO2, PO12)
5. Explain stabilization via integral control. (K1, PO1)

Model Question Paper PAGES: 2
QP CODE:

Reg.No:_____
Name:_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
EIGHTH SEMESTER B.TECH DEGREE EXAMINATION
MONTH & YEAR

Course Code**: EET416**

Course Name: **NONLINEAR SYSTEMS**

Max. Marks: 100 **Duration: 3 Hours**

PART A
Answer all questions
Each question carries 3 marks

1		Qualitatively analyse the following nonlinear system about the equilibrium point $\ddot{y}+0.5\,\dot{y}+2\,y+y^2=0$	3
2		What are limit cycles? Give significance and classify them based on stability.	3
3		Define Poincare Index theorem. Check whether there exist periodic orbits for the system defined below using Poincare index theorem. $\dot{y}-y+y^3=0$	3
4		State the conditions for uniqueness and existence of solutions.	3
5		Check the stability of the nonlinear system using Lyapunov direct method. $(x\_1)^{\cdot}=x\_2$ $(x\_2)^{\cdot}=\ 〚-x\_1-3x\_2〛\_$	3
6		What is meant by domain of attraction of a given system?	3
7		What are positive real transfer functions? Check whether G(s)= [s + 2] / [s + 3]	3

		is a positive real transfer function.	
8		Define absolute stability.	3
9		Find the relative degree for the controlled Van der Pol equation with output $y = x\_1$ $(x\_1)^{\cdot} = x\_2$ $(x\_2)^{\cdot} = -x\_1 + \varepsilon\,(1 - \langle\!\langle x\_1 \rangle\!\rangle\,\hat{}\,2)\,\langle\!\langle x \rangle\!\rangle\,\_2 + u,\ \epsilon > 0$	3
10		What is the concept of gain scheduling?	3
		PART B **(Answer any one full question from each module)**	
		Module 1	
11	a)	Find the equilibrium points of the system defined by the system given below and determine the type of each isolated equilibrium point.Also, plot a rough sketch of the qualitative behaviour near the equilibrium points. $(x\_1)^{\cdot} = 5x\_1 - x\_1\,x\_2$ $(x\_2)^{\cdot} = 3x\_2 + x\_1\,x\_2 - 3\,[\![x\_2]\!]\hat{}\,2$	7
	b	The nonlinear dynamic equation for a pendulum is given by $ml((\theta))^{\cdot\cdot} = -mgsin(\theta) - kl((\theta))^{\cdot}$ where '*l=1'* is the length of the pendulum, '*m'* is the mass of the bob, and θ is the angle subtended by the rod and the vertical axis through the pivot point. '*g*' is the gravitational constant. Choose '*k/m=1*'. Find all the equilibria of the system and determine if the equilibria are stable or not.	7
12	a	What is saddle-node and Pitch fork bifurcation?	6
	b	Obtain the linearized representation of the following system around the origin and check the stability of the linearised system about the origin. $(x\_1)^{\cdot} = \langle\!\langle x\_2 \rangle\!\rangle\,\hat{}\,2 + x\_1\,cos\,x\_2$ $(x\_2)^{\cdot} = x\_2 + (x\_1 + 1)x\_1 + x\_1\,sin\,x\_2$	8

Module 2			
13	a	Define a) Bendixson theorem b) Poincare - Bendixson theorem	6
	c	Check whether the following functions are locally Lipchitz. Give reasons for your claim. *(i)* $f(x,y) = 2xy^{1/3}$ for (x,y) = [0,0] (ii) $f(t,x) = 2tx^2$ for (x,y) = [0,3]	8
14	a)	Obtain the Lipschitz constant for (i) $f(t,y) = -3y + 2$ (ii) $f(t,y) = 2ty\text{^}2$	7
	b	Check whether the system given below has a stable or unstable limit cycle. $((x\_1)^{\cdot} = x\_2 - x\_1\,(\,[\![x\_1]\!]\text{^}2 + [\![x\_2]\!]\text{^}2 - 1))^{\cdot}$ $(x\_2)^{\cdot} = -x\_1 - x\_2\,(\,[\![x\_1]\!]\text{^}2 + [\![x\_2]\!]\text{^}2 - 1)$	7
Module 3			
15		Explain the concept of the domain of attraction using an example.	5
	c)	Use variable gradient method to find a suitable Lyapunov function for the system given below $(x\_1)^{\cdot} = -2x\_1$ $(x\_1)^{\cdot} = -2x\_2 + 2x\_1\ [\![x\_2]\!]\text{^}2$	9
16	a	Define stability in the sense of Lyapunov. What is the difference between asymptotic and exponential stability?	6
	b	State LaSalle's invariance principle. Show that the origin is locally asymptotically stable for the following system using LaSalle's principle. $(x\_1)^{\cdot} = x\_2$ $(x\_2 = -3x\_2)^{\cdot} - [\![x\_1]\!]\text{^}3$	8

Module 4			
17	a)	What is KYP Lemma?	4
	b	State circle criterion. Determine a stability sector from the Nyquist plot of the system using circle criterion. $G(s) = 4/((s-1)(s/3+1)(s/5+1))$	10
18	a)	Using circle criterion, find a sector [a,b] for which the following system is absolutely stable. $G(s) = 1/((s+1)(s+2)(s+3))$	8
	b	Describe Popov stability criterion.	6
Module 5			
19	a)	Define the following terms (i) Diffeomorphism (ii) Lie derivative	6
	b	Check whether the given system can be input-output linearized for output $y = x\_1$ $(x\_1)^{\cdot} = x\_1$ $(x\_2)^{\cdot} = x\_2 + u$	8
20	a)	What is input-output linearization?	6
	b	With a suitable feedback control law, linearize the following system $(x\_1)^{\cdot} = a \sin x\_2$ $(x\_2)^{\cdot} = - \llbracket x\_1 \rrbracket \hat{}\, 2 + u$	8

Syllabus

Module 1
Introduction and background (7 hours)

Non-linear system characteristics and mathematical modelling of a non-linear system, Classification of equilibrium points, Stability of a nonlinear system based on equilibrium points, Bifurcation (construction not included), Phase plane analysis of nonlinear systems.

Module 2

Nonlinear characteristics (8 hours)

Periodic solution of nonlinear systems and existence of limit cycle, Open sets, closed sets, connected sets, Invariant set theorem, Bendixson's theorem and Poincare-Bendixson criteria, Existence and uniqueness of solutions to nonlinear differential equations (Proofs not required), Lipschitz condition.

Module 3

Stability Analysis (7 hours)

Lyapunov stability theorems (Proofs not required)- local stability - local linearization and stability in the small- region of attraction, the direct method of Lyapunov, Construction of Lyapunov functions - Variable gradient and Krasovskii's methods, La Salles's invariance principle.

Module 4

Analysis of feedback systems (8 hours)

Passivity and loop transformations, KYP Lemma (Proof not required), Absolute stability, Circle Criterion, Popov Criterion.

Module 5

Nonlinear control systems design (8 hours)

Feedback linearization, Input state linearization method, Input-output linearization method, Stabilization - regulation via integral control- gain scheduling.

Text Book:

1. Khalil H. K., "Nonlinear Systems", 3/e, Pearson, 2002
2. Gibson J. E., "Nonlinear Automatic Control", Mc Graw Hill, 1963
3. Slotine J. E. and Weiping Li, "Applied Nonlinear Control", Prentice-Hall, 1991

References:

1. Alberto Isidori, “Nonlinear Control Systems: An Introduction”, Springer-Verlag, 1985.
2. M. Vidyasagar, “Nonlinear Systems Analysis”, Prentice-Hall, India, 1991.
3. Shankar Sastry, “Nonlinear System Analysis, Stability and Control”, Springer, 1999.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Introduction and background (7 hours)**	
1.1	Non-linear system characteristics and mathematical modelling of a non-linear system.	2
1.2	Classification of equilibrium points, Stability of a nonlinear system based on equilibrium points.	2
1.3	Bifurcation (construction not included), Phase plane analysis of nonlinear systems.	3
2	**Nonlinear characteristics (8 hours)**	
2.1	Periodic solution of nonlinear systems and existence of limit cycles	2
2.2	Open sets, closed sets, connected sets, Invariant set theorem, Bendixson's theorem and Poincare-Bendixson criteria	4
2.3	Existence and uniqueness of solutions to nonlinear differential equations (Proofs not required), Lipschitz condition.	2
3	**Stability Analysis (7 hours)**	
3.1	Lyapunov stability theorems (Proofs not required)- local stability - local linearization and stability in the small- region of attraction	2
3.2	The direct method of Lyapunov	2
3.3	Construction of Lyapunov functions, La Salles's invariance principle.	3
4	**Analysis of feedback systems (8 hours)**	

4.1	Passivity and loop transformations	2
4.2	KYP Lemma (Proof not required), Absolute stability	2
4.3	Circle Criterion	2
4.4	Popov Criterion	2
5	**Nonlinear control systems design (8 hours)**	
5.1	Feedback linearization	2
5.2	Input state linearization method	2
5.3	Input-output linearization method	2
5.4	Stabilization - regulation via integral control- gain scheduling	2

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET446	COMPUTER NETWORKS	PEC	2	1	0	3

Preamble: Nil

Prerequisite: Nil

Course Outcomes: After the completion of the course, the student will be able to

CO#	CO
1	Explain the computer networks, layered architecture, protocols and physical media used for setting up a network.
2	Identify the role of Data link layer, role of the MAC sub layer and networking devices in Ethernets and wireless LANs
3	Explain routing algorithms and congestion control algorithms and ways to achieve good quality of service.
4	Illustrate the IP address classes, ICMP protocols and other external routing protocols.
5	Explain the services provided by the transport layer and application layer.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2											
CO2	2	1										
CO3	2	1										
CO4	2											
CO5	2											

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	15	15	30
Understand	25	25	50
Apply	10	10	20
Analyse			
Evaluate			
Create			

Mark Distribution

Total Marks	CIE Marks	ESE Marks	ESE Duration
150	50	100	3

Continuous Internal Evaluation Pattern:

Attendance : 10 marks

Continuous Assessment Test : 25 marks

Continuous Assessment Assignment : 15 marks

End Semester Examination Pattern:

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course outcome 1 (CO1) :

1. Compare the OSI and TCP/IP reference model (K2, PO1).
2. Distinguish between Connection oriented and connectionless service (K3, PO1).
3. Explain various performance indicators of computer networks. (K2,PO1)

Course outcome 2 (CO2) :

1. Explain the role of the Data link layer in computer networks. (K2, PO1)
2. Discuss the sliding window protocol for error detection and correction (K2, PO1, PO2).
3. Explain the use of Switches, Routers and Gateways (K2,PO1).

Course outcome 3 (CO3) :

1. What is flooding? (K1, PO1)
2. Explain various routing algorithms (Any one algorithm may be asked) (K2, PO1,PO2)
3. Discuss how congestion control is done in computer networks. (K2, PO1, PO2)
4. What is meant by Quality of service? How can it be improved? (K1, PO1)
5. Compare the performance of various routing algorithms (K3,PO1).

Course outcome 4 (CO4) :

1. Describe the format of IPv4/IPv6 datagram with the help of a diagram, highlighting the significance of each field. (any one may be asked only). (K2, PO1)
2. Explain Subnetting with an example. (K2, PO1)
3. What is the advantage of using DHCP? (K1, PO1)
4. Explain Open Shortest Path First (OSPF) Protocol and Border Gateway Protocol (BGP). (Any one may be asked as a part question) (K2,PO1)

Course outcome 5 (CO5) :

1. Explain the UDP/TCP protocol. (K2,PO1)
2. What is RPC? (K1,PO1)
3. What is the use of DNS? (K1,PO1)
4. Explain how message transfer is done using SMTP. (K2,PO1)
5. Discuss the security issues of FTP. How can it be improved? (K2,PO1)

Model Question Paper

QP CODE: **PAGES: ___**
Reg No:_____
Name:_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

EIGHTH SEMESTER B.TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: EET446

Course Name : Computer Networks

Max Marks: 100 **Duration: 3 Hours**

PART-A

(Answer All Questions. Each question carries 3 marks)

1.	What is a VPN ?		**(10x3= 30 Marks)**
2.	Discuss why fiber optic is preferred over copper wires, when you want to get higher bandwidth in the range of 100Mbps or higher.		
3.	What is the need for framing?		
4.	What is piggybacking ?		
5.	Compare adaptive routing algorithms with the non-adaptive type.		
6.	What is jitter and discuss how it can affect various data transfer applications.		
7.	What is the urgent need for migrating to IPv6 from IPv4?		
8.	Discuss ARP.		
9.	What is the use of DNS?		
10.	What is FTP and discuss its security concerns.		
	PART-B **(Answer any one Questions. Each question carries 14 marks)**		
11.		"Most networks are organized as a stack of layers or levels, each one built upon the one below it". Comment on why a layered approach is adopted with reference to the OSI and TCP/IP reference models.	14
	OR		

12.	a	Distinguish between Connection-Oriented and Connectionless Service	7
	b	Explain the terms Bandwidth, Throughput, Latency, Bandwidth–Delay product.	7
13.		Suppose your organization is spread over 5 buildings in a 100 acre campus, and you are asked to set up an intranet with net connectivity. Discuss how you will set up the network highlighting the use of suitable physical media and various networking devices. A rough architecture diagram is expected.	14
		OR	
14.		Explain CSMA/CD with reference to classic Ethernet LAN,	14
15.		Explain Link state routing.	14
		OR	
16.		Discuss the various means by which congestion control can be achieved.	14
17.		Describe the format of IPv4 datagram with the help of a diagram, highlighting the significance of each field.	14
		OR	
18.		Define Subnetting. What are the advantages of Subnetting? Explain with an example	14
19.		Compare TCP with UDP.	14
		OR	
20.		Explain how message transfer is done using SMTP.	14

Syllabus

Module - 1 (Introduction and Physical Layer)

Introduction – Uses of computer networks, Network hardware, Network software - Protocol hierarchies – Design issues for the layers – Connection oriented versus connectionless service. Reference models – The OSI reference model, The TCP/IP reference model, Comparison of OSI and TCP/IP reference models.

Physical Layer –Transmission media overview – Twisted pair and fiber optics. Performance indicators – Bandwidth, Throughput, Latency, Bandwidth–Delay product.

Module - 2 (Data Link Layer)

Data link layer - Data link layer design issues, Error detection and correction, Sliding window protocols.

Medium Access Control (MAC) sublayer, Channel allocation problem, Multiple access protocols – CSMA, Collision free protocols.

Ethernet – Switched Ethernet, fast Ethernet and gigabit Ethernet.

Wireless LANs - 802.11 – Architecture and protocol stack, Use of Bridges, Repeaters, Hubs, Switches, Routers and Gateways.

Module - 3 (Network Layer)

Network layer design issues. Routing algorithms - The Optimality Principle, Shortest path routing, Flooding, Distance Vector Routing, Link State Routing, Routing for mobile hosts.

Congestion control algorithms – Approaches to congestion control (Details not required).

Quality of Service (QoS) - Requirements, Techniques for achieving good QoS – Traffic shaping, Packet scheduling.

Module - 4 (Network Layer in the Internet)

IPv4 protocol, IP addresses, IPv6**,** Internet Control Protocols - Internet Control Message Protocol (ICMP), Address Resolution Protocol (ARP), Dynamic Host Configuration Protocol (DHCP). Open Shortest Path First (OSPF) Protocol, Border Gateway Protocol (BGP), Internet multicasting.

Module – 5 (Transport Layer and Application Layer)

Transport service – Services provided to the upper layers, Transport service primitives. User Datagram Protocol (UDP) – Introduction, Remote procedure call.

Transmission Control Protocol (TCP) – Introduction, TCP service model, TCP protocol, TCP segment header**,** Connection establishment & release.

Application Layer –Domain Name System (DNS) – overview of DNS name space and Name servers, Electronic mail – Architecture and services- SMTP – IMAP - POP3, World Wide Web (WWW) - Architectural overview, HTTP, File Transfer Protocol (FTP).

Text Book

1. Andrew S. Tanenbaum, Computer Networks, 5/e, Pearson Education India.
2. Behrouz A Forouzan, Data Communication and Networking, 5/e, McGraw Hill Education

Reference Books

1. Larry L Peterson and Bruce S Dave, Computer Networks – A Systems Approach, 5/e, Morgan Kaufmann.
2. Fred Halsall, Computer Networking and the Internet, 5/e.
3. James F. Kurose, Keith W. Ross, Computer Networking: A Top-Down Approach, 6/e.
4. Keshav, An Engineering Approach to Computer Networks, Addison Wesley, 1998.
5. W. Richard Stevens. TCP/IP Illustrated Volume 1, Addison-Wesley, 2005.
6. William Stallings, Computer Networking with Internet Protocols, Prentice-Hall, 2004.

Course Contents and Lecture Schedule

No	Contents	No of Lecture Hrs
Module – 1 (Introduction and Physical Layer) (7 hrs)		
1.1	Introduction – Uses of computer networks	1
1.2	Uses of computer networks, Network hardware	1
1.3	Network software - Protocol hierarchies – Design issues for the layers – Connection oriented versus connectionless service.	1
1.4	Reference models – The OSI reference model, The TCP/IP reference model	1
1.5	Reference models, Comparison of OSI and TCP/IP reference models.	1
1.6	Physical Layer – Transmission media overview – Twisted pair and fiber optics.	1
1.7	Performance indicators – Bandwidth, Throughput, Latency, Bandwidth–Delay product.	1
Module 2 – (Data Link Layer) (8 hrs)		
2.1	Data link layer - Data link layer design issues	1
2.2	Error detection and correction	1
2.3	Sliding window protocols.	1
2.4	Sliding window protocols, Medium Access Control (MAC) sublayer.	1
2.5	Channel allocation problem, Multiple access protocols – CSMA	1
2.6	Collision free protocols.	1
2.7	Ethernet – Switched Ethernet, fast Ethernet and gigabit Ethernet. Wireless LANs - 802.11 – Architecture and protocol stack	1

2.8	Use of Bridges, Repeaters, Hubs, Switches, Routers and Gateways.	1
Module 3 - (Network Layer) (6 hrs)		
3.1	Network layer design issues.	1
3.2	Routing algorithms, The Optimality Principle, Shortest path routing, Flooding.	1
3.3	Distance Vector Routing.	1
3.4	Link State Routing.	1
3.5	Routing for mobile hosts, Congestion control algorithms – Approaches to congestion control (Details not required).	1
3.6	Quality of Service (QoS) - Requirements, Techniques for achieving good QoS – Traffic shaping, Packet scheduling.	1
Module 4 – (Network Layer in the Internet) (7 hrs)		
4.1	Internet Protocol (IP) - IPv4 protocol	1
4.2	IP addresses.	1
4.3	IP addresses – part 2	1
4.4	IPv6	1
4.5	Internet Control Protocols - Internet Control Message Protocol (ICMP), Address Resolution Protocol (ARP), Dynamic Host Configuration Protocol (DHCP).	1
4.6	Open Shortest Path First (OSPF) Protocol.	1
4.7	Border Gateway Protocol (BGP), Internet multicasting.	1
Module 5 - (Transport Layer and Application Layer) (7 hrs)		
5.1	Transport service – Services provided to the upper layers Transport service primitives.	1
5.2	User Datagram Protocol (UDP) – Introduction, Remote procedure call.	1
5.3	Transmission Control Protocol (TCP) – Introduction, TCP	1

	service model, TCP protocol	
5.4	TCP segment header**,** Connection establishment & release.	1
5.5	Application Layer –Domain Name System (DNS) – overview of DNS name space and Name servers	1
5.6	Electronic mail – Architecture and services- SMTP – IMAP - POP3	1
5.7	World Wide Web (WWW) - Architectural overview, HTTP, File Transfer Protocol (FTP).	1

CODE	COURSE NAME	CATEGORY	L	T	P	CREDITS
EET456	DESIGN OF POWER ELECTRONIC SYSTEMS	PEC	3	0	0	3

Preamble : To impart knowledge about the design and protection of power electronic systems.

Prerequisite : EET306 Power Electronics

Course Outcomes : After the completion of the course the student will be able to:

CO 1	Design gate drive circuits for various power semiconductor switches.
CO 2	Design protection circuits for various semiconductor devices.
CO 3	Select appropriate passive components for power electronic circuits.
CO 4	Design the magnetic components for power electronic circuits.
CO 5	Design signal conditioning circuits and passive filters for converters.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	2	3	2	-	-	-	-	-	-	-	2
CO 2	3	2	3	2	-	-	-	-	-	-	-	2
CO 3	3	3	-	-	-	-	-	-	-	-	-	2
CO 4	3	3	3	2	-	-	-	-	-	-	-	2
CO 5	3	2	3	2	-	-	-	-	-	-	-	2

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember (K1)	10	10	20
Understand (K2)	10	10	20
Apply (K3)	20	20	50
Analyse (K4)	10	10	10
Evaluate (K5)	-	-	-
Create (K6)	-	-	-

End Semester Examination Pattern : There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Design a gate/base drive using totem pole arrangement (K1, K3, PO1, PO2, PO4)
2. Design a gate drive using a non-isolated circuit (K1, K3, PO1, PO2, PO4)
3. Design high side and low side switch drives using isolated gate drivers (K1, K3, PO1, PO2, PO4)
4. Explain the boot-strap technique for gate drives using gate drive IC IR 2110 (K1, K2, PO1)

Course Outcome 2 (CO2):

1. Design a turn-off and turn-on snubber circuit for SCR (K1,K3,PO1, PO2, PO4)
2. Design a Snubber circuit for a buck converter (K1, K3, PO1, PO2, PO4)
3. Describe the thermal protection, short-circuit and over-current protection in IGBTs (K1,K2, PO1)
4. Explain the steps for the design of heat sinks (K1,K2, PO1)

Course Outcome 3 (CO3):

1. Explain the different types of inductor and transformer assembly (K1, PO1)
2. Explain the types of capacitors used in power electronic circuits and their selection (K1,K2, PO1)
3. Explain the effect of equivalent series resistance and equivalent series Inductance of capacitors in converter operation (K4, PO1)
4. Explain the filter design for single phase and three phase inverters (K3, PO1, PO2)
5. Describe the various types of power resistors used in power electronic circuits (K1, PO1)

Course Outcome 4 (CO4):

1. Describe the selection of amorphous, ferrite and iron cores used in power electronic circuits(K1,K2)
2. Explain the Inductor design in power electronics circuits (K3)
3. Explain the transformer design in power electronics circuits (K3)
4. Explain the wire selection and skin effect in power electronics circuits (K1,K2)

Course Outcome 5 (CO5):

1. Explain the design of current transformers, resistive shunts, hall-effect based voltage and current sensors for power electronics circuits (K2, K3, PO1)
2. Design input and output filters for single phase and three phase inverters (K3, PO1, PO2, PO4)

3. Explain the corner frequency selection and harmonic filtering performance in inverter circuits (K2,K4, PO1)
4. Explain the various components in an Intelligent Power Module (K1,K2, PO1)

Model Question Paper

QP CODE:

PAGES:2

Reg.No:_____
Name:_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
EIGHTH SEMESTER B.TECH DEGREE EXAMINATION, MONTH & YEAR
Course Code: EET456

Course Name: DESIGN OF POWER ELECTRONIC SYSTEMS

Max. Marks: 100 Duration: 3 Hours

PART A (3 x 10 = 30 Marks)

Answer all Questions. Each question carries 3 Marks

1. A MOSFET has an input capacitance Ciss = 800 pF. A gate resistance of 250 Ω is used along with a gate drive voltage peak of 12 V. If the threshold gate voltage is Vgs(th) = 4 V, how long will it take this gate signal to turn on the MOSFET?
2. Design a gate drive using non-isolated and isolated circuits.
3. Design a turn-off and turn-on snubber circuit for SCR.
4. Design a Snubber circuit for a buck converter.
5. Explain the different types of inductor and transformer assembly.
6. Explain the types of capacitors used in power electronic circuits and their selection.
7. Describe the selection of amorphous, ferrite and iron cores used in power electronic circuits.
8. Explain the Inductor design in power electronics circuits.
9. Design current transformers, resistive shunts, hall-effect based voltage and current sensors for power electronics applications.
10. Design input and output filters for single phase and three phase inverters.

PART B (14 x 5 = 70 Marks)
Answer any one full question from each module. Each question carries 14 Marks

Module 1

11. a) Design high side switch drive using isolated gate drivers. **(6)**

b) Design low side switch drive using isolated gate drivers. **(8)**

12. a) Explain the boot-strap technique for gate drive design using gate drive IC IR 2110 **(8)**

    b) Design a gate drive circuit for IGBT **(6)**

Module 2

13. a) Describe the thermal protection in IGBTs. **(10)**
    b) Explain the steps for the design of heat sinks. **(4)**

14. a) Describe the short-circuit protection in IGBTs **(7)**
    b) Describe the over-current protection in IGBTs **(7)**

Module 3

15. a) Two capacitor values are made by a manufacturer. The two have similar size, and each has an ESL of 20 nH, and tan δ=0.2. One is 1000 μF and the other is 100 μF. Evaluate their ESRs and resonant frequencies. If 10 numbers of 100 μF capacitors are paralleled to make 1000 μF, evaluate the ESR, ESL and the resonant frequency of the paralleled combination. Which (a single 1000 μF or a parallel combination of 10 numbers of 100 μF), is better in terms of operating frequency? (**10**)
    b) Explain the filter design for single phase and three phase inverters **(4)**

16. a) Describe the various types of power resistors used in power electronic circuits. **(6)**

    b) Explain the effect of equivalent series resistance of capacitor **(8)**

Module 4

17. a) Design high frequency transformer in power electronics circuits. **(8)**

    b) Explain the wire selection in power electronics circuits. **(6)**

18. a) A 2 mH inductor design for dc applications is as follows, for a maximum current of 0.5A: Core: 26x19; Aw = 40mm2, AC = 90mm2; N=37; aw = 0.29mm2 (23 SWG). For the above core and windings and N, evaluate the peak flux density, peak current density, window space factor (kw), and the inductance value, for air gap values of 0.08mm and 1mm. **(10)**

    b) Explain the thermal considerations in power electronic circuits **(4)**

Module 5

19. a) Explain the corner frequency selection in inverter circuits **(8)**
    b) Explain the various components in an Intelligent Power Module **(6)**

20. a) Explain the harmonic filtering performance in inverter circuits **(8)**
    b) Explain the methods for reducing stray inductance in power electronic circuits **(6)**

Syllabus

Module 1 (8 hrs)

Gate and base drive design: Gate drive requirements and gate/base drive design for SCRs, BJTs, MOSFETs, IGBTs-Gate drive design using discrete components - open collector, totem pole, non-isolated and isolated- optocoupler, pulse transformer based, use of ICs such as DS0026, TLP250- High side and low side switch driving using isolated gate drivers. Boot-strap technique for gate drives using gate drive IC IR 2110.

Major references: Ref.1, Ref.2, Ref.3

Module 2 (7 hrs)

Design of protection elements: Snubber circuits: Function and types of Snubber circuits, design of turn -off and turn-on snubber. Snubber design for step-down converter. Short-circuit and over-current protection in IGBTs, desaturation protection. Thermal protection, cooling, design and selection of heat sinks (natural cooling only).

Major references: Ref.1, Ref.2,

Module 3 (7 hrs)

Passive elements in Power electronics: Inductors: types of inductors and transformer assembly-. Capacitors: types of capacitors used in power electronic circuits, selection of capacitors, dc link capacitors in inverters, filter capacitors in dc-dc and inverter circuits, equivalent series resistance and equivalent series Inductance of capacitors and their effects in converter operation. Design of filters - input and output filters - typical filter design for single phase and three phase inverters - LC filter - corner frequency selection - harmonic filtering performance – design constraints. Resistors: power resistors, use in snubbers. Resistors for special purpose: high voltage resistors and current shunts.

Major references: Ref.1, Ref.4,

Module 4 (7 hrs)

Magnetics design: Magnetic materials and cores: amorphous, ferrite and iron cores-Inductor and transformer design based on area-product approach. Magnetic characteristics and selection based on loss performance and size, eddy current and hysteresis loss. Thermal considerations, leakage inductance, comparison of sizes of transformer and inductor, wire selection and skin effect.

Major References: Ref.1,2,3,5,6

Module 5 (7 hrs)

Measurements and signal conditioning: Design of current transformers for power electronic applications, resistive shunts, hall-effect based voltage and current sensors, typical design based on hall-effect sensors, signal conditioning circuits- level shifters, anti-aliasing

filters. Minimizing stray inductance in drive circuit, shielding and portioning of drive circuit, reduction of stray inductance in bus bar.Introduction to Intelligent Power Module.

Major References: Ref.6

Assignments/ course projects may be given based on the topic: Demonstrative design of a converter such as Buck converter/ Flyback converter.

Text/Reference Books:

1. Mohan N., T. M. Undeland and W. P. Robbins., Power Electronics, Converters, Applications & Design, Wiley-India, 2002.
2. L. Umanand, Power Electronics – Essentials & Applications, Wiley-India, 2009.
3. V. Ramanarayanan, Course material on 'Switched mode power conversion' 2007.
4. Daniel W. Hart, Power Electronics, Tata McGraw-Hill Education, 2011.
5. Erickson, Robert W., and Maksimovic, Dragan, Fundamentals of Power Electronics, 1997.
6. Krein P. T., Elements of Power Electronics, Oxford University Press, 1998.
7. Joseph Vithayathil, Power Electronics: Principles and Applications, McGraw-Hill College; International edition,1995.
8. Singh M. D. and K. B. Khanchandani, Power Electronics, Tata McGraw Hill, New Delhi, 2008.
9. Muhammad H. Rashid, Power Electronics Circuits, Devices and Applications, Pearson Education, 2014.
10. P.S. Bimbhra, Power Electronics, Khanna Publishers, New Delhi, 1990.

Course Contents and Lecture Schedule:

No.	Topic	No. of Lectures
1	**Design of gate and base drive circuits (8 hours)**	
1.1	Gate drive requirements and gate drive design for SCRs, BJTs, MOSFETs, IGBTs.	3
1.2	Gate drive design using discrete components	3
1.3	High side and low side switch driving using isolated gate drivers	1
1.4	Boot-strap technique for gate drives using gate drive IC IR 2110	1
2	**Design of protection elements (7 hours)**	
2.1	Snubber circuits: Function and types of Snubber circuits, design of turn off and turn-on snubber.	2
2.2	Snubber design for step-down converter.	2
2.3	Short-circuit and over-current protection in IGBTs, desaturation	1

	protection.	
2.4	Thermal protection, cooling, design and selection of heat sink (natural cooling only).	2
3	**Passive elements in Power electronics (7 Hours)**	
3.1	Inductors: types of inductors and transformer assembly	1
3.2	Capacitors: types of capacitors used in power electronic circuits, selection of capacitors	1
3.3	DC link capacitors in inverters, filter capacitors in dc-dc and inverter circuits, equivalent series resistance and equivalent series Inductance of capacitors and their effects in converter operation.	2
3.4	Design of filters: input and output filters - typical filter design for single phase and three phase inverters - LC filter - corner frequency selection - harmonic filtering performance – design constraints.	2
3.5	Resistors: power resistors, their use in snubbers. Resistors for special purpose: high voltage resistors and current shunts.	1
4	**Magnetics design (7 Hours)**	
4.1	Magnetic materials and cores: amorphous, ferrite and iron cores	1
4.2	Inductor and transformer design based on area-product approach	3
4.3	Magnetic characteristics and selection based on loss performance and size, eddy current and hysteresis loss	1
4.4	Thermal considerations, leakage inductance, comparison of sizes of transformer and inductor, wire selection and skin effect	2
5	**Measurements and signal conditioning (7 Hours)**	
5.1	Design of current transformers for power electronic applications, resistive shunts	2
5.2	Hall-effect based voltage and current sensors, typical design based on hall-effect sensors	1
5.3	Signal conditioning circuits- level shifters, anti-aliasing filters	2
5.4	Minimizing stray inductance in drive circuit, shielding and portioning of drive circuit, reduction of stray inductance in bus bar	1
5.5	Introduction to Intelligent Power Module	1

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET418	ELECTRIC AND HYBRID VEHICLES	PEC	2	1	0	3

Preamble: Electric and Hybrid vehicles are gaining popularity globally. This course introduces the fundamental concepts of electric, hybrid and autonomous vehicles, drive trains, electrical machines used, energy storage devices, charging systems and different communication protocols.

Prerequisite : EET 202 -DC Machines and Transformers, EET 307-Synchronous and Induction machines, EET 302-Power Electronics

Course Outcomes : After the completion of the course the student will be able to:

CO 1	Explain the basic concepts of Conventional, Electric, Hybrid EV and Autonomous Vehicles
CO 2	Describe different configurations of electric and hybrid electric drive trains
CO 3	Discuss the propulsion unit for electric and hybrid vehicles
CO 4	Compare various energy storage and EV charging systems
CO 5	Select drive systems and various communication protocols for EV

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	1					2					
CO 2	3	2										
CO 3	3	2										
CO 4	3	3	2									
CO 5	3	1	2									

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember (K1)	20	20	40
Understand (K2)	20	20	40
Apply (K3)	10	10	20
Analyse (K4)	-	-	-
Evaluate (K5)	-	-	-
Create (K6)	-	-	-

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	**50**	**100**	**3 hours**

Continuous Internal Evaluation Pattern:

Attendance : 10 marks

Continuous Assessment Test (2 numbers) : 25 marks

Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern : There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have a maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Give questions indicating bloom's taxonomy level under each CO

Course Outcome 1 (CO1):

1. Which are the resistive forces that retard the motion of a four wheel vehicle?(PO1,K1)
2. Explain briefly the performance parameters of the vehicle.(PO1, PO2,K1)
3. What are the social and environmental importance of EV.(PO7, K1)

Course Outcome 2 (CO2):

1. Architecture and power flow control of hybrid electric vehicle.(PO2, K2)
2. Subsystems of an electric vehicle.(PO1, K1)

3. What is regenerative braking?(PO1, K1)

Course Outcome 3 (CO3):

1. Electric components of an electric vehicle. (PO1, K1)
2. Control of orthogonal flux and torque in a separately excited DC motor(PO2, K2)
3. FOC control concept in PMSM motors.(PO1, PO2,K2)

Course Outcome 4 (CO4):

1. Battery management supporting system for hybrid vehicle.(PO1, K2)
2. Numerical problems in sizing and selection of batteries (PO3, K3)
3. Pin diagrams and differences of various connectors used for EV charging.(PO2,K2)

Course Outcome 5 (CO5):

1. Torque - speed envelope curves of drive train motors (PO2,K1)
2. Numerical Problems in sizing of drive systems (PO3,K3)
3. Different communication protocols used in EV (PO1, K2)

Model Question Paper

QP CODE: **Pages:**

Reg No.:_____

Name:_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY EIGHT SEMESTER B.TECH DEGREE EXAMINATION,

MONTH & YEAR

Course Code: EET 418

Course Name: ELECTRIC AND HYBRID VEHICLES

Max. Marks: 100 **Duration: 3 hours**

PART A

Answer all questions; each question carries 3 marks.

1.	Explain rolling resistance and aerodynamic drag in vehicles.	(3)
2.	Write short notes on gradeability of the automobile system	(3)
3.	With the help of a block diagram, explain the major components of an electric vehicle.	(3)
4.	What is axial balancing?	(3)
5.	What are the electric components used in the propulsion unit of EV/HEV?	(3)

6. List the advantages of PMSM motors over DC and induction motors. (3)

7. Explain the terms specific energy and energy density as applied to batteries. (3)

8. Explain the V2G concept. (3)

9. What is meant by Constant Power Speed Ratio as applied to an electric motor? (3)

10. What is the significance of a communication network in electric/hybrid vehicles? (3)

PART B

Answer any one complete question from each section; each question carries 14 marks

11 (a) Draw and explain ideal traction power plant characteristics of various power plants and various power source characteristics used in electric and hybrid electric vehicles. (8)

(b) Why is a gear system needed for an ICE? Explain with relevant characteristic curves. (6)

OR

12 (a) Explain the levels of automation and its significance in autonomous vehicles (5 marks)

(b) What are the resistive forces acting on the vehicle movement? Obtain the dynamic equation of the vehicle movement.

13 (a) Draw and explain different classification of electric vehicles based on power source configurations. (7)

(b) Explain the different power flow control modes of a typical parallel hybrid system with the help of block diagrams. (7)

OR

14 (a) Explain in detail the EV drivetrain alternatives based on drivetrain configurations (6)

(b) Explain the different power flow control modes of a typical ICE dominated series-parallel hybrid system with the help of block diagrams (8)

15 (a) Explain the Permanent Magnet Synchronous Motor control for application in EV. (10)

(b) Describe the advantages of independent control of flux and torque in SEDC Motor (4)

OR

16	(a)	Discuss in detail the various electrical components used in HEV.	(10)
	(b)	List the advantages of FOC control.	(4)
17	(a)	What is meant by the C rating of a battery? Explain with an example.	(4)
	(b)	Explain the operation, advantages and disadvantages of Fuel cells used in EV.	(10)
		OR	
18	(a)	Explain briefly the different charging systems used for charging of EV.	(8)
	(b)	With pin diagrams, describe the CCS Type 2 connectors used for EV charging.	(6)
19	(a)	A hybrid electric vehicle has two sources- an ICE with output power of 80kW and battery storage. The battery storage is a 150 Ah, C10 battery at 120V. (i).Calculate the battery energy capacity (ii). Without de-rating the Ahr capacity,what is the maximum power that can be supported by the battery? (iii). What is the electrical motor power output if the total efficiency of power converter and motor combination is 98%? (iv). What is the maximum power that can be transmitted to the wheels if the transmission efficiency is 95%?	(8)
	(b)	Explain briefly the factors to be considered while sizing the electric motor for EV.	(6)
		OR	
20	(a)	What does CP and PP pins denote in connectors and explain its functions	(5)
	(b)	Draw and explain the FLEXRAY communication systems used in EV.	(9)

Syllabus

Module 1 - 8 hrs

Introduction to Hybrid Electric Vehicles: History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drive-trains on energy supplies. (2 hrs)

Conventional Vehicles: Basics of vehicle performance, vehicle power source characterization, transmission characteristics, mathematical models to describe vehicle performance. (5 hrs)

Autonomous Vehicles: Levels of automation, significance & effects of automation in vehicles (1 hr)

Module 2 - 7 hrs

Hybrid Electric Drive-trains: Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis. (4 hrs)

Electric Drive-trains: Basic concept of electric traction, introduction to various electric drive-train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis.(3 hrs)

Module 3 - 7 hrs

Electric Propulsion unit: Introduction to electric components used in hybrid and electric vehicles (2 hrs)

DC Drives: Review of Separately excited DC Motor control – Speed and torque equations - Independent control of orthogonal flux and torque - Closed loop control of speed and torque (block diagram only) (2 hrs)

PMSM Drives: PMSM motor basics – Independent control of orthogonal flux and torque (concept only)- Field Oriented Control (FOC) – Sensored and sensorless control (block diagram only) (3 hrs)

Module 4 - 7 hrs

Energy Storage: Introduction to energy storage requirements in Hybrid and Electric Vehicles- Battery based energy storage systems,Battery Management System, Types of battery- Fuel Cell based energy storage systems- Supercapacitors-Hybridization of different energy storage devices (3 hrs)

Overview of Electric Vehicle Battery Chargers - On-board chargers, Electric Vehicle Supply Equipment (EVSE) - Grid to EVSE to On-board chargers to battery pack power flow block schematic diagrams – Types of charging stations - AC Level 1 & 2, DC - Level 3 – V2G concept-Types of Connectors - CHAdeMO, CCS Type1 and 2, GB/T - PIN diagrams and differences (4hrs)

Module 5 - 5 hrs

Sizing the drive system: Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, sizing the power electronics (3 hrs)

Vehicle Communication protocols : Need & requirements - Functions of Control Pilot (CP) and Proximity Pilot (PP) pins, Communication Protocols - CAN, LIN, FLEXRAY (Basics only)- Power line communication (PLC) in EV (2 hrs)

Text Books

1. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003

References:

1. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.
2. Mehrdad Ehsani, YimiGao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.
3. Chris Mi, M A Masrur, D W Gao, " Hybrid Electric Vehicles – Principles and applications with practical perspectives," Wiley, 2011
4. Anderson JM, Nidhi K, Stanley KD, Sorensen P, Samaras C, Oluwatola OA, Autonomous vehicle technology: A guide for policymakers, Rand Corporation,2014

Online Resources:

1. NPTEL courses/Materials (IITG, IITM,IITD) – Electric and Hybrid vehicles
   https://nptel.ac.in/courses/108/103/108103009/ (IIT Guwahati)
   https://nptel.ac.in/courses/108/102/108102121/ (IIT Delhi)
   https://nptel.ac.in/courses/108/106/108106170/ (IIT Madras)
2. FOC Control - video lecture by Texas Instruments
   https://training.ti.com/kr/field-oriented-control-permanent-magnet-motors
3. Sensored and sensorless FOC control of PMSM motors – Application notes (TI, MATLAB)
   https://www.ti.com/lit/an/sprabz0/sprabz0.pdf?ts=1620018267996&ref_url=https%253A%252F%252Fwww.google.com%252F
   https://in.mathworks.com/help/physmod/sps/ref/pmsmfieldorientedcontrol.html
4. Electric Vehicle Conductive AC Charging System
   https://dhi.nic.in/writereaddata/UploadFile/REPORT%20OF%20COMMITTEE636469551875975520.pdf
   Electric Vehicle Conductive AC Charging System

Course Contents and Lecture Schedule:

No.	Topic	No. of Lectures
1	**Introduction to hybrid/electric, conventional & autonomous vehicles (8 hours)**	
1.1	Introduction to Hybrid Electric Vehicles: History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles	1
1.2	Impact of modern drive-trains on energy supplies	1
1.3	Conventional Vehicles: Basics of vehicle performance	1
1.4	Vehicle power source characterization, transmission characteristics	2
1.6	Mathematical models to describe vehicle performance	2

1.7	Autonomous Vehicles: Levels of automation, significance & effects of automation in vehicles	1
2	**Hybrid & Electric drive-trains (7 hours)**	
2.1	Hybrid Electric Drive-trains: Basic concept of hybrid traction	1
2.2	Introduction to various hybrid drive-train topologies	1
2.3	Power flow control in hybrid drive-train topologies, fuel efficiency analysis.	2
2.4	Electric Drive-trains: Basic concept of electric traction, introduction to various electric drive-train topologies	1
2.5	Power flow control in electric drive-train topologies, hub motors, fuel efficiency analysis.	2
3	**Electric Propulsion System (7 Hours)**	
3.1	Electric Propulsion unit: Introduction to electric components used in hybrid and electric vehicles	2
3.2	DC Drives: Review of Separately excited DC Motor control – Speed and torque equations - Independent control of orthogonal flux and torque – Closed loop control of speed and torque (block diagram only)	2
3.3	PMSM Drives: PMSM motor basics – Independent control of orthogonal flux and torque (concept only)	2
3.4	Field Oriented Control (FOC) of Permanent Magnet Synchronous Motor – Sensored and sensorless control (block diagram only)	1
4	**Energy Storage (7 Hours)**	
4.1	Energy Storage: Introduction to energy storage requirements in Hybrid and Electric Vehicles- Battery based energy storage systems, Battery Management System	1
4.2	Types of battery-Lithium ion, Lead acid	1
4.3	Fuel Cell based energy storage systems- Supercapacitors-Hybridization of different energy storage devices	1
4.4	Overview of Electric Vehicle Battery Chargers – On-board chargers, Electric Vehicle Supply Equipment (EVSE) - Grid to EVSE to On-board chargers to battery pack power flow block schematic diagrams	2
4.5	Types of charging stations - AC Level 1 & 2, DC - Level 3	1
4.6	V2G concept-Types of Connectors - CHAdeMO, CCS Type1 and 2, GB/T - PIN diagrams and differences	1

5	**Sizing the drive system (5 Hours)**	
5.1	Sizing the drive system **:**Matching the electric machine and the internal combustion engine (ICE)	1
5.2	Sizing the propulsion motor	1
5.3	Sizing the power electronics	1
5.4	Vehicle Communication protocols : Need and requirements - Functions of Control Pilot (CP) and Proximity Pilot (PP) pins	1
5.5	Communication Protocols - CAN, LIN, FLEXRAY(Basics only) –Power Line Communication (PLC) in EV	1

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET428	INTERNET OF THINGS	PEC	2	1	0	3

Preamble: This elective course is designed for state-of-the-art features to students and enable them to work in the industry where IoT is applied to a great extent**.** Students will also be introduced to the programming of embedded devices used in different levels of IoT application. Moreover, they will get exposed to sensor interfacing and uploading data to cloud services provided by different firms.

Prerequisite: Experience in high level language programming and system design concepts with microcontrollers are required.

Course Outcomes: After the completion of the course the student will be able to

CO 1	Explain the role of computer networks in IoT. (K1)
CO 2	Select the appropriate communication standard for their IoT application. (K2)
CO 3	Use the appropriate sensors and embedded devices to get the data from the "things" and upload to cloud (K2)
CO 4	Develop programs for IoT devices using micropython language. (K3)
CO 5	Utilize the learned information to find an IoT based solution for the problem at hand. (K3)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	2											
CO 2	2											
CO 3	2	2			2							
CO 4	2	3	3	1	2				1			1
CO 5	2	3	3	1	2	2	1		1			1
CO 6												

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	20
Understand	25	25	50
Apply	15	15	30
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Draw and explain the functional block diagram of IoT system.

2. Define the terms a) IP address b) Access point c) Station d) Router e) gateway

3. Explain the enabling technologies of IoT

Course Outcome 2 (CO2)

1. Explain the Wireless Sensor Network (WSN) technology.

2. How the data sensed from things uploaded to cloud?

3. Briefly explain the communication standards in use for connection to cloud service.

Course Outcome 3(CO3):

1. Explain the main features of Raspberry Pi 4 B computer

2. How ESP32 can be used as an embedded device in IoT applications?

3. Briefly explain the use ARM EMBED in IoT application.

Course Outcome 4 (CO4):

1. Prepare a micropython program to enable ESP32 module as an access point.

2. Prepare a micropython program to read analog data using raspberry pi and setup a server.

3. Explain the features of ARM EMBED IoT platform.

Course Outcome 5 (CO5):

1. Explain the application of IoT with suitable block diagram for smart metering of electricty

2. Detail the data sensing and prediction based on IoT applications in smart farming.

3. Detail the features of Industrial IoT with suitable block diagram.

Syllabus

EET 428: INTERNET OF THINGS

Module 1

Introduction: Definition and Characteristics of IoT, Physical Design of IoT: Things in IoT, IoT Protocols, Logical Design of IoT: IoT Functional Blocks, IoT Communication Models, IoT Communication APIs, IoT Enabling Technologies. Design challenges – power consumption and security issues.

Computer networks: Internet-protocols and standards-OSI model- TCP/IP protocol suite. IP addressing – IPv4 and IPv6, Physical layer components- Switch, Router, Access point, station, Server, Client, Port, Gateway. Sizing of network- LAN, MAN, WAN . **(8 hrs)**

Module 2

IoT and M2M Communications: Introduction, M2M, M2M applications, Differences between M2M and IoT, M2M standards- Bluetooth-LE, Zigbee, NFC, Wifi and LoRaWAN. Data logging and cloud services- CoAP, MQTT and JSON. Big data analytics (concepts only)**(6 hrs)**

Module 3

Sensor technologies for IoT- Wireless sensor network. Voltage, Current, Speed, Temperature and humidity sensors and data acquisition using embedded devices- block diagram. Data logging to cloud services- protocols and programming. **(6 hrs.)**

Module 4

Embedded devices for IoT. Introduction to Python programming and embedded programming using micropython. Sensor interfacing and data acquisition using target boards like Raspberry Pi 4B, ARM EMBED, ESP32, Arduino boards. Programming examples for

data logging to cloud using micropython. (Assignments on hardware implementation using these or similar boards may be given.) **(8hrs.)**

Module 5

IoT applications: Energy management and smart grid applications. IoT based home automation, Smart metering for electricity consumers. IoT based weather stations, Agriculture- smart farming, Automobile IoT- Electric vehicles-platform and software, Industrial IoT. **(6 hrs.)**

Text Books

1. Simone Cirani," Internet of things: Architecture, protocols and standards", Wiley, 2019

2. Charles Bell, "MicroPython for the Internet of Things: A Beginner's Guide to Programming with Python on Microcontrollers", Apress, 2017

3. B.K Thripathy, J Anuradha, "Internet of things (IoT) _ technologies, applications, challenges and solutions ", CRC press, 2018

4. Raj Kamal, "Internet of Things: Architecture and Design Principles", McGraw Hill (India) Private Limited.

Reference Books

1. Qusay F. Hassan, " Internet of Things A to Z,: Technologies and applications", IEEE press,2018

2. Gary Smart, "Practical Python Programming for IoT : Build advanced IoT projects using Raspberry Pi 4, MQTT, RESTful APIs, WebSockets, and Python 3, Packt Publishing Ltd, 2020.

3. Gaston C. Hillar , "MQTT Essentials - A Lightweight IoT Protocol" , Packt Publishing Ltd, 2017.

4. Alasdair Gilchrist , "Industry 4.0 The Industrial Internet of Things". Apress, 2016.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Module I**	
1.1	Introduction to IoT, functional block	2
1.2	IoT communication models,Design challenges	2
1.3	Computer networks related topics	4
2	**Module II**	
2.1	Introduction to M2M communications, standards	2
2.2	Data logging and cloud services, MQTT,json	3
2.3	Big data analytics (concepts only)	1
3	**Module III**	

3.1	Sensors and sensor networks	1
3.2	Voltage ,current, temperature sensors and their interfaces	2
3.3	Data logging to cloud services and protocols	3
4	**Module IV**	
4.1	Introduction to embedded devices like Raspberry Pi, ESP32 etc	2
4.2	Introduction to micropython programming	3
4.3	Micropython programming for data logging to cloud	3
5	**Module V**	
5.1	IoT applications in smart grids	3
5.2	IoT application to other applications	1
5.3	IoT applications in electric vehicles and IIoT	2

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET438	ENERGY STORAGE SYSTEMS	PEC	2	1	0	3

Preamble: This course aims to introduce the importance and application of energy storage systems and to familiarize with different energy storage technologies.

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Identify the role of energy storage in power systems
CO 2	Classify thermal, kinetic and potential storage technologies and their applications
CO 3	Compare Electrochemical, Electrostatic and Electromagnetic storage technologies
CO 4	Illustrate energy storage technology in renewable energy integration
CO 5	Summarise energy storage technology applications for smart grids)

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	2										
CO 2	3											
CO 3	3	2	1				1					
CO 4	3	2	1			1	1					1
CO 5	3	1	1			1	1					1

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember (K1)	15	15	30
Understand (K2)	20	20	40
Apply (K3)	15	15	30
Analyse (K4)			
Evaluate (K5)			
Create (K6)			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1)

1. What are the different parts of a complete energy storage unit? (K1, PO1)
2. Explain the Dynamic Duty of storage plant. (K2, PO1,PO2)
3. What are the different types of central store? (K2, PO1)

Course Outcome 2 (CO2)

1. List the applications of thermal energy storage systems. (K1, PO1)
2. Explain hydrogen-based power utility concept.(K2,PO1)
3. What are the different storage containments of hydrogen? (K1, PO1)

Course Outcome 3(CO3)

1. Explain the working of fuel cell along with schematic diagram. (K2, PO1,PO2,PO7)
2. Write short notes on supercapacitors. (K2, PO1)
3. Explain the arrangement of a control and protection system for Super Conducting Magnetic Energy Storage.(K2 , PO1,PO3)

Course Outcome 4 (CO4)

1. Explain small-scale hydroelectric energy. (K2,PO1,PO3,PO6,PO7,PO12)
2. Write short notes on wave energy and its storage system. (K2, PO1, PO7,PO12)
3. What are the different types of renewable power sources? (K1, PO1, PO7,PO12)

Course Outcome 5 (CO5)

1. Explain distributed energy storage system. (K2, PO1, PO3,PO6,PO7,PO12)
2. What are the characteristics of smart grid system? (K1, PO1, PO6,PO7,PO12)
3. What is demand response? (K1, PO1, PO2)

Model Question Paper

QP CODE: Pages:

Reg No.:_____

Name:_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY EIGHTH SEMESTER

B.TECH DEGREE EXAMINATION,

MONTH & YEAR

Course Code: EET438

Course Name: ENERGY STORAGE SYSTEMS

Max. Marks: 100 Duration: 3 hours

PART A

Answer all questions; each question carries 3 marks.

1.	Discuss the power transformation of energy storage system.	(3)
2.	Explain the different components of energy storage system with schematic structure.	(3)
3.	Define Flow equation related to thermal energy storage system.	(3)
4.	Write the difference between hybrid and combined energy storage in power system.	(3)
5.	Explain the chemical reaction of lead acid batteries.	(3)
6.	Write down the basic principle of capacitor bank storage system.	(3)
7.	Classify hydro power plants based on their rated capacity.	(3)
8.	Briefly discuss small-scale hydroelectric energy system.	(3)

9.		What is distributed energy storage system?	(3)
10		List the various layers of smart grid.	(3)

PART B

Answer any one complete question from each section; each question carries 14 marks

11	(a)	Explain static duty of energy storage plant.	(8)
	(b)	With neat diagram explain energy and power balance in a storage unit.	(6)
		OR	
12	(a)	Explain the econometric model of energy storage. Derive the expression for annual cost of the system.	(10)
	(b)	What are the key parameters considered for the comparison of energy storage in power system?	(4)
13	(a)	Discuss the working principle of compressed air energy storage system.	(7)
	(b)	Write short note on flywheel energy storage system.	(7)
		OR	
14	(a)	Write any three industrial methods to produce hydrogen.	(9)
	(b)	Explain 'power to gas' concept.	(5)
15	(a)	Explain the working of Li-ion batteries.	(7)
	(b)	Describe the typical voltage–discharge profile for a battery cell.	(7)
		OR	
16	(a)	Describe basic principle and working of superconducting magnetic energy storage system.	(7)
	(b)	With the help of a block diagram, explain the arrangement of control and	(7)

protection system for superconducting magnetic energy storage system.

17	(a)	What are the main features of renewable energy systems?	(4)
	(b)	Explain the role of storage systems in an integrated power system with grid-connected renewable power sources.	(10)

OR

18	(a)	Explain photovoltaics system.	(4)
	(b)	Discuss the role of storage in an isolated power system with renewable power sources.	(10)
19	(a)	Describe the distributed energy storage system.	(6)
	(b)	"HEV act as a distributed energy generator and storage", justify your answer.	(8)

OR

20	(a)	What is demand response?	(5)
	(b)	Draw and explain the battery SCADA system.	(9)

Syllabus

Module 1

Introduction to energy storage in power systems (6)

Need and role of energy storage systems in power system, General considerations, Energy and power balance in a storage unit, Mathematical model of storage system: modelling of power transformation system (PTS)-Central store (CS) and charge–discharge control system (CDCS), Econometric model of storage system.

Module 2

Overview on Energy storage technologies (7)

Thermal energy: General considerations -Storage media- Containment- Thermal energy storage in a power plant, Potential energy: Pumped hydro-Compressed Air, Kinetic energy: Mechanical- Flywheel , Power to Gas : Hydrogen - Synthetic methane

Module 3

Overview on Energy storage technologies (8)

Electrochemical energy : Batteries- Battery parameters: C-rating -SoC- DoD- Specific Energy-Specific power (numerical examples), Fuel cells, Electrostatic energy (Super Capacitors), Electromagnetic energy (Super conducting Magnetic Energy Storage), Comparative analysis, Environmental impacts of different technologies.

Module 4

Energy storage and renewable power sources (6)

Types of renewable energy sources: Wave - Wind – Tidal – Hydroelectric - Solar thermal technologies and Photovoltaics, Storage role in isolated power systems with renewable power sources, Storage role in an integrated power system with grid-connected renewable power sources

Module 5

Energy storage Applications (7)

Smart grid, Smart microgrid, Smart house, Mobile storage system: Electric vehicles – Grid to Vehicle (G2V)-Vehicle to Grid (V2G), Management and control hierarchy of storage systems - Aggregating energy storage systems and distributed generation (Virtual Power Plant Energy Management with storage systems), Battery SCADA, Hybrid energy storage systems: configurations and applications.

Text Books

1. A.G.Ter-Gazarian, "Energy Storage for Power Systems", Second Edition, The Institution of Engineering and Technology (IET) Publication, UK, (ISBN - 978-1-84919-219-4),2011.

2. Francisco Díaz-González, Andreas Sumper, Oriol Gomis-Bellmunt," Energy Storage in Power Systems" Wiley Publication, ISBN: 978-1-118-97130-7, Mar 2016.

Reference Books

1. Electric Power Research Institute (USA), "Electricity Energy Storage Technology Options: A White Paper Primer on Applications, Costs, and Benefits" (1020676), December 2010.

2. Paul Denholm, Erik Ela, Brendan Kirby and Michael Milligan, "The Role of Energy Storage with Renewable Electricity Generation", National Renewable Energy Laboratory (NREL) -a National Laboratory of the U.S. Department of Energy.

3. P. Nezamabadi and G. B. Gharehpetian, "Electrical energy management of virtual power plants in distribution networks with renewable energy resources and energy storage systems", IEEE *Power Distribution Conference*, 2011.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Introduction to energy storage for power systems: (6)**	
1.1	General considerations- different parts of energy storage unit- static duty of storage plant- dynamic duty of storage plant	2
1.2	Energy and power balance in a storage unit- schematic structure of energy storage	1
1.3	Mathematical model of storage system	1
1.4	Econometric model of storage- capital cost of energy storage- annual cost of storage facility	2
2	**Overview on Energy storage technologies: (7)**	
2.1	Principle of thermal energy storage- sensible heat storage – latent heat storage- containment- thermal energy storage in power plant application	2
2.2	Principle and operation of pumped hydroelectric storage (PHS)- general considerations- schematic diagram	1
2.3	Principle and operation of Compressed Air Energy Storage (CAES)- general considerations- basic principle-industrial application	1
2.4	Principle and operation of Flywheel Energy storage System (FESS)-general considerations -applications	1
2.5	General considerations- synthetic storage media-Hydrogen production-Hydrogen based power utility concept- storage containment for hydrogen-Methods of extraction of methane-	2

	Block diagram Power to gas concept	
3	**Overview on Energy storage technologies (8)**	
3.1	Basic concepts of conventional batteries and flow batteries- Battery parameters- C-rating-SoC- DoD- Specific Energy-Specific power (numerical examples), Fuel cell- Schematic diagram of an electrochemical fuel cell	2
23.2	Super conducting Magnetic Energy Storage (SMES)- basic circuit-principle-advantages	2
3.3	The Supercapacitor Energy Storage System- topology-principle-advantages	2
3.4	Comparative study of different energy storage system based on specific energy, specific power, cycling capability and life in years	2
4	**Energy storage and renewable power sources (6)**	
4.1	Types of renewable power sources- brief description	2
4.2	Storage role in isolated power system with renewable power sources	1
4.3	Storage role in an integrated power system with grid-connected renewable power sources	1
4.4	Small scale hydroelectric energy	1
4.5	Solar thermal technologies and photovoltaics	1
5	**Energy storage Applications (7)**	
5.1	Smart grid-concepts- characteristics- Smart metering	2
5.2	Field of Electromobility- thyristor based battery charger and DC power supply	1
5.3	Vehicle to grid and grid to vehicle charging point topology	1
5.4	Distributed energy storage	1
5.5	Battery SCADA- overview	1
5.6	Hybrid energy storage systems: configurations and applications	1

EET404	COMPREHENSIVE COURSE VIVA	CATEGORY	L	T	P	CREDIT
		PCC	1	0	0	1

Preamble: The objective of this Course viva is to ensure the basic knowledge of each student in the most fundamental core courses in the curriculum. The viva voce shall be conducted based on the core subjects studied from third to eighth semester. This course helps the learner to become competent in placement tests and other competitive examinations.

Guidelines

1. The course should be mapped with a faculty and classes shall be arranged for practicing questions based on the core courses listed in the curriculum.
2. The viva voce will be conducted by the same three member committee assigned for final project phase II evaluation. It comprises of Project coordinator, expert from Industry/research Institute and a senior faculty from a sister department.
3. The pass minimum for this course is 25.
4. The mark will be treated as internal and should be uploaded along with internal marks of other courses.
5. Comprehensive Viva should be conducted along with final project evaluation by the three member committee.

Mark Distribution

Total marks: 50, only CIE, minimum required to pass : 25 Marks

EED416	PROJECT PHASE II	CATEGORY	L	T	P	CREDIT
		PWS	0	0	12	4

Preamble: The course 'Project Work' is mainly intended to evoke the innovation and invention skills in a student. The course will provide an opportunity to synthesize and apply the knowledge and analytical skills learned, to be developed as a prototype or simulation. The project extends to 2 semesters and will be evaluated in the 7th and 8th semester separately, based on the achieved objectives. One third of the project credits shall be completed in 7th semester and two third in 8th semester. It is recommended that the projects may be finalized in the thrust areas of the respective engineering stream or as interdisciplinary projects. Importance should be given to address societal problems and developing indigenous technologies.

Course Objectives

- To apply engineering knowledge in practical problem solving.
- To foster innovation in design of products, processes or systems.
- To develop creative thinking in finding viable solutions to engineering problems.

Course Outcomes [COs]: After successful completion of the course, the students will be able to:

CO1	Model and solve real world problems by applying knowledge across domains (Cognitive knowledge level: **Apply**).
CO2	Develop products, processes or technologies for sustainable and socially relevant applications (Cognitive knowledge level: **Apply**).
CO3	Function effectively as an individual and as a leader in diverse teams and to comprehend and execute designated tasks (Cognitive knowledge level: **Apply**).
CO4	Plan and execute tasks utilizing available resources within timelines, following ethical and professional norms (Cognitive knowledge level: **Apply**).
CO5	Identify technology/research gaps and propose innovative/creative solutions (Cognitive knowledge level: **Analyze**).
CO6	Organize and communicate technical and scientific findings effectively in written and oral forms (Cognitive knowledge level: **Apply**).

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	2	1	2	2	2	1	1	1	1	2
CO2	2	2	2		1	3	3	1	1		1	1
CO3									3	2	2	1
CO4					2			3	2	2	3	2
CO5	2	3	3	1	2							1
CO6					2			2	2	3	1	1

Abstract POs defined by National Board of Accreditation			
PO #	**Broad PO**	**PO#**	**Broad PO**
PO1	Engineering Knowledge	PO7	Environment and Sustainability
PO2	Problem Analysis	PO8	Ethics
PO3	Design/Development of solutions	PO9	Individual and team work
PO4	Conduct investigations of complex problems	PO0	Communication
PO5	Modern tool usage	PO11	Project Management and Finance
PO6	The Engineer and Society	PO12	Lifelong learning

PROJECT PHASE II

Phase 2 Targets

- In depth study of the topic assigned in the light of the report prepared under Phase - I;
- Review and finalization of the approach to the problem relating to the assigned topic.
- Preparing a detailed action plan for conducting the investigation, including teamwork.
- Detailed Analysis/ Modeling / Simulation/ Design/ Problem Solving/Experiment as needed.
- Final development of product/ process, testing, results, conclusions and future directions.
- Preparing a paper for Conference Presentation/ Publication in Journals, if possible.
- Presenting projects in Project Expos conducted by the University at the cluster level and/ or state level as well as others conducted in India and abroad.
- Filing Intellectual Property Rights (IPR) if applicable.
- Preparing a report in the standard format for being evaluated by the Department Assessment Board.
- Final project presentation and viva voce by the assessment board including the external expert.

Evaluation Guidelines & Rubrics

Total: 150 marks (Minimum required to pass: 75 marks).

- Project progress evaluation by guide: 30 Marks.
- Two interim evaluations by the Evaluation Committee: 50 Marks (25 marks for each evaluation).
- Final evaluation by the Final Evaluation committee: 40 Marks
- Quality of the report evaluated by the evaluation committee: 30 Marks

(The evaluation committee comprises HoD or a senior faculty member, Project coordinator and project supervisor. The final evaluation committee comprises of Project coordinator, expert from Industry/research/academic Institute and a senior faculty from a sister department).

Evaluation by the Guide

The guide/supervisor must monitor the progress being carried out by the project groups on regular basis. In case it is found that progress is unsatisfactory it should be reported to the Department Evaluation Committee for necessary action. The presence of each student in the group and their involvement in all stages of execution of the project shall be ensured by the guide. Project evaluation by the guide: 30 Marks. This mark shall be awarded to the students in his/her group by considering the following aspects:

Project Scheduling & Distribution of Work among Team members: Detailed and extensive Scheduling with timelines provided for each phase of project. Work breakdown structure well defined. (5)

Literature survey: Outstanding investigation in all aspects. (4)

Student's Diary/ Daily Log: The main purpose of writing daily diary is to cultivate the habit of documenting and to encourage the students to search for details. It develops the students' thought process and reasoning abilities. The students should record in the daily/weekly activity diary the day to day account of the observations, impressions, information gathered and suggestions given, if any. It should contain the sketches & drawings related to the observations made by the students. The daily/weekly activity diary shall be signed after every day/week by the guide. (7)

Individual Contribution: The contribution of each student at various stages. (9)

Completion of the project: The students should demonstrate the project to their respective guide. The guide shall verify the results and see that the objectives are met. (5)

EVALUATION RUBRICS for PROJECT Phase II: Interim Evaluation - 1						
No.	**Parameters**	**Marks**	**Poor**	**Fair**	**Very Good**	**Outstanding**
2-a	Novelty of idea, and Implementation scope [CO5] [Group Evaluation]	**5**	The project is not addressing any useful requirement. The idea is evolved into a non-implementable one. The work presented so far is lacking any amount of original work by the team.	Some of the aspects of the proposed idea can be implemented. There is still lack of originality in the work done so far by the team. The project is a regularly done theme/topic without any freshness in terms of specifications, features, and/or improvements.	Good evidence of an implementable project. There is some evidence for the originality of the work done by the team . There is fresh specifications/ features/improvements suggested by the team. The team is doing a design from fundamental principles, and there is some independent learning and engineering ingenuity.	The project has evolved into incorporating an outstandingly novel idea. Original work which is not yet reported anywhere else. Evidence for ingenious way of innovation which is also Implementable. Could be a patentable / publishable work.
			(0 – 1 Marks)	(2 – 3 Marks)	(4 Marks)	(5 Marks)
2-b	Effectiveness of task distribution among team members. [CO3] [Group Evaluation]	**5**	No task distribution of any kind. Members are still having no clue on what to do.	Task allocation done, but not effectively, some members do not have any idea of the tasks assigned. Some of the tasks were identified but not followed individually well.	Good evidence of task allocation being done, supported by project journal entries, identification of tasks through discussion etc. However, the task distribution seems to be skewed, and depends a few members heavily than others. Mostly the tasks are being followed by the individual members.	Excellent display of task identification and distribution backed by documentary evidence of team brainstorming, and project journal entries. All members are allocated tasks according to their capabilities, and as much as possible in an equal manner. The individual members are following the tasks in an excellent manner.
			(0 – 1 Marks)	(2 – 3 Marks)	(4 Marks)	(5 Marks)
2-c	Adherence to project schedule. [CO4] [Group Evaluation]	**5**	Little or no evidence of continued planning or scheduling of the project. The students did not stick to the plan what they were going to build nor plan on what materials / resources to use in the project. The students do not have any idea on the budget required even after the end of phase - I. No project journal kept or the journal.	There is some improvement in the primary plan prepared during phase I. There were some ideas on the materials /resources required, but not really thought out. The students have some idea on the finances required, but they have not formalized a budget plan. Schedules were not prepared. The project journal has no useful details on the project.	Good evidence of planning done and being followed up to a good extent after phase I. Materials were listed and thought out, but the plan wasn't followed completely. Schedules were prepared, but not detailed, and needs improvement. Project journal is presented but it is neither complete nor updated regularly.	Excellent evidence of enterprising and extensive project planning and follow-up since phase I. Continued use of project management/version control tool to track the project. Material procurement if applicable is progressing well. Tasks are updated and incorporated in the schedule. A well-kept project journal showed evidence for all the above, in addition to the interaction with the project guide.
			(0 - 1 Marks)	(2 - 3 Marks)	(4 Marks)	(5 Marks)

2-d	Interim Results. [CO6] [Group assessment]	**5**	There are no interim results to show.	The team showed some interim results, but they are not complete / consistent to the current stage, Some corrections are needed.	The interim results showed were good and mostly consistent/correct with respect to the current stage. There is room for improvement.	There were significant interim results presented which clearly shows the progress.
			(0 - 1 Marks)	(2 - 3 Marks)	(4 Marks)	(5 Marks)
2-e	Presentation [Individual assessment]	**5**	Very poor presentation and there is no interim results. The student has no idea about the project proposal.	Presentation is average, and the student has only a feeble idea about the team work.	Good presentation. Student has good idea about the team's project. The overall presentation quality is good.	Exceptionally good presentation. Student has excellent grasp of the project. The quality of presentation is outstanding.
			(0 - 1 Marks)	(2 - 3 Marks)	(4 Marks)	(5 Marks)
Phase-II Interim Evaluation - 1 Total Marks: 25						

EVALUATION RUBRICS for PROJECT Phase II: Interim Evaluation – 2

No	Parameters	Marks	Poor	Fair	Very Good	Outstanding
2-f	Application of engineering knowledge [CO1] [Individual Assessment]	**10**	The student does not show any evidence of applying engineering knowledge on the design and the methodology adopted. The student's contribution in application of engineering knowledge in the project is poor.	The student appears to apply some basic knowledge, but not able to show the design procedure and the methodologies adopted in a comprehensive manner.	The student is able to show some evidence of application of engineering knowledge in the design and development of the project to good extent.	Excellent knowledge in design procedure and its adaptation. The student is able to apply knowledge from engineering domains to the problem and develop solutions.
			(0 – 3 Marks)	(4 – 6 Marks)	(7 - 9 Marks)	(10 Marks)
2-g	Involvement of individual members [CO3] [Individual Assessment]	**5**	No evidence of any Individual participation in the project work.	There is evidence for some amount of individual contribution, but is limited to some of the superficial tasks.	The individual contribution is evident. The student has good amount of involvement in core activities of the project.	Evidence available for the student acting as the core technical lead and has excellent contribution to the project.
			(0 - 1 Marks)	(2 - 3 Marks)	(4 Marks)	(5 Marks)
2-h	Results and inferences upon execution [CO5] [Group Assessment]	**5**	None of the expected outcomes are achieved yet. The team is unable to derive any inferences on the failures/ issues observed. Any kind o f observations or studies are not made.	Only a few of the expected outcomes are achieved. A few inferences are made on the observed failures/issues. No further work suggested.	Many of the expected outcomes are achieved. Many observations and inferences are made, and attempts to identify the issues are done. Some suggestions are made for further work.	Most of the stated outcomes are met. Extensive studies are done and inferences drawn. Most of the failures are addressed and solutions suggested. Clear and valid suggestions made for further work.
			(0 - 1 Marks)	(2 - 3 Marks)	(4 Marks)	(5 Marks)
2-i	Documentation and presentation. ·[CO6] [Individual assessment]	**5**	The individual student has no idea on the presentation of his/her part. The presentation is of poor quality.	Presentation's overall quality needs to be improved.	The individual's presentation performance is satisfactory.	The individual's presentation is done professionally and with great clarity. The individual's performance is excellent.
			(0 - 1 Marks)	(2 - 3 Marks)	(4 Marks)	(5 Marks)
Phase-II Interim Evaluation - 2 Total Marks: 25						

EVALUATION RUBRICS for PROJECT Phase II: Final Evaluation						
No	**Parameters**	**Marks**	**Poor**	**Fair**	**Very Good**	**Outstanding**
2-j	Engineering knowledge. [CO1] [Group Assessment]	10	The team does not show any evidence of applying engineering knowledge on the design and the methodology adopted.	The team is able to show some of the design procedure and the methodologies adopted, but not in a comprehensive manner.	The team is able to show evidence of application of engineering knowledge in the design and development of the project to good extent. There is scope for improvement.	Excellent knowledge in design procedure and its adaptation. The team is able to apply knowledge from engineering domains to the problem and develop an excellent solution.
			(0 – 3 Marks)	(4 – 6 Marks)	(7 - 9 Marks)	(10 Marks)
2-k	Relevance of the project with respect to societal and/or industrial needs. [Group Assessment] [CO2]	5	The project as a whole do not have any societal / industrial relevance at all.	The project has some relevance with respect to social and/or industrial application. The team has however made not much effort to explore further and make it better.	The project is relevant to the society and/or industry. The team is mostly successful in translating the problem into an engineering specification and managed to solve much of it.	The project is exceptionally relevant to society and/or industry. The team has made outstanding contribution while solving the problem in a professional and/ or ethical manner.
			(0 - 1 Marks)	(2 - 3 Marks)	(4 Marks)	(5 Marks)
2-i	Innovation / novelty / Creativity [CO5] [Group Assessment]	5	The project is not addressing any useful requirement. The idea is evolved into a non-implementable one. The work presented so far is lacking any amount of original work by the team.	Some of the aspects of the proposed idea appears to be practical. There is still lack of originality in the work done. The project is a regularly done theme/topic without any freshness in terms of specifications, features, and/ or improvements.	Good evidence of an implementable project. There is some evidence for the originality of the work done by the team. There is fresh specifications/ features/improvements suggested by the team. The team is doing a design from fundamental principles, and there is some independent learning and engineering ingenuity. Could be translated into a product / process if more work is done.	The project has evolved into incorporating an outstandingly novel idea. Original work which is not yet reported anywhere else. Evidence for ingenious way of innovation which is also Implementable. Could be a patentable publishable work.
			(0 - 1 Marks)	(2 - 3 Marks)	(4 Marks)	(5 Marks)
2-m	Quality of results / conclusions / solutions. [CO1] [Group Assessment]	10	None of the expected outcomes are achieved. The team is unable to derive any inferences on the failures/issues observed. Any kind of observations or studies is not made.	Only a few of the expected outcomes are achieved. A few inferences are made on the observed failures/issues. No further work suggested.	Many of the expected outcomes are achieved. Many observations and inferences are made, and attempts to identify the issues are done. Some suggestions are made for further work.	Most of the stated outcomes are met. Extensive studies are done and inferences drawn. Most of the failures are addressed and solutions suggested. Clear and valid suggestions made for further work.
			(0 – 3 Marks)	(4 – 6 Marks)	(7 - 9 Marks)	(10 Marks)

2-n	Presentation - Part I Preparation of slides. [CO6] [Group Assessment].	5	The presentation slides are shallow and in a clumsy format. It does not follow proper organization.	Presentation slides follow professional style formats to some extent. However, its organization is not very good. Language needs to be improved. All references are not cited properly, or acknowledged. Presentation slides needs to be more professional.	Presentation slides follow a good style format and there are only a few issues. Organization of the slides is good. Most of references are cited properly. The flow is good and team presentation is neatly organized. Some of the results are not clearly shown. There is room for improvement.	The presentation slides are exceptionally good. Neatly organized. All references cited properly. Diagrams/Figures, Tables and equations are properly numbered, and l i s ted. Results/ inferences clearly highlighted and readable.
			(0 - 1 Marks)	(2 - 3 Marks)	(4 Marks)	(5 Marks)
	Presentation - Part II: Individual Communication [CO6] [Individual Assessment].	5	The student is not communicating properly. Poor response to questions.	The student is able to explain some of the content. The student requires a lot of prompts to get to the idea. There are language issues.	Good presentation/ communication by the student. The student is able to explain most of the content very well. There are however, a few areas where the student shows lack of preparation. Language is better.	Clear and concise communication exhibited by the student. The presentation is outstanding. Very confident and tackles all the questions without hesitation. Exceptional traits of communicator.
			(0 - 1 Marks)	(2 - 3 Marks)	(4 Marks)	(5 Marks)
Phase-II Final Evaluation, Marks: 40						

EVALUATION RUBRICS for PROJECT Phase II: Report Evaluation						
Sl. No.	**Parameters**	**Marks**	**Poor**	**Fair**	**Very Good**	**Outstanding**
2-o	Report [CO6]	30	The prepared report is shallow and not as per standard format. It does not follow proper organization. Contains mostly unacknowledged content. Lack of effort in preparation is evident. References are not cited. Unprofessional and inconsistent formatting.	Project report follows the standard format to some extent. However, its organization is not very good. Language needs to be improved. All references are not cited properly in the report. There is lack of formatting consistency.	Project report shows evidence of systematic documentation. Report is mostly following the standard style format and there are only a few issues. Organization of the report is good. Mostly consistently formatted. Most of references/sources are cited/ acknowledged properly.	The report is exceptionally good. Neatly organized. All references cited properly. Diagrams/Figures, Tables and equations are properly numbered, and listed and clearly shown. Language is excellent and follows professional styles. Consistent formatting and exceptional readability.
			(0 - 11 Marks)	(12 - 18 Marks)	(19 - 28 Marks)	(29 - 30 Marks)
Phase - II Project Report Marks: 30						