SEMESTER VII

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET401	DESIGN OF MACHINE ELEMENTS	PCC	2	1	0	3

Preamble: This course focuses on important topics in design of machine elements. It covers the topics of shaft design with due consideration based on strength and rigidity. The course also includes the design procedure of flat belts and connecting rod of IC engines. The other topics included are journal bearings design, ball and roller bearings, spur gear and helical gear deign considerations. The syllabus also covers design procedure of bevel gear and worm gear.

Prerequisite: MET304 Dynamics and Design of Machinery

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

CO 1	Design shafts based on strength, rigidity and design for static and fatigue loads, design flat belts and connecting rod of IC engines
CO 2	Design clutches and brakes
CO 3	Analyse sliding contact bearings and understand design procedure of journal, ball and roller bearings.
CO 4	Design Spur gear and helical gear
CO 5	Design Bevel gears and worm gears

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

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember			
Understand	20	20	30
Apply	30	30	70
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. What is critical speed of a shaft?
2. What are the causes of failure in shafts?
3. Differentiate between torsional rigidity and lateral rigidity of shaft.
4. Enumerate the various types of flat belt drives.
5. Explain why I section is usually preferred in the case of a connecting rod?

Course Outcome 2 (CO2)

1. What is the function of a clutch?
2. Why are cone clutches better than disc clutches?
3. What is the principle of operation of a centrifugal clutch? What are its applications?
4. What are the advantages and disadvantages of band brake?
5. What are the types of brake lining?

Course Outcome 3 (CO3):

1. Explain hydrodynamic theory.
2. Discuss the significance of bearing modulus in the design of journal bearing?
3. Briefly describe the design procedure of Journal bearings
4. Define static and dynamic load carrying capacity of ball bearing.

5. What is L_{10} and L_{50} life of ball bearing?

Course Outcome 4 (CO4):

1. State and explain law of gearing.
2. Give an account on different modes of failure of gear tooth.
3. Explain why dynamic factors need to be considered in the design of gears.
4. Explain interference and undercutting in gears
5. What are the advantages of helical gears over spur gears?
6. What is beam strength in case of helical gears?

Course Outcome 5 (CO5):

1. What are the uses of bevel gears?
2. Classify bevel gears.
3. What is formative number of teeth in case of bevel gears?
4. What are the characteristics of worm gears?
5. Enumerate the applications of worm gears?
6. Describe the design procedure of worm gears?

Model Question Paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

VII SEMESTER BTECH DEGREE EXAMINATION

MET401: DESIGN OF MACHINE ELEMENTS

Maximum: 100Marks Duration:3 hours

Use of Machine Design Data Book is permitted.

PART A

Answer all questions, each question carries 3 marks

1. Compare the strength and stiffness of a hollow shaft of same outside diameter as that of a solid shaft.
2. Explain about the material for used for flat belts
3. How clutch is different from coupling?
4. What are the requirements for a good friction material used for the brakes?
5. What are the types of lubrication for bearings?
6. What are the causes of bearing failure?
7. Draw a neat sketch and indicate terminology used in spur Gear
8. What is virtual or equivalent number of teeth in case of helical gears?
9. What is a herringbone gear? What are its advantages?
10. Why a worm set can only be used as jack and hoists for raising loads. (10×3=30Marks)

PART B

Answer one full question from each module

MODULE 1

11. a) A shaft is supported by two bearings 1 m apart. A 600 mm diameter pulley is mounted at a distance of 300 mm to the right of left hand bearing and this drives a pulley directly below it with the help of a belt having maximum tension of 2.25 kN. Another pulley 400 mm diameter is placed 200 mm to the left of right hand bearing and is driven with the help of electric motor and belt, which is placed horizontally to the right. The angle of contact for both the pulley is 1800 and μ=0.24. Determine the suitable diameter for a solid shaft .The allowable working stress is 63 MPa in tension and 42 MPa in shear for the material of the shaft. Assume that the torque on one pulley is equal to that on the other pulley. (10 marks)

    b) Differentiate between torsional rigidity and lateral rigidity of shaft. (4 marks)

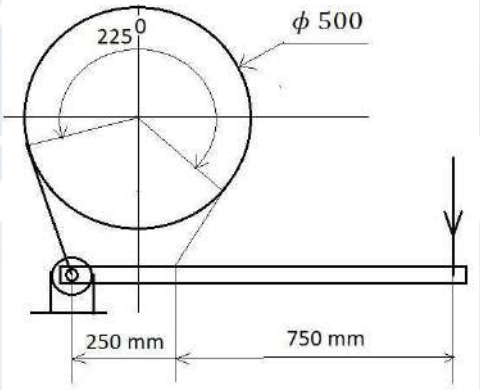
12. Design a flat belt drive for a compressor running at 670 rpm, which is driven by a 25 kW, 1340 rpm motor. Space is available for a centre distance of 3 m. The belt is open type. (14 marks)

MODULE 2

13. a) Determine the main dimensions of a cone clutch faced with leather to transmit 30 kW at 750 rpm from an electric motor to an air compressor. Assume an over load factor of 1.75. Due to possibility of contamination of lining, a low value of coefficient of friction 0.2 is recommended. (11 marks)

b) Distinguish between multiple plate clutch and cone clutch (3 marks)

14. a)A simple band brake as shown in figure below is to be designed to absorb a power of 32 kW at a rated speed of 850 rpm. Assume $\mu = 0.25$. Determine, (i) The effort required to stop clockwise rotation of the brake drum, (ii) The effort required to stop counter clockwise rotation of the brake drum,(iii) The dimensions of the rectangular cross-section of the brake lever assuming its depth to be twice the width, and (iv) the dimensions of the cross-section of the band assuming its width to be ten times the thickness. (10 marks)



b) What are the different types of brakes? (4 marks)

MODULE 3

15. A 360^{o} hydrodynamic journal bearing operates at 1200 rpm and carries a load of 5.5 k N. The journal diameter is 55 mm and length is 55 mm. The bearing is lubricated with SAE 20 oil and the operating temperature of oil is 79^{o}C. Assume radial clearance as 0.025 mm and the attitude angle as 60^{o}. Determine: (i) bearing pressure, (ii) Attitude, (iii) minimum film thickness, (iv)heat generated, (v) heat dissipated, if the ambient temperature is 25^{o}C, and (vi) amount of artificial cooling if necessary. (14 marks)

16. a) A single row deep groove ball bearing has a dynamic load capacity of 40210 N and operates on the work cycle consists of radial load of 2000 N at 1000 rpm for 25 % of the time, radial load of 5000 N at 1500 rpm for 50 % of time, and radial load of 3000 N at

700 rpm for the remaining 25 % of time. Calculate the expected life of the bearing in hours. (10 marks)

b) Explain the mechanism of fluid film lubrication (4 marks)

MODULE 4

17. A motor shaft rotating at 1440 rpm has to transmit 15 kW power to a low speed shaft running at 500 rpm. A 200 pressure angle full depth involute system of gear tooth is used. The pinion has 25 teeth. Both gear and pinion are made of cast iron having allowable static strength of 55 MPa. Design a suitable spur gear drive and check the design for dynamic load and wear. (14 marks)

18. A helical gear speed reducer is to be designed. The rated power of the speed reducer is 75 kW at a pinion speed of 1200 rpm. The speed ratio is 3:1. For medium shock conditions and 24 hr operation, design the gear pair. The teeth are20^{o} full depth involute in the normal plane and helix angle is 30^{o}. (14 marks)

MODULE 5

19. a) A pair of straight tooth bevel gears at right angles is to transmit 5 kW at 1200 rpm of the pinion. The diameter of the pinion is 80 mm and the speed reduction is 3.5:1. The tooth form is 20o full depth involute. Both the pinion and gear are made of cast iron with allowable stress of 55 MPa. Determine module and face width from the standpoint of strength. And also check the design from the standpoint of dynamic load and wear.

(14 marks)

20. Design a worm gear drive to transmit 20 HP from worm at 1440 rpm to the worm wheel that should be rotated at 40 $\pm$ 2% rpm. (14 marks)

Syllabus

Module 1

Shafting:- material, design considerations, causes of failure in shafts, design based on strength, rigidity, and critical speed, design for static and fatigue loads, repeated loading, reversed bending.

Design of flat belt:- material for belts, slip of the belts, creep, centrifugal tension, Power transmitted by flat belts, Design procedure of flat belts

Design of connecting rod in IC engine.

Module 2

Design of clutches: -single and multiple plate clutch, cone clutch, centrifugal clutch.

Design of brakes: -band brakes, block brakes, simple and differential band brake, internal expanding shoe brake.

Module 3

Sliding contact bearing: - lubrication, lubricants, viscosity, journal bearings, hydrodynamic theory, Petroff's equation, bearing characteristic number, Sommerfeld number, Heat generated in bearings, Heat dissipated by bearings, Design procedure of Journal bearings.

Ball and roller bearings: - Types, bearing life, static and dynamic load capacity, Stribeck's Equation, selection of bearings, selection of taper roller bearings, Design procedure of Ball and roller bearings, Needle bearings.

Module 4

Gears: - Materials of gears, terminology of spur Gear, Interference and undercutting, Gear tooth failures, Beam strength of Gear tooth, Estimation of module, Buckingham's equation for dynamic load, wear load, endurance strength of tooth, Gear proportions, Merits and demerits of each type of gears, Design procedure of Spur gear.

Helical gears: - Terminology, Virtual or equivalent number of teeth, Tooth proportions, Beam strength, and Wear strength of Helical gears, Design procedure of Helical gear

Module 5

Bevel gears: - Classification, Terminology, Pitch angle for bevel gears, Strength of bevel gear, beam strength, wear tooth load, Formative number of teeth, Design procedure of Bevel gear.

Worm gears: - Characteristics of worm gears, Terminology, Advantages and disadvantages, Applications, Terms in Worm gear, Strength of Worm gear, Dynamic strength, Wear tooth load, Design procedure of Worm gear.

Design Data Books (permitted for reference in the university examination)

1. Mahadevan, K., and K. Balaveera Reddy, Design Data Handbook, Mechanical Engineers in SI and Metric Units. CBS Publishers & Distributors, New Delhi, 2018.
2. NarayanaIyengar B.R &Lingaiah K, Machine Design Data Handbook, Tata McGraw Hill/Suma Publications, 1984
3. PSG Design Data, DPV Printers, Coimbatore, 2012

Reference Books

1. J. E. Shigley, *Mechanical Engineering Design*, McGraw Hill,2003
2. Jalaludeen, *Machine Design*, Anuradha Publications, 2016
3. V.B.Bhandari, *Design of Machine elements*, McGraw Hill, 2016
4. Juvinall R.C &Marshek K.M., *Fundamentals of Machine Component Design*, John Wiley, 2011
5. M. F. Spotts, T. E. Shoup, *Design of Machine Elements*, Pearson Education, 2006
6. RajendraKarwa, *Machine Design*, Laxmi Publications (P) LTD, New Delhi, 2006
7. Siegel, Maleev& Hartman, *Mechanical Design of Machines*, International Book Company, 1983

Course Contents and Lecture Schedule

Module	Topic	No. of Lectures
1.1	Shafting: - material, design considerations, causes of failure in shafts, design based on strength, rigidity, and critical speed, design for static and fatigue loads, repeated loading, reversed bending.	5
1.2	Design of flat belt:- material for belts, slip of the belts, creep, centrifugal tension, Power transmitted by flat belts, Design procedure of flat belts	3
1.3	Design of connecting rod in IC engine.	2
2.1	Design of clutches:-single and multiple plate clutch,cone clutch,centrifugal clutch	2
2.2	Design of brakes:-band brakes,block brakes,simple and differential band brake, internal expanding shoe brake.	3
3.1	Sliding contact bearing:- lubrication, lubricants, viscosity, journal bearings, hydrodynamic theory, Petroff's equation, bearing characteristic number, Sommerfeld number, Heat generated in bearings, Heat dissipated by bearings, Design procedure of Journal bearings.	4
3.2	Ball and roller bearings:- Types, bearing life, static and dynamic load capacity, Stribeck's Equation, selection of bearings, selection of taper roller bearings, Design procedure of Ball and	3

	roller bearings, Needle bearings.	
4.1	Gears:- Materials of gears, terminology of spur Gear, Interference and undercutting, Gear tooth failures, Beam strength of Gear tooth, Estimation of module, Buckingham's equation for dynamic load, wear load, endurance strength of tooth, Gear proportions, Merits and demerits of each type of gears, Design procedure of Spur gear.	5
4.2	Helical gears:- Terminology, Virtual or equivalent number of teeth, Tooth proportions, Beam strength, and Wear strength of Helical gears, Design procedure of Helical gear	3
5.1	Bevel gears:- Classification, Terminology, Pitch angle for bevel gears, Strength of bevel gear, beam strength, wear tooth load, Formative number of teeth, Design procedure of Bevel gear.	3
5.2	Worm gears:- Characteristics of worm gears, Terminology, Advantages and disadvantages, Applications, Terms in Worm gear, Strength of Worm gear, Dynamic strength, Wear tooth load, Design procedure of Worm gear.	2

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MEL411	MECHANICAL ENGINEERING LAB	PCC	0	0	3	2

Preamble: The course is intended to enable the students to get an exposure to equipment and exercises related to machine dynamics, cutting forces in milling machine, basics of pneumatic and hydraulic devices, basic concepts of stepper motors, basic ideas of data acquisition systems and automation.

Prerequisite: Should have undergone courses on Engineering Mechanics, Theory of Machines, Machine Tools.

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

CO 1	Get practical knowledge on design and analysis of mechanisms in the machines.
CO 2	Measure the cutting forces associated with milling machining operations.
CO 3	Apply the basic concepts of hydraulic and pneumatic actuators and their applications in product and processes
CO 4	Use appropriate systems for data acquisition and control of product and processes

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	75	75	2.5 hours

Continuous Internal Evaluation Pattern:

Attendance	:	15 marks
Continuous Assessment	:	30 marks
Internal Test (Immediately before the second series test)	:	30 marks

End Semester Examination Pattern: The following guidelines should be followed regarding award of marks

(a) Preliminary work : 15 Marks
(b) Implementing the work/Conducting the experiment : 10 Marks
(c) Performance, result and inference (usage of equipments and trouble shooting) : 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 entire syllabus 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 Exercises/Experiments: (Lab experiments may be given considering 12 sessions of 3 hours each. Minimum 10 experiments to be performed.)

1. Experiment on Whirling of shaft
2. Experiment on Gyroscope
3. Experiment on Universal governor apparatus
4. Experiment on Free vibration analysis
5. Experiment on Forced vibration analysis
6. Experiment on any Non destructive test.
7. Exercises on Milling Machine - slab milling/gear cutting
8. Milling forces – Milling parameters – measurement of milling forces in slab milling operations
9. Exercises on pneumatic circuits using pneumatic trainer unit
10. Exercises on hydraulic circuits using hydraulic trainer unit
11. Exercises on electro pneumatic and electro hydraulic circuits using trainer units
12. Exercises on 3-D printing
13. Exercises on Motion controller using AC/DC motor, servo motors and encoders to determine the operating characteristics.
14. Exercises on stepper motor to determine the operating characteristics.
15. Exercises on PC based data acquisition system with any software.
16. Study of SCADA and PLC programming
17. Interfacing SCADA with PLC and PC.
18. Controlling variable speed drive through PLC/SCADA

Reference Books

1. C.E.Wilson, P. Sadler, Kinematics and Dynamics of Machinery, Pearson Education, 2005
2. D.H.Myskza, Machines and Mechanisms Applied Kinematic Analysis, Pearson Education, 2013
3. W.Bolton, Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering, Person Education Limited, New Delhi, 2007
4. K.P.Ramachandran, G.K.Vijayaraghavan, M.S.Balasundaram, Mechatronics: Integrated Mechanical Electronic Systems, Wiley India Pvt. Ltd., New Delhi, 2008.
5. Serope Kalpakjian, Steven R. Schmid - Manufacturing Engineering and Technology, Pearson

MEQ413	SEMINAR	CATEGORY	L	T	P	CREDIT
		PWS	0	0	3	2

Preamble: The course 'Seminar' is intended to enable a B.Tech graduate to read, understand, present and prepare report about an academic document. The learner shall search in the literature including peer reviewed journals, conference, books, project reports etc., and identify an appropriate paper/thesis/report in her/his area of interest, in consultation with her/his seminar guide. This course can help the learner to experience how a presentation can be made about a selected academic document and also empower her/him to prepare a technical report.

Course Objectives:

- To do literature survey in a selected area ofstudy.
- To understand an academic document from the literate and to give a presentation about it.
- To prepare a technical report.

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

CO1	Identify academic documents from the literature which are related to her/his areas of interest (Cognitive knowledge level: **Apply**).
CO2	Read and apprehend an academic document from the literature which is related to her/ his areas of interest (Cognitive knowledge level: **Analyze**).
CO3	Prepare a presentation about an academic document (Cognitive knowledge level: **Create**).
CO4	Give a presentation about an academic document (Cognitive knowledge level: **Apply**).
CO5	Prepare a technical report (Cognitive knowledge level: **Create**).

Mapping of course outcomes with program outcomes:

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

Abstract POs defined by National Board of Accreditation			
PO#	**Broad PO**	**PO#**	**Broad PO**
PO1	Engineering Knowledge	PO7	Environment and Sustainability
PO2	Problem Analysis	PO8	Ethics
PO3	Design/Development of solutions	PO9	Individual and team work
PO4	Conduct investigations of complex problems	PO10	Communication
PO5	Modern tool usage	PO11	Project Management and Finance
PO6	The Engineer and Society	PO12	Life long learning

General Guidelines

- The Department shall form an Internal Evaluation Committee (IEC) for the seminar with academic coordinator for that program as the Chairperson/Chairman and seminar coordinator & seminar guide as members. During the seminar presentation of a student, all members of IEC shall be present.
- Formation of IEC and guide allotment shall be completed within a week after the University examination (or last working day) of the previous semester.
- Guide shall provide required input to their students regarding the selection of topic/ paper.
- Choosing a seminar topic: The topic for a UG seminar should be current and broad based rather than a very specific research work. It's advisable to choose a topic for the Seminar to be closely linked to the final year project area. Every member of the project team could choose or be assigned Seminar topics that covers various aspects linked to the Project area.
- A topic/paper relevant to the discipline shall be selected by the student during the semester break.
- Topic/Paper shall be finalized in the first week of the semester and shall be submitted to the IEC.
- The IEC shall approve the selected topic/paper by the second week of the semester.
- Accurate references from genuine peer reviewed published material to be given in the report and to be verified.

Evaluation pattern

Total marks: 100, only CIE, minimum required to pass 50

Seminar Guide: 20 marks (Background Knowledge – 10 (The guide shall give deserving marks for a candidate based on the candidate's background knowledge about the topic selected), Relevance of the paper/topic selected – 10).

Seminar Coordinator: 20 marks (Seminar Diary – 10 (Each student shall maintain a seminar diary and the guide shall monitor the progress of the seminar work on a weekly basis and shall approve the entries in the seminar diary during the weekly meeting with the student), Attendance – 10).

Presentation: 40 marks to be awarded by the IEC (Clarity of presentation – 10, Interactions – 10 (to be based on the candidate's ability to answer questions during the interactive session of her/his presentation), Overall participation – 10 (to be given based on her/his involvement during interactive sessions of presentations by other students), Quality of the slides – 10).

Report: 20 marks to be awarded by the IEC (check for technical content, overall quality, templates followed, adequacy of references etc.).

MED415	PROJECT PHASE I	CATEGORY	L	T	P	CREDIT
		PWS	0	0	6	2

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

Course Objectives

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

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

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

Mapping of course outcomes with program outcomes

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

Abstract POs defined by National Board of Accreditation			
PO#	**Broad PO**	**PO#**	**Broad PO**
PO1	Engineering Knowledge	PO7	Environment and Sustainability
PO2	Problem Analysis	PO8	Ethics
PO3	Design/Development of solutions	PO9	Individual and team work
PO4	Conduct investigations of complex problems	PO10	Communication
PO5	Modern tool usage	PO11	Project Management and Finance
PO6	The Engineer and Society	PO12	Lifelong learning

PROJECT PHASE I

Phase 1 Target

- Literature study/survey of published literature on the assigned topic
- Formulation of objectives
- Formulation of hypothesis/ design/ methodology
- Formulation of work plan and task allocation.
- Block level design documentation
- Seeking project funds from various agencies
- Preliminary Analysis/Modeling/Simulation/Experiment/Design/Feasibility study
- Preparation of Phase 1 report

Evaluation Guidelines & Rubrics

Total: 100 marks (Minimum required to pass: 50 marks).

- Project progress evaluation by guide: 30 Marks.
- Interim evaluation by the Evaluation Committee: 20 Marks.
- Final Evaluation by the Evaluation Committee: 30 Marks.
- Project Phase - I Report (By Evaluation Committee): 20 Marks.

(The evaluation committee comprises HoD or a senior faculty member, Project coordinator and project supervisor).

Evaluation by the Guide

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

Topic Selection: innovativeness, social relevance etc. (2)

Problem definition: Identification of the social, environmental and ethical issues of the project problem. (2)

Purpose and need of the project: Detailed and extensive explanation of the purpose and need of the project. (3)

Project Objectives: All objectives of the proposed work are well defined; Steps to be followed to solve the defined problem are clearly specified. (2)

Project Scheduling & Distribution of Work among Team members: Detailed and extensive Scheduling with timelines provided for each phase of project. Work breakdown structure well defined. (3)

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

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

Individual Contribution: The contribution of each student at various stages. (7)

EVALUATION RUBRICS for PROJECT Phase I: Interim Evaluation						
No.	**Parameters**	**Marks**	**Poor**	**Fair**	**Very Good**	**Outstanding**
1-a	Topic identification, selection, formulation of objectives and/or literature survey. (Group assessment) [CO1]	10	The team has failed to come with a relevant topic in time. Needed full assistance to find a topic from the guide. They do not respond to suggestions from the evaluation committee and/or the guide. No literature review was conducted. The team tried to gather easy information without verifying the authenticity. No objectives formed yet.	The team has identified a topic. The originally selected topic lacks substance and needs to be revised. There were suggestions given to improve the relevance and quality of the project topic. Only a few relevant references were consulted/ studied and there is no clear evidence to show the team's understanding on the same. Some objectives identified, but not clear enough.	Good evidence of the group thinking and brainstorming on what they are going to build. The results of the brainstorming are documented and the selection of topic is relevant. The review of related references was good, but there is scope of improvement. Objectives formed with good clarity, however some objectives are not realistic enough.	The group has brainstormed in an excellent manner on what they were going to build. The topic selected is highly relevant, real world problem and is potentially innovative. The group shows extreme interest in the topic and has conducted extensive literature survey in connection with the topic. The team has come up with clear objectives which are feasible.
			(0 – 3 Marks)	(4 – 6 Marks)	(7 - 9 Marks)	(10 Marks)
1-b	Project Planning, Scheduling and Resource/ Tasks Identification and allocation. (Group assessment) [CO4]	10	No evidence of planning or scheduling of the project. The students did not plan what they were going to build or plan on what materials / resources to use in the project. The students do not have any idea on the budget required. The team has not yet decided on who does what. No project journal kept.	Some evidence of a primary plan. There were some ideas on the materials /resources required, but not really thought out. The students have some idea on the finances required, but they have not formalized a budget plan. Schedules were not prepared. The project journal has no details. Some evidence on task allocation among the team members.	Good evidence of planning done. Materials were listed and thought out, but the plan wasn't quite complete. Schedules were prepared, but not detailed, and needs improvement. Project journal is presented but it is not complete in all respect / detailed. There is better task allocation and individual members understand about their tasks. There is room for improvement.	Excellent evidence of enterprising and extensive project planning. Gantt charts were used to depict detailed project scheduling. A project management/version control tool is used to track the project, which shows familiarity with modern tools. All materials / resources were identified and listed and anticipation of procuring time is done. Detailed budgeting is done. All tasks were identified and incorporated in the schedule. A well-kept project journal shows evidence for all the above, in addition to the interaction with the project guide. Each member knows well about their individual tasks.
			(0 – 3 Marks)	(4 – 6 Marks)	(7 - 9 Marks)	(10 Marks)
Phase 1 Interim Evaluation Total Marks: 20						

EVALUATION RUBRICS for PROJECT Phase I: Final Evaluation

Sl. No.	Parameters	Marks	Poor	Fair	Very Good	Outstanding
1-c	Formulation of Design and/or Methodology and Progress. (Group assessment) [CO1]	5	None of the team members show any evidence of knowledge about the design and the methodology adopted till now/ to be adopted in the later stages. The team has not progressed from the previous stage of evaluation.	The students have some knowledge on the design procedure to be adopted, and the methodologies. However, the team has not made much progress in the design, and yet to catch up with the project plan.	The students are comfortable with design methods adopted, and they have made some progress as per the plan. The methodologies are understood to a large extent.	Shows clear evidence of having a well- defined design methodology and adherence to it. Excellent knowledge in design procedure and its adaptation. Adherence to project plan is commendable.
			(0 – 1 Marks)	(2 – 3 Marks)	(4 Marks)	(5 Marks)
1-d	Individual and Teamwork Leadership (Individual assessment) [CO3]	10	The student does not show any interest in the project activities, and is a passive member.	The student show some interest and participates in some of the activities. However, the activities are mostly easy and superficial in nature.	The student shows very good interest in project, and takes up tasks and attempts to complete them. Shows excellent responsibility and team skills. Supports the other members well.	The student takes a leadership position and supports the other team members and leads the project. Shows clear evidence of leadership.
			(0 – 3 Marks)	(4 – 6 Marks)	(7 - 9 Marks)	(10 Marks)
1-e	Preliminary Analysis/ Modeling / Simulation/ Experiment / Design/ Feasibility study [CO1]	10	The team has not done any preliminary work with respect to the analysis/modeling/ simulation/experiment/desig n/feasibility study/ algorithm development.	The team has started doing some preliminary work with respect to the project. The students however are not prepared enough for the work and they need to improve a lot.	There is some evidence to show that the team has done good amount of preliminary investigation and design/ analysis/ modeling etc. They can improve further.	Strong evidence for excellent progress in the project. The team has completed the required preliminary work already and are poised to finish the phase I in an excellent manner. They have shown results to prove their progress.
			(0 – 3 Marks)	(4 – 6 Marks)	(7 - 9 Marks)	(10 Marks)

1-f	Documentation and presentation. (Individual & group assessment). [CO6]	5	The team did not document the work at all. The project journal/diary is not presented. The presentation was shallow in content and dull in appearance. The individual student has no idea on the presentation of his/her part.	Some documentation is done, but not extensive. Interaction with the guide is minimal. Presentation include some points of interest, but overall quality needs to be improved. Individual performance to be improved.	Most of the project details were documented well enough. There is scope for improvement. The presentation is satisfactory. Individual performance is good.	The project stages are extensively documented in the report. Professional documentation tools like LaTeX were used to document the progress of the project along with the project journal. The documentation structure is well-planned and can easily grow into the project report. The presentation is done professionally and with great clarity. The individual's performance is excellent.
			(0 – 1 Marks)	(2 – 3 Marks)	(4 Marks)	(5 Marks)
Total		**30**	**Phase - I Final Evaluation Marks: 30**			

EVALUATION RUBRICS for PROJECT Phase I: Report Evaluation						
Sl. No.	**Parameters**	**Marks**	**Poor**	**Fair**	**Very Good**	**Outstanding**
1-g	Report [CO6]	20	The prepared report is shallow and not as per standard format. It does not follow proper organization. Contains mostly Unacknowledged content. Lack of effort in preparation is evident.	Project report follows the standard format to some extent. However, its organization is not very good. Language needs to be improved. All references are not cited properly in the report.	Project report shows evidence of systematic documentation. Report is following the standard format and there are only a few issues. Organization of the report is good. Most of references are cited properly.	The report is exceptionally good. Neatly organized. All references cited properly. Diagrams/Figures, Tables and equations are properly numbered, and listed and clearly shown. Language is excellent and follows standard styles.
			(0 - 7 Marks)	(8 - 12 Marks)	(13 - 19 Marks)	(20 Marks)
Phase - I Project Report Marks: 20						

SEMESTER VII

PROGRAM ELECTIVE II

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET413	ADVANCED METHODS IN NON DESTRUCTIVE TESTING	PEC	2	1	0	3

Preamble:

1. To develop a fundamental knowledge about the advanced techniques and the recent developments in non-destructive testing so as to control the quality in manufacturing engineering components

2. To gain practical knowledge in non-destructive testing (NDT)processes and provide a detailed discussion on the advanced non destructive testing methods

3. To equip them with the knowledge of different NDT methods in complex geometries and enable them to select the appropriate methods for better evaluation.

4.To gain advanced knowledge of ultrasonic testing and X- ray radiography which enables them to perform inspection of samples.

5 To equip them with the knowledge of different NDT methods so as to control the quality in manufacturing of engineering components.

Prerequisite: NIL

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

CO 1	Understand the theoretical and practical knowledge in methods of non-destructive testing processes
CO 2	Understand the knowledge of advanced methods in ultrasonic testing which enables them to perform inspection of samples.
CO 3	Illustrate complete theoretical and practical understanding of the radiographic testing, interpretation and evaluation.
CO 4	Understand the recent advances in the field of non-destructive testing
CO 5	Outline the recent and advanced developments in radiography testing

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1.How visual inspection helps in non-destructive testing?

2.What is the use of field indicators in MPI?

3.What are the different types of developers ?Describe the properties of good liquid penetrant.

4.What are the applications of eddy current testing?

Course Outcome 2 (CO2):

1.Describe the method of generating ultrasonic waves.

2.Explain the features of ultrasonic guided waves.

3. Describe the features of electromagnetic acoustic transducer .

4.Describe a method of detecting kissing bonds in friction stir welds of aero structures.

Course Outcome 3 (CO3):

1.Explain the radiography testing using Cobalt 60 isotopes.

2.Describe image quality indicators in Radiography testing.

3.Explain the principle of radiation.

4.How the quality of a good radiograph is assessed.

Course Outcome 4 (CO4):

1.Illustrate the procedure of phased array inspection.

2.Describe the techniques of Time of flight diffraction.

3.Explain the methods of structural health monitoring.

4.Explain the use of Synthetic aperture focussing technique.

Course Outcome 5 (CO5):

1.Describe a technique for inspecting and monitoring the behaviour of equipment and materials performing under stress.

2.Suggest a suitable inspection method for detecting potential problems in energised electrical components.

3.Explain the advantages of digital radiography in medical application compared to conventional x-ray film radiography.

4. Describe the applications of Computed Tomography in industry.

Model Question paper

Reg No.:_____		Name:_____	
APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY			
Course Code: MET 413			
Course Name: Advanced methods in Non Destructive Testing			
Max. Marks: 100			Duration: 3 Hours
PART A			
		(Answer all questions; each question carries 3 marks)	Marks
1		Explain any three Visual aids used in visual inspection.	3
2		Describe the principle of liquid penetrant inspection.	3
3		What is Snell's law of critical angle?	3
4		What is laser shearography?	3
5		What is radiographic sensitivity?	3
6		What are the properties of X-rays?	3
7		What is neutron radiography?	3
8		Explain the concept of structural health monitoring.	3
9		Differentiate between digital radiography and computed tomography.	3
10		Describe the applications of thermography testing.	3
PART B			
(Answer one full question from each module, each question carries 14 marks)			
Module -1			
11	a)	With a simple sketch, explain any two magnetisation techniques used in magnetic particle inspection.	8
	b)	Explain the procedure of magnetic particle inspection of casting.	6

12	a)	With sketches, explain eddy current inspection process.	8
	b)	Explain various methods of liquid penetrant inspection.	6
Module -2			
13	a)	Explain the methods of generating ultrasonic waves.	8
	b)	Describe the features of Electro Magnetic Acoustic Transducer.	6
14	a)	Explain the concept of laser ultrasonics.	8
	b)	Explain various modes of display in ultrasonic testing.	6
Module -3			
15	a)	What are the safety measures to be followed in radiography testing?	8
	b)	What is sensitometry? Discuss the importance of characteristics curves.	6
16	a)	What is Real time radiography? Explain its advantages.	8
	b)	Explain the procedure of film processing in radiography testing.	6
Module -4			
17	a)	Explain the principle of phased array techniques.	8
	b)	Describe the theory of time of flight diffraction (TOFD).	6
18	a)	Explain the features of Flash radiography for material motion detection.	8
	b)	What are the applications of thermography testing?	6
Module -5			
19	a)	Explain the principle of acoustic emission inspection.	8
	b)	Explain any four types of leak testing..	6
20	a)	Describe two methods of thermography testing.	8
	b)	Explain the industrial applications of computed tomography.	6

Syllabus

Module 1

Visual Testing -Liquid Penetrant Testing-Magnetic Particle Testing- Magnetic Particle Testing Equipment- Eddy Current Testing – Selection of testing methods- Codes, Standards and Specifications.

Module 2

Fundamentals of Ultrasonic Waves-- Snell's law and critical angles – Fresnel and Fraunhofer effects– wave propagation in other engineering materials. Generation of ultrasonic waves– contact testing, immersion testing. Ultrasonic Guided Waves- Basics of guided waves– Generation of guided waves–Introduction to Electro –Magnetic Acoustic Transducer(EMAT -Optical methods in Ultrasonics- Laser Ultrasonics –optical detection of ultrasound – measurement of in plane displacement and velocity – Laser shearography – Applications

Module 3

Basic Principles of Radiography -Film Radiography -Radiographic Image Quality and Radiographic Techniques -Radiation Detectors and Safety - Principle of radiation- Special Radiographic Techniques and Interpretation of radiographs of Fluoroscopy-Real-time radioscopy – Principle of neutron radiography - – Principle and application of in-motion and flash radiography- Interpretation of radiographs:- Interpretation for welds, castings etc, applications, various case studies, Inspection standards - applicable codes, standards and specifications (ASME, ASTM, AWS, BS, IBR etc.)

Module 4

Phased Array Techniques- Principles of phased array inspection – phased array probes and their characteristics – Phased array wedges – Focal law– Beam shaping, steering –Scanning with phased array probes- linear, sectorial, C scan. Time of Flight Diffraction Theory and principles of Time of Flight Diffraction (TOFD)–Data acquisition and interpretation– TOFD techniques – selection of probe angle– calibration and optimization, optimizing angles– flaw location and sizing– codes and standards–interpretation, evaluation, applications. Introduction to Synthetic Aperture Focusing Technique (SAFT). Structural Health Monitoring (SHM)-methods- strain gauging- genetic algorithm

Module 5

Acoustic emission inspection-Leak Testing - -Thermographic NDE- Contact and non contact thermal inspection methods– Heat sensitive paints – Heat sensitive papers -Inspection methods – Infrared radiation and infrared detectors–thermo mechanical behavior of materials– IR imaging in aerospace applications-Digital Radiography and Computed Tomography (CT) -computed radiography(CR) and direct radiography (DR) -industrial CT.

Text Books

1. J.Prasad and C. G. K. Nair, Non-Destructive Test and Evaluation of Materials, Tata McGraw-Hill Education, 2nd edition (2011).
2.. B.Raj, T. Jayakumar and M. Thavasimuthu, Practical Non Destructive Testing, Alpha Science International Limited, 3rd edition (2007).
3. J. L. Rose, Ultrasonic waves in solid media, Cambridge University Press, (2004).
4. A.S. Paipetis,T. E Matikas and D. G. Aggelis, Emerging Technologies in Non-Destructive Testing, CRC Press, (2012).

Reference Books

1. X. P. V. Maldague, Nondestructive evaluation of materials by infrared thermography, Springer-Verlag, 1st edition, (1993
2. Non-Destructive Examination and Quality Control, ASM International, Vol.17, 9th edition (1989)
3. J. Krautkramer and H. Krautkramer, Ultrasonic Testing of Materials, Springer, 4th edition (1990).
4.L. W. Schmerr, Fundamentals of Ultrasonic Phased Arrays, Springer, (2014)

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1.1	**Visual Testing** Fundamentals of Visual Testing – vision, lighting, material attributes, environmental factors, visual perception, direct and indirect methods **Liquid Penetrant Testing** Principles – types and properties of liquid penetrants – developers – advantages and limitations of various methods - selection of penetrant method - Applicable codes and standards	3
1.2	**Magnetic Particle Testing** Theory of magnetism – ferromagnetic, paramagnetic materials – characteristics of magnetic fields	2
1.3	**Magnetic Particle Testing Equipment** Selecting the method of magnetization, inspection materials, magnetic particle inspection of castings and welding – Dry continuous method, wet residual method- Applicable codes and standards	2
1.4	**Eddy Current Testing** Generation of eddy currents – effect of change of impedance on instrumentation – properties of eddy currents – eddy current sensing elements, probes, type of coil arrangement Applicable codes and standards.	2
2.1	**Fundamentals of Ultrasonic Waves** Nature of sound waves, wave propagation in metals– modes of sound wave generation – longitudinal waves, transverse waves, surface waves, lamb waves– Snell's law and critical angles – Fresnel and Fraunhofer effects– wave propagation in other engineering materials.	2

2.2	**Generation of ultrasonic waves** Methods of ultrasonic wave generation – piezo electric effect, piezo electric materials and their properties – crystal cuts and mode of vibration – Ultrasonic search Units (transducers), types (straight, angle, dual)	2
2.3	**Ultrasonic Inspection Methods and Equipment** Principle of pulse echo method, through transmission method, resonance method – Advantages, limitations – contact testing, immersion testing.	2
2.4	**Ultrasonic Guided Waves-** Basics of guided waves– Generation of guided waves–Introduction to Electro –Magnetic Acoustic Transducer -EMAT Optical methods in Ultrasonics- Laser Ultrasonics –bulk wave and lamb wave generation mechanisms – optical detection of ultrasound – measurement of in plane displacement and velocity – Laser shearography – Applications	3
3.1	**Basic Principles of Radiography -** Radio isotopic sources X-ray source generation and properties – industrial X-ray tubes **Film Radiography -**X-ray film – structure and types for industrial radiography – sensitometric properties – use of film, characteristic curves (H & D curve).	2
3.2	**Radiographic Image Quality and Radiographic Techniques** Radiographic sensitivity –single and double wall Radiography – panoramic radiography-procedure shooting sketch/technique sheets	3
3.3	**Radiation Detectors and Safety** Special and SI Units of radiation – Principle of radiation	2
4.1	**Special Radiographic Techniques and Interpretation of radiographs** Principles and applications of Fluoroscopy/Real-time radioscopy – advantages and limitations –recent advances, intensifier tubes, vidicon tubes etc– Principle of neutron radiography - attenuation of neutrons - direct and indirect technique - advantages and limitations – Principle and application of in-motion and flash radiography. *Interpretation of radiographs:-* Interpretation for welds, castings etc, applications, various case studies, Inspection standards - applicable codes, standards and specifications (ASME, ASTM, AWS, BS, IBR etc.	3
4.2	**Phased Array Techniques** Principles of phased array inspection – phased array probes and their characteristics – Phased array wedges – Focal law– Beam shaping, steering –Scanning with phased array probes- linear, sectorial, C scan.	2
4.3	**Time of Flight Diffraction** Theory and principles of Time of Flight Diffraction (TOFD)–Data acquisition and interpretation–	2

	TOFD techniques – selection of probe angle– calibration and optimization, optimizing angles– flaw location and sizing– codes and standards–interpretation, evaluation, applications	
4.4	*Introduction to Synthetic Aperture Focusing Technique (SAFT).***Structural Health Monitoring (SHM)**-methods- strain gauging- genetic algorithm-	2
5.1	**Acoustic emission inspection** Principles and Theory – Signal Propagation – Physical Considerations – The AE Process Chain - Time Considerations – AE Parameters –AE testing during grinding – pipelines – steam turbines – AE location of faults in power transformers. .	2
5.2	**Leak Testing** Introduction to leak testing– objectives – terminologies – measurement of leakage –Types of leak – Types of flow in leaks – Principles of Fluid dynamics – Leak Testing of Pressure Systems Without and with a Tracer Gas – Halogen diode leak testing – Helium mass spectrometer leak testing and subsystems –Leak testing for special applications-standards.	2
5.3	**Thermographic NDE** Introduction and fundamentals to infrared and thermal testing– Heat transfer – Active and passive techniques – Lock in and pulse thermography– Contact and non contact thermal inspection methods– Heat sensitive paints – Heat sensitive papers – thermally quenched phosphors liquid crystals -Inspection methods – Infrared radiation and infrared detectors–thermo mechanical behavior of materials	3
5.4	**Digital Radiography and Computed Tomography (CT)** Principles of Digital Radiography-Methods of digital radiography – digitization of X-ray films – computed radiography(CR) and direct radiography (DR) – process of image formation in CR – comparison of film, CR and DR method. Computed Tomography – industrial CT.	2

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET423	OPTIMIZATION TECHNIQUES AND APPLICATIONS	PEC	2	1	0	3

Preamble: This course introduces the students to the concept of solving engineering problems by developing linear and non-linear mathematical models. The models involve objectives and constraints in terms of the relevant design variables. The student learns to apply a suitable mathematical programming technique to solve the developed model. The course includes Linear Programming, Integer Programing, Dynamic Programming, Classical Optimization and Metaheuristic techniques.

Prerequisite: Basic concepts of linear algebra.

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

CO 1	Formulate engineering problems as mathematical programming problems.
CO 2	Apply Simplex and dual Simplex methods to solve linear programming problems.
CO 3	Analyse the sensitivity of the model parameters
CO 4	Solve integer programming problems.
CO 5	Apply Dynamic Programming techniques to solve sequential optimization problems
CO 6	Apply classical optimization techniques and algorithms to solve nonlinear optimization problems.

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

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember			5
Understand			5
Apply	30	30	40
Analyse	10	10	20
Evaluate	10	10	20
Create			10

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Consider a chocolate manufacturing company that produces only two types of chocolate – A and B. Both the chocolates require Milk and Choco only. Each unit of A requires 1 unit of Milk and 3 units of Choco, and each unit of B requires 1 unit of Milk and 2 units of Choco. The company kitchen has a total of 5 units of Milk and 12 units of Choco. On each sale, the company makes a profit of Rs 6 per unit A sold, and Rs 5 per unit B sold. Now, the company wishes to maximize its profit. Formulate the problem as a LPP and determine how many units of A and B should it produce respectively?

2. A person wishes to invest Rs.14,000. He has identified four investment opportunities. Investment 1 requires an investment of $5,000 and has a present value (a time-discounted value) of $8,000; Investment 2 requires $7,000 and has a value of $11,000; Investment 3 requires $4,000 and has a value of $6,000; and Investment 4 requires $3,000 and has a value of $4,000. Into which investments should he place his money so as to maximize the total present value?

3. Find the dimensions of a box of largest volume that can be inscribed in a sphere of unit radius.

Course Outcome 2 (CO2)

1. Solve the following LPP using simplex method.
   Minimize $Z = 4x_1 + x_2$
   Subject to:
   $3x_1 + x_2 = 3$;
   $4x_1 + 3x_2 \geq 6$;

$x_1 + 2x_2 \leq 4;$
$x_1, x_2 \geq 0;$

2. Show that the Big-M method will conclude that the following LPP has no feasible solution.

Maximize $Z = 2x_1 + 5x_2$
Subject to:
$3x_1 + 2x_2 \geq 6;$
$2x_1 + x_2 \leq 2;$
$x_1, x_2 \geq 0;$

3. Generate the dual simplex iterations for the LPP given below and find the solution.

Minimize $Z = 5x_1 + 6x_2$
Subject to :
$x_1 + x_2 \geq 2;$
$4x_1 + x_2 \geq 4;$
$x_1, x_2 \geq 0;$

Course Outcome 3(CO3):

1. The following LPP has an optimal solution of $x_1 = 320$; $x_2 = 360$ and Objective function value = 4360.

Maximize $Z = 8x_1 + 5x_2$
Subject to:
$2x_1 + 1x_2 \leq 1000;$
$3x_1 + 4x_2 \leq 2400;$
$x_1 + x_2 \leq 700;$
$x_1 - x_2 \leq 350;$
$x_1, x_2 \geq 0.$

Carry out sensitivity analysis to determine the range in which the objective function coefficients can vary keeping the current solution as optimal.

2. Determine the shadow price corresponding to the first constraint for the LPP given in the previous question.

3. Describe the concept of shadow price and reduced cost.

Course Outcome 4 (CO4):

1. Solve the following integer programming problem using Branch and Bound algorithm.

Maximize $Z = 5x_1 + 4x_2;$
Subject to:
$x_1 + x_2 \leq 5;$
$10x_1 + 6x_2 \leq 45;$
$x_1, x_2 \geq 0$, and integers.

2. Solve the following integer programming problem using the cutting plane algorithm.

Maximize $Z = 7x_1 + 10x_2$
Subject to:
$-x_1 + 3x_2 \leq 6;$

$7x_1 + x_2 \leq 35;$

$x_1, x_2 \geq 0$, and integers.

3. Solve the following integer programming problem.

Maximize $Z = 2x_1 + 3x_2$

Subject to:

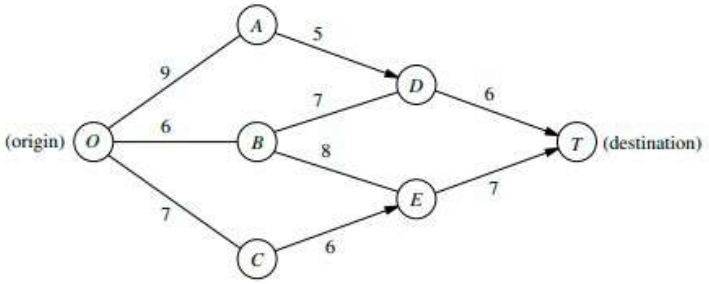
$5x_1 + 7x_2 \leq 35;$

$4x_1 + 9x_2 \leq 36;$

$x_1, x_2 \geq 0$, and integers.

Course Outcome 5 (CO5):

1. Find the shortest distance between the origin and destination for the network given below using dynamic programming.



2. What is Bellman's principle of optimality?

3. A college student has 7 days remaining before the final examinations for four courses, and she wants to allocate this study time as effectively as possible. She needs at least 1 day on each course, and likes to concentrate on just one course each day. So she wants to allocate 1, 2, 3, or 4 days to each course. She decides to use dynamic programming to make these allocations to maximize the total grade points to be obtained from the four courses. She estimates that the alternative allocations for each course would yield the number of grade points shown in the table given below. Solve this problem using dynamic programming.

Study Days	Estimated grade points			
	Course 1	Course 2	Course 3	Course 4
1	3	5	2	6
2	5	5	4	7
3	6	6	7	9
4	7	9	8	9

Course Outcome 6 (CO6):

1. Maximize the function $f(x_1, x_2, x_3) = x_1 + 2x_2 + x_2x_3 - x_1^2 - x_2^2 - x_3^2$

2. Find the solution for the following problem using the Lagrange multiplier method.

Minimize $f(x, y) = 5x^{-1}y^{-2}$

subject to : $g(x,y) = x^2 + y^2 - 9 = 0$

3. Use the Fibonacci search method to minimize the function

Model Question Paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
VII SEMESTER BTECH DEGREE EXAMINATION
MET423: OPTIMIZATION TECHNIQUES AND APPLICATIONS

Maximum : 100 Marks Duration : 3 hrs.

PART A

Answer all questions. Each question carries 3 marks.

1. How is degeneracy identified in the simplex procedure?
2. What is the role of artificial variables in simplex method?
3. Write the dual for the following LPP.

   Maximize $Z = 5x_1 + 4x_2$;
   Subject to:
   $x_1 + x_2 \leq 5$;
   $10x_1 + 6x_2 \leq 45$;
   $x_1, x_2 \geq 0$.
4. What is meant by shadow price?
5. Explain the importance of integer programming models and their applications.
6. What is Bellman's principle of optimality?
7. Find the extreme points of the function

$$f(x) = 12x^5 - 45x^4 + 40x^3 + 5$$

8. State the necessary and sufficient conditions for the maximum of a multivariable function $f(X)$.
9. Find the Hessian matrix of the function $f(x) = 3x_1^2x_2^2 - x_2^2x_3^3$
10. Describe the procedure of Golden Section search method.

PART B

Answer one full question from each module

Module 1

11. a) Consider a chocolate manufacturing company that produces only two types of chocolate – A and B. Both the chocolates require Milk and Choco only. Each unit of A requires 1 unit of Milk and 3 units of Choco, and each unit of B requires 1 unit of Milk and 2 units of Choco. The company kitchen has a total of 5 units of Milk and 12 units of Choco. On each sale, the company makes a profit of Rs 6 per unit A sold, and Rs 5 per unit B sold. Now, the company wishes to maximize its profit. Formulate the problem as a

LPP and graphically determine how many units of A and B should it produce respectively?

(5 Marks)

b) Use Simplex method to solve the following LPP.

Minimize $Z = 4x_1 + x_2$

Subject to:

$3x_1 + x_2 = 3;$

$4x_1 + 3x_2 \geq 6;$

$x_1 + 2x_2 \leq 4;$

$x_1, x_2 \geq 0;$

(9 Marks)

12. Solve the following LPP using Simplex method and carry out sensitivity analysis to determine the range in which the objective function coefficients can vary keeping the current solution as optimal.

Maximize $Z = 8x_1 + 5x_2$

Subject to:

$2x_1 + 1x_2 \leq 1000;$

$3x_1 + 4x_2 \leq 2400;$

$x_1 + x_2 \leq 700;$

$x_1 - x_2 \leq 350;$

$x_1, x_2 \geq 0.$

(14 Marks)

Module 2

13. Generate the dual simplex iterations for the LPP given below and find the solution.

Minimize $Z = 5x_1 + 6x_2$

Subject to :

$x_1 + x_2 \geq 2;$

$4x_1 + x_2 \geq 4;$

$x_1, x_2 \geq 0;$

(14 Marks)

14. Solve the following integer programming problem using Branch and Bound algorithm.

Maximize $Z = 2x_1 + 3x_2$

Subject to:

$5x_1 + 7x_2 \leq 35;$

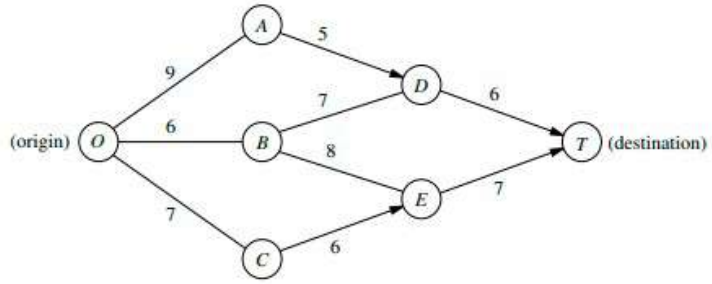
$4x_1 + 9x_2 \leq 36;$

$x_1, x_2 \geq 0$, and integers

(14 Marks)

Module 3

15. Find the shortest distance between the origin and destination for the network given below using dynamic programming.



(14 Marks)

16. A candidate in an election wants to purchase TV time for a total of four commercials on TV stations located in four areas. Based on polling information, an estimate is made of the number of votes that can be won in the different areas depending upon the number of commercials run. These estimates are given in the table in thousands of votes. Use dynamic programming to find how the four commercials should be distributed among the four areas to maximize the estimated number of votes won.

Commercials	Area			
	1	2	3	4
0	0	0	0	0
1	4	6	5	3
2	7	8	9	7
3	9	10	10	12
4	12	11	12	14

(14 Marks)

Module 4

17. a) Find the extreme points of the function $f(X) = x_1^3 + x_2^3 + 2x_1^2 + 4x_2^2 + 6$

(6 Marks)

b) Find the maximum of the function $f(X) = 2x_1 + x_2 + 10$; subject to $g(X) = x_1 + 2x_2^2 = 3$ using the Lagrange multiplier method.

(8 Marks)

18. a) Find the dimensions of a box of largest volume that can be inscribed in a sphere of unit radius. (6 Marks)

b) Maximize the function $f(x_1, x_2, x_3) = x_1 + 2x_2 + x_2x_3 - x_1^2 - x_2^2 - x_3^2$ (8 Marks)

Module 5

19. a) Minimize the function $f(x) = 0.65 - [0.75/(1+x^2)] - 0.65x \tan^{-1}(1/x)$ in the interval [0,3] using the Fibonacci method with n = 6. (7 Marks)

b) Use the steepest descent method to search for the minimum for the function $f(x, y) = 25x^2 + y^2$. Start at (1, 3) with a step size of 0.5 (7 Marks)

20. a) Use the golden section search method to minimize the function $f(x) = x^4 - 14x^3 + 60x^2 - 70x$ in the range [0,2]. (7 Marks)

b) Solve $\cos x = 2x$ using Newton Raphson method. Carry out 4 iterations. (7 Marks)

Syllabus

Module 1

Formulation of engineering problems as mathematical programming models: Linear Programming formulations.

Solutions to Linear Programming Problems: Simplex method – Big-M and 2-phase methods – Sensitivity Analysis for the objective function coefficients and right hand side coefficients of constraints - Exceptional cases in LPP.

Module 2

Duality concept in LPP - Dual Simplex method.

Integer Programming problem: Applications of Integer Programming problems - Integer Programming algorithms - Cutting Plane method - Branch and Bound method.

Module 3

Dynamic Programming: Bellman's principle of optimality - Forward recursion and backward recursion - Application problems- Shortest route and Knapsack problems.

Module 4

Classical optimization techniques: Single variable optimization - Multivariable optimization with no constraints - Optimization with equality constraints - Method of Lagrange Multipliers - Optimization with inequality constraints - Kuhn-Tucker conditions.

Module 5

Algorithms for unconstrained optimization: Fibonacci search method - Golden section search method -Hooke and Jeeve's method - Newton-Raphson method - Cauchy's (Steepest descent) method.

Text Books

1. Hamdy A. Taha, "Operations Research, An Introduction", Pearson Education, 10th edition, 2019.
2. S. S. Rao, "Engineering Optimization, Theory and Practice", New Age International, 3rd edition, 2013

Reference Books

1. N. V. S. Raju, " Optimization Methods for Engineers", Prentice-Hall of India, 1st edition, 2014
2. Ravindran, Philips and Solberg, "Operations Research, Principles and Practice", Wiley, 2nd edition, 2007

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Module 1**	
1.1	Formulation of engineering problems as mathematical programming models.	1
1.2	Linear Programming models, Examples	1
1.3	Graphical method to solve LPP	1
1.4	Simplex method, Introduction	1
1.5	Example problems using Simplex method	2
1.6	Big-M method and 2-phase method	2
1.7	Sensitivity analysis	2
1.8	Exceptional cases	1
2	**Module 2**	
2.1	Duality concept in LPP	1
2.2	Dual Simplex method	2
2.3	Integer Programming problem – Introduction and applications.	1
2.4	Branch and Bound method	2
2.5	Cutting Plane method	2
3	**Module 3**	
3.1	Dynamic Programming- Introduction and Bellman's principle of optimality	1
3.2	Forward recursion and backward recursion	1
3.3	Application problems -Shortest route problem	2
3.4	Knapsack problem	2
4	**Module 4**	
4.1	Classical optimization – Introduction- Single variable optimization	1
4.2	Multivariable optimization with no constraints	2
4.3	Optimization with equality constraints - Method of Lagrange	2

	Multipliers	
4.4	Optimization with inequality constraints - Kuhn-Tucker conditions.	2
5	**Module 5**	
5.1	Algorithms for unconstrained optimization- Introduction	1
5.2	Fibonacci search method	1
5.3	Golden section search method	1
5.4	Hooke and Jeeve's method	1
5.5	Newton-Raphson method.	1
5.6	Cauchy's (Steepest descent) method	1

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET433	FINITE ELEMENT METHOD	PEC	2	1	0	3

Preamble: This course is meant to serve as an introduction to the basic aspects of Finite Element formulation for the undergraduate student. Some formulation schemes for the numerical solution of field problems leading to matrix equations amenable for solution with the aid of computer, forms content of this course. This three (3) credit elective course has retained almost all the contents of a core course in this subject offered usually. Learning the basics of the formulation should help the student know better about the scope as well as the limitations of a particular choice while modeling (for example, while choosing an element type for solution).

Prerequisite: MET332 ADVANCED MECHANICS OF SOLIDS

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

CO 1	Apply Matrix methods for solution of some one-dimensional Stress problems based on FEM approach.
CO 2	Analyse some structural analysis problems involving beams and trusses, using FEM.
CO 3	Formulate computational scheme for two-dimensional structural analysis based on Total Potential Energy Method.
CO 4	Apply the strategy of coordinate transformation using natural coordinates, and subsequent solution, employing the Isoparametric formulation.
CO 5	Formulate Galerkin's weighted residual technique of simple one dimensional (1- D) problem and natural frequency analysis in 1 D problem

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

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember			
Understand	10	10	30
Apply	40	40	70
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions:

Course Outcome 1 (CO1):

1. List various computational schemes involving Matrix methods for solution of boundary value problems.
2. List the mathematical strategies for converting (partial) differential equations into matrix equations.
3. Apply the direct method of FEM formulation to introduce Matrix methods in one-dimensional problems.
4. Apply the Principle of Total Potential energy to formulate FEM equations for 1-D spring element.

Course Outcome 2 (CO2)

1. Formulate the rotation matrix for coordinate transformation between local and global coordinates.

2. Assembly and solution for truss analysis.

3. Formulate stiffness matrix for beam problem.

4. Solution of beam problems using FEM.

Course Outcome 3(CO3):

1.Review of the constitutive matrix [D] for Plane-stress and Plane-strain cases.

2.Derivation of two-dimensional FEM equations for stress-analysis, using the Total Potential energy approach.

3. Formulate shape functions for some two dimensional elements.

4. Formulate strain-displacement gradient matrix [B] for the 3node triangular element (CST) and four node rectangular elements.

5. Assembly, application of boundary conditions and solution of problems involving CST.

Course Outcome 4 (CO4):

1. Demonstrate the motivation for Coordinate transformation using natural coordinates for formulations involving higher order elements.

2. Deduction of shape functions in terms of natural coordinates using Serendipity and Lagrange's Interpolation methods.

3. Perform Isoparametric formulation to derive stiffness matrix for (i) the general four node Quadrilateral element and (ii) eight node Quadrilateral element.

4. Perform Numerical integration in two-dimensions using Gauss Quadrature.

5. Illustration of solution of a structural problem for nodal unknowns, employing the above features (isoparametric formulation and Gaussian integration).

Course Outcome 5 (CO5):

1. Apply Galerkin's technique for FEM formulation.

2. Solve 1-D heat transfer problems employing FEM.

3. Formulate vibration problems using FEM

4. Solve Natural frequency (single degree of freedom, undamped) problems using FEM

5. Discuss practical aspects of FEM modelling.

Model Question Paper

MODEL QUESTION PAPER APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SEVENTH SEMESTER B.TECH DEGREE EXAMINATION

Course Code : MET433 **Course Name : FINITE ELEMENT METHOD**

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

PART – A

(ANSWER ALL QUESTIONS, EACH QUESTION CARRIES 3 MARKS)

1. Compare and contrast FEM, FDM and FVM
2. Comment on the sources of errors in a FEM solution
3. What are local and global coordinates? How are they connected in a planar truss problem?
4. Explain the *Fixed end reactions method* in solving beam problems.
5. Make a short note on the Total potential energy method of formulating a FEM problem.
6. What are degrees of freedom in the context of an FEM element for structural analysis?
7. What is the motivation for coordinate transformation employing natural coordinates?
8. Evaluate the following integral using two-point Gauss Quadrature. Sampling points are at $\pm 1/\sqrt{3}$, and both weights are equal to unity.

$$\int_{-1}^{1} (x^2 + 2x + 2)\, dx$$

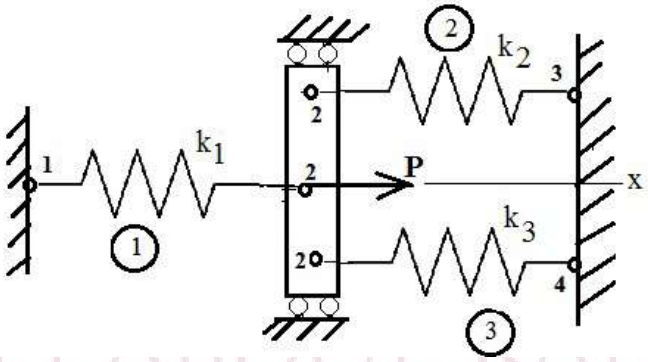
9. How is the natural frequency of a system related to the eigen-value ?
10. Comment on the convergence of a static-structural FE simulation run.

PART – B

(ANSWER ONE FULL QUESTION FROM EACH MODULE)

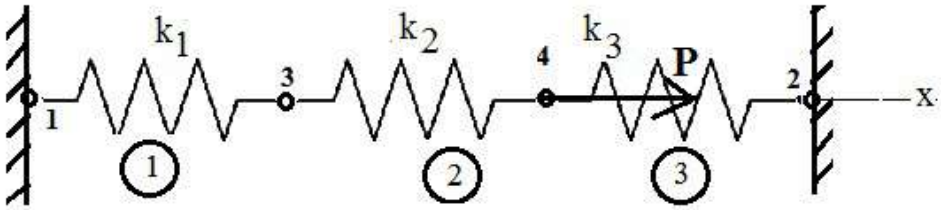
MODULE – 1

11. For the assembly shown, formulate the global stiffness matrix, and equations (in matrix form) for the solution of the unknown global displacements and forces. P= 2kN, k1=1000 kN/m, k2=k3=500 kN/m. (14 Marks)



OR

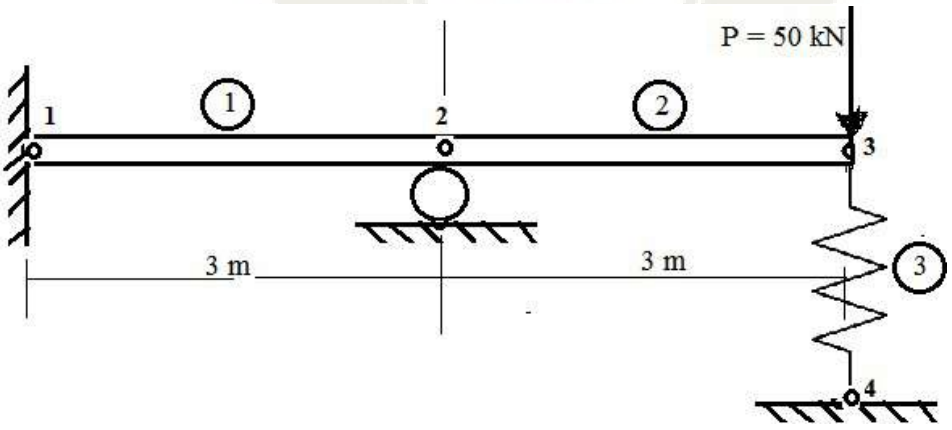
12. Using Total Potential Energy Principle, derive the global stiffness matrix for the following assemblage of spring elements in series applied by a force (P) applied at node-4, along the x-axis. Subsequently, using the numerical values provided, find displacements at nodes 2 and 4, reaction forces at nodes 1 and 2, the force in each spring. P= 450 N, k1=10,000 N/m, k2=20,000 N/m, k3=10,000 N/m. (14 Marks)



MODULE – 2

13. (a) Derive the stiffness matrix for an element for a planar truss problem in terms of the components of the rotation (transformation) matrix. (6 Marks)

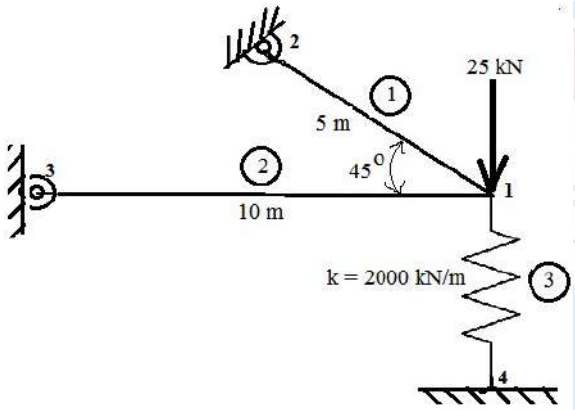
(b) Determine the nodal displacements and rotations and the global and element forces for the beam supported and loaded as shown. E = 210 GPa, Moment of inertia of cross-section, 'I' = 2X 10^{-4} m^4, and spring stiffness= 200kN/m. (8 Marks)



OR

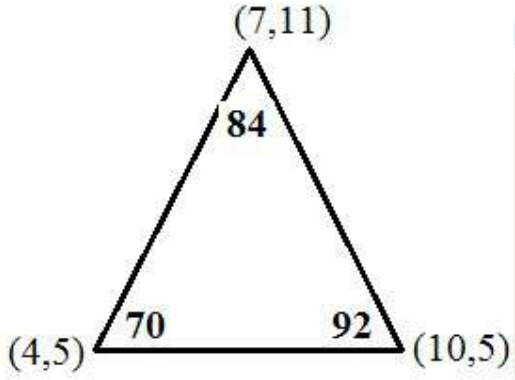
14. (a) Derive the stiffness matrix for FEM analysis used to analyse beam problems based on Euler-Bernoulli theory. (5 Marks)

(b) Find stresses in the truss (rod) elements, if both rods have E = 210 GPa, and area of cross section $5.0X10^{-2}$ m^2 (9 Marks)



MODULE – 3

15. (a) Values for the field variable at the nodes (coordinates as indicated) of a triangular element are as shown. Assign appropriate node numbers and evaluate shape functions and calculate the value of the field variable at the coordinates (5,7). (9 Marks)

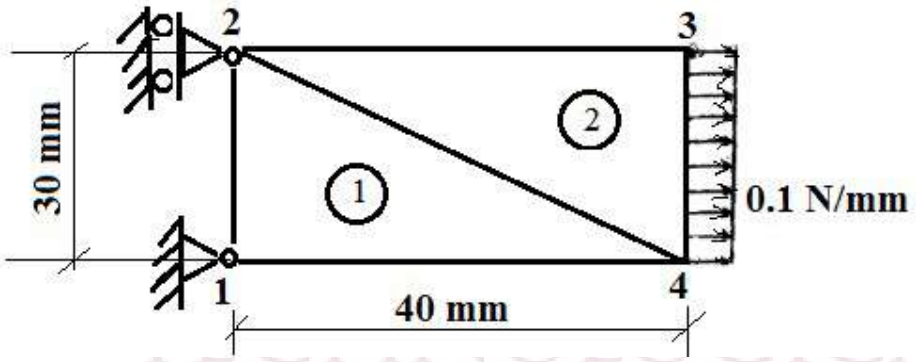


(b) For a 2D stress analysis problem employing a three noded triangular element, with vertices at (0,1), (0,-1) and (2,0), evaluate the Strain-DIsplacement Martrix. (5 Marks)

OR

16. (a) A thin plate as shown is pulled by a uniform load as shown. Should it be treated as a plane-stress problem or Plane strain prblem? Justify. Accordingly, for the two-element

discretization shown, evaluate the Strain-Displavement Matrices and the Constitutive matrix. E = 200 GPa, Poissons ration is 0.3 and thickness t= 10mm. (9 Marks)



(b) What are the unknown variables at each node and the boundary conditions>? How will you detrmine the stiffness matrix (need not compute the stiffness matrix)? Give the Load vector. (5 Marks)

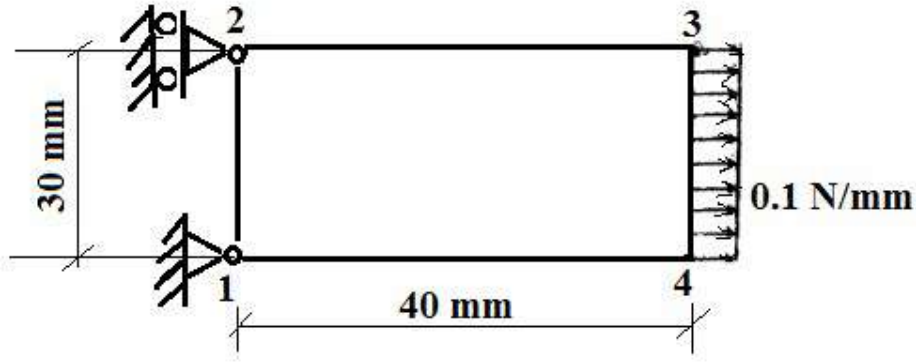
MODULE – 4

17. (a) For a 4 node quadrilateral element for two dimensional stress analysis, derive expression for the Jacobian Matrix connecting the derivatives in (X,Y) and (ξ, η) coordinates (8 Marks)

(b) If the nodes of a quadrilateral with coordinates (x_1,y_1), (x_2,y_2), (x_3,y_3), (x_4,y_4), are (20,20), (40, 30), (50,50) and (15,40), evaluate the Jacobian at $\xi=0.5$, $\eta=0.5$ (6 Marks)

OR

18. A bilinear rectangular element is loaded as shown. If the Jacibian at $\xi=1/3$, $\eta=1/3$ is given by $\begin{bmatrix} 2 & 0 \\ 0 & 1.5 \end{bmatrix}$, evaluate the corresponding B Matrix. (10 Marks)



(b) What are the boundary conditions for this problem if the displacements at each node 'i' are represented as u_i and v_i. (1 Mark)

(c) If the problem is solved and displacements obtained, how can the strains be determined? And also, stresses? (solutions not intended) (3 Marks).

MODULE – 5

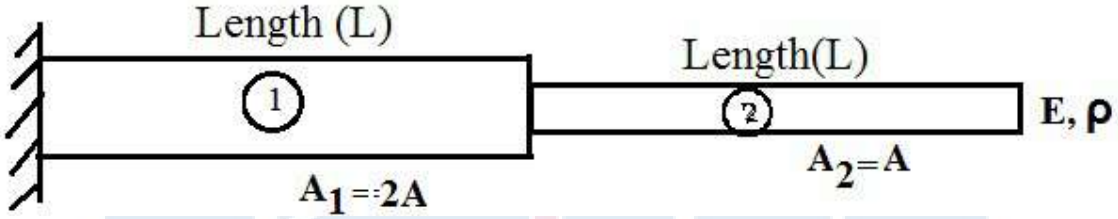
19. (a) Using the Galerkin's Weak formulation, derive the finite element equations for a one-dimensional steady state heat conduction problem with constant thermal conductivity and no heat generation. (8 marks)

(b) A heat transfer fin of radius 1cm and length 5 cm is attached to a boiler-wall maintained at 140^{o}C and the other end is exposed to atmosphere. Find the temperature (at steady state) of the tip exposed to atmosphere and also at a point at 0.5 cm from the free end, by employing a two-element finite elements assembly. The curved surface of the fin is well insulated. T= 40^{o}C, h=10 W/cm^{2o}C. K=70W/cm^{o}C. (6 marks)

OR

20. Derive the finite element equations for free vibration analysis due to axial displacements of rod elements using Galerkin's technique (8 marks)

(b) Determine the first two natural frequencies of longitudinal vibrations of the stepped steel bar shown. All dimensions are in mm. E= 200 GPa, ρ= 7800N/m^3, length L=500 mm. (6 marks)



Syllabus

Module 1 (9 Hours)

FEM as a numerical computational tool in Computer Aided Design & Analysis- general features of numerical solutions-general strategy of Matrix Methods in Computational Mechanics- overview of similar numerical methods (FDM, FEM, FVM, BEM)-overview of general formulation methods leading to Matrix equations (Stiffness (direct) method, Potential energy method, Galerkin's etc.) - commercial and free FEM packages.

Direct approach of formulating the FEM equations for 1D stress problems:– element stiffness – assembly of elements – properties of [K] matrix – treatment of boundary conditions- stress computation – support reaction – simple problems.

Application of the Principle of Total Potential energy to formulate FEM equations for 1-D spring element. Simple problems involving assemblage of spring elements.

Module 2 (8 Hours)

Plane truss element formulation – coordinate transformation – local and global coordinates – element matrices – assembly of elements – treatment of boundary conditions – stress calculation –Planar truss problems .

Beam element: Beam relationships – 1-D beam element FE formulation - element stiffness matrix – load considerations – boundary conditions –solution of problems.

Module 3 (8 Hours)

Review of Constitutive Matrix [D] for Plane-stress and Plane-strain formulations- derivation of two-dimensional FEM equations for stress-analysis, using the Total Potential energy approach- Shape functions, equations for displacement field in terms of nodal displacements for (i) the 3noded triangular element (CST) and (ii) four-node-rectangular elements. Strain-displacement gradient matrix [B] for the above elements- numerical problems involving 3-node-triangular elements.

Module 4 (9 Hours)

Motivation for Coordinate transformation using natural coordinates, deduction of shape functions in terms of natural coordinates: Serendipity and Lagrange's Interpolation methods- Isoparametric formulation for (i) the general four- node- Quadrilateral element and (ii) eight-node- Quadrilateral element (curved boundaries)- Gauss Quadrature in 2-dimensions- Illustrative examples.

Module 5 (7Hours)

Strong and Weak form , , Galerkin's weighted residual FEM formulation ; One dimensional axially loaded bar, heat flow in a bar- numerical problems.

FEM formulation for (undamped) Natural frequency estimation in 1-D structural problems – simple examples.

Practical considerations in FEM analysis: aspect ratio and element types, use of symmetry in analysis, natural subdivisions at discontinuities, h and p methods of refinement, handling concentrated point loads and infinite stress in some geometries (re-entrant corners)-treatment of infinite medium, connecting different types of elements. Convergence of solution (demonstration of the above aspects in a FEM software environment recommended).

Text Books

1. Daryl L. Logan, "A First Course in the Finite Element Method", Cengage Learning India Pvt. Ltd., 5th edition, 2012.

2. . Seshu P., "Textbook of Finite Element Analysis", PHI Learning Private Ltd., Ninth printing, 2010.

Reference Books

1. Robert D Cook, David S Malkus, Michael E. Plesha and Robert J. Witt , "Concepts And Applications of Finite Element Analysis", Wiley Student Edition, 4th Edition, 2007.
2. J. N. Reddy, "An Introduction to the Finite Element Method", McGraw Hill International 4th Edition, 2018.
3.S. S. Rao, "The Finite Element Method in Engineering", Butterworth-Heinemann Ltd; 3rd Revised edition, 1999.
4.K. J. Bathe, "Finite Element Procedures in Engineering Analysis", Prentice Hall, Pearson Education Inc., 2nd edition, 2014.
5.O. C. Zienkiewics, R. L. Taylor, "The Finite Element Method," Vol I & II, John Wiley & Sons Inc. 5th edition, 2000.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Module-1 (8 Hours)**	
1.1	FEM as a numerical tool - general features of numerical solutions-general strategy of Matrix Methods.	1 Hour
1.2	Overview of FDM, FEM, FVM, BEM-overview of general formulation methods leading to Matrix equations.	1 Hour
1.3	Direct approach of formulating the FEM equations for 1D stressl problems:– element stiffness – assembly of elements – properties of [K] matrix – treatment of boundary conditions- stress computation – support reaction	2 Hours
1.4	Application of the Principle of Total Potential energy to formulate FEM equations for 1-D spring element.	1 Hour
1.5	Numerical Problems on direct method and Potential Energy Principle	3 Hours
2	**Module-2 (6 Hours)**	
2.1	Truss element formulation – coordinate transformation – local and global coordinates – element matrices	1 Hour
2.2	Assembly of elements – treatment of boundary conditions – stress calculation –Planar truss problems .	1 Hour
2.3	Tutorial on truss problems	1 Hour
2.4	1-D beam element FE formulation - element stiffness matrix –	1 Hour
2.5	Load considerations – boundary conditions for Beams	1 Hour
2.6	Tutorial on Beam problems	1 Hour
3	**Module-3 (7 Hours)**	
3.1	derivation of two-dimensional FEM equations for stress-analysis, using the Total Potential energy approach.	2 Hours
3.2	Shape functions, equations for displacement field in terms of nodal displacements for (i) the three-node-triangular element (CST) and (ii) four-node-rectangular elements.	2 Hours

3.3	Strain-displacement gradient matrix [B] for the above elements-	1 Hour
3.4	Tutorial Problems involving 3-node-triangular elements.	2 Hours
4	**Module-4 (8 Hours)**	
4.1	Coordinate transformation using natural coordinates, of shape functions in terms of natural coordinates: Serendipity and Lagrange's Interpolation methods.	2 Hours
4.2	- Isoparametric formulation for (i) the general four- node-Quadrilateral element and	2 Hours
4.3	Isoparametric formulation for (i) the general four- node-Quadrilateral element and (ii) eight-nod- Quadrilateral element (curved boundaries)	2 Hours
4.4	Gauss Quadrature in 2-dimensions- Illustrative examples.	1 Hour
4.5	Tutorial Problems involving isoparametric formulation.	1 Hour
5	**Module-5 (7 Hours)**	
5.1	Strong and weak form of simple problem	1 Hour
5.2	Galerkin's formulation of one dimensional axially loaded bar	1 Hours
5.3	Galerkin's formulation of one dimensional Heat flow in a bar	1 Hours
5.4	FEM formulation for (undamped) Natural frequency estimation in	1 Hour
5.5	Tutorial problems on 1-D problem	1 Hour
5.6	Practical considerations in FEM analysis and demonstration of these aspects in a FEM software environment.	2 Hours

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET443	AEROSPACE ENGINEERING	PEC	2	1	0	3

Preamble : This course provides fundamentals of aerospace engineering and understanding of flight instruments. To educate students the fundamental aerospace disciplines necessary to carry out the design of an aerospace vehicle or systems.

Prerequisite : Nil

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

CO1	Explain the characteristics of atmosphere
CO2	Discuss airfoil theory, 2D, 3D or Finite aero foils
CO3	Explain perform analysis of flight dynamics of aircrafts
CO4	Understand different flight instruments
CO5	Discuss the principles of wind tunnel testing

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	20	20	20
Apply	20	20	70
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions:

Course Outcome 1 (CO1):

1. What is meant by Standard atmosphere? Explain how the variation of pressure and density at different altitudes can be calculated.
2. With the help of a diagram explain the variation of temperature in different regions of atmosphere.

Course Outcome 2 (CO2):

1. Derive the expression for induced drag.
2. Write a summary of different drags that are acting on a 3D aerofoil.
3. With sketches compare the maximum lift produced by different high lift arrangements with that of a plane aerofoil.

Course Outcome 3 (CO3):

1. Derive the general two-dimensional translational equations of motion of an airplane in accelerated flight.
2. Explain how Froude's momentum theory can be used to calculate the efficiency of a propeller?
3. Show that at the velocity for minimum power required the airplane is flying at the angle of attack that corresponds to a maximum $Cl^{3/2}/Cd$.

Course Outcome 4 (CO4):

1. Explain the working of vertical speed indicator of an aircraft.
2. Explain the working of turn and bank indicator of an aircraft.
3. Explain the working of air temperature indicator of an aircraft.

Course Outcome 5 (CO5):

1. Explain the working of an indraft wind tunnel.
2. A low subsonic wind tunnel has a diffuser of area ratio 9. At a test section velocity of 30m/s and a temperature of 330K, the diffuser is found to have 90% efficiency. If the pressure at the inlet to the diffuser is 1.195 x 10^5N/m^2. Calculate the head loss in the diffuser.
3. Explain the working of supersonic wind tunnel.

Model Question Paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

VIII SEMESTER B.TECH DEGREE EXAMINATION

MET443: AEROSPACE ENGINEERING

Maximum: 100 Marks **Duration: 3 hours**

PART A

Answer all questions, each question carries 3 marks

1. Explain the variation of temperature in various regimes of earth's atmosphere.
2. Draw the pressure distribution around a 2-D aerofoil.
3. Explain span efficiency factor.
4. What is meant by aerodynamic center?
5. What are the various propeller coefficients?
6. Derive an expression for circular velocity.
7. Define the terms Range and Endurance of an aircraft?
8. How aerodynamic balancing of control surfaces is done in aircraft?
9. What do you mean by wind tunnel balances?
10. What is meant by range and endurance of an aircraft?

(10 X 3 = 30 marks)

PART B

Answer one full question from each module

Module 1

11. a) What do you mean by temperature, pressure and density altitudes? (4 marks)

    b) Consider an airplane flying at an altitude where the pressure and temperature are 25.37 Kpa and 216.66 K, respectively. Calculate the pressure and density altitudes at which the airplane is flying. (10 marks)

12. a) Explain how lift coefficient can be obtained from pressure coefficient. (4 marks)

b) An aircraft having wing span 9.6m and wing area 17m2 produces a lift of 80,000N when flying at 120m/s. Calculate the induced drag when flying at sea level, Assume e=0.8 (10 marks)

Module 2

13. a) An aircraft having wing span 9.6m and wing area $17m^2$ produces a lift of 80000N when flying at 120m/s. Calculate the induced drag when flying at sea level, Assume e=0.8 (10 marks)

    b) Write some methods to reduce the wing tip vortices. (4 marks)

14. a) Explain Prandl's lifting line theory? (4 marks)

    b) Explain how the prandl's lifting line theory can be used to calculate the aerodynamic characteristics of a finite wing. (10 marks)

Module 3

15. a) Derive the expression for thrust required for a level unaccelerated flight. (8 marks)

    b) Obtain the condition for minimum thrust required for a level unaccelerated flight (6 marks)

16. a) What do you mean by power off glide? Derive the expression to find glide angle. (7 marks)

    b) Derive the Brequet range equation for a propeller driven airplane (7 marks)

Module 4

17. a) What is meant by static and dynamic stability of an aircraft. (7 marks)

    b) With Sketch, explain the working of airspeed indicator. . (7 marks)

18. a) Explain the working and functions of different gyroscopic instruments used in aircrafts. (7 marks)

    b) With the help of diagram, explain the working of different control surfaces of aircrafts. (7 marks)

Module 5

19. a) Explain the types of engines used for subsonic aircraft. (7 marks)

    b) Define orbital velocity? Derive the expression for it. (7 marks)

20. a) Explain the working of an Indraft wind tunnel. (7 marks)
    b) Briefly explain important space missions of ISRO. (7 marks)

Syllabus

Module 1

The atmosphere - characteristics of troposphere, stratosphere, thermosphere, and ionosphere - pressure, temperature and density variations in the atmosphere. Application of dimensional analysis – aerodynamic force – model study and similitude. 2D aero foils -Nomenclature and classification- pressure distribution in inviscid and real flows- momentum and circulation theory of aero foil- characteristics.

Module 2

3D or finite aero foils – effect of releasing the wingtips- wing tip vortices- replacement of finite wing by horse shoe vertex system, lifting line theory-wing load distribution – aspect ratio, induced drag calculation of induced drag from momentum considerations. Skin friction and from drag- changes in finite wing plan shape

Module 3

Propellers – momentum and blade element theories –propeller coefficients and charts. Aircraft performance-straight and level flight –power required and power available graphs for propeller and jet aircraft. Gliding and climbing –rate of climb-service and absolute ceilings-gliding angle and speed of flattest glide takeoff and landing performance – length of runway required- aircraft ground run- circling flight – radius of tightest turn-jet and rocket assisted take –off high lift devices-range and endurance of airplanes-charts for piston and jet engine aircrafts.

Module 4

Flight Instruments-airspeed indicator, calculation of true air speed-altimeter, gyro horizon - direction indicator-vertical speed indicator –turn and back indicator-air temperature indicator. (Brief description and qualitative ideas only). Ideas on stability-static and dynamic stability- longitudinal, lateral and directional stability- controls of an aero plane-aerodynamic balancing of control surfaces- mass balancing (Qualitative ideas only).

Module 5

Principles of wind tunnel testing –open and closed type wind tunnels-wind tunnel balance supersonic wind tunnels. Study of subsonic, Transonic, and supersonic aircraft engines (Description with figures only).Elementary ideas on space travel-calculation of earth orbiting and escape velocities ignoring air resistance and assuming circular orbit.

Text Books:

1. Anderson, Fundamentals of Aerodynamics, McGraw-Hill, 2010
2. A.C. Kermode, Mechanics of flight, Prentice Hall, 2007
3. EHJ Pallett, Aircraft Instruments and Integrated systems, Longman,1992

Reference Books:

1. Houghton and brock, Aerodynamics for Engineering Student, Hodder & Stoughton,1977

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1	**Module 1**	
1.1	The atmosphere - characteristics of troposphere, stratosphere, thermosphere, and ionosphere - pressure, temperature and density variations in the atmosphere.	**3**
1.21.2	Application of dimensional analysis – aerodynamic force – model study and similitude	**1**
.21.3	2D aero foils -Nomenclature and classification- pressure distribution in inviscid and real flows- momentum and circulation theory of aero foil- characteristics.	**3**
2	**Module 2**	
2.1	3D or finite aero foils – effect of releasing the wingtips-wing tip vortices- replacement of finite wing by horse shoe vertex system, lifting line theory-wing load distribution – aspect ratio, induced drag calculation of induced drag from momentum considerations. Skin friction and from drag-changes in finite wing plan shape	**7**
3	**Module 3**	
3.1	Propellers – momentum and blade element theories – propeller coefficients and charts. Aircraft performance-straight and level flight –power required and power available graphs for propeller and jet aircraft.	**4**
1.23.2	Gliding and climbing –rate of climb-service and absolute ceilings-gliding angle and speed of flattest glide takeoff and landing performance – length of runway required-aircraft ground run- circling flight – radius of tightest turn-jet and rocket assisted take –off high lift devices-range and endurance of airplanes-charts for piston and jet engine aircrafts.	**4**
4	**Module 4**	
4.1	Flight Instruments-airspeed indicator, calculation of true air speed-altimeter, gyro horizon -direction indicator-vertical speed indicator –turn and back indicator-air temperature indicator.	**4**
4.1	Ideas on stability-static and dynamic stability-longitudinal, lateral and directional stability- controls of an aero plane- aerodynamic balancing of control surfaces-mass balancing	**3**
5	**Module 5**	

5.1	Principles of wind tunnel testing –open and closed type wind tunnels-wind tunnel balance supersonic wind tunnels. Study of subsonic, Transonic, and supersonic aircraft engines. Elementary ideas on space travel-calculation of earth orbiting and escape velocities ignoring air resistance and assuming circular orbit.	**7**

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET453	HYBRID AND ELECTRIC VEHICLES	PEC	2	1	0	3

Preamble: This course aims to introduce the students to general overview of Hybrid Electric vehicle, Architecture of Hybrid Electric Drive Trains, control of various motors and drive with its different configuration. The course will also cover the power transmission of Electric vehicles and its components. The energy storage system with its management, charging methods and various sensors of Electric vehicles has been included. This course also covers the vehicle validation with its integration, Hardware & Software Interfaces, Chassis design, and Battery Positioning of Hybrid Electric vehicle.

Prerequisite: Nil

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

CO 1	Explain the general architecture of Electric vehicles
CO 2	Describe various motors and drives of Electric vehicles
CO 3	Explain details of power transmission of Electric vehicles and select the appropriate components based on requirement
CO 4	Describe charging, various sensors and battery management of Electric vehicles
CO 5	Apply vector tool simulation, do vehicle validation, chassis design and battery positioning of Electric vehicles

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

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	20	20	20
Apply	20	20	70
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1 With the help of block diagram explain the major components of an electric vehicle

2 Explain the EV drivetrain alternatives based on power source configuration

3 Which are the resistive forces that retard the motion of a four-wheel vehicle? Show with a diagram

Course Outcome 2 (CO2)

1 How the electric motors used in EVs differs from that of used in industrial application

2 Explain the physical concept of torque production in Induction motor

3 Enlist the strategies for maintaining constant magnetic flux

Course Outcome 3(CO3):

1 What is field oriented control

2 Why higher number of gears are not used in Electric vehicle

3 Explain the single speed reduction in Electric vehicles

Course Outcome 4 (CO4):

1 Explain the battery charging and equalization

2 What is the importance of efficient battery thermal management in electric vehicle

3 Enlist different charging protocols in Electric vehicles

Course Outcome 5 (CO5):

1 What is the importance of electric vehicle validation

2 What is electric control unit in Electric vehicle

3 Where is the high voltage battery located in an electric vehicle

Model Question Paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SEVENTH SEMESTER B.TECH DEGREE EXAMINATION

Course Code : MET453

Course Name : Hybrid and Electric vehicles

Max. Marks : 100 Duration : 3 Hours

PART – A

(*ANSWER ALL QUESTIONS, EACH QUESTION CARRIES 3 MARKS*)

1 Differentiate between the design of Parallel HEV and Series HEV.
2 Identify the major components of the power train of a pure Electric vehicle.
3 Mention the type of electric motor suitable for an Electric vehicle. Substantiate your answer.
4 Give the sketch of a Brushless DC motor. Show the major parts in the sketch.
5 What are the basic switching elements used in EVs?
6 Give the significance of Power Speed Ratio as applied to an electric motor in an EV.
7 What is meant by a sensor? Identify any 3 sensors used in EVs and give their functions.
8 Explain how a regenerative braking system helps to increase the range of an EV.
9 Draw the basic architecture of CAN .Explain its function in HEV
10 What are the design issues encountered by a system integration engineer in HEV development ?

PART – B

(*ANSWER ONE FULL QUESTION FROM EACH MODULE*)

Syllabus

Module 1

11 a) With an example, explain the socio economic impact of EVs in the Indian Scenario (8 Marks)

b) Why the first generation EVs had a premature death? In your opinion who is behind this ? .Give the facts to substantiate your answer. (6 Marks)

12 a)

Compute Forces due to drag, rolling resistance and gradient for the following vehicles assuming $\rho = 1.2$ (kg/m^3) and $\theta = 8°$. For the three vehicles given in the table, find Aerodynamic drag at velocity v1 and v2; also find rolling resistance at two velocities.

Vehicle	GVW (kg)	C_D	Area(sqm)	μ	v1(kmph)	v2(kmph)	Tyre radius (m)
2-wheeler	200	0.9	0.6	0.015	30	80	0.28
3-wheeler	600	0.45	1.6	0.015	30	80	0.2
4-wheeler	1500	0.3	2.5	0.015	30	80	0.3

(7 Marks)

b) What are the basic functions of a Power train ? Illustrate the concept in HEV scenario. (7 Marks)

Module 2

13 a) Differentiate between SPM and IPM based on Torque characteristics (8 Marks)

b) A vehicle is cruising at 36 kmph, the applied voltage is 25V, the BEMF is 24V and the winding resistance is 20 mΩ

How much current is the motor drawing?

What is the power delivered to the vehicle?

What is the load torque due to the vehicle, reflected on the motor?

What is the efficiency of the motor?

If the applied voltage were increased by 1V, what will be the final speed of the vehicle? (6 Marks)

14 a) What are the latest innovations in the design of high efficiency magnets ? Explain (7 Marks)

b) What are the important losses during electric to mechanical conversion in EVs? (7 Marks)

Module 3

15) a) Why a gear system is needed in EVs ? Explain with a comparison with its ICE counterpart (7 Marks)

b) What are the basic function of a motor controller ? Explain its role in the performance of EV in various terrains (7 Marks)

16) a) Why gear optimization in needed inEVs ? Explain with a practical example.

(8 Marks)

b) An EV has a DC source but works on AC motor. Explain in detail how the conversion is carried out ? (6 Marks)

Module 4

17 a) How battery selection is done in EVs? Explain by taking an Electric scooter as an example . (8 Marks)

b) A 3.5 V battery is at 2.7 V at SOC of 0% and 4.3 V at 100%. This implies the voltage of the battery lies in between 3.5 ± Delta % volts . What is Delta? (6 Marks)

18 a) Explain the design procedure of a BMS for an E-rikshaw right from the requirements (10 Marks)

b) Explain active thermal managent in bateery pack design. (6 Marks)

Module 5

19 a) Draw the electric diagram showing interconnections between a)ECU b)ABS sensor

c) Air conditioner using CAN protocol in HEV and explain its working (7 Marks)

b) What are the major hurdles faced in HEV integration? Explain by taking an Electric truck as an example (7 Marks)

20 a) What are the features differ in the design of chassis for a conventional ICE and HEV (7 Marks)

b) What are the challenges in the hardware /software interfacing in an HEV? Explain based on an example. (7 Marks)

Syllabus

Module 1

Introduction to Hybrid Electric Vehicles(HEV): History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles. Types of EVs, Review of Vehicle dynamics; Hybrid Electric Drive train. General configuration of Electric hybrid vehicles. Electric Vehicle (EV) Drive train Alternatives Based on Drive train Configuration.

Module 2

Induction motors and drives, configuration, controls and applications in EV/HEV's; Permanent magnet motors-neodymium and ferrite and samarium cobalt types and drives configuration, Brushless DC Motor (BLDC), Interior Permanent magnet (IPM), Switch reluctance motors (SRM) W-Axial,3 phase Induction controls and applications in EV/HEV's

Module 3

Motor Controllers/Inverters, Selection of automotive IGBT and MOSFET's, Field Oriented Control (FOC) & Space Vector Pulse Width Modulation (SVPWM) of Motors, Gearbox, selection of gear ratio, Different kinds of gearboxes, Gearbox optimisation, Transmission, Different kinds of transmission.

Module 4

EV charging, Fast charger, DC charger, AC charger, Battery swapping, Different charging protocols CHAdeMO,*CCS2,GB/T,* Customised charging protocols, Battery Box Engineering, Battery Management Bus Bar design, Battery Pack Design, Various Sensors and Sensing methods, Battery Safety Standards, Thermal Management – Battery

Module 5

Vehicle Validation, System Integration, Controller Area Networking (CAN) and Vector Tools Simulation, Vehicle Sensors specific to EV sensors interfaced to the ECU's in the vehicle network, Hardware & Software Interfaces and Implementation challenges and examples to solve, Chassis design, Battery Positioning.

Text Books

1. Husain I," Electric and Hybrid Vehicles": Design Fundamentals Boca Raton, CRC Press 2003

Reference Books

1. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003. 2.

2.Mehrdad Ehsani, YimiGao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.

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

4. Sandeep Dhameja, "Electric Vehicle Battery Systems", Newnes, 2000
.http://nptel.ac.in/courses/108103009/

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Module 1**	**8 Hours**
1.1	Introduction to Hybrid Electric Vehicles(HEV): History of hybrid and electric vehicles	2
1.2	social and environmental importance of hybrid and electric vehicles	1
1.3	Types of EVs,	1
1.4	Review of Vehicle dynamics;	2
1.5	Hybrid Electric Drive train. General configuration of Electric hybrid vehicles	1
1.6	Electric Vehicle (EV) Drive train Alternatives Based on Drive train Configuration.	1
2	**Module 2**	**8 Hours**
2.1	Induction motors and drives, configuration, controls and applications in EV/HEV's	2
2.2	Permanent magnet motors	1
2.3	neodymium and ferrite and samarium cobalt types and drives configuration	1
2.4	Brushless DC Motor (BLDC), Interior Permanent magnet (IPM),	

2.5	Switch reluctance motors (SRM	2
2.6	W-Axial,3 phase Induction controls and applications in EV/HEV's	1
	3 phase Induction controls and applications in EV/HEV's	1
3	**Module 3**	**7 Hours**
3.1	Motor Controllers/Inverters, Selection of automotive IGBT and MOSFET's	2
3.2	Field Oriented Control (FOC) & Space Vector Pulse Width Modulation (SVPWM) of Motors	1
3.3	Gearbox, selection of gear ratio, Different kinds of gearboxes	2
3.4	Gearbox optimisation, Transmission,	1
3.5	Different kinds of transmission	1
4	**Module 4**	**7 Hours**
4.1	EV charging, Fast charger, DC charger, AC charger, Battery swapping	1
4.2	Different charging protocols CHAdeMO,CCS2,GB/T, Customised charging protocols,	2
4.3	Battery Box Engineering, Battery Management	1
4.4	Bus Bar design, Battery Pack Design	1
4.5	Various Sensors and Sensing methods,	1
4.6	Battery Safety Standards, Thermal Management – Batter	1
5	**Module 5**	**7 Hours**
5.1	Vehicle Validation, System Integration	1
5.2	Controller Area Networking (CAN) and Vector Tools Simulation,	1
5.3	Vehicle Sensors specific to EV sensors interfaced to the ECU's in the vehicle network,	2
5.4	Hardware & Software Interfaces	1
5.5	and Implementation challenges and examples to solve	1
5.6	Chassis design, Battery Positioning	1

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET463	OPERATIONS MANAGEMENT	PEC	2	1	0	3

Preamble: This course is designed to facilitate the students to acquire knowledge about operations management concepts, tools and techniques. This course covers system concept of production, facility location analysis, facility layout, line balancing, demand forecasting, aggregate planning, material requirement planning and production scheduling. It empowers the students to amalgamate their knowledge and thus inculcate the skills needed to apply these concepts, tools and techniques in industry.

Prerequisite: Nil

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

CO 1	Understand operations, production system and perform facility location analysis.
CO 2	Impart knowledge of facility layout, layout planning and perform line balancing.
CO 3	Compute demand forecast and forecast accuracy.
CO 4	Perform aggregate planning and materials requirement planning.
CO 5	Apply various algorithms for production scheduling.

Mapping of Course Outcomes with Program Outcomes

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

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	20	20	30
Apply	20	20	60
Analyse			
Evaluate			
Create			

Mark Distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Demonstrate the concept of operations management.
2. List the type of production system with examples.
3. Determine the location of a facility.

Course Outcome 2 (CO2):

1. List different types of facility layouts with examples.
2. Describe layout design procedures.
3. Group the activities for line balancing.

Course Outcome 3 (CO3):

1. Demonstrate need and uses of demand forecasting.
2. Compute demand forecast.
3. Compare demand forecasts from different methods.

Course Outcome 4 (CO4):

1. Compare aggregate planning strategies.
2. Demonstrate lot sizing techniques for MRP.

3. Compute MRP tables.

Course Outcome 5 (CO5):

1. Illustrate the concept of production scheduling.

2. Identify scheduling objectives might be appropriate for different manufacturing environments.

3. Find production schedule using various techniques.

Model Question Paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SEVENTH SMESTER B. TECH DEGREE EXAMINATION

Course Code: MET463

Course Name: OPERATIONS MANAGEMENT

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

PART A

(ANSWER ALL QUESTIONS, EACH QUESTION CARRIES 3 MARKS)

1. What are the criteria for make or buy decisions.
2. Explain how you would reengineer a process you find troubling.
3. How does a cellular layout combine a product and process layout?
4. State the basic differences between construction type and improvement type layout algorithms.
5. Describe the difference between short- and long-range forecasts.
6. What is the difference between a trend and a cycle and a seasonal pattern?
7. Differentiate between level production strategy and chase demand strategy.
8. What are the basic inputs for MRP?
9. Explain the concept of single machine scheduling problem.
10. What is Gantt chart and when are they used so often?

PART B

(ANSWER ONE FULL QUESTION FROM EACH MODULE, EACH QUESTION CARRIES 14 MARKS)

MODULE 1

11. What activities are involved in the operations function? How do operations interact with other functional areas?

12. A development company is attempting to determine the location for a new outlet mall. The region where the outlet mall will be constructed includes four towns, which together

have a sizable population base. The grid map coordinates of the four towns and the population of each are as follows:

Town	Coordinates		Population (10,000s)
	x	y	
1	30	60	6.5
2	50	40	4.2
3	10	70	5.9
4	40	30	3.5

a. Determine the best location for the outlet mall using the centre-of-gravity method.

b. Plot four towns and the location of the new mall on a grid map.

MODULE 2

13. Describe systematic layout planning. Narrate the steps of CRAFT and ALDEP.

14. Consider the following assembly network relationships of a product. The number of shifts per day is two and the number of working hours per shift is 8. The company aims to produce 80 units of product per day. Group the activities into workstations using rank positional weight method and compute balancing efficiency.

Operations Number	1	2	3	4	5	6	7	8	9	10
Immediate Preceding Tasks	-	1	1	1	2, 3	3, 4	5	5, 6	4, 6	7, 8, 9
Duration (min)	7	2	2	5	8	3	4	7	9	8

MODULE 3

15. What the effect on the exponential smoothing model will increasing the smoothing constant have? How does adjusted exponential smoothing differ from exponential smoothing? What determines the choice of the smoothing constant for trend in an adjusted exponential smoothing model?

16. The following table represents the sales data of milk (in litres) sold by a milk booth.

Month	1	2	3	4	5	6	7	8
Sales	90	106	92	114	108	98	99	115

a. Compute a 3-month moving average forecast for months 4 through 9.

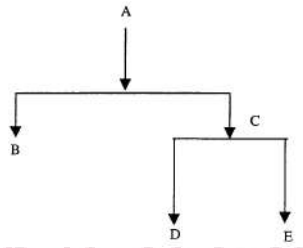
b. Computer a weighted 3-month moving average forecast for months 4 through 9. Assign weights of 0.50, 0.30, and 0.20 to the months in sequence, starting with the most recent month.

c. Compare the two forecasts using MAD. Which forecast appears to be more accurate?

MODULE 4

17. Describe the output of aggregate planning. When is aggregate planning most useful? Discuss the advantages and disadvantages of using part time workers, subcontracting work, and building up inventory as strategies for meeting demand.

18. Given the following Product structure, BOM, MPS and inventory status, compute MRP tables for all items.



Product Structure

Bill of Materials

Part	Order Quantity	Lead Time (Week)	Inventory on Hand
A	350	1	220
B	400	2	250
C	800	1	120
D	850	1	105
E	250	1	250

Master Production Schedule

Month	1	2	3	4	5	6
Demand	200	-	-	240	150	220

MODULE 5

19. Define the term 'scheduling'. Explain the different performance measures in scheduling? Give examples of four types of operations and suggest which scheduling objectives might be appropriate for each.

20. Consider the following n jobs parallel identical machines problem

Job - j	1	2	3	4	5	6	7	8	9
t_j	5	21	16	6	25	19	20	10	6
w_j	3	2	4	2	4	3	1	2	1

Find the schedule which will minimize the weighted mean flow time, if the number of parallel identical machines is three.

Syllabus

Module 1

Introduction to operations management: operations function, operations strategy, system concept of production, types of production system – job shop production – batch production – mass production, process planning, make or buy decisions, process reengineering.

Facilities location: Facility location factors, location analysis techniques – location factor rating – center of gravity technique – load distance technique. (7 hours)

Module 2

Capacities and facilities: capacity planning**,** facility layout – objectives, types of layout – process layout – product layout – fixed position layout – cellular layout, systematic layout planning, layout design procedures – CRAFT – CORELAP – ALDEP.

Assembly line balancing: methods for line balancing – rank positional weight method – COMSOAL. (7 hours)

Module 3

Demand forecasting: need and uses of forecasting, components of forecasting demand, time series methods – moving average – weighted moving average – exponential smoothing – adjusted exponential smoothing – linear regression – seasonal adjustments, forecast accuracy. (7 hours)

Module 4

Aggregate planning: aggregate planning strategies – heuristic method for aggregate planning.

Materials requirement planning: objectives, master production schedule, bill of materials, MRP calculations, lot sizing in MRP – economic order quantity method for lot sizing – minimum cost per period method – periodic order quantity method – least unit cost method, evolution from MRP to manufacturing resource planning (MRP II). (7 hours)

Module 5

Introduction to production scheduling: objectives – processing characteristics and constraints – performance measures, Gantt chart, single machine scheduling – SPT rule to minimize mean flow time – EDD rule to maximum lateness, parallel processors – minimization of makespan – mean weighted flow time – McNaughton's algorithm, flow shop scheduling – extension of Johnson's rule for 3 machine problem – Palmer's heuristic. (7 hours)

Text Books

1. Roberta S. Russell and Bernard W. Taylor III, Operations Management, John Wiley & Sons, Inc., Seventh Edition, 2011.
2. R. Paneerselvam, Production and Operations Management, PHI, 2010

Reference Books

1. P. B. Mahapatra, Operations Management: A Quantitative Approach, PHI, 2010
2. G. Sreenivasan, Quantitative Models in Operations and Supply Chain Management, PHI.
3. Heizer and Render, Operations Management, Pearson Education, Eleventh Edition

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Module 1**	
1.1	Introduction to operations management: operations function, operations strategy, system concept of production, types of production system – job shop production – batch production – mass production.	3
1.2	Process planning, make or buy decisions, process reengineering.	2
1.3	Facilities location: Facility location factors, location analysis techniques – location factor rating – center of gravity technique – load distance technique.	2
2	**Module 2**	
2.1	Capacities and facilities: capacity planning, facility layout – objectives, types of layout – process layout – product layout – fixed position layout – cellular layout.	2
2.2	Systematic layout planning, layout design procedures – CRAFT – CORELAP – ALDEP.	3
2.3	Assembly line balancing: methods for line balancing – rank positional weight method – COMSOAL.	2
3	**Module 3**	
3.1	Demand forecasting: need and uses of forecasting, components of forecasting demand.	2
3.2	Time series methods – moving average – weighted moving average – exponential smoothing – adjusted exponential smoothing.	3
3.3	Linear regression – seasonal adjustments, forecast accuracy.	2
4	**Module 4**	
4.1	Aggregate planning: aggregate planning strategies – heuristic method for aggregate planning.	3
4.2	Materials requirement planning: objectives, master production schedule, bill of materials, MRP calculations, lot sizing in MRP – economic order quantity method for lot sizing – minimum cost per period method – periodic order quantity method – least unit cost method.	3
4.3	Evolution from MRP to manufacturing resource planning (MRP II).	1
5	**Module 5**	

5.1	Introduction to production scheduling: objectives – processing characteristics and constraints – performance measures, Gantt chart.	2
5.2	Single machine scheduling – SPT rule to minimize mean flow time – EDD rule to maximum lateness, parallel processors – minimization of makespan – mean weighted flow time – McNaughton's algorithm.	3
5.3	Flow shop scheduling – extension of Johnson's rule for 3 machine problem – Palmer's heuristic.	2

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET473	AIR CONDITIONING AND REFRIGERATION	PEC	2	1	0	3

Preamble: The objectives of the course are:

- To introduce refrigeration and air conditioning systems.
- To impart knowledge in basics of vapour compression system and methods to improve efficiency.
- To understand working principle of vapour absorption refrigeration and steam jet refrigeration.
- To familiarize the components of refrigeration systems and to select environment friendly refrigerants
- To determine the capacity requirement of ac machine for an application.

Pre-requisite:MET 202 Engineering Thermodynamics.

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

CO 1	Explain the basics of refrigeration process.
CO 2	Analyse the vapour compression refrigeration system and to improve the performance.
CO 3	Describe vapour absorption and steam refrigeration system.
CO 4	Design refrigeration system by selecting suitable components and environmentally refrigerant.
CO 5	Evaluate the cooling load and capacity requirement of ac machine

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

Assessment Pattern

Bloom's Category	Continuous Assessment			End Semester Examination
	Assignment (%)	Test 1 (%)	Test 2 (%)	
Remember	25	20	20	10
Understand	25	40	40	20
Apply	25	40	40	70
Analyse	25			
Evaluate				
Create				

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define COP of a refrigeration machine and heat pump?
2. What is a boot strap refrigeration system?
3. Why aircrafts prefer air refrigeration system?

Course Outcome 2 (CO2)

1. Explain Vapour refrigeration system with the help of pressure- enthalpy diagram?

2. Explain flash inter-cooling method of improving efficiency of vapour compression system?

3. Explain cascade system with the help of neat diagram?

Course Outcome 3 (CO3):

1. Describe steam jet refrigeration system with the help of neat diagram?

2. Explain Lithium Bromide water absorption system. What are the advantages over ammonia absorption system?

3. Compare vapour absorption system with vapour compression system?

Course Outcome 4 (CO4):

1. Explain ODP and GWP of a refrigerant?

2. Explain scroll compressor with the help of neat sketch?

3. Explain the working principle and use of cooling tower with the help of a neat sketch?

Course Outcome 5 (CO5):

1. An Auditorium has seating capacity 800 people is to be maintained at 23°C DBTand50% RH. The outdoor conditions are 40°C DBT and 27°C WBT. The various loads in the office are: Solar heat gain 10KW, sensible heat gain per occupant 80W, Latent heat per occupant 70W, Lighting load 5KW, Sensible heating load from other sources 12KW, Infiltration load 0.3m^3/sec. Outdoor air and return air is mixed in the ratio of 1: 6 ,before cooling coil (processing unit) and then supplied to room. The supply temperature cannot be lower than 12^0C .find capacity of the plant required, mass flow rate of air?

2. What is ESR, ISEER, GSHF and RSHF? Explain?

3. Explain different psychrometric process and represent it in a psychrometric chart?

Model Question Paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

MET 473- AIR CONDITIONING AND REFRIGERATION.

Maximum: 100 Marks **Duration: 3 hours**

PART A

Answer all questions. Each question carries 3 marks

1. Define COP of a refrigeration machine and heat pump?
2. Why aircrafts prefer air refrigeration system?
3. Explain Vapour refrigeration system with the help of pressure- enthalpy diagram?
4. Write sub cooling of condenser out let method improving COP of vapour compression system with the help of p-h diagram.
5. Compare vapour absorption system with vapour compression system?
6. Compare steam jet refrigeration system with vapour compression system?
7. Explain ODP and GWP of a refrigerant?
8. Explain the method of detection of leakage of refrigerant?
9. What are ESR, ISEER, GSHF and RSHF?
10. What is IPLV of an air conditioner? (10 X 3 = 30 Marks)

PART B

Answer one full question from each module

MODULE 1

11. a.Explain the application of refrigeration? 4 marks

b. A boot strap air refrigeration system is used for a flight to takes 20 TONS of cooling loads. The ambient conditions are air conditions are 5 ^{0}C and 0.85 Bar. The air pressure increases to 1.1 bars due to ramming action, which is considered to be ideal. The output pressure of the main air compressor is 3.5 Bar and this is further compressed in the secondary compressor to 4.5 Bar. The isentropic efficiency of both main and secondary compressors is 90% and that of cooling turbine is 80%. Heat exchanger effectiveness is 0.6, for both primary and secondary heat exchangers.Determine: Power required taking the cabin load; COP of the system, the turbine runs the secondary compressor and uses its surplus power to run the fan for blowing ram air, Cabin to be maintained at pressure as 1 Bar, 25^0 C?

10 marks

12. a. What are the limitations of Carnot refrigeration cycle? 4 marks

b. In an aero plane uses air-refrigeration system, the air at 5 bars and 200°C is bled-off from the main compressor and is cooled in a heat exchanger with the use of ram air. The pressure and temperature of the air leaving the heat exchanger are 4.5 bar and 40°C. The ram air is forced through the heat exchanger by a fan run by expander turbine. The air coming out from the heat exchanger is passed through an expander and then supplied to the cabin at I bar, the pressure loss between the expander and cabin is 0.2 bars. If the air flow rate through the expander turbine is 30 kg/mm. find the followings- The temperature of the air leaving the expander, The kW delivered to the ram air which is passed through the heat exchanger, The refrigeration capacity in tons of refrigeration if the cold air coming out from the expander turbine is tempered by mixing with bypassed warm air and delivered to the cabin. The temperature of the air leaving the cabin is limited to 25° C.

Assume the followings:

Isentropic efficiency of the expander turbine = 75%.

γ (for air) = 1.4, Cp (for air) = 1KJ/kg-K

Neglect heat losses. 10 marks

MODULE II

13. a. A refrigerating machine using F12 as working fluid works between the temperatures 18°C and 37°C. The enthalpy of liquid at 37°C is 72 KJ/kg. The enthalpies of F12 entering and leaving the compressor are 195 KJ/kg and 227 KJ/kg respectively. The rate of circulation of refrigerant is 2 kg/min and efficiency of compressor is 85% Determine; Capacity of the plant in TONS of refrigeration. Power required running the plant, COP of the plant? 7 marks

b. Explain Sub cooling by liquid vapour regenerative heat exchanger method of improving COP of vapour compression system with the help of necessary sketch? . 7 marks

14. a. A simple vapour compression cycle using Freon 22 is designed for a load of 100 TR. The suction condition of the refrigerant is saturated vapour at 5°C and discharge condition is super heated at 40°C. Calculate (a) The mass flow rate of refrigerant; (b) The COP.? 7 marks

b. Explain the Multi stage compression (with flash inter cooling) method of improving COP with the help of line diagram and P- h diagram? 7 marks

MODULE III

15.a. Electrolux vapours absorption system of refrigeration with the help of line diagram? 7 marks

b. explains Steam jet refrigeration system with the help of line diagram what are the applications, relative merits and demerits? 7 marks

16. a. Explain Lithium Bromide water system. What are the merits and demerits of the system? 8 marks

b. Compare water absorption system and vapour compression system? What are the relative merits and demerits? 6 marks

MODULE IV

17. a. Explain different types of refrigerants available and their relative merits and demerits? 7 marks

b. Explain the working of Scroll compressor with the help of neat sketch? 7 marks

18.a. Explain reciprocating compressor with the help of neat diagram? What are the relative merits and demerits? 7 marks

b. Explain working of a cooling tower with the help of a neat sketch. What are the applications of cooling tower? 7 marks

MODULE V

19a. An Auditorium has seating capacity 800 people is to be maintained at 23°C DBTand50% RH. The outdoor conditions are 40°C DBT and 27°C WBT. The various loads in the office are: Solar heat gain 10KW, sensible heat gain per occupant 80W, Latent heat per occupant 70W, Lighting load 5KW, Sensible heating load from other sources 12KW, Infiltration load 0.3m^3/sec. Outdoor air and return air is mixed in the ratio of 1: 6 ,before cooling coil (processing unit) and then supplied to room. The supply temperature cannot be lower than 12^{0}C .find capacity of the plant required, mass flow rate of air 12 marks

b. Define absolute humidity and relative humidity? 2 marks

20 a. An office for seating 30 occupants is to be maintained at 22°C DBTand55% RH. The outdoor conditions are 36°C DBT and 27°C WBT. The various loads In the office are: Solar heat gain 8500W, Sensible heat gain per occupant 83W, Latent heat gain per occupant 100W, Lighting load 2500W,Sensible heat load from other sources 12000W, infiltration load 15 cubic meter/minute .Assuming 40% fresh air and 60% of re-circulated air passing through the evaporator coil and ADP of the coil is 8 ^{0}C. Find capacity of the plant and mass flow rate of air? 12 marks

b. What is dew point temperature and represent it in the psychrometric chart? 2 marks

Syllabus

Module 1- Introduction to refrigeration

Introduction –applications of refrigeration. Thermodynamics of refrigeration- reversed Carnot cycle, Limitations, heat pump, COP, Unit of refrigeration- Air refrigeration systems- Reversed Joule cycle, Air craft refrigeration systems, comparison, Boot strap system. Numerical examples.

Module 2 Vapour compression refrigeration.

Vapour compression systems- representation on T- s and P- h Diagrams. COP- Effect of operating parameters on COP – methods of improving COP of simple cycle- super- heating , under cooling, Liquid suction heat exchanger, actual cycle.Multi pressure systems - multi compression and multi evaporator, systems, Inter cooling - flash inter cooling and flash gas removal- numerical examples,

Cryogenic temperature system, Cascade system.

Module 3 Vapour absorption and steam jet refrigeration.

Vapour absorption systems - Ammonia – water system - simple system- drawbacks-Lithium Bromide water system- Electrolux- comparison with vapour compression system. Steam jet refrigeration. Applications, relative merits and demerits.

Module 4 Refrigeration system components

Refrigeration system components- Compressors, condensers, expansion devices, evaporators. Cooling towers- Different types and their application fields- Refrigerant leakage and detection – charging of refrigerant.

Refrigerants and their properties, CFC, HCFC, HFC, HC refrigerants -Eco-friendly Refrigerants, ODP, GWP, selection of refrigerants for different applications

Module 5 Air conditioning.

Psychrometric, Psychrometric properties- dry, wet and dew point temperature – humidity, specific humidity, absolute humidity, relative humidity and degree of saturation- enthalpy of moisture- adiabatic saturation process -psychrometers. psychometric chart- Psychometric processes- adiabatic mixing- sensible heating and cooling- humidifying and dehumidifying, air washer – bypass factor- sensible heat factor-RSHF and GSHF line- Design condition- Apparent dew point temperature – Numerical examples.

Air conditioning- applications, Comfort air conditioning- factors affecting human comfort. Effective temperature – comfort chart. Unitary and central system comparison. Capacity determination-cooling load estimation. COP, EER, IEER, IPLV, star rating, specification of capacity TONs, HP, Numerical examples.

Text Books

1. Refrigeration and Air Conditioning, Arora C.P, Tata McGraw hill.

2. A Course in Refrigeration and air conditioning Arora S. C. and S. Domkundwar, Dhanpat Rai and Company. 2002

3. A text book of Refrigeration and air conditioning – R.K .Regiput, Katson books.

4. Refrigeration and air conditioning - Ahamadul Ameen Eastern economy addition.

5. Heating, Ventilating, and Air Conditioning: Analysis and Design, Faye C. Mcquiston, Jerald D. Parker, Jeffrey D. Spitler, John Wiley and sons. New York

Data books

1. Refrigeration tables and charts including air conditioning data, C P Kothandaraman , New Age International.

2. Refrigeration and air conditioning data book, Domkunduwar and Domkundwar, Dhanpat Rai & co.

Reference books

1. ASHRAE Handbook 201(Volume 1,2,3)

2. Principles of heating ventilation and air conditioning in building, john Dixon, Delmar learning

3. Analysis and design of heating ventilation and air conditioning system, Herbert W stanferd and Adam F spach, CRC press -Taylor and Francis.

Course Contents and Lecture Schedule

MODULE	TOPICS	HOURS ALLOTED
1	Introduction –applications of refrigeration.	**2-0-0**
	Thermodynamics of refrigeration- reversed Carnot cycle, Limitations, heat pump, COP ,Unit of refrigeration- Air refrigeration systems- Reversed Joule cycle, Air craft refrigeration systems, comparison.	**2-1-0**
	Boot strap system. Numerical examples	**2-1-0**
2	Vapour compression systems- representation on T- s and P- h Diagrams. COP- Effect of operating parameters on COP	**2-1-0**
	methods of improving COP of simple cycle- super- heating , under cooling, Liquid suction heat exchanger, actual cycle.Multi pressure systems - multi compression and multi evaporator, systems, Inter cooling - flash inter cooling and flash gas removal-	**2-1-0**

	numerical examples .	
	Cryogenic temperature system, Cascade system.	**2-0-0**
3	Vapour absorption systems - Steam jet refrigeration. Applications, relative merits and demerits - simple system- drawbacks-Lithium Bromide water system.	**3-1-0**
	Electrolux- comparison with vapour compression system.	**1-0-0**
	Steam jet refrigeration. Applications, relative merits and demerits	**1-0-0**
4	Refrigeration system components- Compressors, condensers, expansion devices, evaporators.	**2-1-0**
	Cooling towers- Different types and their application fields- Refrigerant leakage and detection – charging of refrigerant.	**2-0-0**
	Refrigerants and their properties, CFC, HCFC, HFC, HC refrigerants -Eco-friendly Refrigerants, ODP, GWP, selection of refrigerants for different applications.	**2-0-0**
5	Psychrometric, Psychrometric properties- dry, wet and dew point temperature – humidity, specific humidity, absolute humidity, relative humidity and degree of saturation- enthalpy of moisture- adiabatic saturation process -psychrometers. psychometric chart- Psychometric processes- adiabatic mixing- sensible heating and cooling- humidifying and dehumidifying, air washer – bypass factor- sensible heat factor-RSHF and GSHF line- Design condition- Apparent dew point temperature – Numerical examples.	**3-1-0**
	Air conditioning- applications, Comfort air conditioning- factors affecting human comfort. Effective temperature – comfort chart. Unitary and central system comparison. Capacity determination- cooling load estimation. COP, EER, IEER, IPLV, star rating, specification of capacity TONs, HP, Numerical examples.	**3-1-0**

SEMESTER VII

OPEN ELECTIVE

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET415	INTRODUCTION TO BUSINESS ANALYTICS	OEC	2	1	0	3

Prerequisite: Basic knowledge of information systems, statistics, and business environment

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

CO 1	Understand the fundamentals of business intelligence, analytics, and data science.
CO 2	Use real life data for effective decision making using statistical models.
CO 3	Understand the basic concepts of data warehousing and use of data mining techniques for business analytics.
CO 4	Describe text analytics and understand the need for text mining.
CO 5	Understand the essence of business performance management and business reporting.
CO 6	Explore emerging technologies, legal and ethical issues that may impact analytics and business intelligence.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

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

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions:

CO 1 Understand the fundamentals of business intelligence, analytics and data science

1. Differentiate between predictive analytics and prescriptive analytics.
2. What is online transaction processing system?
3. List and describe the major components of Business Intelligence.

CO 2 Use real life data for effective decision making using statistical models

1. What are the various measures of dispersion?
2. Write a short note on time series forecasting.
3. What is data pre-processing? Why is it required?

CO 3 Understand the basic concepts of data warehousing and use of data mining techniques for business analytics

1. What is a data warehouse?
2. Identify five specific applications of data mining and a few common characteristics.
3. List five software tools used for data mining applications.

CO 4 Describe text analytics and understand the need for text mining

1. Why is the popularity of text mining as an analytics tool increasing?
2. Explain the importance of text mining in academia.
3. What is web mining? List the applications of web mining

CO 5 Understand the essence of business performance management and business reporting

1. What are the various functions an effective business report fulfils?
2. What is a performance measurement system? How does it work?
3. Explain the role of business analytics in human resource management.

CO 6 Explore emerging technologies, legal and ethical issues that may impact analytics and business intelligence.

1. How does cloud computing affect Business Intelligence?
2. How does traditional analytics make use of location-based data?
3. List a few legal issues of analytics.

Model Question Paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SEVENTH SEMESTER B.TECH DEGREE EXAMINATION

MET415: INTRODUCTION TO BUSINESS ANALYTICS

Time: 3hours

Maximum marks: 100

PART-A (Answer all Questions)

1	Define Business Intelligence. How will you relate it with Business Analytics?	
2	What do you understand by the term Big Data?	
3	What are the measures of central tendency?	
4	Under what circumstances the use of inter-quartile range becomes essential?	
5	How does a data warehouse differ from a transactional database?	
6	Distinguish between text mining and web mining?	
7	What are the distinguishing features of Key Performance Indicators?	
8	What are the three components of a Business Performance System?	
9	There are serious privacy concerns in analytics. Comment.	
10	Name at least three major cloud service providers.	**(3x10=30)**

PART-B

11	Detail at least seven key system-oriented trends that have fostered the growth of Business Intelligence based decision making.	14
	OR	
12	Explain the various levels of analytics	14
13 a	What are the characteristics that define the readiness level of data for an analytic study?	9
b	Differentiate between structured and unstructured data.	5
	OR	
14	What is logistic regression? With a suitable example, explain the steps involved.	14
15 a	What are the important steps in data mining?	9
	What are data lakes? Compare it with a data warehouse.	5
	OR	
16 a	Write a short note on sentiment analysis	6
b	What is social media analytics? Explain its significance in business.	8
17 a	What are the main differences among line, bar and pi charts? When should you use one over the others?	7
b	What is an information dashboards? Why are they so popular?	7
	OR	

18	List and briefly describe the four phases of Business Performance Management Cycle	1	4
19	What are the major issues managers have to keep in mind while exploring IoT?	7	
	What are the potential benefits of using geo-spatial data for analytics? Give examples.	7	
	OR		
20	List a few ethical issues in analytics.	7	
	Describe new organisational units that are created because of analytics	7	

Syllabus

Module 1 (6 Hours)	**Introduction to Business Intelligence-** Definition, Need, and Evolution of Business Intelligence System and its components. **Introduction to Business Analytics-** Definition- Levels of Analytics – Descriptive, Predictive and Prescriptive Analytics- Application of business analytics in industries- case studies. **Transaction Processing and Analytic Processing-** Fundamentals of OLAP and OLTP **Introduction to Big Data Analytics-** Characteristics- Sources of Big Data.
Module 2 (10 Hours)	**Data-** Definition- Sources of Data- Readiness Level of Data for Analytic study- Unstructured and structured data- classification of data- Data pre-processing- Steps in data pre-processing. **Statistical Modelling for Business Analytics-** Descriptive Statistics- Measures of Central Tendency and Dispersion- Quartiles and inter-quartile range. **Regression Modelling for Inferential Statistics**- Linear Regression, Logistic Regression and Time Series Forecasting.
Module 3 (8 Hours)	**Data Warehousing:** Characteristics- Design Considerations for data warehouse- Data warehousing process- Data Lakes. **Data Mining:** Concepts - Data mining process- Applications- Software Tools. **Text and Web Analytics:** Text analytics and text mining overview - Text mining applications - Sentiment Analysis- Web mining overview- Fundamentals of Social media analytics
Module 4 (6 Hours)	**Business Reporting-** Concepts- Different types of charts and graphs- Data Visualisation and Visual Analytics **Business Performance Management:** Business performance management cycle- Performance Measurement System- Key Performance Indicators **Analytics in Business Support Functions-** Sales & Marketing, Human Resources, Financial Analytics, Production and operations analytics
Module 5 (5 Hours)	**Recent Trends, Privacy and Managerial Considerations in Analytics:** Use of Internet of Things for Business Analytics - Cloud Computing and Business Analytics- Location Based Analytics for Organisations - Issues of Legality, Privacy and Ethics- Impacts of Analytics in Organisations

Text Book

1.R. Sharda, D. Delen, and E. Turban, "Business Intelligence, Analytics, and Data Science: A Managerial Perspective", Pearson, 4th edition, 2018.

Reference Books

1.R. N. Prasad and S. Acharya, "Fundamentals of Business Analytics", Wiley, 2nd Edition, 2016

2.J. R. Evans, "Business Analytics", Pearson, 3rd Edition, 2019.

3. A. Maheshwari, "**Data Analytics**", McGraw Hill Education, 1st Edition, 2017

4. Business Analytics for Managers: Taking Business Intelligence Beyond Reporting, 2nd Edition, Wiley, 2016

Course Contents and Lecture Schedule

No	Topic	Hours
Module 1 (6 Hours)		
1.1	Introduction to Business Intelligence- Definition, Need, and Evolution of Business Intelligence System and its components	1
1.2	Introduction to Business Analytics- Definition- Levels of Analytics	1
1.3	Descriptive, Predictive and Prescriptive Analytics	1
1.4	Application of business analytics in industries- case studies	1
1.5	Transaction Processing and Analytic Processing- Fundamentals of OLAP and OLTP	1
1.6	Introduction to Big Data Analytics- Characteristics- Sources of Big Data	1
Module II (10 Hours)		
2.1	Data- Definition- Sources of Data- Readiness Level- Unstructured and structured data	1
2.2	Classification of data- Data Pre-processing- Steps in data pre-processing	1
2.3	Statistical Modelling for Business Analytics- Descriptive Statistics- Measures of Central Tendency and Dispersion	2
2.4	Quartiles and inter-quartile range.	1
2.5	Regression Modelling for Inferential Statistics- Linear Regression.	2
2.6	Logistic Regression	2
2.7	Time Series Forecasting	1
Module III (8 Hours)		
3.1	Data Warehousing: Characteristics- Design Considerations for data warehouse- Data warehousing process- Data Lakes	2
3.2	Data Mining: Concepts - Data mining process	1
3.3	Applications of Data Mining	1
3.4	Software Tools	1
3.5	Text & Web Analytics: Text analytics and text mining overview	1
3.6	Text mining applications- Sentiment Analysis	1
3.7	Web mining overview- Fundamentals of Social media analytics	1
Module IV (6 Hours)		
4.1	Business Reporting- Concepts- Different types of charts and graphs-	1
4.2	Data Visualisation and Visual Analytics	1
4.3	Business Performance Management: Business performance management cycle-	1
4.4	Performance Measurement System- Key Performance Indicators	1

4.5	Analytics in Business Support Functions- Sales & Marketing, Human Resources, Financial Analytics, Production and operations analytics	2
Module V (5 Hours)		
5.1	Use of Internet of Things for Business Analytics - Cloud Computing and Business Analytics	2
5.2	Location Based Analytics for Organisations	1
5.3	Issues of Legality, Privacy and Ethics	1
5.4	Impacts of Analytics in Organisations	1

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET425	QUANTITATIVE TECHNIQUES FOR ENGINEERS	OEC	2	1	0	3

Preamble: This course is designed to facilitate the students to acquire knowledge about quantitative techniques for engineers. This course covers linear programming, transportation problem, assignment problem, sequencing problem, network analysis, decision theory, game theory, queuing theory and simulation. It empowers the students to amalgamate their knowledge and thus inculcate the skills needed to apply these techniques in industry.

Prerequisite: Nil

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

CO 1	Solve problems using linear programming methods.
CO 2	Solve transportation problems and assignment problems.
CO 3	Solve sequencing problems and perform network analysis.
CO 4	Apply decision theory and game theory.
CO 5	Apply queuing theory and perform simulation for queuing problems.

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

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	10	10	20
Apply	30	30	70
Analyse			
Evaluate			
Create			

Mark Distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Demonstrate the applications of quantitative techniques.
2. Formulate mathematical model for the given problem.
3. Apply linear programming methods to get the optimum solution.

Course Outcome 2 (CO2):

1. Identify the applications of transportation problems and assignment problems.
2. Solve transportation problem to get the initial feasible solution or optimum solution.
3. Solve assignment problem in order to minimize the total cost.

Course Outcome 3 (CO3):

1. Demonstrate assumptions of sequencing problems.
2. Determine the optimal sequence of operations.
3. Construct project network diagram and perform network analysis.

Course Outcome 4 (CO4):

1. Compare various decision making conditions.
2. Determine the optimal decision based on the given criterion.
3. Determine the optimal strategies and value of the game**.**

Course Outcome 5 (CO5):

1. Illustrate the concept of simulation.
2. Demonstrate Monte Carlo simulation for a queuing system.
3. Determine the parameters of the queuing system.

Model Question Paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SEVENTH SMESTER B. TECH DEGREE EXAMINATION

Course Code: MET425

Course Name: QUANTITATIVE TECHNIQUES FOR ENGINEERS

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

PART A

(ANSWER ALL QUESTIONS, EACH QUESTION CARRIES 3 MARKS)

1. Discuss the applications of quantitative techniques.
2. Explain alternate optimum solution, unbounded solution and infeasible solution.
3. What are the applications of transportation problem?
4. Explain the similarity between transportation problem and assignment problem.
5. What are the assumptions in sequencing problem?
6. What is crashing of project network?
7. Differentiate between decision under certainty and decision under risk.
8. Explain players, strategy and saddle point of game theory.
9. Define simulation and its advantages.
10. Discuss the steps of Monte Carlo simulation.

PART B

(ANSWER ONE FULL QUESTION FROM EACH MODULE, EACH QUESTION CARRIES 14 MARKS)

MODULE 1

11. Solve the following LP problem using simplex method.

Maximize $Z = 3X_1 + 5X_2$

Subject to

$X_1 + X_2 \leq 4$

$3X_1 + 2X_2 \leq 18$

X_1 and $X_2 \geq 0$

12. A company produces 2 types of hats A and B. Every hat A requires twice as much labour time as the second hat B. If the company produces only hat B then it can produce a total of 500 hats per day. The market limits daily sales of hat A and B to 150 and 250 respectively. The profit on hat A and B are Rs. 8 and Rs. 5 respectively. Solve graphically to get the optimum solution.

MODULE 2

13. Obtain the initial basic feasible solution for the following transportation problem using (a) North west corner rule (b) Least cost cell method (c) Vogel's approximation method

	Warehouses				
Plants		X	Y	Z	Supply
	A	8	7	3	60

	B	3	8	9	70
	C	11	3	5	80
	Demand	50	80	80	

State which of the methods is better

14. Solve the following assignment problem in order to minimize the total cost. The costs of doing different jobs by different operators are given below.

	Operator					
Job		1	2	3	4	5
	1	5	6	8	6	4
	2	4	8	7	7	5
	3	7	7	4	5	4
	4	6	5	6	7	5
	5	4	7	8	6	8

MODULE 3

15. Find an optimal sequence for processing five jobs through four machines in the order A-B-C-D-E. Find the total minimum elapsed time if no passing of jobs is permitted. Also find idle time on each machine.

Jobs	Machines				
	A	B	C	D	E
1	9	7	5	4	11
2	8	8	6	7	12
3	7	6	7	8	10
4	10	5	5	4	8

16. Consider the data of a project summarized in the following table.

Activity	Immediate Predecessor(s)	Duration (weeks)		
		a	m	b
A	-	3	5	8
B	-	6	7	9
C	A	4	5	9
D	B	3	5	8
E	A	4	6	9
F	C, D	5	8	11
G	C, D. E	3	6	9
H	F	1	2	9

a. Construct the project network
b. Find the expected duration and variance of each activity
c. Find the critical path and expected project completion time.
d. What is the probability of completing the project on or before 35 weeks?

MODULE 4

17. Consider the following cost matrix and determine the best order size using the minimax criterion.

		Demand (D_j)				
		50	100	150	200	250
Order Size (Q_i)	75	950	1200	575	-675	-1425
	150	50	1700	2000	2250	1600
	225	-850	850	2550	3550	4525
	300	-1800	600	1800	2000	5000

Also obtain best order size based on the Hurwicz criterion ($\alpha = 0.5$).

18. Solve the following pay-off matrix. Also determine the optimal strategies and value of the game.

		A	
		1	2
B	1	10	8
	2	6	12

MODULE 5

19. A weighting station has single weighing bridge. The arrival rate of the vehicles coming to the weighting station follows Poisson distribution and it is 45 vehicles per hour. The service rate also follows Poisson distribution and it is 55 vehicles per hour. In front of the weighing bridge, the waiting space is sufficient for a maximum of 10 vehicles. Find the following;

a. Average waiting number of vehicles in the queue in front of the weighing bridge as well as in the weighing station.
b. Average waiting time per vehicle in front of the weighing bridge as well as in the weighing station.

20. The arrival rate of customers at a banking counter follows Poisson distribution with a mean of 30 per hour. The service rate of the counter clerk also follows Poisson distribution with a mean of 45 per hour.

a. What is the probability of having 0 customer in the system?
b. What is the probability of having 12 customers in the system?
c. Find L_s, L_q, W_s and W_q.

Syllabus

Module 1

Introduction to quantitative techniques – basics of operations research – applications. Linear programming – problem formulation – graphical method – simplex method – big-m method – two–phase method – duality in linear programming. (7 hours)

Module 2

Transportation problem – formulation – balanced & unbalanced transportation problems – north west corner rule – least cost method – Vogel's approximation method – stepping stone method. Assignment problem – formulation – optimal solution – Hungarian algorithm – variants of assignment problems. (7 hours)

Module 3

Sequencing problem – terminology and notations – assumptions – problems with n jobs through two machines – problems with n jobs through three machines – problems with n jobs through m machines. Network analysis – basic terms – network construction – time analysis – critical path method (CPM) – programme evaluation and review technique (PERT) – cost considerations in network analysis – crashing. (7 hours)

Module 4

Decision theory – steps in decision theory approach – decision making conditions – decisions under conditions of risk – decisions under uncertainty conditions – decision tree analysis. Game theory – games with saddle points – games without saddle points – 2 x 2 games – graphical method for m x 2 & 2 x n games. (7 hours)

Module 5

Introduction to queuing theory – terminologies – classification of queuing models – single server problems – multi server problems. Simulation – generation of random numbers – Monte Carlo simulation – queuing simulation model. (7 hours)

Text Books

1. Paneerselvam, R., Operations Research, Prentice Hall of India, New Delhi, 2017.
2. Taha, H. A., Operations Research: An Introduction, Pearson, 2013.

Reference Books

1. Miller, D. M. and Schmidt, J. W., Industrial Engineering and Operations Research, John Wiley & Sons, Signapore, 1990.
2. Goel, B. S. and Mittal, S. K., Operations Research, Pragati Prakashan, Meerut, 1999.
3. Banks, J., Carson, J. S., Nelson, B. L., and Nicol, D. M., Discrete-Event System Simulation, Third Edition, Pearson Education, Inc., 2001.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Module 1**	
1.1	Introduction to quantitative techniques – basics of operations research – applications.	1
1.2	Linear programming – problem formulation – graphical method.	2
1.3	simplex method – big-m method – two–phase method – duality in linear programming.	4
2	**Module 2**	
2.1	Transportation problem – formulation – balanced & unbalanced transportation problems – north west corner rule – least cost method	2
2.2	Vogel's method – stepping stone method.	2
2.3	Assignment problem – formulation – optimal solution – Hungarian algorithm – variants of assignment problems.	3
3	**Module 3**	
3.1	Sequencing problem – terminology and notations – assumptions – problems with n jobs through two machines – problems with n jobs through three machines – problems with n jobs through m machines.	2
3.2	Network analysis – basic terms – network construction – time analysis – critical path method (CPM).	2
3.3	Programme evaluation and review technique (PERT) – cost considerations in network analysis – crashing.	3
4	**Module 4**	
4.1	Decision theory – steps in decision theory approach – decision making conditions – decisions under conditions of risk.	2
4.2	Decisions under uncertainty conditions – decision tree analysis.	2
4.3	Game theory – games with saddle points – games without saddle points – 2 x 2 games – graphical method for m x 2 & 2 x n games.	3
5	**Module 5**	
5.1	Introduction to queuing theory – terminologies – classification of queuing models – single server problems.	3
5.2	Multi server problems.	3
5.3	Simulation – generation of random numbers – Monte Carlo simulation – queuing simulation model.	2

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET435	AUTOMOTIVE TECHNOLOGY	OEC	2	1	0	3

Preamble: The objective of this course is

- To know the anatomy of automobile in general
- To understand the working of different automotive systems and subsystems
- To update the latest developments in automobiles

Prerequisite: EST 120 Basics of Mechanical Engineering

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

CO 1	Explain different automotive systems and subsystems .
CO 2	Illustrate the working of transmission, suspension, steering and braking systems of an automobile.
CO 3	Summarize the basic technology in electric vehicles.
CO 4	Explain the various safety, security and comfort systems in automotive technology.

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	✓											✓
CO 2	✓											✓
CO 3	✓											✓
CO 4	✓											✓

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember			
Understand	50	50	100
Apply			
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the injection system in an SI engine.
2. Differentiate between MPFI and CRDI.
3. Describe an automobile engine layout and its components.

Course Outcome 2 (CO2)

1. Explain Ackermann steering mechanism with a neat sketch.
2. Explain in detail the working and function of ABS braking system.
3. Describe the need of clutch and gearbox in an automobile?

Course Outcome 3 (CO3):

1. What is the difference between an electric vehicle and a hybrid vehicle?
2. List out the differences in the chassis design of an electric vehicle comparing with the conventional chassis.
3. Explain the basic operation of a fuel cell.

Course Outcome 4 (CO4):

1. Explain the various safety features employed in automotive technology?
2. Explain the air conditioning system in an automobile.
3. Describe the functions of electro-mechanical and electronic immobilizers in the security of an automobile?

Model Question Paper

Max. Marks: 100 Duration: 3 Hours

PART A *(30 marks)*

Answer all questions, each carries 3 marks.

1. Explain turbocharger lag and the methods to reduce it.
2. Identify the difference between SI .and CI engine.
3. Describe automated manual transmission.
4. Explain the principle of dry friction clutch.
5. Compare between drum and disc brakes.
6. Summarize the features of hydro pneumatic suspension system .
7. Indicate the advantage of EV over conventional IC engines.
8. Explain Ackermann principle in steering mechanism system.
9. Explain the working of remote keyless entry in a vehicle.
10. Describe the child lock safety system.

PART B *(70 marks)*

Answer any one question from each module, each carries 14 marks.

Module 1

11. a) Distinguish between MPFI and CRDI systems. (6)

    b) Explain the working and advantages of turbocharger with a neat sketch (8)

12. Explain the fuel supply system, injection system and ignition system in an SI engine. (14)

Module 2

13. a) Discuss the working of Pull type diaphragm clutch with a neat sketch. (8)

    b) Cite the principle of operation of an electromagnetic clutch . (6)

14.	a)	Explain the need of a gear box and the common troubles encountered in gear boxes along with suitable remedies .	(8)
	b)	Describe the working of an epicyclic gear box.	(6)

Module 3

15.	a)	Represent the features of McPherson strut suspension system with a neat sketch.	(8)
	b)	Explain the function of an antiroll bar in a four wheeled vehicle .	(6)
16.	a)	Discuss the working and advantages of ABS over conventional systems.	(8)
	b)	Explain the properties of friction lining and pad materials	(6)

Module 4

17.	a)	Differentiate between over steering and under steering.	(8)
	b)	Illustrate the rack and pinion steering gear box system.	(6)
18.	a)	Explain the basic principle of a hydrogen fuel cell and its efficiency.	(8)
	b)	Indicate different type of batteries used in an electric vehicle.	(6)

Module 5

19.	a)	Explain the air conditioning system in an automobile.	(8)
	b)	Discuss the methods to control the aerodynamic lift in vehicles.	(6)
20.	a)	Classify active and passive safety systems in a car.	(8)
	b)	Explain how an electronic immobilizer can prevent the vehicle theft.	(6)

Syllabus

Module 1 (7 hours)

Automobile system layout- Engine and its components, SI and CI engine, working principle, Fuel supply and injection system-comparison, multiport fuel injection (MPFI) and common rail direct injection (CRDI) systems. Ignition system, Engine emission and standards.

Super charging systems: fundamentals, naturally aspirated engines and supercharged engines– Turbo charger, turbo lag

Module 2 (7 hours)

Friction clutch: Principle, dry friction clutches- Pull type diaphragm clutch, multiple diaphragm clutch, multi-plate hydraulically operated automatic transmission clutch, semi centrifugal clutch, fully automatic centrifugal clutch, and integral single plate diaphragm clutch. Electromagnetic clutch operation. wet clutch, clutch friction materials, fluid friction coupling.

Manual transmission- Need of gear box, power to weight ratio, speed operating range-five speed and reverse sliding mesh, constant mesh, and synchromesh gear boxes. Automatic transmission- Epicyclic gear box - torque convertor – Over drives. Automated manual transmission.

Module 3 (7 hours)

Suspension system: - Types of suspension springs, suspension geometry and terminology, types of suspension systems, independent suspension, Antiroll bar, Hydrogen suspension, hydro pneumatic suspension, suspension roll center and body roll.

Brakes: Principle of brake, classification of brakes-mechanical and hydraulic brakes- Drum and Disc brakes, properties of friction lining and pad materials, Anti-Lock Braking system (ABS), principle of operation and types of ABS.

Module 4 (7 hours)

Steering: -basic principle of a steering system– Ackermann –over steer and under steer – Steering geometry -slip angle, camber, king pin inclination, caster, toe-in and toe-out. Steering gear box–types- need of power assisted steering.

Electric Vehicle Technology (EVT): EV Architecture, types of batteries, battery parameters, super capacitors. Fuel cells and its efficiency. EV Chassis – requirements, suspension for EVs. Recent Electric vehicles- Electric mobility aids. Future of electric vehicles –Tesla S, Maglev trains, Electric rail road systems.

Module 5 (7 hours)

Safety-Active and passive safety, air bags, seat belt tightening system, forward collision warning system, child lock, advanced safety systems.

Comfort system –Automotive air-conditioning, aerodynamics lift and drag reduction, adaptive cruise control, tilt-able steering column and power window and advanced comfort system.

Security system -Anti theft technology-mechanical, electromechanical and electronic immobilizers, alarm system and remote keyless entry.

Text Books

1. Heinz Heisler, Vehicle and engine technology, Butterworth-Heinemann, 2nd edition,1998.

2. R.B. Gupta., Auto design , Satya Prakashan Publishers, New Delhi, 2016 .

3. James Larminie and John Lowry, Electric vehicle technology explained, Wiley publications, 2nd edition, 2015.

4. Kirpal Singh, Automobile Engineering Vol.1 & Vol.2, Standard Publishers, 13th edition, 2020.

Reference Books

1.V.A.W. Hillier, Fundamentals of modern vehicle technology, Butterworth-Heinemann, 2nd edition,1998.

2.Tom Denton, Electric and Hybrid Vehicles, Routledge Publishers, 2nd edition, 2020.

3.Ljubo Vlacic, Michel Parent and Fumio Harashima, Intelligent vehicle technologies, Butterworth-Heinemann publications, Oxford 2001.

4.ShimoKim and Rakesh Shresta, Automotive Cyber Security: Introduction Challenges and Standardization, Springer, Singapore, 1st edition. 2020.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Automobile system layout**	
1.1	Engine and its components- IC engines, piston, rings, pin, flywheel, connecting rod.	1
1.2	SI and CI engine, working principle	1
1.3	Fuel supply and injection system-comparison	1
1.4	MPFI and CRDI systems	1
1.5	Ignition system	1
1.6	Engine emission and standards	1
1.7	Super charging systems	1
2	**Clutch and transmission**	
2.1	Principle of dry friction clutches- Single plate clutch, Multi plate hydraulically operated automatic transmission clutch.	1
2.2	Semi centrifugal clutch, fully automatic centrifugal clutch	1
2.3	Integral single plate diaphragm clutch, Electromagnetic clutch	1

	operation.	
2.4	Clutch friction materials, wet clutches, fluid friction coupling.	1
2.5	Need of gear box, power to weight ratio, speed operating range .Sliding mesh, constant mesh and synchromesh gear boxes.	1
2.6	Epicyclic gear box, Torque convertor	1
2.7	Over drives, Automated manual transmission.	1
3	**Suspension and brake**	
3.1	Suspension system: - Types of suspension springs, suspension geometry and terminology.	1
3.2	Types of suspension systems ,independent suspension.	1
3.3	Antiroll bar, Hydrogen suspension, hydro pneumatic suspension.	1
3.4	Suspension roll center and body roll.	1
3.5	Brakes: Principle of brake, classification of brakes, mechanical and hydraulic brakes.	1
3.6	Drum and Disc brakes, properties of friction lining and pad materials	1
3.7	Anti-Lock Braking system (ABS), principle of operation and types of ABS.	1
4	**Steering and Electric vehicle technology**	
4.1	Ackermann steering mechanism, over steer and under steer .	1
4.2	Steering geometry -slip angle, camber, king pin inclination, caster, toe-in and toe-out.	1
4.3	Steering gear box, Types of steering gear box, need of power assisted steering.	1
4.4	EV Architecture, types of batteries, battery parameters, super capacitors. Fuel cells and its efficiency.	1
4.5	Super capacitors. Fuel cells and its efficiency.	1
4.6	EV Chassis – requirements, suspension for EVs. Recent Electric vehicles- Electric mobility aids.	1
4.7	Future of electric vehicles –Tesla S, Maglev trains, Electric rail road systems.	1

5	**Safety, control and security in automotive technology**	
5.1	Safety-Active and passive safety, air bags, seat belt tightening system,	1
5.2	Forward collision warning system, child lock antilock braking system	1
5.3	Comfort system - Automotive air-conditioning, aerodynamics lift and drag reduction,	1
5.4	Adaptive cruise control, tilt-able steering column, power window and advanced comfort system	2
5.5	Anti-theft technology-mechanical, electromechanical and electronic immobilizers.	1
5.6	Alarm system and remote keyless entry.	1

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET445	RENEWABLE ENERGY ENGINEERING	OEC	2	1	0	3

Preamble: The course is intended to give knowledge of various renewable energy sources, systems and applications and the need in the present context. Students will be able to compare different renewable energy techniques and choose the most appropriate based on local conditions. To equip students in working with projects and to take up research work in connected areas.

Prerequisite: Nil

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

CO1	Explain renewable energy sources and evaluate the implication of renewable energy. To predict solar radiation at a location
CO2	Explain solar energy collectors, storages, solar cell characteristics and applications
CO3	Explain the different types of wind power machines and control strategies of wind turbines
CO4	Explain the ocean energy and conversion devices and different Geothermal sources
CO5	Explain biomass energy conversion devices. Calculate the Net Present value and payback period

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

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	20	20	20
Apply	20	20	70
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions:

Course Outcome 1 (CO1):

1. What are the main renewable energy sources? Advantages and limitations
2. What is energy efficiency? How is it different from renewable energy use?
3. Define terms : Angle of Incidence, Declination, Solar constant

Course Outcome 2 (CO2):

1. Discuss different types of solar collectors
2. Discuss about different types of thermal storage devices
3. Draw the I-V characteristics of Solar cell under varying temperature and irradiation level

Course Outcome 3 (CO3):

1. Types of wind turbine and components
2. Difference between wind mill and wind turbine
3. Explain importance of drag and lift force in wind power generation.

Course Outcome 4 (CO4):

1. Explain with neat sketch the working of hybrid OTEC system
2. Explain with neat sketch the vapour dominated geothermal system

Course Outcome 5 (CO5):

1. Distinguish between Fixed dome plant and floating dome type biomass plant.
2. Write a short note on solar saving.
3. Derive expression for payback period

Model Question Paper

MODEL QUESTION PAPER

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

VII SEMESTER B.TECH DEGREE EXAMINATION

MET445 RENEWABLE ENERGY ENGINEERING

Maximum: 100 Marks **Duration: 3 hours**

PART A

Answer all questions, each question carries 3 marks

1. Discuss in brief advantages of renewable energy.
2. Explain the following terms related to solar geometry (i) Hour Angle ((ii) Zenith Angle (iii) Surface azimuth angle
3. List different types of solar collectors
4. Discuss about solar pond
5. List the different methods used to estimate wind speed at a location.
6. What are the advantages of wind energy conversion systems?
7. List the geothermal resources.
8. Discuss advantages and disadvantages of a tidal power plant
9. Name the different processes used for hydrogen production
10. List the need for economic analysis of renewable energy system.

(10 X 3 = 30 marks)

PART B

Answer one full question from each module

Module 1

11. Elucidate the necessity of energy storage in the context of renewable sources of energy (14 Marks)
12. (a) Calculate the number of daylight hours in Srinagar for 22nd June .The latitude of Srinagar as 34º05'N. (4 Marks)

(b) Compare the construction and working of Pyranometer and Pyrheliometer. (10 Marks)

Module 2

13. (a) How solar thermal power plants classified. List the methods for converting solar energy into electric power (10 Marks)

(b) Briefly explain the applications of a solar PV system.. (4 Marks)

14. (a) Draw and explain the operation of flat plate collectors. (10 Marks)

(b) Explain the thermal methods of energy storage (4 Marks)

Module 3

15. With a neat diagram explain the construction of a propeller type wind power system (14 marks)
16. (a) Derive the expression for power in the wind turbine. (7 marks)

b) Explain control mechanism in wind turbines (7 marks)

Module 4

17. State the principle of Ocean Thermal Energy Conversion (OTEC). Explain working of closed cycle OTEC system. (14 marks)
18. . Explain binary cycle Geothermal system (14 marks)

Module 5

19. Explain the construction and working of KVIC (floating type) bio gas plant (14 marks)
20. a.Define (1) Payback time (2) Return on investment .
    (3) Life cycle cost (6 marks)
    b. A solar PV system consisting with two lamps, a battery and other associated components cost Rs. 55000. The cost of conventional energy saved due to its installation is Rs. 4000 in the first year and this cost inflates at the rate of 5 % per year. Assume discounting rate is 9%. Calculate the payback period of the system with and without discounting (8 marks)

Syllabus

Module 1

The Energy Scenario- Commercial energy sources -World's production and reserves-India' Production and reserves, Energy Alternatives, Need for alternatives –solar option-nuclear options

Principles of solar radiation : Solar radiation outside the earth's atmosphere and at the earth's surface , Solar Constant, Basic Sun-Earth Angles, Instruments for measuring solar radiation and sunshine , Solar radiation data

Module 2

Solar Energy collectors: Solar thermal collectors -Flat plate collectors –Solar concentrators (parabolic trough, parabolic dish, Central Tower Collector) –Solar Air Heaters

Solar thermal electric power generation -Thermal Energy storage, sensible heat storage, latent heat storage , Thermo chemical storage , photovoltaic system for power generation , Solar pond -Solar Cells-Types of solar cells , principle of working and performance characteristics, Production process- Block diagram only

Applications- Solar space heating and cooling of buildings, solar pumping, solar cooker, solar still, solar drier, solar refrigeration and air-conditioning, heliostat, solar furnace

Module 3

Wind Energy- classification of wind turbines and power performance curve, Energy in wind, calculation of energy content, Power coefficients, Betz limit theory, , tip speed ratio, solidity of turbine' power control strategies, Basic principles of Wind Energy Conversion Systems (WECS), Classification of WECS, Parts of WECS

Module 4

Ocean Energy – Devices for Wave Energy conversion, Ocean Thermal Energy Conversion (OTEC): Principle of OTEC system, Methods of OTEC power generation – Open Cycle (Claude cycle), Closed Cycle (Anderson cycle) and Hybrid cycle (block diagram description of OTEC); Geothermal energy: Introduction, hot dry rock resources, magma resources, vapor and liquid dominated systems, binary cycle, advantages and disadvantages

Module 5

Bio Mass Energy- Biomass conversion technologies –Bio Gasification, Bio ethanol, Bio Diesel , Biogas production from waste biomass, factors affecting biogas generation Bio Gas -KVIC and Janata model ,Hydrogen Energy – various routes for production of Hydrogen energy,

Economic Analysis – Initial and annual cost, basic definitions, present worth calculations, repayment of loan in equal annual installments, annual savings, cumulative saving and life cycle cost, economic analysis of add on solar system, payback period(derivation)

Text Books:

1. S P Sukhatme , J K Nayak, Solar Energy: Principles of Thermal Collection and Storage, Mc Graw Hill ,2015
2. Tiwari G N, Ghosal M K ,Fundamentals of renewable energy sources, Alpha Science International Ltd.,2007
3. Jefferson W Tester et.a., Sustainable Energy Choosing among options,PHI,2006

Reference Books:

1. D.P. Kothari Renewable energy resources and emerging technologies, Prentice Hall of India Pvt. Ltd,2011
2. Mehmet KanoğluYunus A. Çengel John M. Cimbala , Fundamentals and Applications of Renewable Energy, Mc Graw Hill ,2019
3. Roland Wengenmayr, Thomas Buhrke, 'Renewable Energy: Sustainable energy concepts for the future, Wiley – VCH, 2012

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1	**The Energy Scenario**	**(5)**
1.1	Commercial energy sources -World's production and reserves India' Production and reserves	**1**
1.2	,Energy Alternatives- Need for alternatives –solar options	**1**
	Principles of solar radiation	
1.3	Solar radiation outside the earth's atmosphere and at the earth's surface , Solar Constant,	**1**
1.4	Basic Sun-Earth Angles, Instruments for measuring solar radiation and sunshine , Solar radiation data	**2**
2	**Solar Energy**	**(11)**
2.3	Solar thermal collectors -Flat plate collectors	**2**
2.4	Solar concentrators (parabolic trough, parabolic dish, Central Tower Collector	**2**
2.5	Solar Air Heaters-types - Solar thermal electric power generation Thermal Energy storage, sensible heat storage, latent heat storage , Thermo chemical storage	**2**
2.7	Photovoltaic system for power generation	**2**
2.8	Solar Cells-Types of solar cells , principle of working and performance characteristics, Production process- Block diagram only	**2**
2.9	Applications- Solar space heating and cooling of buildings, solar pumping, solar cooker, solar still, solar drier, solar refrigeration and air-conditioning, heliostat, solar furnace	**1**
3	**Wind Energy**	**(6)**
3.1	Classification of wind turbines	**1**
3.2	power performance curve, Energy in wind, calculation of energy content,	**2**
3.3	Power coefficients, Betz limit theory, , tip speed ratio, solidity of turbine' power control strategies	**2**
3.4	Basic principles of Wind Energy Conversion Systems (WECS), Classification of WECS, Parts of WECS	**1**
4	**Ocean Energy**	**(6)**
4.1	Devices for Wave Energy conversion Ocean Thermal Energy Conversion (OTEC): Principle of OTEC system,	**1**

4.2	Methods of OTEC power generation – Open Cycle (Claude cycle), Closed Cycle (Anderson cycle) and Hybrid cycle (block diagram description of OTEC)	**2**
4.3	Geothermal energy: Introduction , hot dry rock resources, magma resources	**1**
4.4	vapor and liquid dominated systems, binary cycle, advantages and disadvantages	**2**
5	**Bio Mass Energy**	**(8)**
5.1	Biomass conversion technologies –Bio Gasification, Bio ethanol, Bio Diesel	**1**
5.2	Biogas production from waste biomass, factors affecting biogas generation Bio Gas -KVIC and Janata model.	**2**
5.3	Hydrogen Energy – various routes for production of Hydrogen energy	**1**
5.3	**Economic Analysis – I**nitial and annual cost, basic definitions,	**1**
5.4	present worth calculations, repayment of loan in equal annual installments, annual savings, cumulative saving and life cycle cost	**2**
5.5	economic analysis of add on solar system, payback period(derivation)	**1**

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET455	QUALITY ENGINEERING AND MANAGEMENT	OEC	2	1	0	3

Preamble: This course is designed to facilitate the students to understand the concept and culture of total quality management. It empowers the students by inculcating the skills to use quality control techniques and other quality tools in solving quality-related problems and apply these principles in an industry. This course will also amalgamate their knowledge about the importance of customer satisfaction through desired quality at a competitive price.

Prerequisite: NIL

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

CO 1	To be conversant with important terms for quality management in organisations
CO 2	Have a complete theoretical and practical understanding of the contributions of Quality Gurus
CO 3	Demonstrate knowledge of the underlying principles of strategic quality management
CO 4	Identify various human dimensions of TQM
CO 5	Implement different tools and techniques in TQM
CO 6	Implement different statistical quality control 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					2						3
CO 2	2											2
CO 3	2	2	2						3		1	3
CO 4	3					3			3		1	3
CO 5	2	3	3	2	2				2		2	2
CO 6	2	3	3	2	2				2		2	2

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination (in %)
	1 (in %)	2 (in %)	
Remember	20	20	20
Understand	60	40	40
Apply	20	40	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 (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Distinguish between quality control and inspection.

2. What are the TQM axioms?

3. What are the enablers of total quality?

Course Outcome 2 (CO2)

1. Describe the Deming approach to TQM.

2. List out Crosby's fourteen steps for quality improvement.

3. Describe Juran’s quality trilogy.

Course Outcome 3(CO3):

1. Define strategic quality management.

2. With examples, describe the classification of quality costs.

3. Describe the concepts of Kaizen approach.

Course Outcome 4 (CO4):

1. What is meant by employee empowerment with respect to total quality management?
2. What are self managing teams?
3. Describe the importance of leadership in TQM

Course Outcome 5 (CO5):

1. “X and R charts always go hand in hand”. Elaborate.
2. What are the measures of Central tendency and dispersion?
3. Describe the principles of cause and effect diagram.

Course Outcome 6 (CO6):

1. Explain a typical OC curve for a control chart?
2. What are the effects of sample size on control limits?
3. Enumerate the differences between destructive and non-destructive testing methods.

Model Question Paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SEVENTH SEMESTER B.TECH DEGREE EXAMINATION

Course Code: MET455 Course Name: Quality Engineering and Management

Max. Marks: 100 Duration: 3 Hours

PART A

Answer ALL questions, each carries 3 marks.

1. Define the term" Quality control".
2. What are the enablers of total quality?
3. Describe the concept of Quality Function Deployment
4. What are the obstacles to achieving successful strategic quality management?
5. What is meant by employee empowerment?
6. Describe the importance of leadership in TQM
7. What are the applications of control charts?
8. Differentiate between 100% inspection and sampling with suitable examples.
9. Describe the principles of cause and effect diagram.
10. What are the benefits of quality auditing?

PART B

11.a) Compare Juran and Deming approaches (7)
b) Explain the characteristics of Total Quality Management. (7)

OR

12 a) Explain the three TQM axioms. (12)
b) Define Quality Planning. (2)

13. Describe the steps to be followed to integrate quality into strategic management journey of an organization. (14)

OR

14. (a) Enumerate the objectives of 5S . (7)
(b) Describe the components of Quality cost. (7)

15. What are self managing teams? What are the benefits and problems associated with them? Indicate the key steps to be followed to implement them in organizations. (14)

OR

16. What are the ingredients for success for a quality director? What are the activities to be carried out by a quality director towards assisting upper management with strategic management (14)

17. With the aid of examples, describe the types of failure. (14)

OR

18. What are the different phases of a bath tub curve? With the help of a sketch, illustrate the important features of each phase. (14)

19. Describe the steps to be followed for conducting a quality audit. (14)

OR

20. Following are the data on the quality costs incurred in a manufacturing company in a month:

Title of the quality cost	Amount in Rupees
Product audits	1,000
Scrap Disposal	50,000
Concessions and Downgrading	40,000
Calibration	2,000
Quality planning	500
Manufacturing losses	30,000
System failure	40,000
Test materials	5,000
Training	2,000
Customer returns	25,000

Classify the above quality costs into preventive, appraisal and failure costs. Conduct Pareto analysis and comment on the results. Suggest a proposal with anticipation on the quality costs observable in future. (14)

Syllabus

Module 1

Introduction to Quality Engineering - Definitions of the terms - quality, quality planning, quality control, quality assurance, quality management, Total Quality Management (TQM)- overview on TQM - the TQM axioms - consequences of total quality- Barriers to TQM- Deming approach to TQM – Juran's quality trilogy- Crosby's fourteen steps for quality improvement

Module 2

Strategic Quality Management: Cost of Quality- Customer satisfaction- Quality Function Deployment (QFD)- Integrating quality into strategic management - obstacles to achieving successful strategic quality management- Concepts of 5S, Six Sigma, Kaizen.

Module 3

Human dimensions of TQM – Top management commitment- Leadership for TQM- Change management- resources for quality activities - training for quality –Employee involvement, motivation empowerment- teamwork- self managing teams - role of the quality director- Quality System: ISO 9000 family of standards.

Module 4

Quality control and Inspection- Destructive and non-destructive testing methods- process capability- Statistical quality control –Acceptance sampling- causes of variation in quality-control charts for X and R, Problems- Reliability-types and causes of failures- Bath tub curve.-System reliability- life testing.

Module 5

Supporting Tools, Activities And Techniques in TQM Projects : Affinity diagram - brainstorming - cause and effect analysis - process flow chart – check sheets- Scatter diagram - Pareto chart- Histogram and fundamentals of statistics - Taguchi's robust design- Total Productive maintenance- Failure Mode and Effect Analysis - Quality auditing- types and benefits.

Text Books

1. Besterfield Dale H. , Besterfield Carol, Besterfield Glen H., Besterfield Mary, Urdhwareshe Hemant, Urdhwareshe Rashmi, "Total Quality Management (TQM) 5e", Pearson Education, 2018.

2. Subburaj Ramasamy, "Total Quality Management", McGraw Hill Education,, 2017.

3. Dr. K.C. Arora, "Total Quality Management", S K Kataria and Sons, 2013.

4. Suganthi, L and Anand A Samuel, "Total Quality Management", Prentice Hall India Learning Private Limited, 2009.

5. Juran J M and Gryna, F M, "Quality Planning and Analysis - From Product Development through Use", Tata McGraw Hill Publishing Limited, New Delhi, Third Edition, 2004.

Reference Books

1. Logothetics N, "Managing for Total Quality - From Deming to Taguchi and SPC", Prentice Hall Ltd., New Delhi, 1997.
2. Deming W E, "Out of the Crisis," MIT Press, Cambridge, MA, 1982.
3. Juran J M and Juran on "Leadership for Quality" An Executive Handbook, The Free Press, New York, 1989.
4. Salor J H, "TQM-FIeld Manual," McGraw Hill, New York, 1992.
5. Crosby P B, "Quality is Free" McGraw Hill, New York, 1979.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Introduction to Quality Engineering**	
1.1	Definitions of the terms - quality, quality planning, quality control, quality assurance, quality management	2
1.2	Total Quality Management (TQM)- overview on TQM - the TQM axioms - consequences of total quality- Barriers to TQM	2
1.3	Deming approach to TQM - Juran quality trilogy- Crosby's fourteen steps for quality improvement	3
2	**Strategic Quality Management**	
2.1	Cost of Quality- Customer satisfaction- Quality Function Deployment (QFD)	2
2.2	Integrating quality into strategic management - quality and the management cycle	1
2.3	obstacles to achieving successful strategic quality management	1
2.4	Concepts of 5S, Six Sigma, Kaizen	2
3	**Human dimensions of TQM**	
3.1	Top management commitment- Leadership for TQM- Change management	2
3.2	Resources for quality activities - training for quality	1
3.3	Employee involvement, motivation, empowerment	2
3.3	Teamwork- self managing teams - role of the quality director	1
3.4	Quality System: ISO 9000 family of standards.	1
4	**Quality control and Inspection**	
4.1	Destructive and non-destructive testing methods	1
4.2	Process capability- Statistical quality control –acceptance sampling- causes of variation in quality	2
4.3	Control charts for X and R. Reliability-	3

4.4	causes of failures- Bath tub curve	1
4.5	System reliability- life testing	1
5	**Supporting Tools, Activities And Techniques in TQM Projects**	
5.1	Affinity diagram - brainstorming	1
5.2	Cause and effect analysis - process flow chart – check sheets- Scatter diagram - Pareto chart	3
5.3	Histogram and fundamentals of statistics	1
5.4	Taguchi's robust design- Total Productive maintenance- Failure Mode and Effect Analysis	2
5.5	Quality auditing- types and benefits	1

SEMESTER VII

MINOR

MED481	MINI PROJECT	CATEGORY	L	T	P	CREDIT
		PWS	0	0	3	4

Preamble: Mini Project Phase I: A Project topic must be selected either from research literature or the students themselves may propose suitable topics in consultation with their guides. The object of Project Work I is to enable the student to take up investigative study in the broad field of Mechanical Engineering, either fully theoretical/practical or involving both theoretical and practical work to be assigned by the Department on a group of three/four students, under the guidance of a Supervisor. This is expected to provide a good initiation for the student(s) in R&D work. The assignment to normally include:

- Survey and study of published literature on the assigned topic;
- Preparing an Action Plan for conducting the investigation, including team work;
- Working out a preliminary Approach to the Problem relating to the assigned topic;
- Block level design documentation
- Conducting preliminary Analysis/ Modelling/ Simulation/ Experiment/ Design/ Feasibility;
- Preparing a Written Report on the Study conducted for presentation to the Department;

CO1	Identify and synthesize problems and propose solutions to them.
CO2	Prepare work plan and liaison with the team in completing as per schedule.
CO3	Validate the above solutions by theoretical calculations and through experimental
CO4	Write technical reports and develop proper communication skills.
CO5	Present the data and defend ideas.

Mapping of course outcomes with program outcomes

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

*1-slight/low mapping, 2- moderate/medium mapping, 3-substantial/high mapping

Assessment Pattern

The End Semester Evaluation (ESE) will be conducted as an internal evaluation based on the product, the report and a viva- voce examination, conducted by a 3-member committee appointed by Head of the Department comprising HoD or a senior faculty member, academic coordinator for that program and project guide/coordinator. The Committee will be evaluating the level of completion and demonstration of functionality/specifications, presentation, oral examination, working knowledge and involvement.

The Continuous Internal Evaluation (CIE) is conducted by evaluating the progress of the mini project through minimum of TWO reviews. At the time of the 1st review, students are supposed to propose a new system/design/idea, after completing a thorough literature study of the existing systms under their chosen area. In the 2nd review students are expected to highlight the implementation details of the proposed solution. The review committee should assess the extent to which the implementation reflects the proposed design. A well coded, assembled and completely functional product is the expected output at this stage. The final CIE mark is the average of 1st and 2nd review marks.

A zeroth review may be conducted before the beginning of the project to give a chance for the students to present their area of interest or problem domain or conduct open brain storming sessions for innovative ideas. Zeroth review will not be a part of the CIE evaluation process.

Marks Distribution

Total Marks	CIE	ESE
150	75	75

Continuous Internal Evaluation Pattern:

Attendance : 10 marks
Marks awarded by Guide : 15 marks
Project Report : 10 marks
Evaluation by the Committee : 40 Marks

End Semester Examination Pattern: The following guidelines should be followed regarding award of marks.

(a) Demonstration : 50 Marks
(b) Project report : 10 Marks
(d) Viva voce : 15marks

Course Plan

In this course, each group consisting of three/four members is expected to design and develop a moderately complex software/hardware system with practical applications. This should be a working model. The basic concept of product design may be taken into consideration.

Students should identify a topic of interest in consultation with Faculty-in-charge of miniproject/Advisor. Review the literature and gather information pertaining to the chosen topic. State the objectives and develop a methodology to achieve the objectives. Carryout the design/fabrication or develop codes/programs to achieve the objectives. Demonstrate the novelty of the project through the results and outputs. The progress of the mini project is evaluated based on a minimum of two reviews**.**

The review committee may be constituted by the Head of the Department. A project report is required at the end of the semester. The product has to be demonstrated for its full design specifications. Innovative design concepts, reliability considerations, aesthetics/ergonomic aspects taken care of in the project shall be given due weight.

SEMESTER VII

HONOURS

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET495	ADVANCED THEORY OF VIBRATIONS	VAC	4	0	0	4

Preamble:

- To understand the principles of vibration theory.
- To introduce techniques for solving vibration problems.
- To enable development of mathematical model for engineering problems in vibrations.

Prerequisite: MET 304 Dynamics and Design of Machinery

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

CO 1	Analyse the single degree of freedom vibration system with and without damping
CO 2	Analyse forced harmonic vibration and two degree of freedom system
CO 3	Analyse the multi degree of freedom system and the Eigen value problem
CO 4	Solve vibration of continuous systems and transient vibrations
CO 5	Solve the numerical methods used in vibration analysis

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

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember			
Understand	10	10	30
Apply	40	40	70
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain about different types of vibrating mechanisms.
2. Describe Energy method and Rayleigh method.
3. Explain the different damping mechanisms.

Course Outcome 2 (CO2)

1. Describe about the magnification factor and transmissibility.
2. What is normal mode vibration and coordinate coupling.
3. Explain the working of seismometer and accelerometer.

Course Outcome 3(CO3):

1. Describe about Dynamic vibration absorbers and Vibration dampers
2. Explain the mode shape and Modal analysis.
3. What is Eigen value and Eigen vector.

Course Outcome 4 (CO4):

1. Discuss about the vibrating strings and longitudinal vibration of rods.
2. Explain the Torsional vibration of rods
3. Explain the Transient vibrations

Course Outcome 5 (CO5):

1. Explain Matrix Iteration and Stodola method– Dunkerley's method
2. Differentiate between Rayleigh method and Rayleigh –Ritz method
3. What is Holzer procedure for vibration analysis

Model Question Paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SEVENTH SEMESTER B. TECH DEGREE EXAMINATION
Course Code: MET 475
Course Name: ADVANCED THEORY OF VIBRATIONS
Max. Marks: 100 **Duration: 3 Hours**

PART – A

(ANSWER ALL QUESTIONS, EACH QUESTION CARRIES 3 MARKS)

1. Distinguish between longitudinal, transverse and torsional vibrations?
2. What are beats?
3. Explain the working of a vibrometer?
4. How does the forcetransmitted to the base change as the speed of the machine increases?
5. What is orthogonality of modes?
6. What are influence coefficients?
7. What is the Duhamel Integral? What is its use?
8. State the boundary conditions at the end of a string.
9. What is the basic principle used in Holzer's method?
10. Write short notes on n Rayleigh Ritz Method.

PART – B

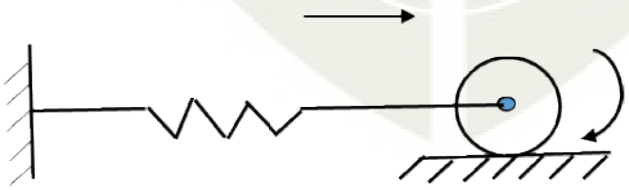
(ANSWER ONE FULL QUESTION FROM EACH MODULE)

MODULE – 1

11. A machine of mass 18kg is supported on springs of total stiffness 12N/mm and dashpot of 0.2Ns/m damping. The system is initially at rest and a velocity of 120mm/s is imparted to the machine. Determine the displacement and velocity of machine as a function of time?

(14 marks)

12. A circular cylinder as shown below, has a mass 6kg and radius 20cm, which is joined to the fixture by a spring having stiffness 5000N/m. It is free to roll on the horizontal surface without slipping. Find the natural frequency of the system?



(14 marks)

Module 2

13. A machine component having a mass of 3kg vibrates in a viscous medium. If a harmonic force 40N is applied on the on the system causes a resonant amplitude of 15mm with a period of 0.25second, find the damping coefficient? Find the increase in the amplitude of the forced when the damper is removed, if the frequency of exciting force is changed to 4 Hz?

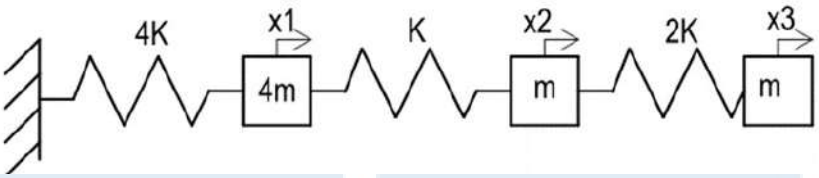
(14 marks)

14. Design Derive the general equation for damped free vibration of a single degree of freedom system? Arrive at the equation of under damped system?

(14 marks)

Module 3

15. Find out the natural frequency of the system given below usinginfluence coefficient method?



(14 marks)

16. A reciprocating machine has a weight of 250N which runs at a constant speed of 500rpm. It was found after final installation that the forcing frequency is very close to the natural frequency of the system. Find the mass of the dynamic absorber to be added to the system, the nearest natural frequency of the system should be at least 25 percent from the impressed frequency? (14 marks)

Module 4

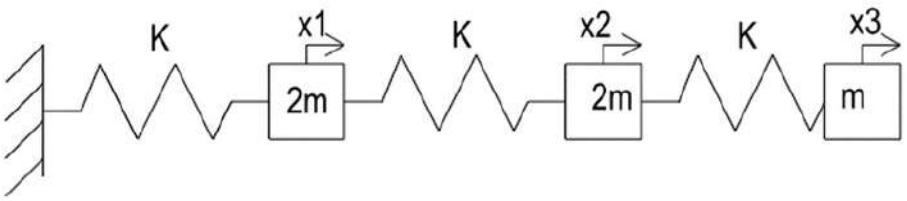
17. Derive an expression for the torsional vibration in case of a shaft having torque T acting at both the ends? (14 marks)

18. a) Derive the impulse response function of a damped free vibration system? (7 marks)
b) A trailer being pulled at a high speed, hits a h cm high curb. Considering the trailer to be single degree of freedom system, analyse the system for the response.

(7 marks)

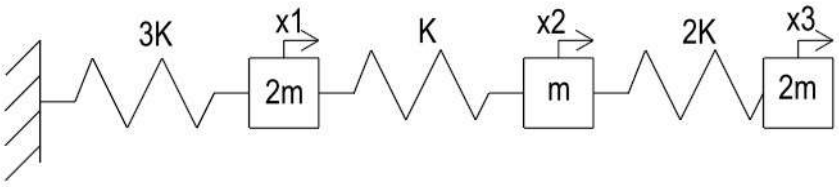
Module 5

19. Using Stodola technique determine the first natural frequency of the following system?



(14 marks)

20. Find out the natural frequency of the system given below using matrix iteration method?



(14 marks)

Syllabus

Module 1

Introduction to mechanical vibrations- Definitions -Types of vibrations- Degrees of freedom- Oscillatory motion – Periodic motion- Beat phenomenon

Free vibration of single degree of freedom systems with damping - Natural frequency using Energy method- Rayleigh method- Newton's method

Free vibration of single degree of freedom systems with damping- Viscous damping- Logarithmic decrement-

Coulomb damping- - Structural damping

Module 2

Forced harmonic vibration- Magnification Factor-Transmissibility-Vibration Isolation-Base Excitation-Rotating unbalance- whirling of shafts- Resonance

Vibration measuring instruments- Seismometer-Accelerometer

Two degree of freedom systems- Generalized co-ordinates- Normal mode vibration-Principal co-ordinates-Coordinate coupling.

Module 3

Dynamic vibration absorbers- Vibration dampers- Numerical problems

Multi degree of freedom systems- Matrix formulation- Influence Coefficients-Flexibility Matrix-Stiffness matrix

Eigen Value problem: Eigen value and Eigen Vectors-Natural Frequency- mode shape - Orthogonality of normal modes-Modal analysis

Module 4

Vibration of continuous systems-Vibrating strings- Longitudinal vibration of rods—Torsional vibration of rods

Transient vibrations- Impulse excitation- Convolution integral,Response to Arbitrary Loading.

Module 5

Numerical methods - Matrix Iteration – Stodola – Dunkerley's method - Rayleigh method – Rayleigh –Ritz method -Holzer procedure

Text Books

1. A. G. Ambekar, "Mechanical Vibrations and Noise Engineering, PHI, New Delhi

2. V.P. Singh "Mechanical Vibrations" DhanpatRai& Co (Pvt) Ltd.

Reference Books

1. Thomson W.T , Theory of Vibration with Applications., PHI, New Delhi

2. Rao V and J Srinivas, Mechanical Vibrations, PHI, New Delhi

3. S.S Rao, Mechanical Vibrations, Pearson Education India

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Module 1**	
1.1	Introduction to mechanical vibrations- Definitions -Types of vibrations- Degrees of freedom- Oscillatory motion – Periodic motion- Beat phenomenon	3
1.2	Free vibration of single degree of freedom (DOF) systems with damping - Natural frequency using Energy method- Rayleigh method- Newton's method	3
1.3	Free vibration of single degree of freedom (DOF) systems with damping- Viscous damping- Logarithmic decrement- Coulomb damping- - Structural damping	3
2	**Module 2**	
2.1	Forced harmonic vibration- Magnification Factor- Transmissibility-Vibration Isolation-Base Excitation-Rotating unbalance- whirling of shafts- Resonance	4
2.2	Vibration measuring instruments- Seismometer-Accelerometer	2
2.3	Two degree of freedom systems- Generalized co-ordinates- Normal mode vibration-Principal co-ordinates-Coordinate coupling.	4
3	**Module 3**	
3.1	Dynamic vibration absorbers- Vibration dampers- Numerical problems	2
3.2	Multi degree of freedom systems- Matrix formulation- Influence Coefficients-Flexibility Matrix-Stiffness matrix	4
3.3	Eigen Value problem: Eigen value and Eigen Vectors-Natural Frequency- mode shape -Modal analysis	4
4	**Module 4**	
4.1	Vibration of continuous systems-Vibrating strings- Longitudinal vibration of rods—Torsional vibration of rods	4
4.2	Transient vibrations- Impulse excitation- Convolution integral.	4
5	**Module 5**	
5.1	Numerical methods - Matrix Iteration – Stodola – Dunkerley's method -	4
5.2	Rayleigh method – Rayleigh –Ritz method -Holzer procedure	4

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET497	COMPUTATIONAL METHODS IN FLUID FLOW AND HEAT TRANSFER	VAC	3	1	0	4

Preamble: COMPUTATIONAL METHODS IN FLUID FLOW & HEAT TRANSFER focuses on basic concept and principles of numerically solving governing equations for fluid flow and heat transfer problems.

Prerequisite: MET203 Mechanics of Fluids, MET302 Heat and Mass Transfer

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

CO 1	Explain physical and mathematical classifications partial differential equations, discretization, Steady one-dimensional conduction in Cartesian and cylindrical coordinates,,
CO 2	Analyse One-, two, and three-dimensional steady state and transient heat conduction problems in Cartesian and cylindrical coordinates
CO 3	Explain Explicit, implicit, Crank-Nicholson and ADIschemes,; consistency, stability and convergence.
CO 4	Analyse finite volume method for diffusion and convection

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	✓	✓	✓									
CO 2	✓	✓	✓									
CO 3	✓	✓	✓									
CO 4	✓	✓	✓									

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	20
Understand	20	20	40
Apply	10	10	20
Analyse	10	10	20
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

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

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the concept of discretization.

2. Explain the term " Rate of Convergence".

Course Outcome 2 (CO2)

1. Differentiate between Dirichlet and Newmann Boundary conditions.

2. Explain how discretization of irregular boundaries are done ?

Course Outcome 3(CO3):

1. Explain the significance of ADI scheme

2. Give the stability criterion of Crank Nicholson Scheme.

Course Outcome 4 (CO4):

1. Explain the reason for using finite volume method for convection and diffusion problems?

2. Differentiate between Hybrid and Upwind Schemes.

Model Question Paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SEVENTH SEMESTER B.TECH DEGREE EXAMINATION

Course Code: MET497

Course Name: COMPUTATIONAL METHODS IN FLUID FLOW & HEAT TRANSFER

Max. Marks: 100 Duration: 3 Hours

PART – A

(ANSWER ALL QUESTIONS, EACH QUESTION CARRIES 3 MARKS)

1. What are the various errors encountered in the solution by computational methods?

2. Describe the Tridiagonal matrix algorithm (TDMA)

3. Explain the significance of line by line method of solutions

4. Give two examples of Dirichlet boundary conditions

5.Distinguish between Explicit and Implicit schemes, compare the advantages and disadvantages for each.

6. Write Crank-Nicolson FDE for $\frac{\partial u}{\partial t} = \alpha \frac{\partial^2 u}{\partial x^2}$

7. Write a typical convection and diffusion equation in conservative form.

8. What is the benefit of conservative form of equations?

9. Differentiate between SIMPLE and SIMPLER algorthms

10. Write short notes on QUICK scheme

PART – B

(ANSWER ONE FULL QUESTION FROM EACH MODULE)

MODULE – 1

11. a) What is under relaxation? Give one formula each for PSOR and LSOR. (7 Marks)

b) Why stability is to be ensured for numerical schemes? How is it done? (7 marks)

OR

12. With the help of suitable examples explain Taylor's series approach and polynomial fitting approach (14 marks)

MODULE – 2

13. a) Explain formation of discritized equations for regular and irregular boundaries with suitable examples (14 marks)

OR

14. Explain solution procedure for two dimensional steady state heat conduction problems (14 marks)

MODULE – 3

15. a) Write and explain the ADI formulation for the PDE $\frac{\partial u}{dt} = ¿ \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}$ (9 marks)

b)Write Crank-Nicolson FDE for $\frac{\partial u}{\partial t} = \alpha \frac{\partial^2 u}{\partial x^2}$ (5 marks)

OR

16. a) Write the ADI formulation for the PDE $\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0$ (6 marks)

b) Explain the stability criterion of ADI and Crank Nicolson Schemes. (8 marks)

MODULE – 4

17. Discuss advantages and limitations of the following with respect to convection and diffusion equation

i) Upwind scheme

ii) Hybrid scheme

iii) Power-Law scheme (14 Marks)

OR

18. a) Write a typical convection and diffusion equation in conservative form. (7 marks)

b) Explain the concept of false diffusion (7 marks)

MODULE – 5

19. a) What is the main difficulty in solving momentum equations (4 marks)

b) How the pressure correction equation is formulated for SIMPLE procedure

(10 Marks)

OR

20. a) Explain the sequence of operations in the SIMPLE procedure with a flowchart (7 marks)

b) Explain the significance of SIMPLEC scheme using example (7 marks)

Syllabus

Module 1

Experimental, theoretical and numerical methods of predictions, physical and mathematical classifications partial differential equations; computational economy; numerical stability; validationof numerical results; round-off-error and accuracy of numerical results; iterative convergence, condition for convergence, rate of convergence; under and over relaxations, termination of iteration; tridiagonal matrix algorithm; discretization, converting derivativesto their finite difference forms, Taylor's series approach,polynomial fitting approach; discretization error.

Module 2

Steady one-dimensional conduction in Cartesian and cylindrical coordinates; handling of boundary conditions; two dimensional steady state conduction problems in Cartesian and cylindrical coordinates, point-by-point and line-by-line method of solution, dealing with Dirichlet, Neumann, and bins type boundary conditions, formation of discritized equations for regular and irregular boundaries and interfaces.

Module 3

One-, two, and three-dimensional transient heat conduction problems in Cartesian and cylindrical coordinates , explicit, implicit, Crank Nicholson and ADI schemes..Stability criterion of these schemes, conservation form and conservative property of partial differential and finite difference equations

Module 4

Finite volume method for diffusion and convection–diffusion problems, steady one dimensional convection and diffusion; upwind, hybrid and power-law schemes, discretization of equation for two dimension, false diffusion,

Module 5

SIMPLE, SIMPLER, SIMPLEC and QUICK schemes, solution algorithms for pressure velocity coupling in steady flows; numerical marching techniques, two dimensional parabolic flows with heat transfer.

Text Books

1. Anderson, D. A, Tannehill, J. C., and R. H. Pletcher, R. H., Computational Fluid Mechanics and Heat Transfer, Second Edition, Taylor & Francis,1995.

Reference Books

1. T.J. Chung, Computational Fluid dynamics, Cambridge University Press, South Asian Edition, 2003.

2. Muraleedhar, K. and T. Sundararaja, T., Computational Fluid Flow and Heat Transfer, Second Edition, Narosa Publishing House, 2003.

3. Patankar, S. V., Numerical Heat Transfer and Fluid Flow, Hemisphere, 1980.

4. Versteeg, H. K. and W. Malalasekera, An Introduction to Computational Fluid Dynamics: The Finite Volume Method, Addison Wesley–Longman,1995.

5. Hornbeck, R. W., Numerical Marching Techniques for Fluid Flows with Heat Transfer, NASA, SP – 297, 1973.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1.1	Experimental, theoretical and numerical methods of predictions, physical and mathematical classifications partial differential equations; computational economy;	4
1.2	Validationof numerical results; round-off-error and accuracy of numerical results; iterative convergence, condition for convergence, rate of convergence; under and over relaxations,	3
1.3	Termination of iteration; tridiagonal matrix algorithm; discretization, converting derivativesto their finite difference forms, Taylor's series approach,polynomial fitting approach; discretization error.	3
2.1	Steady one-dimensional conduction in Cartesian and cylindrical coordinates; handling of boundary conditions; two dimensional steady state conduction problems in Cartesian and cylindrical coordinates,	3
2.2	Point-by-point and line-by-line method of solution, dealing with Dirichlet, Neumann, and bins type boundary conditions	2
2.3	Formation of discritized equations for regular and irregular boundaries and interfaces.	2
3.1	One-, two, and three-dimensional transient heat conduction problems in Cartesian and cylindrical coordinates , explicit,implicit, Crank Nicholson and ADI schemes	4

3.2	Stability criterion of these schemes, conservation form and conservative property of partial differential and finite difference equations	3
4.1	Finite volume method for diffusion and convection–diffusion problems, steady one dimensional convection and diffusion;	3
4.2	Upwind, hybrid and power-law schemes, discretization of equation for two dimension, false diffusion,	3
5.1	SIMPLE, SIMPLER, SIMPLEC and QUICK schemes, solution algorithms for pressure velocity coupling in steady flows;	3
5.2	Numerical marching techniques, two dimensional parabolic flows with heat transfer.	2

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET499	PRECISION MACHINING	VAC	3	1	0	4

Preamble: This course is conceived to help students understand design and process issues associated with precision machining. The course introduces a few precision machining processes as well.

Prerequisite: Nil

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

CO 1	Contrast basic premises of normal machining and precision machining
CO 2	Relate consideration of error and sources of error and role of kinematic design in establishing precision.
CO 3	Explain various sensors and AE based monitoring in precision machining environment
CO 4	Outline the basics of process planning for precision machining
CO 5	Explain various precision machining processes.

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

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1 (marks)	2 (marks)	(marks)
Remember	20	20	40
Understand	20	20	40
Apply	10	10	20
Analyse	-	-	-
Evaluate	-	-	-
Create	-	-	-

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern

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

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. What is Abbe's principle? List an instrument each which (a) obeys Abbe's principle (b) disobeys Abbe's principle.
2. List down various methods for testing roundness. Explain precision spindle method for checking roundness with a suitable diagram.
3. With the help of a neat diagram, explain surface roughness terminology.

Course Outcome 2 (CO2):

1. With the help of a suitable diagram, show the directions in which errors occur for a conventional machine tool.
2. What is an error budget? How does an error budget flow chart help in generating it?
3. Describe thermal effects in precision machining.

Course Outcome 3 (CO3):

1. Explain AE based topographical mapping of grinding wheels.
2. Describe AE based monitoring of face milling.
3. Explain fast AE RMS analysis for wheel condition monitoring.

Course Outcome 4 (CO4):

1. Define capability ratio.
2. Discuss the basics of process planning in precision machining process?
3. Illustrate with an example the application of capability ratio in process planning.

Course Outcome 5 (CO5):

1. Discuss typical fly cutting diamond machine configurations.
2. Discuss tool-workpiece configurations for conical- circumferential milling.
3. Discuss the tool geometry of a typical single point diamond tool.

Model Question Paper

MET499 PRECISION MACHINING

Max. Marks: 100 Duration: 3 hours

Part−A

Answer all questions. Each question carries 3 marks

.

1. Enumerate critical elements in precision manufacturing.
2. Clearly distinguish the terms accuracy, precision and resolution.
3. Distinguish between kinematic design and elastically averaged design.
4. What do you understand by macroscale and microscale structural compliance?
5. Which are the basic sensor types used in precision manufacturing set ups?
6. Tabulate various forms of energy converted by sensors.
7. Define process capability.
8. What are the factors that affect precision during machining?
9. Differentiate between fixed abrasive process and loose abrasive process.
10. Draw a schematic and hence outline a nano-grinding process.

Part−B

Answer one full question from each module.

Module I

11. Differentiate normal machining, precision machining and ultra-precision machining with examples (14 marks)

OR

12. Describe various “competitive drivers” of precision manufacturing. (14 marks)

Module II

13. What do you understand by microscale and macroscale structural compliance. Explain. (14 marks)

OR

14. With the help of a neat diagram explain Air bearing grinding spindle. (14 marks)

Module III

15. Explain requirements for sensor technology for precision machining. (14 marks)

OR

16. Describe an optical system for monitoring of grinding wheel topography. (14 marks)

Module IV

17. Describe how process capability can be used as a planning metric for transition from one process stage to another. (14 marks)

OR

18. Discuss four levels of integration between the tasks of design, manufacturing and finishing. (14 marks)

Module V

19. With the help of a diagram explain CMP process. (14 marks)

OR

20. Explain the process of diamond turning with suitable diagrams. (14 marks)

Syllabus

Module 1

Introduction to precision machining: Competitive drivers for precision machining. Definition of terms- accuracy, precision and resolution. Metrology and measurement- Abbe's principle. Measurement of dimension and angle- measurement of form- straightness, flatness and roundness. Measurement of surface roughness.

Module 2

Sources of error in precision machining: Mechanical errors- errors due to machine elements, thermal errors, Error due to compliance and vibration. Error budget- error budget flow chart- (elementary idea only). Role of kinematic design in precision. Principles of design and utilisation of bearings-aerostatic bearings.

Module 3

Sensors in precision machining: Classification of basic sensor types- overview of sensors in manufacturing- applications- AE based monitoring of grinding wheel dressing- fast AE RMS analysis of wheel condition monitoring (description only). Topographical mapping of grinding wheel. AE based monitoring of face milling.

Module 4

Process planning for precision machining: process planning basics-factors which influence precision-process capability-relationship between process variability and product specification- process capability as a planning metric.

Module 5

Precision machining processes: Diamond turning and milling, fly cutting diamond machine configuration- features of diamond machine tool design- applications. Configuration for conical circumferential milling- applications. Typical single point diamond tool geometry. Abrasive processes-fixed and loose. Nano grinding-Chemical mechanical Planarization (CMP)- precision manufacturing applications.

Text Books and References

1. David Dornfeld, Dae-Eun Lee, Precision Manfacturing, Springer, 2008
2. V.C. Venkatesh, Sudin Izman, Precision Engineering, Tata McGraw- Hill, 2007
3. Michael N. Morgan, Andrew Shaw, Otar Mgaloblishvili, Precision Machining VI, Transtech publications Ltd, Switzerland, 2012

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1.1	Introduction to precision machining.	1
1.2	Philosophy of precision machine design	1
1.3	Competitive drivers for precision machining	2
1.4	Definition of terms- accuracy, precision and resolution	1
1.5	Metrology and measurement – Abbe's principle	1
1.6	Measurement of dimension and angle	1
1.7	Measurement of form- straightness, flatness and roundness	1
1.8	Measurement of surface roughness	1
2.1	Sources of error in precision machining	2
2.2	Mechanical errors – errors due to machine elements, thermal errors	2
2.3	Errors due to compliance and vibration	1
2.4	Error budget	1
2.5	Error budget flow chart	1
2.6	Role of kinematic design in precision	1
2.7	Principles of design and utilisation of bearings – Aerostatic bearings	1
3.1	Sensors in Precision Machining- classification	2
3.2	Overview of sensors and applications	1
3.3	AE based monitoring of grinding wheel dressing	1
3.4	Description of Fast AE RMS analysis of wheel condition monitoring	1
3.5	Topographical mapping of grinding wheel	1

3.6	AE based monitoring of face milling	1
4.1	Process planning for precision machining	2
4.2	Process planning basics	1
4.3	Factors influencing precision.	1
4.4	Process capability	2
4.5	Relationship between process variability and product specification	1
4.6	Process capability as a planning metric	1
5.1	Precision machining Processes – Diamond turning and milling	1
5.2	Fly cutting diamond machine configuration	1
5.3	Features of diamond machine tool design-applications	1
5.4	Configuration for conical circumferential milling- applications	1
5.5	Typical single point diamond tool geometry	1
5.6	Abrasive processes- fixed and loose	1
5.7	Nano grinding	1
5.8	Chemical Mechanical Planarization	1
5.9	Precision manufacturing applications	1