SEMESTER VI

SLOT	COURSENO	COURSES	L-T-P	HOURS	CREDIT
A	EET302	LINEARCONTROLSYSTEMS	2-2-0	4	4
B	EET304	POWERSYSTEMSII	3-1-0	4	4
C	EET306	POWERELECTRONICS	3-1-0	4	4
D	EET312	BIOMEDICALINSTRUMENTATION	2-1-0	3	3
E	HUT310	MANAGEMENTFORENGINEERS	3-0-0	3	3
F	EET308	COMREHENSIVECOURSEWORK	1-0-0	1	1
S	EEL332	POWERSYSTEMSLAB	0-0-3	3	2
T	EEL334	POWERELECTRONICSLAB	0-0-3	3	2
R/H	EET394	GENERALISED MACHINETHEORY(HONOR)	3-1-0	4*	4
		TOTAL		**28/32**	**23/27**

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET302	**LINEAR CONTROL SYSTEMS**	**PCC**	**2**	**2**	**0**	**4**

Preamble: This course aims to provide a strong foundation on classical control theory. Modelling, time domain analysis, frequency domain analysis and stability analysis of linear systems based on transfer function approach will be discussed. The compensator design of linear systems is also introduced.

Prerequisite : Basics of Circuits and Networks, Signals and Systems

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

CO 1	Describe the role of various control blocks and components in feedback systems.
CO 2	Analyse the time domain responses of the linear systems.
CO 3	Apply Root locus technique to assess the performance of linear systems.
CO 4	Analyse the stability of the given LTI systems.
CO 5	Analyse the frequency domain response of the given LTI systems.
CO 6	Design compensators using time domain and frequency domain techniques.

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	3	-	-	-	-	-	-	-	-	-	1
CO 2	3	3	3	-	-	-	-	-	-	-	-	2
CO 3	3	3	3	-	2	-	-	-	-	-	-	2
CO 4	3	3	3	-	-	-	-	-	-	-	-	3
CO 5	3	3	3	-	2	-	-	-	-	-	-	3
CO 6	3	3	3	2	-	-	-	-	-	-	-	3

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)	10	10	20
Apply (K3)	30	30	60
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 any one. Each question carries 14 marks and can have maximum 2 sub-divisions.

Course Level Assessment Questions:

Course Outcome 1 (CO1)

1. Derive and explain the transfer function of AC servo motor.
2. With the help of suitable sketches explain the need for a lead compensator.
3. Explain how does the feedback element affect the performance of the closed loop system.

Course Outcome 2 (CO2):

1. Obtain the different time domain specifications for a given second order system with impulse input.
2. Determine the value of the natural frequency of oscillation ω_n for the unity feedback system with forward transfer function $G_p(s) = \frac{K}{s(s+10)}$, which results in a critically damped response. Also analyse the effect of K on damping factor.
3. Problems related to static error constant and steady state error for a given input.

Course Outcome 3(CO3):

1. Determine the value of K such that the closed loop system with $G(s)H(s) = \frac{K}{s\,(s+1)\,(s+4)}$ is oscillatory, using Root locus.
2. Construct the Root locus for the closed loop system with $G(s)H(s) = \frac{K}{s\,(s^2 + 2s + 2)}$? Determine the value of K to achieve a damping factor of 0.5?
3. Problems on root locus for systems with positive feedback.

Course Outcome 4 (CO4):

1. Problems related to application of Routh's stability criterion for analysing the stability of a given system.
2. Problems related to assess the stability of the given system using Bode plot.
3. Problem related to the analysis of given system using Nyquist stability criterion.

Course Outcome 5 (CO5):

1. Determine the value of K such that the gain margin for the system with $G(s)H(s) = \frac{K}{s\,(s+1)\,(s+5)}$ equals to 2.

2. Determine the phase margin to assess the stability of the system with $G(s)H(s) = \frac{2}{s\ (s+1)\ (s+4)}$
3. Derive and explain the dependence of resonant peak on damping factor.

Course Outcome 6 (CO6):

1. Problems related to the design of lead compensator using Bode plot.
2. Problems related to the design of lag compensator using Root locus technique.
3. Design the parameters of an electrical lag circuit with f_1= 200 Hz and f_2= 1kHz

Model Question Paper

PAGES: 2

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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SIXTH SEMESTER B.TECH DEGREE EXAMINATION

MONTH & YEAR

Course Code**: EET302**

Course Name: **LINEAR CONTROL SYSTEMS**

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

PART A

Answer all Questions. Each question carries 3 Marks

1 Give a comparison between open loop and closed loop control systems with suitable examples.

2 Derive the dependence of φ_m and α of a lead compensator and hence explain the restrictions on the selection of α?

3 For a closed loop system with $G(s) = \frac{1}{s\ (s+5)}$; and H(s) = 0.05, calculate the steady state error constants.

4 Check the stability of the system given by the characteristic equation, $G(s) = s^5 + 2s^4 + 4s^3 + 8s^2 + 16s + 32$; using Routh criterion.

5 With suitable sketches explain how the addition of poles to the open-loop transfer function affect the root locus plots.

6 Explain Ziegler – Nichol’s PID tuning rules.

7 Explain the features of non-minimum phase systems with a suitable example.

8 How do you determine the gain margin of a system, with the help of Bode plot?

9 State and explain Nyquist stability criterion.

10 Discuss the procedure for Lag compensator design using Root locus technique.

PART B

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

Module 1

11 a) Derive the transfer function of an Armature controlled dc servo motor. Assess the effect of time constants on the system performance. **(9)**

b) Compare the effect of H(s) on the pole-zero plot of the closed loop system with $G(s) = \frac{s+3}{(s^2+3s+2)}$ with: i) derivative feed back H(s)= s; ii) integral feedback H(s)=1/s. **(5)**

12 a) Why compensation is necessary in feedback control system? What are the factors to be considered for choosing the feedback compensation? **(6)**

b) With relevant characteristics explain the operation of the following control devices. i) Synchro error detector, ii) Tachogenerator. **(8)**

Module 2

13 a) Derive an expression for the step response of a critically damped second order system? Explain the dependency of Mp on damping factor. **(9)**

b) Determine the value of K and the natural frequency of oscillation ω_n for the unity feedback system with forward transfer function $G(s) = \frac{K}{s(s+10)}$, which results in a critically damped response when subjected to a unit step input.

Also determine the steady state error for unit velocity input. **(5)**

14 a) A unity feedback system is characterized by an open loop transfer function $G(s) = \frac{20}{(s^2+5s+5)}$. Determine the transient response when subjected to a unit step input and sketch the response. Evaluate the maximum overshoot and the corresponding peak time of the system. . **(9)**

b) Using Routh criterion determine the value of K for which the unity feedback closed loop system with $G(s) = \frac{K}{s(s^2+20s+8)}$ is stable. . **(5)**

Module 3

15 a) Design a lag lead compensator with open loop transfer function $G(s) = \frac{K}{s(s+0.5)}$ to satisfy the following specifications (i) damping ratio of the dominant closed loop poles is 0.5 (ii) Undamped natural frequency of the dominant closed loop poles ω_n = 5 rad/sec iii) Velocity error constant K_v = 80. **(10)**

b) Compare between PI and PD controllers. **(4)**

16 a) Sketch root locus for a system with $G(s)H(s) = \frac{K(s+1)}{s(s+4)}$. Hence determine the range of K for the system stability. . **(9)**

b) With help of suitable sketches, explain how does Angle and Magnitude criteria of Root locus method help in control system design. **(5)**

Module 4

17 a) The open-loop transfer function of a unity feedback system is $G(s)=\frac{K}{s(0.5s+1)(0.04s+1)}$.Use asymptotic approach to plot the Bode diagram and determine the value of K for a gain margin of 10 dB. **(8)**

b) Compare between the polar plots for $G(s)H(s)=\frac{K}{(s+4)}$ and $G(s)H(s)=\frac{K(s-4)}{(s+4)}$. **(6)**

18 a) Draw the polar plot of an open loop transfer function $G(s)=\frac{6}{(s+1)(s+2)}$ and comment on the phase margin and gain margin. **(8)**

b) Explain the detrimental effects of transportation lag, using Bode plot. **(6)**

Module 5

19 a) Draw Nyquist plot for the system whose open loop transfer function is $G(s)H(s)=\frac{K}{s(s+2)(s+10)}$. Determine the range of K for which the closed loop system is stable. **(9)**

b) Write a short note on Nichols chart. . **(5)**

20 a) Design a phase lead compensator for a unity feedback system given by the open loop transfer function $G(s)=\frac{K}{s(S+1)}$ to meet the following specifications (i) phase margin of the system > 45 deg (ii) ess for unit ramp <1/15 (iii) gain crossover frequency must be 7.5 rad/sec. **(11)**

b) Explain the design constrains on the selection of corner frequencies of lag compensator. **(3)**

Syllabus

Module 1

Feedback Control Systems (9 hours)

Open loop and closed loop control systems- Examples of automatic control systems - Transfer function approach to feed back control systems – Effect of feedback

Control system components – Control applications of DC and AC servo motors, Tacho generator, Synchro, Gyroscope and Stepper motor

Controllers- Types of controllers & Compensators - Transfer function and basic characteristics of lag, lead and lag-lead phase compensators.

Module 2

Performance Analysis of Control Systems (9 hours)

Time domain analysis of control systems: Time domain specifications of transient and steady state responses- Impulse and Step responses of first and second order systems- Pole dominance for higher order systems.

Error analysis: Steady state error analysis and error constants -Dynamic error coefficients.

Stability Analysis: Concept of BIBO stability and Asymptotic stability- Time response for various pole locations- stability of feedback systems - Routh's stability criterion- Relative stability

Module 3

Root Locus Analysis and Compensator Design (11 hours)

Root locus technique: Construction of Root locus- stability analysis- effect of addition of poles and zeroes- Effect of positive feedback systems on Root locus

Design of Compensators: Design of lag, lead and lag-lead compensators using Root locus technique.

PID controllers: PID tuning using Ziegler-Nichols methods.

Simulation based analysis: Introduction to simulation tools like MATLAB/ SCILAB or equivalent for Root locus based analysis (Demo/Assignment only)

Module 4

Frequency domain analysis (9 hours)

Frequency domain specifications- correlation between time domain and frequency domain responses

Polar plot: Concepts of gain margin and phase margin- stability analysis

Bode Plot: Construction- Concepts of gain margin and phase margin- stability analysis, Effect of Transportation lag and Non-minimum phase systems.

Module 5

Nyquist stability criterion and Compensator Design using Bode Plot (9 hours)

Nyquist criterion: Nyquist plot- Stability criterion- Analysis

Introduction to Log magnitude vs. phase plot and Nichols chart (concepts only) - Compensator design using Bode plot: Design of lag, lead and lag-lead compensator using Bode plot.

Simulation based analysis: Introduction to simulation tools like MATLAB/ SCILAB or equivalent for various frequency domain plots and analysis (Demo/Assignment only).

Textbooks

1. Nagarath I. J. and Gopal M., Control System Engineering, 5/e, New Age Publishers
2. Ogata K, Modern Control Engineering, 5/e, Prentice Hall of India.
3. Nise N. S, Control Systems Engineering, 6/e, Wiley Eastern
4. Dorf R. C. and Bishop R. H, Modern Control Systems, 12/e, Pearson Education

Reference Books

1. Kuo B. C, Automatic Control Systems, 7/e, Prentice Hall of India
2. Desai M. D., Control System Components, Prentice Hall of India, 2008
3. Gopal M., Control Systems Principles and Design, 4/e, Tata McGraw Hill.
4. Imthias Ahamed T. P, Control Systems, Phasor Books, 2016

Course Contents and Lecture Schedule:

Module	**Topic coverage**	**No. of Lectures**
1	**Feedback Control Systems (9 hours)**	
1.1	Terminology and basic structure of Open loop and Closed loop control systems- Examples of Automatic control systems (block diagram representations only)	2
1.2	Transfer function approach to feed back control systems- Effect of feedback- Characteristic equation- poles and zeroes- type and order.	2
1.3	Control system components: Transfer functions of DC and AC servo motors –Control applications of Tacho generator, Synchro, Gyroscope and Stepper motor	3
1.4	Need for controllers: Types of controllers – Feedback, Cascade and Feed forward controllers Compensators: Transfer function and basics characteristics of lag, lead, and lag-lead phase compensators	2
2	**Performance Analysis of Control Systems (9 hours)**	
2.1	Time domain analysis of control systems: Time domain specifications of transient and steady state responses-Impulse and Step responses of First order systems- Impulse and Step responses of Second order systems- Pole dominance for higher order systems	3

2.2	Error analysis: Steady state error analysis - static error coefficient of Type 0, 1, 2 systems. Dynamic error coefficients	2
2.3	Stability Analysis: Concept of stability-BIBO stability and Asymptotic stability- Time response for various pole locations- stability of feedback systems	2
2.4	Application of Routh's stability criterion to control system analysis- Relative stability	2
3	**Root Locus Analysis and Compensator Design (11 hours)**	
3.1	Root locus technique: General rules for constructing Root loci – stability from root loci -	3
3.2	Effect of addition of poles and zeros on Root locus	1
3.3	Effect of positive feedback systems on Root locus	1
3.4	Design using Root locus: Design of lead compensator using root locus.	2
3.5	Design of lag compensator using root locus.	1
3.6	Design of lag-lead compensator using root locus	1
3.7	PID Controllers: Need for P, PI and PID controllers	1
3.8	Design of P, PI and PID controller using Ziegler-Nichols tuning method.	1
3.9	Simulation based analysis: Introduction to simulation tools like MATLAB/ SCILAB or equivalent simulation software and tool boxes for Root locus based analysis (Demo/Assignment only)	
4	**Frequency domain analysis (9 hours)**	
4.1	Frequency domain specifications- correlation between time domain and frequency domain responses	2
4.2	Polar plot: Concepts of gain margin and phase margin- stability analysis	2
4.3	Bode Plot: Construction of Bode plots- gain margin and phase margin- Stability analysis based on Bode plot	4
4.4	Effect of Transportation lag and Non-minimum phase systems	1
5	**Nyquist stability criterion and Compensator Design using Bode Plot (9 hours)**	
5.1	Nyquist stability criterion: Nyquist plot- Stability criterion- Analysis	3
5.2	Introduction to Log magnitude vs. phase plot and Nichols chart	1
5.3	Design using Bode plot: Design of lead compensator using Bode plot.	2
5.4	Design of Lag compensator using Bode plot.	2
5.5	Design of Lag- lead compensator using Bode plot	1
5.6	Simulation based analysis: Introduction to simulation tools like MATLAB/ SCILAB or equivalent simulation software and tool boxes for various frequency domain plots and analysis (Demo/Assignment only).	

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET304	POWER SYSTEMS II	PCC	3	1	0	4

Preamble: The basic objective of this course is to deliver fundamental concepts in power system analysis. The steady state and transient analysis of electrical power system is comprehensively covered in this course ranging extensively using the conventional methods as well as advanced mathematics.

Prerequisite: EET 301 Power Systems I

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

CO 1	Apply the per unit scheme for any power system network and compute the fault levels.
CO 2	Analyse the voltage profile of any given power system network using iterative methods.
CO 3	Analysethe steady state and transient stability of power system networks.
CO 4	Model the control scheme of power systems.
CO 5	Schedule optimal generation scheme.

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	3										2
CO 2	3	3	2									2
CO 3	3	3	2									1
CO 4	3	2										
CO 5	3	3	1								3	1

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)	30	30	60
Analyse (K4)	-	-	-
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. Why do we adopt per unit scheme of representation? (K2)
2. Which is the most frequent fault and which is the most severe fault? Substantiate with equation. (K2, K3)

Course Outcome 2 (CO2):

1. How is consistency followed in load flow studies? (K4)
2. How does acceleration factor improve convergence in Gauss Siedel Load flow? (K4)

Course Outcome 3 (CO3):

1. Differentiate between steady state and transient stability? (K1, K2)
2. Derive a swing equation. (K3)

Course Outcome 4 (CO4):

1. What is the significance of Inertia constant? (K3)
2. Draw the schematic representation of AGC. Show the frequency deviation pattern. (K1, K2, K3)

Course Outcome 5 (CO5):

1. What are penalty factors? Explain the significance. (K2, K3)
2. Why do we need Unit commitment? Explain with an example. (K3)

Model Question paper

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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SIXTH SEMESTER B.TECH DEGREE EXAMINATION,
MONTH & YEAR
Course Code: EET 304

Course Name: POWER SYSTEMS II

Max. Marks: 100 Duration: 3 Hours

PART A (3 x 10 = 30 Marks)

Answer all Questions. Each question carries 3 Marks

1. The generator neutral grounding impedance appears as 3Zn in the zero-sequence net work. Why?
2. A single-phase transformer is rated at 110/440 V, 3 KVA. Its leakage reactance measured on 110 V side is 0.05 ohm. Determine the leakage impedance referred to 440 V side.
3. What is the need of slack bus in load flow analysis?
4. A power system consists of 300 buses out of which 20 buses are generator buses and 25 buses are provided with reactive power support. All other buses are load buses. Determine the size of the Newton Raphson load flow Jacobian matrix.
5. Explain critical clearing angle and its significance with respect to the stability of a power system.
6. Explain Equal Area criterion and state the assumptions made.
7. Draw the basic block diagram of Automatic Voltage Regulator.
8. Discuss the application of SCADA in power system monitoring
9. Explain unit commitment? List out the constraints on unit commitment.
10. Write the conditions for the optimal power dispatch in a lossless system.

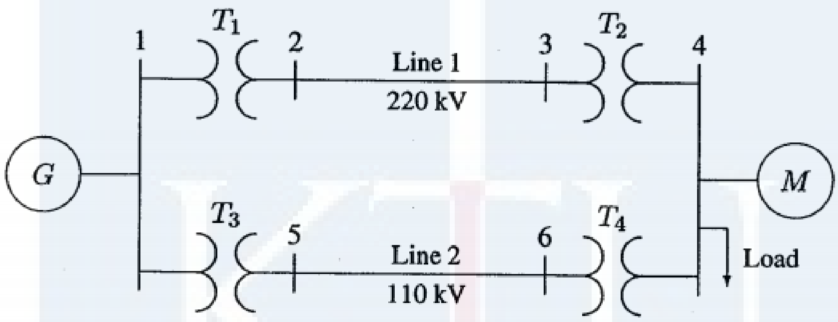
PART B (14 x 5 = 70 Marks)
Answer any one full question from each module. Each question carries 14 Marks

Module I

1. a)The one-line diagram of a three phase power system is shown in figure below. Select the common base of 100 MVA and 22 kV on the generator side. Draw an impedance diagram with all impedances including the load impedance marked in per unit. The

manufacturer's data for each device is given as follows. The three phase load at bus 4 absorbs 57 MVA, .6 power factor lagging at 10.45 kV. Line1 and Line 2 have reactances of 48.4Ω and 65.43Ω, respectively.

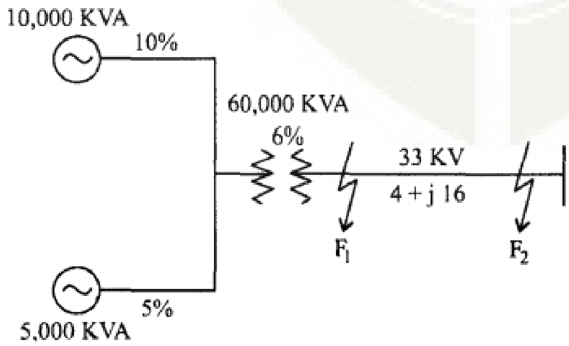
G	90 MVA	22 kV	X=18%
T_1	50 MVA	22/220 kV	X=10%
T_2	40 MVA	220/11 kV	X=6%
T_3	40 MVA	22/110 kV	X=6.4%
T_4	40 MVA	110/11 kV	X=8%
M	66.5 MVA	10.45 kV	X=18.5%



(10)

b) What are the advantages of pu system? Obtain the expression for converting the per unit impedance expressed on one base to another. **(4)**

2. a) A 33 KV line has a resistance of 4 ohm and reactance of 16 ohm respectively. The line is connected to a generating station bus bars through a 6000 KVA step up transformer which has a reactance of 6%. The station has two generators rated 10,000 KVA with 10% reactance and 5000 KVA with 5% reactance. Calculate the fault current and short circuit KVA when a 3-phase fault occurs at the HV terminals of the transformers and at the load end of the line.

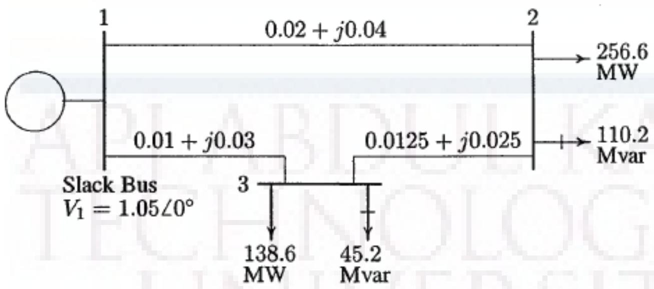


3. **(10)**

b) Explain the different types of current limiting reactors. **(4)**

Module II

4. a)For the system shown in figure obtain the load flow solution at the end of 2 iterations by Gauss Seidel method . The line impedances are marked in per unit on a 100 MVA base.



(10)

b) Explain DC load flow. **(4)**

5. Consider the three bus system shown below. Each of the three lines have aseries impedance of 0.02+j0.08 pu and a total shunt admittance of j0.02 pu. The specified quantities at the buses are tabulated below.

Bus	Real load Demand, P_D	Reactive load demand, Q_D	Real power Generation, P_G	Reactive power Generation, Q_G	Voltage specification
1	2.0	1.0	Unspecified	Unspecified	$V_1 = 1.04 + j0$
2	0.0	0.0	0.5	1.0	Unspecified
3	1.5	0.6	0.0	$Q_{G3} = ?$	$\| V_3 \| = 1.04$

Controllable reactive power source is available at bus 3 with the constraint $0 \leq Q_{G3} \leq 1.5$pu. Find the load flow solution using FDLF method (one iteration).

(14)

Module III

6. a) Starting from first principles, derive swing equation of a synchronous machine. **(6)**

   b) Two generators rated at 4-pole, 50 Hz, 50 MW 0.85 p.f (lag) with moment of inertia28,000 kg-m^2 and 2-pole, 50Hz, 75 MW 0.82 p.f (lag) with moment of inertia 5,000 kg-m^2 are connected by a transmission line. Find the inertia constant of each machine and the inertia constant of single equivalent machine connected to infinite bus. Take 100 MVA base. **(8)**

7. a) A 50 Hz generator is delivering 50% of the power that it is capable of delivering through a transmission line to an infinite bus. A fault occurs that increases the reactance between the generator and the infinite bus to 500% of the value before the

fault. When the fault is isolated, the maximum power that can be delivered is 75% of the original maximum value. Determine the critical clearing angle for the condition described. **(10)**

b) Explain Equal Area criterion and state the assumptions made. **(4)**

Module IV

8. a)Two turboalternators rated for 110 MW and 210 MW have governor drop characteristics of 5 per cent from no load to full load. They are connected in parallel to share a load of 250 MW. Determine the load shared by each machine assuming free governor action. **(10)**

b) Enumerate the reasons for keeping strict limits on the system frequency variations. **(4)**

9. a) Develop and explain the block diagram of automatic load frequency control of anisolated power system. **(10)**

b) A 100 MVA synchronous generator operates on full load at a frequency of 50 Hz. Inertia constant is 8 MJ/MVA. The load is suddenly reduced 100 MW. Due to time lag in governor system, the steam valve begins to close after 0.4 seconds. Determine the change in frequency that occurs in this time. **(4)**

Module V

10. a)The fuel inputs per hour of plants 1 and 2 are given as

$F_1 = 0.2\ P_1^{\ 2} + 40\ P_1 + 120$ Rs. per hr

$F_2 = 0.25\ P_2^2 + 30\ P_2 + 150$Rs. per hr

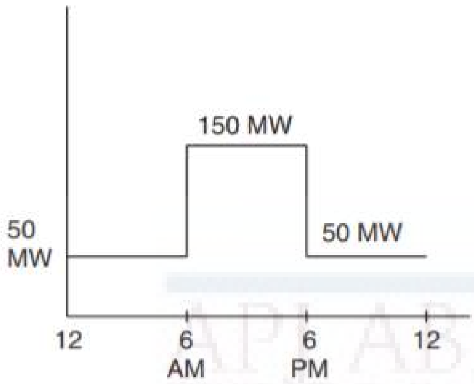
Determine the economic operating schedule and the corresponding cost of generation if the maximum and minimum loading on each unit is 100 MW and 25 MW, the demand is 180 MW, and transmission losses are neglected. If the load is equally shared by both the units, determine the saving obtained by loading the units as per equal incremental productioncost. **(6)**

b) Assume that the fuel input in Btu per hour for units 1 and 2 are given by

$F_1 = (8P_1 + 0.024\ P_1^2 + 80)10^6$

$F2 = (6P_2 + 0.04\ P_2^2 + 120)10^6$

The maximum and minimum loads on the units are 100 MW and 10 MW respectively. Determine the minimum cost of generation when the following load (as per Figure given below) is supplied. The cost of fuel is Rs. 2 per million Btu.



(8)

11. a) A 2 bus system consist of two power plants connected by a transmission line. The cost curve characteristics of the two plants are

$C_1 = 0.01P_1^2 + 16P_1 + 20$ Rs/hr

$C_2 = 0.02P_2^2 + 20P_2 + 40$ Rs/hr

When a power of 120 MW is transmitted from plant 1 to load (near to plant 2), a loss of 14 MW is occurred. Determine the optimal scheduling of plants and load demand, if cost of received power is 30 Rs./MWhr. **(10)**

b) The incremental fuel cost of two generating units G_1 and G_2 is given by $IC_1 = 25+0.2P_1$, $IC_2 = 32+0.2P_2$, where P_1 and P_2 are real powers generated by the unit. Find the economic allocation for a total load of 250 MW. Neglect the transmission losses. **(4)**

Syllabus

Module I (10 hours)

Per unit quantities-single phase and three phase- Symmetrical components- sequence networks- Fault calculations-symmetrical and unsymmetrical- Fault level of installations- Limiters - Contingency ranking.

Module II (8 hours)

Load flow studies – Introduction-types-network model formulation and admittance matrix, Gauss-Siedel (two iterations), Newton-Raphson (Qualitative analysis only) and Fast Decoupled method (two iterations) - principle of DC load flow - Introduction to distribution flow.

Module III (10 hours)

Power system stability - steady state, dynamic and transient stability-power angle curve-steady state stability limit -mechanics of angular motion-swing equation - solution of swing equation - Point by Point method - RK method - Equal area criterion application - methods of improving stability limits - Phasor Measurement Units- Wide Area Monitoring Systems

Module IV (10 hours)

Turbines and speed governors-Inertia-Automatic Generation Control: Load frequency control: single area and two area systems - Subsynchronous Resonance - Automatic voltage control -Exciter Control- SCADA systems

Module V (8 hours)

Economic Operation - Distribution of load between units within a plant - transmission loss as a function of plant generation - distribution of load between plants - method of computing penalty factors and loss coefficients. Unit commitment: Introduction — constraints on unit commitments: spinning reserve, thermal unit constraints- hydro constraints.

References:

1. Hadi Saadat, *Power System Analysis,* 2/e, McGraw Hill, 2002.
2. D. P. Kothari and I. J. Nagrath, *Modern Power System Analysis*, 2/e, TMH, 2009.
3. Kundur P., *Power system Stability and Control*, McGraw Hill, 2006
4. Cotton H. and H. Barbera, Transmission & Distribution of Electrical Energy, 3/e, Hodder and Stoughton, 1978.
5. Gupta B. R., *Power System Analysis and Design*, S. Chand, New Delhi, 2006.
6. Gupta J.B., Transmission *& Distribution of Electrical Power*, S.K. Kataria& Sons, 2009.
7. Soni, M.L., P. V. Gupta and U. S. Bhatnagar, *A Course in Electrical Power*, Dhanpat Rai& Sons, New Delhi, 1984.
8. John J Grainger and William D Stevenson, *Power System Analysis*, 4/e, McGraw Hill, 1994.
9. Uppal S. L. and S. Rao, *Electrical Power Systems*, Khanna Publishers, 2009.
10. Wadhwa C. L., *Electrical Power Systems*, 33/e, New Age International, 2004.
11. Weedy B. M., B. J. Cory, N. Jenkins, J. B. Ekanayake and G. Strbac, *Electric Power System*, John Wiley & Sons, 2012.

Course Contents and Lecture Schedule:

No	Topic	No. of Lectures
1	**Module I(10 hours)**	
1.1	Per unit quantities-single phase and three phase.- -Numerical Problems	2
1.2	Symmetrical components- sequence networks-Numerical Problems	3
1.3	Fault calculations-symmetrical and unsymmetrical-Numerical Problems	3
1.4	Fault level of installations- Limiters-Numerical Problems	2
2	**Module 2(8 Hours)**	

2.1	Load flow studies – Introduction-types	1
2.2	Network model formulation and admittance matrix-Numerical Problems	2
2.3	Gauss-Siedel (two iterations) -Numerical Problems not more than three buses	1
2.4	Newton-Raphson (Qualitative analysis only)	2
2.5	Fast Decoupled method (two iterations) -Numerical Problems not more than three buses	1
2.6	Principle of DC load flow. Introduction to distribution flow.	1
3	**Module 3(10 hours)**	
3.1	Power system stability steady state, dynamic and transient stability--Numerical Problems	2
3.2	power angle curve-steady state stability limit --Numerical Problems	2
3.3	Point by Point method Equal area criterion application-Numerical Problems. RK method-(Abstract idea only)	2
3.4	Methods of improving stability limits-Numerical Problems	2
3.5	Contingency ranking-SSR-(Abstract idea only) – PMUs and Wide area monitoring systems	2
4	**Module IV (10 hours)**	
4.1	Turbines and speed governors-inertia.	2
4.2	Automatic Generation Control: Load frequency control: single area and two area systems-Numerical Problems	3
4.3	Automatic voltage control -Exciter Control.	2
4.4	SCADA systems--(Abstract idea only)	1
4.5	Phasor Measurement Unit- Wide Area Monitoring Systems-(Abstract idea only)	2
5	**Module V (8 hours)**	
5.1	Economic Operation Distribution of load between units within a plant transmission loss as a function of plant generation distribution of load between plants-Numerical Problems	3
5.2	Method of computing penalty factors and loss coefficients-Numerical Problems	2

5.3	Unit commitment: Introduction — Constraints on unit commitments: Spinning reserve, Thermal unit constraints- Hydro constraints- Numerical Problems.	3

CODE	COURSE NAME	CATEGORY	L	T	P	CREDITS
EET306	POWER ELECTRONICS	PCC	3	1	0	4

Preamble: To impart knowledge about the power semiconductor devices, the operation of various power converters and its applications.

Prerequisite: Basics of Electrical Engineering / Introduction to Electrical Engineering/ Basics of Electronics Engineering

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

CO 1	Explain the operation of modern power semiconductor devices and its characteristics.
CO 2	Analyse the working of controlled rectifiers.
CO 3	Explain the working of AC voltage controllers, inverters and PWM techniques.
CO 4	Compare the performance of different dc-dc converters.
CO 5	Describe basic drive schemes for ac and dc motors.

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	-	1	-	-	-	-	-	-	-	-
CO 2	3	2	1	2	-	-	-	-	-	-	-	2
CO 3	3	3	-	-	-	-	-	-	-	-	-	-
CO 4	3	3	2	2	-	-	-	-	-	-	-	2
CO 5	3	2	-	-	-	-	-	-	-	-	-	2

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**		**End Semester Examination**
	1	**2**	
Remember (K1)	10	10	20
Understand (K2)	20	20	30
Apply (K3)	20	20	50
Analyse (K4)	-	-	-
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. Explain the working and switching characteristics of SCR, MOSFET, IGBT (K1)
2. Give a brief description on wide band-gap power devices (K1)
3. Draw and explain the switching characteristics of SCR (K1, K2)
4. Discuss the protection circuits for SCR (K2)
5. Explain different types of isolation in gate drive for power converter circuits (K1, K2)

Course Outcome 2 (CO2):

1. Describe the working with waveforms of single phase half wave rectifiers for different firing angles. (K1)
2. Describe the working with waveforms of single phase fully controlled rectifiers for different firing angles and loads.(K2)
3. Describe the working with waveforms of single phase half controlled rectifiers for different firing angles and loads.(K2)
4. Describe the working with waveforms of three phase rectifiers fordifferent firing angles and loads. (K2)
5. Problems in finding the average output voltage of rectifier. (K2, K3)

Course Outcome 3 (CO3):

1. Explain the working of ACVC with R and RL loads. (K1)
2. Explain single phase inverter for R and RL loads, problems in finding the output voltage, THD of inverter. (K2, K3)
3. Explain 3 phase mode 120^0 and 180^0 conduction modes. (K4)
4. Explain single phase current source inverter PWM Inverter. (K1)
5. Explain single pulse PWM, multiple pulse,and sinusoidalPWM technique (K1, K2)

Course Outcome 4 (CO4):

1. Explain the working of step up and step down converters. (K1, K2)
2. Problems related to step up and step down converters. (K2, K3)
3. Analyse the working of Buck, Boost & Buck Boost regulators. (K3, K4)
4. Design the value of filter inductor & capacitance in regulators. (K3, K4)
5. Problems in Buck, Boost & Buck Boost regulators. (K2, K3)

Course Outcome 5 (CO5):

1. Explain the block diagram of an electric drive (K1,K2)
2. Explain the working of single phase rectifier fed DC drive (K2, K3)
3. Explain the chopper controller DC drive (K2,K3)
4. Explain the four quadrant operation of a DC drive (K2, K3)
5. Explain the v/f control of Induction motor drive (K3,K4)

Model Question paper

QP CODE:

PAGES:2

Reg.No:_______________
Name:_______________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SIXTH SEMESTER B.TECH DEGREE EXAMINATION, MONTH & YEAR
Course Code: EET 306

Course Name: POWER ELECTRONICS

Max. Marks: 100 Duration: 3 Hours

PART A (3 x 10 = 30 Marks)

Answer all Questions. Each question carries 3 Marks

1. Explain different turn on methods of SCR.
2. Describe the reverse recovery characteristics of a power diode.
3. Draw the input and output voltage waveforms of single phase half controlled rectifier feeding RL load in continuous and discontinuous conduction mode.
4. Explain with neat sketches, the input and output voltage waveforms of 3ø half controlled rectifier with R load for a firing angle of 30^0.
5. Compare voltage source and current source inverters.
6. Explain the terms modulation index and frequency modulation ratio related to pulse width modulation.
7. Explain time ratio control method to vary the output voltage in choppers.
8. Derive the expression for output voltage of a Buck Converter.
9. What are the advantages of electric drives?
10. Explain regenerative braking control in drives.

PART B (14 x 5 = 70 Marks)

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

Module 1

11. a) Explain the two transistor analogy of SCR. **(6)**

b) Compare the switching characteristics of IGBT. **(8)**

12. a) Explain the structural details of MOSFET. **(8)**

b) Write short note on wideband gap devices. **(6)**

Module 2

13. a) Explain the operation of single phase full wave controlled rectifier without freewheeling diode, when feeding RL load. **(10)**

b) Write short notes on pulse transformer. **(4)**

14. a)The full-wave controlled bridge rectifier has an AC input of 220 V rms at 50 Hz and a 20 ohmload resistor. The delay angle is 40^0. Determine the average current in the load, the power absorbed by the load, and the source volt-amperes. **(7)**

b) Draw the circuit of 3 phase fully controlled rectifier with RLE load and explain the working for $\alpha=60^0$ with necessary waveforms. Derive the expression for output voltage. **(7)**

Module 3

15. a) Explain the 120^0 conduction mode of a three-phase bridge inverter with output voltage waveforms, indicating the devices conducting in each state. **(10)**

b) Write short notes of THD. **(4)**

16. a) Explain sinusoidal PWM technique for varying the magnitude of output voltage in a single-phase inverter . **(6)**

b) Briefly explain current source inverter **(8)**

Module 4

17. a) Explain the working of a Buck-Boost regulator, showing relevant waveforms and derive the expression for its output voltage. **(8)**

b) Design a DC-DC Converter with 12 V input and 200 V output at upto 50 W. The ripple in the output voltage and input current should not exceed +- 5% and +- 20% respectively. Select suitable device and switching frequency. **(6)**

18. a) Describe the working of four quadrant chopper in all the four quadrants with relevant circuit diagrams. **(10)**

    b) Briefly explain the current limit control in dc-dc converter **(4)**

Module 5

19. a) Explain the working of a single phase full converter drive **(8)**

    b) Explain the working of a four quadrant chopper drive **(6)**

20. a) Explain the stator voltage control for Induction motor drive **(8)**

    b) Explain the working of v/f control of Induction motor drive **(6)**

Syllabus

Module 1 - 11 hrs

Introduction to Power Electronics-Scope and applications-power electronics vs signal electronics (1 hr)
Structure and principle of operation ofpower devices- Power diode, Power MOSFET & IGBT – switching characteristics - comparison. Basic principles of wideband gap devices-SiC, GaN (4 hrs)
SCR- Structure, Static characteristics & Switching (turn-on & turn-off) characteristics - di/dt& dv/dt protection – Turn-on methods of SCR - Two transistor analogy (5 hr)

Gate triggering circuits – Requirements of isolation and synchronization in gate drive circuits- Opto and pulse transformer based isolation (1hr)

Module 2 - 9 hrs

Controlled Rectifiers (Single Phase) – Half-wave controlled rectifier with R load– Fully controlled and half controlled bridge rectifier with R, RL and RLE loads (continuous & discontinuous conduction) – Output voltage equation- related simple problems(5 hrs)

Controlled Rectifiers (3-Phase) - 3-phase half-wave controlled rectifier with R load – Fully controlled & half-controlled bridge converter with RLE load (continuous conduction, ripple free) – Output voltage equation-Waveforms for various triggering angles (detailed mathematical analysis not required) (4 hrs)

Module 3 - 9 hrs

AC voltage controllers (ACVC) – 1-phase full-wave ACVC with R, & RL loads – Waveforms – RMS output voltage, Input power factor with R load (2 hrs)

Inverters – Voltage Source Inverters– 1-phase half-bridge & full bridge inverter with R and RL loads – THD in output voltage – 3-phase bridge inverter with R load – 120° and 180° conduction modes– Current Source Inverters-1-phase capacitor commutated CSI.(5 hrs)

Voltage control in 1-phase inverters – Pulse width modulation – Single pulse width, Multiple pulse width and Sine-triangle PWM (unipolar & bipolar modulation) – Modulation Index - Frequency modulation ratio.(2 hrs)

Module 4 - 8 hrs

DC-DC converters – Step down and Step up choppers – Single-quadrant, Two-quadrant and Four quadrant chopper – Pulse width modulation & current limit control in dc-dc converters. (4 hrs)
Switching regulators – Buck, Boost & Buck-boost –Operation with continuous conduction mode – Waveforms – Design of Power circuits (switch selection, filter inductance and capacitance) (4 hrs)

Module 5 - 11 hrs

Electric Drive: Introduction to electric drives – Block diagram – advantages of electric drives- types of load – classification of load torque (2 hrs)

DC Drives: Single phase semi converter and single phase fully controlled converter drives. Dual Converters for Speed control of DC motor-1-phase and 3-phase configurations; Simultaneous and Non-simultaneous operation. Chopper controlled DC drives- Single quadrant chopper drives- Regenerative braking control- Two quadrant chopper drives- Four quadrant chopper drives(6 hrs)

AC Drives: Three phase induction motor speed control. Stator voltage control – stator frequency control - Stator voltage and frequency control (v/f) (3 hrs)

(It is expected to emphasize the ease of independent control of field flux and armature flux in SEDC motor and relate the same with Induction motor)

Text Books

1. Muhammad H. Rashid, Power Electronics Circuits, Devices and Applications, Pearson Education
2. Daniel W. Hart, Power Electronics, Tata McGraw-Hill Education
3. P.S. Bimbhra, Power Electronics, Khanna Publishers, New Delhi

References:

1. Mohan N., T. M. Undeland and W. P. Robbins., Power Electronics, Converters,

Applications & Design, Wiley-India
2. Fundamentals of Power Electronics, Erickson, Robert W., and Maksimovic, Dragan.
3. Krein P. T., Elements of Power Electronics, Oxford University Press, 1998.
4. L. Umanand, Power Electronics – Essentials & Applications, Wiley-India
5. Singh M. D. and K. B. Khanchandani, Power Electronics, Tata McGraw Hill, New Delhi, 2008.
6. Joseph Vithayathil, Power Electronics: Principles and Applications, McGraw-Hill College; International edition ,1995
7. Application notes on SiC and GaN, www.infineon.com. [online]
8. Evolution of wide Band-gap Semi-conductors for power devices expanding field of applications. Technical review, Vol 4, Toshiba Corporation, 2018
9. Milligan, J. W., Sheppard, S., Pribble, W., Wu, Y.-F., Muller, G., &Palmour, J. W. (2007). SiC and GaN Wide Bandgap Device Technology Overview, 2007 IEEE Radar Conference. doi:10.1109/radar.2007.374395.
10. Vedam Subramaniam “Electric drives (concepts and applications)”, Tata McGraw-Hill, 2001.
11. G. K. Dubey, Fundamentals of Electric Drives, Narosa publishers, second edition, 2010.

Course Contents and Lecture Schedule:

No.	Topic	No. of Lectures
1	**Power Devices (11 hours)**	
1.1	Introduction to Power Electronics: Scope and applications-power electronics vs signal electronics.	1
1.2	Structure, principle of operation, switching characteristics of Power Devices- Power Diode, Power MOSFET & IGBT – Comparison	3
1.3	Basic principles of wideband gap devices-SiC, GaN	1
1.4	SCR- Structure, Static characteristics & Switching (turn-on & turn-off) characteristics - di/dt& dv/dt protection – Turn-on methods of SCR - Two transistor analogy	5
1.5	Requirements of isolation and synchronization in gate drive circuits- Opto and pulse transformer based isolation	1
2	**Single phase and three phase controlled rectifiers (9 hours)**	
2.1	Half-wave controlled rectifier with R load	2
2.2	1-phase fully controlled bridge rectifier with R, RL and RLE loads (continuous & discontinuous conduction) – Output voltage equation	2
2.3	1-phase half controlled bridge rectifier with R, RL and RLE loads	1
2.4	3-phase half-wave controlled rectifier with R load	2
2.5	3-phase fully controlled & half-controlled converter with RLE load (continuous conduction, ripple free) – Output voltage equation.	2

3	**Inverters and Voltage control in single phase inverters (9 Hours)**	
3.1	Applications of AC-AC converters – Single phase full-wave AC voltage controllers with R, & RL loads- Waveforms	1
3.2	RMS output voltage, Input power factor with R load	1
3.3	Voltage Source Inverters– 1-phase Half-bridge & Full bridge inverter with R and RL loads– THD in output voltage	2
3.4	3-phase bridge inverter with R load – 120° and 180° conduction modes	2
3.5	Current Source Inverters-1-phase capacitor commutated CSI.	1
3.6	Pulse Width Modulation – Single pulse width, Multiple pulse width and Sine-triangle PWM (bipolar modulation) – Modulation Index - Frequency modulation ratio.	2
4	**DC-DC converters (8 Hours)**	
4.1	Step down and Step up choppers – Single-quadrant chopper	2
4.2	Two-quadrant and Four-quadrant chopper – Pulse width modulation &current limit control in dc-dc converters.	2
4.3	Buck, Boost & Buck-boost –Operation with continuous conduction mode – Waveforms	3
4.4	Design of Power circuits (switch selection, filter inductance and capacitance)	1
5	**Electric drives (11 Hours)**	
5.1	Electric Drive: Introduction to electric drives – Block diagram – advantages of electric drives- types of load – classification of load torque	2
5.2	DC Drives: Single phase semi converter and single phase fully controlled converter drives. Dual Converters for Speed control of DC motor-1-phase and 3-phase configurations; Simultaneous and Non-simultaneous operation.	3
5.3	Chopper controlled DC drives. Single quadrant chopper drives. Regenerative braking control. Two quadrant chopper drives. Four quadrant chopper drives	3
5.4	AC Drives: Three phase induction motor speed control. Stator voltage control – stator frequency control - Stator voltage and frequency control (v/f) (3 hrs)	3

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET308	COMPREHENSIVE COURSE WORK	PCC	1	0	0	1

Preamble: The objective of this Course work is to ensure the comprehensive knowledge of each student in the most fundamental Program core courses in the curriculum. Five core courses credited from Semesters 3, 4 and 5 are chosen for the detailed study in this course work. This course has an End Semester Objective Test conducted by the University for 50 marks. One hour is assigned per week for this course for conducting mock tests of objective nature in all the listed five courses.

Prerequisite:
1.EET 201 Circuits and Networks
2. EET 202 DC Machines and Transformers
3. EET 206 Digital Electronics
4. EET 301 Power Systems I
5. EET 305 Signals and Systems

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

CO 1	Apply the knowledge of circuit theorems to solve the problems in electrical networks
CO 2	Evaluate the performance of DC machines and Transformers under different loading conditions
CO 3	Identify appropriate digital components to realise any combinational or sequential logic.
CO 4	Apply the knowledge of Power generation, transmission and distribution to select appropriate components for power system operation.
CO 5	Apply appropriate mathematical concepts to analyse continuous time and discrete time signals and 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
CO1	3	3										2
CO2	3	2										2
CO3	3	3	1		1							2
CO4	3	3				1	1	1			1	2
CO5	3	3	1		1							2

Assessment Pattern

Bloom's Category	End Semester Examination
Remember	10
Understand	20
Apply	20
Analyse	
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
50	0	50	1 hour

End Semester Examination Pattern: Objective Questions with multiple choice (Four). Question paper include Fifty Questions of One mark each covering the five identified courses.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. A circuit with resistor, inductor and capacitor in series is resonant at f_0 Hz. If all the component values are now doubled, the new resonant frequency is

a) 2 f_0
b) Still f_0
c) f_0 /2
d) f_0 /4

2. The line A to neutral voltage is $10<15^0$ V for a balance three phase star connected load with phase sequence ABC. The voltage of line B with respect to line C is given by

a) $10\sqrt{3}<105^0$ V
b) $10<105^0$ V
c) $10\sqrt{3}<75^0$ V
d) $-10\sqrt{3}<90^0$ V

3. The average power delivered to an impedance (4-j3)Ω by a current 5cos(100πt+100)A is

a) 44.2 W
b) 50 W
c) 62.5 W
d) 125 W

Course Outcome 2 (CO2)

1. The DC motor which can provide zero speed regulation at full load without any controller is

a) Series
b) Shunt
c) Cumulatively compound
d) Differentially compound

2. For a single phase, two winding transformer, the supply frequency and voltage are both increased by 10%. The percentage changes in the hysteresis and eddy current loss, respectively are

a) 10 and 21
b) -10 and 21
c) 21 and 10
d) -21 and 10

3. Match the following

List I-Performance Variables	List II-Proportional to
A. Armature emf (E)	1. Flux (ϕ), speed (ω), Armature Current(Ia)
B. Developed Torque (T)	2. ϕ and ω only
C. Developed Power (P)	3. ϕ and Ia only
	4. Ia and ω only
	5. Ia only

Choices:

	A	B	C
a)	3	3	1
b)	2	5	4
c)	3	5	4
d)	2	3	1

Course Outcome 3(CO3):

1. The SOP (sum of products) form of a Boolean function is ∑(0, 1, 3, 7, 11), where inputs are A, B, C, D (A is MSB and D is LSB). The equivalent minimized expression of the function is

a) (B’+C)(A’+C)(A’+B’)(C’+D)
b) (B’+C)(A’+C)(A’+C’)(C’+D)
c) (B’+C)(A’+C)(A’+C’)(C’+D’)
d) (B’+C)(A+B’)(A’+B’)(C’+D)

2. A cascade of three identical modulo-5 counters has an overall modulus of

a) 5
b) 25
c) 125
d) 625

3. The octal equivalent of the HEX number AB.CD is

a) 253.314
b) 253.632
c) 526.314
d) 526.632

Course Outcome 4 (CO4):

1. Corona losses are minimized when

a) Conductor size is reduced
b) Smoothness of the conductor is reduced
c) Sharp points are provided in the line hardware
d) Current density in the conductors is reduced

2. Keeping in view the cost and overall effectiveness, the following Circuit Breaker is best suited for capacitor bank switching

a) Vacuum
b) Air Blast
c) SF_6
d) Oil

3. The horizontally placed conductors of a single phase line operating at 50Hz are having outside diameter of 1.6cm and the spacing between centres of the conductors is 6m. The permittivity of free space is 8.854 x 10^{-12} F/m. The capacitance to ground per kilometre of each line is

a) 4.2 x 10^{-9} F

b) 4.2×10^{-12} F
c) 8.4×10^{-9} F
d) 8.4×10^{-12} F

Course Outcome 5 (CO5):

1. Consider a continuous time system with input x(t) and output y(t) given by y(t)=x(t)cos(t). This system is

a) Linear and time invariant
b) Non-linear and time invariant
c) Linear and time varying
d) Non-linear time varying

2. Signal Flow Graph is used to obtain

a) Stability of the system
b) Transfer Function of a system
c) Controllability of a system
d) Observability of a system

3. The steady state error due to a step input for Type 1 system is

a) Zero
b) Infinity
c) 1
d) 0.5

Syllabus

Full Syllabus of all Five selected Courses.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Circuits and Networks**	
1.1	Mock Test on Module 1 and Module 2	**1**
1.2	Mock Test on Module 3, Module 4 and Module 5	**1**
1.3	Feedback and Remedial	**1**
2	**DC Machines and Transformers**	
2.1	Mock Test on Module 1, Module 2 and Module 3	**1**
2.2	Mock Test on Module 4 and Module 5	**1**
2.3	Feedback and Remedial	**1**
3	**Digital Electronics**	
3.1	Mock Test on Module 1 and Module 2	**1**
3.2	Mock Test on Module 3, Module 4 and Module 5	**1**

3.3	Feedback and Remedial	**1**
4	**Power Systems I**	
4.1	Mock Test on Module 1, Module 2 and Module 3	**1**
4.2	Mock Test on Module 4 and Module 5	**1**
4.3	Mock Test on Module 1, Module 2 and Module 3	**1**
5	**Signals and Systems**	
5.1	Mock Test on Module 1, Module 2 and Module 3	**1**
5.2	Mock Test on Module 4 and Module 5	**1**
5.3	Feedback and Remedial	**1**

CODE	COURSE	CATEGORY	L	T	P	CREDIT
EEL332	**POWER SYSTEMS LAB**	**PCC**	**0**	**0**	**3**	**2**

Preamble : This Laboratory Course will provide a perfect platform for the students to do hands-on practise with hardware and software in Power Systems. The experiments include simulation of power system analysis in steady state and transient state. The Hardware experiments cover Protective Relaying and High Voltage Testing. Successful completion of this lab will certainly make the students equipped for any Power Industry.

Prerequisite : EET301Power Systems I

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

CO 1	Develop mathematical models and conduct steady state and transient analysis of power system networks using standard software.
CO 2	Develop a frequency domain model of power system networks and conduct the stability analysis.
CO 3	Conduct appropriate tests for any power system component as per standards.
CO 4	Conduct site inspection and evaluate performance ratio of solar power plant.

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	3	2	3	3			3	2	3		3
CO 2	3	2	1	3	3			1	2	3		2
CO 3	3	1	1	3	3	3	1	3	3	3		3
CO 4	3	1	1	3	3	3	3	3	3	3	2	3

ASSESSMENT PATTERN:

Mark distribution :

Total Marks	CIE	ESE	ESE Duration
150	75	75	3 hours

Continuous Internal Evaluation (CIE) Pattern:

Attendance	Regular Lab work	Internal Test	Course Project	Total
15	30	25	5	75

Internal Test Evaluation (Immediately before the second series test)

End Semester Examination Pattern:

The following guidelines should be followed regarding award of marks:

(a) Preliminary work (Type of Test, circuit diagram and diagram for simulation): 15 Marks
(b) Simulation in software and Conducting the experiment (Procedure) : 10 Marks
(c) Performance, result and inference (usage of equipment and troubleshooting): 25 Marks
(d) Viva voce : 20 marks
(e) Record : 5 Marks

General instructions : Practical examination to be conducted immediately after the second series test covering the entire syllabus given. Each student has to do both software and hardware parts for the examination. Evaluation is a serious process that is to be conducted under the equal responsibility of both the internal and external examiners. The number of candidates evaluated per day should not exceed 20. Students shall be allowed for the University examination only on submitting the duly certified record. The external examiner shall endorse the record.

LIST OF EXPERIMENTS:

Part A: POWER SYSTEM SIMULATION EXPERIMENTS

1. Y-Bus Formulation(Basic Programming): Effect of change in topology
2. Transmission Line Modelling (Basic Programming): ABCD constants
3. Load Flow Analysis –Gauss-Siedel Method, Newton-Raphson Method,Fast Decoupled Method – Effect of change in load/generation schedule
4. Load Flow Analysis –Gauss-Siedel Method, Newton-Raphson Method,Fast Decoupled Method – Effect of change in real power/reactive power limits
5. Short Circuit Analysis – Symmetrical Faults and Unsymmetrical Faults
6. Contingency Ranking
7. Transient Stability Analysis
8. Automatic Generation Control – Single Area, Two Area
9. Distribution Systems with Solar PV units
10. Reactive Power Control.
11. Ferranti Effect and Reactive Power Compensation.
12. Plot the IV characteristics of a PV module and determine Maximum Power Point.

Part B: POWER SYSTEM COMPONENT TESTING (Hardware experiments)

1. High voltage testing -Power frequency/Impulse
2. High voltage testing -DC
3. Smart metering
4. Relay Testing - Over current relay /Earth fault(Electromechanical/Static/Numerical)
5. Relay Testing –Voltage relay/ Impedance Relay (Electromechanical/Static/Numerical)
6. Insulation Testing – LT & HT Cable
7. Earth Resistance
8. Testing of CT and PT
9. Testing of transformer oil
10. Testing of dielectric strength of solid insulating materials
11. Testing of dielectric strength of air
12. Power factor improvement

Instructions:

Both software and hardware experiments are included. **At least 12 experiments (4 hardware experiments are mandatory) and one Mini Project.** Any additional experiment can be treated as Beyond the Syllabus. **Students have to do software simulation and a hardware testing for the End semester examination.**

Mandatory Course Project:

Design a solar power plant (rooftop or ground mounted).Conduct site inspection and feasibility study. Design the components to be used and calculate the performance ratio. Prepare a concise project report giving justifications to the choices made and the economic analysis.

Students have to do a mandatory course project (group size not more than 4 students-individual may be preferred).A report isalso to be submitted. Performance can be evaluated along with the internal test and a maximum of 5 marks shall be awarded.

Reference Books:

1. HadiSaadat, *Power System Analysis*, 2/e, McGraw Hill, 2002.
2. Kothari D. P. and I. J. Nagrath, *Modern Power System Analysis*, 2/e, TMH, 2009
3. M. S. Naidu, V. Kamaraju, *High Voltage Engineering*, Tata McGraw-Hill Education, 2004
4. Wadhwa C. L., *Electrical Power Systems*, 3/e, New Age International, 2009.
5. IEC 61850.
6. IEEE 1547 and 2030 Standards.
7. IS Codes for Testing of Power System components.
8. IEC 61724-1:2017Performance of Solar Power Plants.

CODE	COURSE	CATEGORY	L	T	P	CREDIT
EEL334	**POWER ELECTRONICS LAB**	**PCC**	**0**	**0**	**3**	**2**

Preamble : Impart practical knowledge for the design and setup of different power electronic converters and its application for motor control.

Prerequisite : Power Electronics (EET306)

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

CO 1	Determine the characteristics of SCR and design triggering circuits for SCR based circuits.
CO 2	Design, set up and analyse single phase AC voltage controllers.
CO 3	Design, set up and test suitable gate drives for MOSFET/IGBT.
CO 4	Design, set up and test basic inverter topologies.
CO 5	Design and set up dc-dc converters.
CO 6	Develop simulation models of dc-dc converters, rectifiers and inverters using modern simulation tools.

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	3	2	2	2	-	-	-	3	2	-	3
CO 2	3	3	2	2	2	-	-	-	3	2	-	3
CO 3	3	3	2	2	2	-	-	-	3	2	-	3
CO 4	3	3	2	2	2	-	-	-	3	2	-	3
CO 5	3	3	2	2	2	-	-	-	3	2	-	3
CO 6	3	3	2	2	3	-	-	-	3	2	-	3

ASSESSMENT PATTERN:

Mark distribution:

Total Marks	CIE marks	ESE marks	ESE Duration
150	75	75	3 hours

Continuous Internal Evaluation (CIE) Pattern:

Attendance	Regular Lab work	Internal Test	Course Project	Total
15	30	25	5	**75**

Internal Test Evaluation (Immediately before the second series test

End Semester Examination (ESE) Pattern:

The following guidelines should be followed regarding award of marks:

a) Preliminary Work : 15Marks
b) Implementing the work/Conducting the experiment : 10Marks
c) Performance, result and inference (usage of equipments and troubleshooting) : 25Marks
d) Viva voce : 20marks
e) Record : 5Marks

General instructions : Practical examination is to be conducted immediately after the second series test after conducting 12 experiments from the list of experiments given below. Evaluation is a serious process that is to be conducted under the equal responsibility of both the internal and external examiners. The number of candidates evaluated per day should not exceed 20. Students shall be allowed for the University examination only on submitting the duly certified record. The external examiner shall endorse the record.

LIST OF EXPERIMENTS:
(12 experiments are mandatory)

HARDWARE EXPERIMENTS: (A minimum of 8 experiments are mandatory)

1. **Static characteristics of SCR**

Aim: To determine the minimum gate current & gate voltage required to trigger the SCR also to measure the latching current, holding current and to plot the static characteristics of SCR

2. **R and RC firing scheme for SCR control**

Aim: To design and set up a half wave controlled rectifier with R and RC firing circuits and plot voltage waveform across the load and thyristor for different firing angles.Also determine the minimum and maximum firing angles of this circuit.

3. **Line Synchronised Triggering Circuits of SCR**

Aim: To design and set-up line synchronized Ramp Trigger and Digital Trigger circuits of SCR and observe the waveforms

4. **AC Voltage Controller**

Aim: To study the single phase AC voltage controller using TRIAC/SCRs. Set-up a single phase AC voltage controller & observe waveforms across load resistance for different firing angles.

5. **Gate Driver Circuits for MOSFET/IGBT**

Aim: To design and test a gate driver circuit for triggering half bridge inverter using MOSFET / IGBT using industry-standard MOSFET drive ICs/Circuits. To test the driving of floating and ground-referenced configurations.

6. Single Phase fully Controlled SCR bridge rectifier

Aim: To design and set up a single phase full converter with RL/RLE loads and observethe waveforms with and without freewheeling diode.

7. Design of Inductor/Transformer

Aim: To design and fabricate an inductor/transformer to be used in power electronic circuits.

8. Design and set-up buck/ boost / buck-boost converters

Aim: To design and set up the buck/boost/buck-boost converter and analyse the characteristics of the same.

9. Switching characteristics of MOSFET

Aim: To study and understand the switching characteristics of a power MOSFET.

10. Single-phase half bridge/full bridge inverter using power MOSFET/IGBT

Aim: To design and set up a single phase half-bridge/full-bridge inverter and observe the waveforms across load and firing pulses.

11. Single-phase sine PWM inverter with LC filter

Aim: To design and set up a single phase sine PWM inverter with LC filter using microcontroller

12. Three phase sine PWM Inverter using IGBT

Aim: To set up a 3-phase PWM Inverter with RL load and observe the waveforms

13. Speed control of DC motor using chopper

Aim: To Control the speed of a DC motor using a step-down chopper

14. Speed control of 3-phase induction motor

Aim: To Control the speed of a 3-phase induction motor using V/f control method.

SIMULATION EXPERIMENTS: (A minimum of 4 experiments are mandatory)

15. Simulation of 1-phase fully-controlled and half-controlled rectifier fed separately excited DC motor

Aim: To simulate 1-phase fully-controlled and half-controlled rectifier fed Separately Excited DC motor and observe the speed, torque, armature current, armature voltage, source current waveforms and find the THD in source current and input power factor.

16. Simulation of Dual Converter – 4 quadrant operation of separately excited DC motor

Aim: To simulate a dual converter for a separately excited DC motor and to understand the four quadrant operation

17. Simulation of buck/boost/buck-boost converters

Aim: To simulate a buck, boost and buck boost converter using MATLAB/equivalent or any other simulation platform and analyse the performance under various duty ratio/ switching frequency.

18. Simulation of single phase & three phase sine PWM inverters.

Aim: To simulate a single phase and three phase sine PWM inverter using MATLAB/equivalent

19. Simulation of 3-phase fully-controlled converter with R, RL, RLE loads

Aim: To simulate a 3-phase fully controlled converter with R,RL and RLE loads and observe the waveform in MATLAB simulink/equivalent.

20. Comparative study of PWM and Square wave inverters.

Aim:-To analyse THD, fundamental component of output voltage in PWM and Square wave inverters (single phase) using MATLAB/equivalent.

Mandatory Group Project Work : Students have to do a mandatory micro project (group size not more than 5 students) preferably a simulation work. A report also is to be submitted. Performance can be evaluated along with the internal test and a maximum of 5 marks shall be awarded.

Reference Books:

1. L. Umanand: Power Electronics – Essentials & Applications, Wiley-India
2. Mohan, Undeland, Robbins: Power Electronics, Converters, Applications & Design, Wiley-India
3. Muhammad H. Rashid: Power Electronics Circuits, Devices and Applications, Pearson Education
4. Ned Mohan A: "First course on power electronics and drives", MNPERE, 2003 Edn.

HUT 310	Management for Engineers	Category	L	T	P	Credit
		HMC	3	0	0	3

Preamble: This course is intended to help the students to learn the basic concepts and functions of management and its role in the performance of an organization and to understand various decision-making approaches available for managers to achieve excellence. Learners shall have a broad view of different functional areas of management like operations, human resource, finance and marketing.

Prerequisite: Nil

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

CO1	Explain the characteristics of management in the contemporary context (Cognitive Knowledge level: **Understand**).
CO2	Describe the functions of management (Cognitive Knowledge level: **Understand**).
CO3	Demonstrate ability in decision making process and productivity analysis (Cognitive Knowledge level: **Understand**).
CO4	Illustrate project management technique and develop a project schedule (Cognitive Knowledge level: **Apply**).
CO5	Summarize the functional areas of management (Cognitive Knowledge level: **Understand**).
CO6	Comprehend the concept of entrepreneurship and create business plans (Cognitive Knowledge level: **Understand**).

Mapping of course outcomes with program outcomes

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

Abstract POs defined by National Board of Accreditation			
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	PO10	Communication
PO5	Modern tool usage	PO11	Project Management and Finance
PO6	The Engineer and Society	PO12	Life long learning

Assessment Pattern

Bloom's Category	Test 1 (Marks in percentage)	Test 2 (Marks in percentage)	End Semester Examination (Marks in percentage)
Remember	15	15	30
Understand	15	15	30
Apply	20	20	40
Analyse			
Evaluate			
Create			

Mark Distribution

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

Continuous Internal Evaluation Pattern:

Attendance : 10 marks

Continuous Assessment - Test : 25 marks

Continuous Assessment - Assignment : 15 marks

Internal Examination Pattern:

Each of the two internal examinations has to be conducted out of 50 marks. First series test shall be preferably conducted after completing the first half of the syllabus and the second series test shall be preferably conducted after completing remaining part of the syllabus. There will be two parts: Part A and Part B. Part A contains 5 questions (preferably, 2 questions each from the completed modules and 1 question from the partly completed module), having 3 marks for each question adding up to 15 marks for part A. Students should answer all questions from Part A. Part B contains 7 questions (preferably, 3 questions each from the completed modules and 1 question from the partly completed module), each with 7 marks. Out of the 7 questions, a student should answer any 5.

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 a student should answer any one. Each question can have maximum 2 sub-divisions and carries 14 marks.

SYLLABUS

HUT 310 Management for Engineers (35 hrs)

Module 1 (Introduction to management Theory- 7 Hours)

Introduction to management theory, Management Defined, Characteristic of Management, Management as an art-profession, System approaches to Management, Task and Responsibilities of a professional Manager, Levels of Manager and Skill required.

Module 2 (management and organization- 5 hours)

Management Process, Planning types , Mission, Goals, Strategy, Programmes, Procedures, Organising, Principles of Organisation, Delegation, Span of Control, Organisation Structures, Directing, Leadership, Motivation, Controlling..

Module 3 (productivity and decision making- 7 hours)

Concept of productivity and its measurement; Competitiveness; Decision making process; decision making under certainty, risk and uncertainty; Decision trees; Models of decision making.

. Module 4 (project management- 8 hours)

Project Management, Network construction, Arrow diagram, Redundancy. CPM and PERT Networks, Scheduling computations, PERT time estimates, Probability of completion of project, Introduction to crashing.

Module 5 (functional areas of management- 8 hours)

Introduction to functional areas of management, Operations management, Human resources management, Marketing management, Financial management, Entrepreneurship, Business plans, Corporate social responsibility, Patents and Intellectual property rights.

References:

1. H. Koontz, and H. Weihrich, Essentials of Management: An International Perspective. 8th ed., McGraw-Hill, 2009.

2. P C Tripathi and P N Reddy, Principles of management, TMH, 4th edition, 2008.

3. P. Kotler, K. L. Keller, A. Koshy, and M. Jha, Marketing Management: A South Asian Perspective. 14th ed., Pearson, 2012.

4. M. Y. Khan, and P. K. Jain, Financial Management, Tata-McGraw Hill, 2008.

5. R. D. Hisrich, and M. P. Peters, Entrepreneurship: Strategy, Developing, and Managing a New Enterprise, 4th ed., McGraw-Hill Education, 1997.

6. D. J. Sumanth, Productivity Engineering and Management, McGraw-Hill Education, 1985.

7. K.Ashwathappa, 'Human Resources and Personnel Management', TMH, 3 rd edition, 2005.

8. R. B. Chase, Ravi Shankar and F. R. Jacobs, Operations and Supply Chain Management, 14th ed. McGraw Hill Education (India), 2015.

Sample Course Level Assessment Questions

Course Outcome1 (CO1): Explain the systems approach to management?

Course Outcome 2 (CO2): Explain the following terms with a suitable example Goal, Objective, and Strategy.

Course Outcome 3 (CO3): Mr. Shyam is the author of what promises to be a successful novel. He has the option to either publish the novel himself or through a publisher. The publisher is offering Mr. Shyam Rs. 20,000 for signing the contract. If the novel is successful, it will sell 200,000 copies. Else, it will sell 10,000 copies only. The publisher pays a Re. 1 royalty per copy. A market survey indicates that there is a 70% chance that the novel will be successful. If Mr. Shyam undertakes publishing, he will incur an initial cost of Rs. 90,000 for printing and marketing., but each copy sold will net him Rs. 2. Based on the given information and the decision analysis method, determine whether Mr. Shyam should accept the publisher's offer or publish the novel himself.

Course Outcome 4 (CO4): Explain the concepts of crashing and dummy activity in project management.

Course Outcome 5 (CO5): Derive the expression for the Economic order quantity (EOQ)?

Course Outcome 6 (CO6): Briefly explain the theories of Entrepreneurial motivation.?

Model Question Paper

QP CODE: PAGES: 4

Reg No:_______________ Name:_________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FOURTH SEMESTER B.TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: HUT 310

Course name: Management for Engineers

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

PART-A (Answer All Questions. Each question carries 3 marks)

1. “Management is getting things done through other.” Elaborate.

2. Comment on the true nature of management. Is it a science or an art?

3. Planning is looking ahead and controlling is looking back. Comment with suitable examples

4. Explain the process of communication?

5. Explain the hierarchy of objectives?

6. Explain the types of decisions?

7. Describe the Economic man model?

8. Explain the concepts of crashing and dummy activity in project management.

9. Differentiate the quantitative and qualitative methods in forecasting.

10. What are the key metrics for sustainability measurement? What makes the measurement and reporting of sustainability challenging?

PART-B (Answer any one question from each module)

11. a) Explain the systems approach to management. **(10)**

b) Describe the roles of a manager **(4)**

OR

12. a) Explain the 14 principles of administrative management? **(10)**

b) Explain the different managerial skills (**4)**

13. a) What are planning premises, explain the classification of planning premises. **(10)**

b) Distinguish between strategy and policy. How can policies be made effective. **(4)**

OR

14 a) Explain three motivational theories. **(9)**

b) Describe the managerial grid. **(5)**

15. a) Modern forest management uses controlled fires to reduce fire hazards and to stimulate new forest growth. Management has the option to postpone or plan a burning. In a specific forest tract, if burning is postponed, a general administrative cost of Rs. 300 is incurred. If a controlled burning is planned, there is a 50% chance that good weather will prevail and burning will cost Rs. 3200. The results of the burning may be either successful with probability 0.6 or marginal with probability 0.4. Successful execution will result in an estimated benefit of Rs. 6000, and marginal execution will provide only Rs. 3000 in benefits. If the weather is poor, burning will be cancelled incurring a cost of Rs. 1200 and no benefit. i) Develop a decision tree for the problem. (ii) Analyse the decision tree and determine the optimal course of action. **(8)**

b) Student tuition at ABC University is $100 per semester credit hour. The Education department supplements the university revenue by matching student tuition, dollars per dollars. Average class size for typical three credit course is 50 students. Labour costs are $4000 per class, material costs are $20 per student, and overhead cost are $25,000 per class. (a) Determine the total factor productivity. (b) If instructors deliver lecture 14 hours per week and the semester lasts for 16 weeks, what is the labour productivity? **(6)**

OR

16. a) An ice-cream retailer buys ice cream at a cost of Rs. 13 per cup and sells it for Rs. 20 per cup; any remaining unsold at the end of the day, can be disposed at a salvage price of Rs. 2.5 per cup. Past sales have ranged between 13 and 17 cups per day; there is no reason to believe that

sales volume will take on any other magnitude in future. Find the expected monetary value and EOL, if the sales history has the following probabilities: **(9)**

Market Size	13	14	15	16	17
Probability	0.10	0.15	0.15	0.25	0.35

b) At Modem Lumber Company, Kishore the president and a producer of an apple crates sold to growers, has been able, with his current equipment, to produce 240 crates per 100 logs. He currently purchases 100 logs per day, and each log required 3 labour hours to process. He believes that he can hire a professional buyer who can buy a better quality log at the same cost. If this is the case, he increases his production to 260 crates per 100 logs. His labour hours will increase by 8 hours per day. What will be the impact on productivity (measured in crates per labour-hour) if the buyer is hired? What is the growth in productivity in this case? **(5)**

17. a) A project has the following list of activities and time estimates:

Activity	**Time (Days)**	**Immediate Predecessors**
A	1	-
B	4	A
C	3	A
D	7	A
E	6	B
F	2	C, D
G	7	E, F
H	9	D
I	4	G, H

(a) Draw the network. (b) Show the early start and early finish times. (c) Show the critical path. **(10)**

b) An opinion survey involves designing and printing questionnaires, hiring and training personnel, selecting participants, mailing questionnaires and analysing data. Develop the precedence relationships and construct the project network. **(4)**

OR

18. a) The following table shows the precedence requirements, normal and crash times, and normal and crash costs for a construction project:

Activity	Immediate Predecessors	Required Time (Weeks)		Cost (Rs.)	
		Normal	Crash	Normal	Crash
A	-	4	2	10,000	11,000
B	A	3	2	6,000	9,000
C	A	2	1	4,000	6,000
D	B	5	3	14,000	18,000
E	B, C	1	1	9,000	9,000
F	C	3	2	7,000	8,000
G	E, F	4	2	13,000	25,000
H	D, E	4	1	11,000	18,000
I	H, G	6	5	20,000	29,000

Draw the network. (b) Determine the critical path. (c) Determine the optimal duration and the associated cost. **(10)**

b) Differentiate between CPM and PERT. **(4)**

19. a) What is meant by market segmentation and explain the process of market segmentation **(8)**

b) The Honda Co. in India has a division that manufactures two-wheel motorcycles. Its budgeted sales for Model G in 2019 are 80,00,000 units. Honda's target ending inventory is 10,00, 000 units and its beginning inventory is 12, 00, 000 units. The company's budgeted selling price to its distributors and dealers is Rs. 40, 000 per motorcycle. Honda procures all its wheels from an outside supplier. No defective wheels are accepted. Honda's needs for extra wheels for replacement parts are ordered by a separate division of the company. The company's target ending inventory is 3,00,000 wheels and its beginning inventory is 2,00,000 wheels. The budgeted purchase price is Rs. 1,600 per wheel.

(a) Compute the budgeted revenue in rupees.

(b) Compute the number of motorcycles to be produced.

Compute the budgeted purchases of wheels in units and in rupees.? **(6)**

OR

20. a) a) "Human Resource Management policies and principles contribute to effectiveness, continuity and stability of the organization". Discuss. (b) What is a budget? Explain how sales budget and production budgets are prepared? **(10)**

b) Distinguish between the following: (a) Assets and Liabilities (b) Production concept and Marketing concept (c) Needs and Wants (d) Design functions and Operational control functions in operations **(4)**

Teaching Plan

Sl.No	TOPIC	SESSION
	Module I	
1.1	Introduction to management	1
1.2	Levels of managers and skill required	2
1.3	Classical management theories	3
1.4	neo-classical management theories	4
1.5	modern management theories	5
1.6	System approaches to Management,	6
1.7	Task and Responsibilities of a professional Manager	7
	Module 2	
2.1	Management process – planning	8
2.2	Mission – objectives – goals – strategy – policies – programmes – procedures	9
2.3	Organizing, principles of organizing, organization structures	10
2.4	Directing, Leadership	11
2.5	Motivation, Controlling	12
	Module III	
3.1	Concept of productivity and its measurement Competitiveness	13
3.2	Decision making process;	14
3.3	Models in decision making	15
3.4	Decision making under certainty and risk	16
3.5	Decision making under uncertainty	17
3.6	Decision trees	18
3.7	Models of decision making.	19
	Module IV	
4.1	Project Management	20

Sl.No	TOPIC	SESSION
	Module I	
4.2	Network construction	21
4.3	Arrow diagram, Redundancy	22
4.4	CPM and PERT Networks	23
4.5	Scheduling computations	24
4.6	PERT time estimates	25
4.7	Probability of completion of project	26
4.8	Introduction to crashing	
	Module V	
5.1	Introduction to functional areas of management,	28
5.2	Operations management	29
5.3	Human resources management ,	30
5.4	Marketing management	31
5.5	Financial management	32
5.6	Entrepreneurship,	33
5.7	Business plans	34
5.8	Corporate social responsibility, Patents and Intellectual property rights	35

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET312	BIOMEDICAL INSTRUMENTATION	PEC	2	1	0	3

Preamble :**Nil**

Prerequisite :**Measurements and Instrumentation**

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

CO 1	Explain the basics of anatomy and physiology of human body.
CO 2	Explain different techniques for the measurement of various physiological parameters.
CO 3	Describe modern imaging techniques for medical diagnosis
CO 4	Identify the various therapeutic equipments used in biomedical field
CO 5	Discuss the patient safety measures and recent advancements in medical field.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	2	-	-	-	-	2	-	-	-	-	-	-
CO 2	2	-	2	-	-	2	-	-	-	-	-	-
CO 3	2	-	2	-	-	2	-	-	-	-	2	-
CO 4	2	2	-	-	-	2	-	-	-	-	2	-
CO 5	2	2	2	-	-	2	-	-	-	-	-	1

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**		**End Semester Examination**
	1	**2**	
Remember	15	15	30
Understand	20	20	40
Apply	15	15	30
Analyse			
Evaluate			
Create			

End Semester Examination Pattern : There will be two parts; Part A and Part B. **Part A**contain 10 questions (each carrying 3 marks) with 2 questions from each module. Students should answer all questions.

Part B contains 2 questions from each module, out of which students should answer any one. Each question can have maximum 2 sub-divisions and carries 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the anatomy of heart and cardiac system.
2. Describe the physiology of respiratory system.
3. Discuss the generation and propagation of action potential with neat sketches.
4. Explain electrode theory and Nernst equation.
5. Draw and explain the equivalent circuit of skin electrode interface.
6. Discuss about surface electrodes.
7. What are the applications of needle electrodes?
8. What are microelectrodes?
9. What are the different bioelectrical potentials generated in human body?

Course Outcome 2 (CO2):

1. What are the problems encountered in measuring living systems?
2. Explain the direct method of blood pressure measurement.
3. Explain the indirect method of blood pressure measurement.
4. Explain the Oscillometric method of blood pressure measurement.
5. Explain the Ultrasonic method of blood pressure measurement.
6. Explain the method of blood flow measurement using electromagnetic blood flowmeter.
7. Explain the method of blood flow measurement using Ultrasonic blood flowmeter.
8. Explain the measurement of Cardiac output.
9. What is phonocardiography?
10. Explain the measurement of respiratory parameters using spirometer.

Course Outcome 3(CO3):

1. Explain ECG with a neat block diagram.
2. What is Einthoven triangle?
3. With neat sketches explain the different electrode placement schemes of ECG.
4. Explain the 10-20 system of EEG electrodes placement.
5. Draw and explain the block diagram of EEG machine.
6. Draw and explain the block diagram of EMG recorder.
7. What are the applications of EEG waveforms?
8. Draw the different EEG waveforms and state its frequency.

Course Outcome 4 (CO4):

1. Explain the generation of X-rays and also mention its applications in biomedical engineering.
2. What are the types of CAT scanning?
3. Explain the principle of MRI scanning.
4. Explain the principle of PET scanning.
5. Explain demand pacemaker with a neat block diagram.
6. Why a dual peak DC defibrillator preferred over DC defibrillator?

7. Explain artificial kidney with neat sketches.
8. Explain shortwave diathermy.
9. Explain microwave diathermy.

Course Outcome 5 (CO5):

1. Discuss the need for ventilators.
2. Draw and explain the block diagram of infant incubator.
3. Explain lithotripsy.
4. What is a heart lung machine**?**
5. What are the different methods of accident prevention in hospitals?
6. Differentiate between macro shock and micro shock.
7. Explain the physiological effects of electric current.
8. Draw the block diagram of a telemetry system.
9. What are the chemical blood tests carried out in a clinical laboratory?
10. Enumerate the application of robotics in medical field.

Model Question paper
QP CODE:

PAGES: 2

Reg. No:_______________
Name:_______________

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

Course Code: EET312

Course Name: Biomedical Instrumentation

Max. Marks: 100 Duration: 3 Hours

PART A (3 x 10 = 30 Marks)

Answer all Questions. Each question carries 3 Marks

1. What are Microelectrodes?
2. What are the different bioelectrical potentials generated in human body?
3. Explain the measurement of Cardiac output.
4. What is Phonocardiography?
5. What are the applications of EEG waveforms?
6. Explain the 10-20 system of EEG electrodes placement.
7. What are the types of CAT scanning?
8. Explain the principle of MRI scanning.
9. What are the different methods of accident prevention in hospitals?
10. Discuss the need for ventilators.

PART B (14 x 5 = 70 Marks)

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

Module 1

11. a) Discuss the generation and propagation of action potential with neat sketches. **(8)**

b) Draw and explain the equivalent circuit of skin electrode interface. **(6)**

12. a) Briefly explain different Bio potential electrodes. **(10)**

b) Discuss about surface electrodes. **(4)**

Module 2

13. a) Explain the Ultrasonic method of blood pressure measurement. **(7)**

b) Explain the method of blood flow measurement using electromagnetic blood flow meter **(7)**

14. a) Explain the direct method of blood pressure measurement. **(7)**

b) Explain the measurement of respiratory parameters using Spirometer **(7)**

Module 3

15. a) Draw and explain the block diagram of EEG machine. **(8)**

b) Explain the significance of Einthoven triangle. **(6)**

16. a)Draw the different EEG waveforms and state its frequency **(7)**

b) Explain ECG with a neat block diagram **(7)**

Module 4

17. a)Explain the generation of X-rays and also mention its applications in biomedical engineering. **(14)**

18. a)Explain the principle of CAT scanning **(7)**

b) Explain the principle of MRI scanning **(7)**

Module 5

19. a) Draw the block diagram of infant incubator and explain **(10)**

b) Write a note on medical robotics **(4)**

20. a) What are the chemical blood tests carried out in a clinical laboratory **(10)**

b) Explain artificial kidney with neat sketches **(4)**

Syllabus

Module 1

Human Physiological systems:Brief discussion of Heart andCardio-vascular system-Physiology of Respiratory system - Anatomy of Nervous and Muscular systems-Problems encountered in measuring living systems

Bioelectric potential: Resting and action potential - Generation and propagation - Bioelectric potentials associated with physiology systems (ECG, EEG and EMG).

Bio potential Electrodes: Theory – Surface electrode – Microelectrode-Needle electrodes.

Transducers for biomedical applications: Transducers for the measurement of pressure, temperature and respiration rate.

Module 2

Measurement of blood pressure:Direct and indirect measurement – Oscillometric method – Ultrasonic method-Measurement of blood flow and cardiac output- Plethysmography –Photo electric and Impedance Plethysmographs-Measurement of heart sounds –Phonocardiography.

Cardiac measurements: Electro-conduction system of the heart- Electro-cardiography – Electrodes and leads – Einthoven triangle- ECG read out devices-ECG machine – block diagram

Module 3

Measurements from the nervous system:Neuronal communication-EEG waveforms and features - 10-20 electrode measurement- EEG Block diagram – Brain-Computer interfacing.

Muscle response: Electromyography- Block diagram of EMG recorders – Nerve conduction velocity measurement

Measurements of respiratory parameters: Spiro meter-Pneumograph

Module 4

Modern Imaging Systems: Basic X-ray machines - CAT scanner- Principle of operation - scanning components - Ultrasonic Imaging principle - types of Ultrasound Imaging - MRI and PET scanning(Principle only).

Therapeutic equipment: Cardiac Pacemakers - De-fibrillators - Hemodialysis machines - Artificial kidney – Lithotripsy - Short wave and Micro wave Diathermy machines

Module 5

Ventilators - Heart Lung machine - Infant Incubators

Instruments for clinical laboratory: Test on blood cells – Chemical tests

Electrical safety: Physiological effects of electric current – Shock hazards from electrical equipment – Method of accident prevention.

Introduction to Tele- medicine - Introduction to medical robotics

Text Books

L. Cromwell, F. J. Weibell and L. A. Pfeiffer, "Biomedical Instrumentation Measurements", Pearson education, Delhi, 1990.

J. G. Webster, "Medical Instrumentation, Application and Design", John Wiley and Sons

Reference Books

1. R. S. Khandpur, "Handbook of Biomedical Instrumentation", Tata McGraw Hill
2. J. J. Carr and J. M. Brown, "Introduction to Biomedical Equipment Technology", Pearson Education
3. AchimSchweikard, "Medical Robotics", Springer

Course Contents and Lecture Schedule

Sl. No.	Topic	No. of Lectures
1	**Human Physiology Systems and Transducers (8 hours)**	
1.1	Problems encountered in measuring living systems - Cardio-vascular – Respiratory- nervous and muscular systems of the body.	2
1.2	Electrode theory-Bioelectric potential - Resting and action potential - Generation and propagation.	1
1.3	Bioelectric potentials associated with physiology systems (ECG, EEG and EMG).	1
1.4	Electrodes Theory - Surface electrode - Needle electrode - Microelectrode	2
1.5	Transducers for the measurement of Pressure, temperature and respiration rate.	2
2	**Cardio Vascular System Measurements(8 hours)**	
2.1	Measurement of blood pressure – direct and indirect measurement – Oscillometric measurement –Ultrasonic method	2
2.2	Measurement of blood flow and cardiac output -Plethysmography – Photo electric and Impedance Plethysmographs	3
2.3	Measurement of heart sounds –Phonocardiography.	1

2.4	Electro-conduction system of the heart - Electro Cardiography – Electrodes and leads – Einthoven triangle.	1
2.5	ECG read out devices - ECG machine – Block diagram	1
3	**Nervous System and its Measurements(7 hours)**	
3.1	Neuronal communication - Measurements from the nervous system.	1
3.2	Electroencephalography- Lead system -10-20 Electrode system,	1
3.3	EEG Block diagram - EEG waveforms and features – Brain-Computer interfacing.	2
3.4	Electromyography- Block diagram of EMG recorders - Nerve conduction velocity	2
3.5	Respiratory parameters measurements – Spiro meter - Pneumography.	1
4	**Modern Imaging Systems and Therapeutic Equipment(7 hours)**	
4.1	Basic X-ray machines	1
4.2	CAT Scanner- Principle of operation - Scanning components	1
4.3	Ultrasonic imaging principle - Types of Ultrasound imaging - MRI and PET scanning(Principle only).	2
4.4	Cardiac pace makers - De-fibrillators	1
4.5	Hemo-dialysis machines -Artificial kidney -Lithotripsy	1
4.6	Short wave and Micro wave diathermy machines	1
5	**Instrumentation for Patient Support and Safety(6 hours)**	
5.1	Ventilators - Heart lung machine - Infant incubators	1
5.2	Instruments for clinical laboratory – Test on blood cells – Chemical tests	1
5.3	Electrical safety– Physiological effects of electric current	1
5.4	Shock hazards from electrical equipment - Method of accident prevention	1
5.5	Introduction to tele- medicine	1
5.6	Introduction to medical robotics	1

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET394	**GENERALIZED MACHINE THEORY**	**VAC**	**4**	**0**	**0**	**4**

Preamble: Nil

Prerequisite: DC Machines and Transformers. Synchronous and Induction machines

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

CO 1	Develop the basic two pole model representation of electrical machines using the basic concepts of generalized theory.
CO 2	Develop the linear transformation equations of rotating electrical machines incorporating the concept of power invariance.
CO 3	Apply linear transformation for the steady state and transient analysis of different types of rotating electrical machines.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	2	2	2	-	-	-	-	-	-	-	-	**2**
CO 2	3	3	2	**2**	-	-	-	-	-	-	-	**2**
CO 3	3	3	3	**2**	-	-	-	-	-	-	-	**2**

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**		**End Semester Examination**
Remember	5	5	10
Understand	10	10	20
Apply	35	35	70
Analyse			
Evaluate			
Create			

End Semester Examination Pattern : There will be two parts; Part A and Part B. **Part A** contains 10 questions (each carrying 3 marks) with 2 questions from each module. Students should answer all questions.

Part B contains 2 questions from each module, out of which students should answer any one. Each question can have maximum 2 sub-divisions and carries 14 marks.

Part A: 10 Questions x 3 marks=30 marks, **Part B:** 5 Questions x 14 marks =70 marks

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain Kron's Primitive Machine of rotating electrical machines.
2. Describe the essential features of rotating electrical machines.
3. Draw the basic two pole machine diagram of DC Compound Machine.
4. Develop an expression for the electrical torque of the Kron's Primitive Machine.

Course Outcome 2 (CO2):

1. What are the advantages of having power invariance in transformations.
2. Deduce Parks transformations relating three phase currents to its corresponding d- q axis currents.
3. Draw the generalized model of a DC series machine and derive the voltage equation in matrix form.
4. Explain the physical significance of Park's transformations.

Course Outcome 3 (CO3):

1. Explain the steady state analysis of a separately excited DC motor and derive the expression for electromagnetic torque. Also plot the shunt characteristics and speed versus armature voltage characteristics.
2. Obtain the expression for the steady state torque when balanced poly phase supply is impressed on the stator winding of three phase Induction motor
3. Draw the equivalent circuit of a three phase induction motor with the help of its generalized model.
4. Investigate the transient behaviour of a separately excited DC generator under the following operating condition: sudden application of a step field excitation to the field under no load, i_a =0 and for constant no load speed ω_{r0} and explore the variation of armature voltage.

Model Question paper

QP CODE:

PAGES: 2

Reg.No:_______________
Name:_________________

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

Course Code: EET394
Course Name: GENERALIZED MACHINE THEORY

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

PART A

Answer all questions. Each Question Carries 3 marks

1. Sketch the basic two pole representation of the following machines
   i) DC shunt machine with interpoles ii) DC compound machine
2. Explain linear transformations as used in electrical machines.
3. What is Kron's primitive machine?
4. Enumerate the limitations of generalized theory of electrical machines.
5. Derive an expression for rotational mutual inductance or motional inductance of DC generator
6. Derive the transfer function of separately excited DC motor under on no load operation.
7. Draw the power angle characteristics of salient pole and cylindrical rotor synchronous machine.
8. Draw the torque slip characteristics of three phase Induction motor.
9. Explain equivalent circuit of single phase Induction motor.
10. Compare single phase and poly phase Induction motor.

PART B

Answer any one full question from each module. Each question carries 14 marks.

Module 1

11. a) Write the voltage equations for Kron's primitive machine in matrix form. **(9)**
    b) Derive the expression for transformer and speed voltages in the armature along the quadrature axis. **(5)**
12. Derive electrical torque expression of Kron's primitive machine in terms of reluctance and show that no torque is produced by interaction between flux and current on the same axis. **(14**

Module 2

13. Explain Park's transformations to transform currents between a rotating balanced three phase (a, b, c) winding to a pseudo stationary two phase (d, q) winding. Assume equal number of turns on all coils **(14)**

14. a) Explain the physical concept of Park's transformation **(7)**

b) Explain the term invariance of power as applied to electrical machines. Show the power invariance is maintained under this transformation. **(7)**

Module 3

15. a) Derive the voltage and torque equation of a DC series motor from its generalized mathematical model. **(7)**

b) Obtain the steady state analysis of a separately excited DC motor and plot the shunt characteristics. Also derive the expression for torque. **(7)**

16. a) A separately excited DC generator gives a no load output voltage of 240 V at a speed of ωr and a field current of 3 A. Find the generated emf per field ampere, Kg. **(5)**

b) Investigate the transient behaviour of a separately excited DC generator under the following operating condition:

i) Sudden application of a step field excitation to the field under no load, $i_a = 0$ and for constant no load speed ωr0 and explore the variation of armature voltage. **(9)**

Module 4

17) a) Derive the power expression for salient pole synchronous machine in terms of load angle δ and draw the power angle characteristics. **(7)**

b) Derive the voltage equations in matrix form for a three phase synchronous machine with no amortisseurs. **(7)**

18) Derive the equivalent circuit of a poly phase induction motor with the help of its generalized mathematical model. **(14)**

Module 5

19) Derive the electromagnetic torque equations from the primitive machine model of a single phase induction motor by applying cross field theory. **(14)**

20) Explain the double field revolving theory of single phase Induction motor. **(14)**

Syllabus

Module 1

Unified approach to the analysis of electrical machine performance - per unit system - Basic two polemodel of rotating machines- Primitive machine -Conventions -transformer and rotational voltages in the armature voltage and torque equations, resistance, inductance and torque matrix.

Module 2

Transformations-passive linear transformation in machines-invariance of power-transformation from a displaced brush axis-transformation from three phase to two phase and from rotating axes to stationary axes-Physical concept of Park's transformation.

Module 3

DC Machines: Application of generalized theory to separately excited DC generator: steady state and transient analysis, Separately excited DC motor- steady state and transient analysis, Transfer function of separately excited DC generator and motor- DC shunt and series motors: Steady state analysis and characteristics.

Module 4

Synchronous Machines: synchronous machine reactance and time constants-Primitive machine model of synchronous machine with damper windings on both axes. Balanced steady state analysis-power angle curves.

Induction Machines: Primitive machine representation. Transformation- Steady state operation-Equivalent circuit. Torque slip characteristics.

Module 5

Single phase induction motor- Revolving Field Theory equivalent circuit- Voltage and Torque equations-Cross field theory-Comparison between single phase and poly phase induction motor.

Text Books

1) Bhimbra P. S., “Generalized Theory of Electrical Machines”, Khanna Publishers, 6thedition, Delhi 2017.
2) Charles V. Johnes, “Unified Theory of Electrical Machines”. New York, Plenum Press, 1985.
3) Bernad Adkins, Ronald G Harley, “General theory of AC Machines”. London, Springer Publications, 2013.

Reference Books

1) Charles Concordia,” Synchronous Machines- Theory and Performance”, John Wiley and Sons Incorporate, Newyork.1988.
2) Say M. G., “Introduction to Unified Theory of Electrical Machines”, Pitman Publishing, 1978.

3) Alexander SLangsdorf, "Theory of Alternating Current Machinery", Tata McGraw Hill, 2nd revised edition, 2001.

Course Contents and Lecture Schedule

Sl. No.	Topic	No. of Lectures
1	**Two pole Model (10 Hours)**	
1.1	Introduction- Essentials of rotating machines-Electromechanical energy conversion. Conventions.	1
1.2	Idealised machine diagram of DC Compound machine, DC shunt machine, Synchronous motor, Induction motor, Single phase AC motor.	2
1.3	Per unit system, Advantages of per unit system, Expression for self inductance of a machine, Mutual flux linking.	1
1.4	Transformer and speed voltages in the armature, transformer with movable secondary.	2
1.5	Kron's primitive machine, Leakage flux in machines with more than two windings. Fundamental assumptions.	2
1.6	Voltage equations, Stator field coils, Armature coils, Equations of armature voltage in matrix form,	2
2	**Linear Transformations (8 Hours)**	
2.1	Linear transformation in machines- power invariance, Transformations from a displaced brush axis.	2
2.2	Transformations from three phase to two phase (a,b,c) to (α,β,0) transformation matrix.	3
2.3	Transformation from rotating axes (α,β,0) to stationary axes (d,q,0).	2
2.4	Power invariance: problems on transformations	1
3	**DC Machines (10 Hours)**	
3.1	DC machines, Separately excited DC generators, Rotational mutual inductance, Steady state and transient analysis, Armature terminal voltage.	2
3.2	Transfer function of DC machines, Separately excited generator under no load and loaded condition, Numerical Problems.	2
3.3	Steady state analysis and Shunt characteristics of DC machine.	2

3.4	DC series motor, Schematic diagram of Primitive model, Interconnection between armature and field, Torque and speed expression, Different characteristics.	2
3.5	DC shunt motor, Schematic diagram, primitive model, Steady state analysis, Torque-Current and Speed-Current characteristics, Condition for maximum torque.	2
4	**Synchronous and Three Phase Induction Motors(10 Hours)**	
4.1	Poly phase Synchronous machine, Basic structure, Assumptions, Parameters, Synchronous resistance, inductance and mutual inductance between armature and field.	2
4.2	Armature self-inductance, Armature mutual inductance, General synchronous machine parameters, Amplitude of second harmonic component.	2
4.3	Steady state power angle characteristics, reluctance power, Cylindrical rotor machine and salient pole machine, Phasor diagram, Pull out torque, Maximum power.	2
4.4	Polyphase induction machine, Voltage expression, Transformations fromαβ to d-q and vice versa, Expression for electromagnetic torque.	2
4.5	Steady state analysis, Voltage equation in new variables, Connection matrix,	1
4.6	Equivalent circuit of an induction machine, Short circuited and open circuited two winding transformer.	1
5	**Single Phase Induction Motors(7 Hours)**	
5.1	Single phase induction motor, Basic structure, Assumptions, Primitive Machine Model.	2
5.2	Electrical Performance Equations, Voltage Matrix.	2
5.3	Steady state analysis, Equivalent Circuit	2
5.4	Numerical Problems	1