SEMESTER -3

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MUT 201	Fluid Mechanics and Machinery	PCC	3	1	0	4

Preamble: The objective of learning Fluid Mechanics and Machinery is to understand, the fundamental concepts of fluid mechanics, various flow measuring instruments and their applications, various types of hydraulic pumps and their characteristic parameters. By learning the course, one must be able to analyse various problems on fluid statics, kinetics and dynamics and the various types of hydraulic turbines and their operating principles.

Prerequisite: Introduction to Mechanical Engineering Sciences

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

CO 1	Understand the fundamental concepts of fluid mechanics
CO 2	Analyse various problems on fluid statics, kinetics and dynamics
CO 3	Understand various flow measuring instruments and their applications
CO 4	Analyse the various types of hydraulic turbines and their operating principles
CO 5	Understand the various types of hydraulic pumps and their characteristic parameters
CO 6	Do innovative projects by analysing existing fluid systems and design new fluid systems using the principles learned

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

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	20	20	20
Understand	20	20	40
Apply	10	10	40
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. State the basic properties of fluid.
2. Differentiate Newtonian and non- Newtonian fluids.
3. Define Newton's law of viscosity.

Course Outcome 2 (CO2)

1. State Bernoulli's equation for fluid dynamics
2. List the various pressure measuring instruments.
3. Define Darcy- Weisbach equation

Course Outcome 3(CO3):

1. State the concepts of laminar and turbulent boundary layer
2. List the various flow measuring instruments.
3. Describe the different velocity measuring methods.

Course Outcome 4 (CO4):

1. Explain the impact of jets on vanes.
2. Differentiate Impulse and Reaction Turbines
3. List the importance of draft tubes, surge tanks, cavitation in turbines

Course Outcome 5 (CO5):

1. Illustrate the working of Positive displacement pumps.

2. Explain the importance of multistage pumps

3. Describe about the Rotary motion of liquids.

Course Outcome 6 (CO6):

1. Design an orifice meter to measure the oxygen flow rate for an experiment set-up

2. Compare and analyse the properties Francis and Kaplan turbines

Syllabus

Module 1

Fundamental concepts: Properties of fluid - density, specific weight, viscosity, surface tension, capillarity, vapour pressure, bulk modulus, compressibility, velocity, rate of shear strain, Newton's law of viscosity, Newtonian and non-Newtonian fluids, real and ideal fluids, incompressible and compressible fluids.

Module 2

Fluid statics: Atmospheric pressure, gauge pressure and absolute pressure. Pascal's Law, measurement of pressure - piezo meter, manometers, pressure gauges.
Fluid kinematics and dynamics: Types of flow, path line, streak line and stream line. Continuity equation, Euler's equation, Bernoulli's equation. Reynolds experiment, Reynold's number. Hagen- Poiseuille equation, head loss due to friction, friction, Darcy- Weisbach equation, Chezy's formula (No derivations), compounding pipes, branching of pipes, siphon effect, water hammer transmission of power through pipes (simple problems)

Module 3

Boundary layer theory: Basic concepts, laminar and turbulent boundary layer, displacement, momentum, energy thickness, drag and lift, separation of boundary layer.
Flow rate measurements- venturi and orifice meters, notches and weirs (description only for notches, weirs and meters), practical applications, velocity measurements- Pitot tube and Pitot –static tube.

Module 4

Hydraulic turbines: Impact of jets on vanes - flat, curved, stationary and moving vanes - radial flow over vanes. Impulse and Reaction Turbines – Pelton Wheel constructional features - speed ratio, jet ratio & work done, losses and efficiencies, (theory only)

Francis turbine constructional features, work done and efficiencies – axial flow turbine (Kaplan) constructional features, work done and efficiencies(theory only), draft tubes, surge tanks, cavitation in turbines

Module 5

Positive displacement pumps: reciprocating pump, indicator diagram, air vessels and their purposes, slip, negative slip and work required and efficiency, effect of acceleration and friction on indicator diagram (no derivations), multi cylinder pumps.
Rotary motion of liquids: – free, forced and spiral vortex flows, (no derivations), centrifugal pump, working principle, impeller, casings, manometric head, work, efficiency and losses, priming, specific speed, multistage pumps, selection of pumps, pump characteristics

Text Books

1. *Fluid Mechanics and Hydraulic Machines* by Dr.R.K.Bansal.Revided Ninth Edition. Modi P. N. and S. M. Seth, *Hydraulics & Fluid Mechanics*, S.B.H Publishers, New Delhi, 2002.
2. Kumar D. S., *Fluid Mechanics and Fluid Power Engineering,* S. K. Kataria & Sons, New Delhi, 1998.

Reference Books

1. J. F. Douglas, "Fluid Mechanics", Pearson education.
2. Cengel Y. A. and J. M. Cimbala, Fluid Mechanics, Tata McGraw Hill, 2013
3. Robert W. Fox and Mc Donald, "Introduction to fluid dynamics", John Wiley and sons
4. K. Subrahmanya, "Theory and applications of fluid mechanics", (TMH)
5. Shames. I. H, "Mechanics of fluids".
6. Jagadish Lal, "Fluid mechanics and Hydraulic machines".
7. R K Bansal, "Hydraulic Machines

Model Question paper

QP CODE:
PAGES:2

Reg. No: ______________ **Name :______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

THIRD SEMESTER B.TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: MUT 201

Course Name: Fluid Mechanics and Machinery

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

PART A

Answer all Questions.
Each question carries 5 Marks

1. Define the following :
   a. Specific gravity. b.Viscosity.
2. Explain Newton's law of viscosity.
3. Differentiate between gauge pressure and absolute pressure.
4. Explain Reynold's experiment on Laminar flow.
5. Define specific speed of a turbine.
6. Derive the expression for work done by a jet on a curved vane moving with a velocity *u.*
7. Define the working of a reciprocating pump.
8. Explain the function of air vessels.
9. Describe the function of the casing in centrifugal pump.
10. What do you mean by NPSH ?

PART B

Answer any one full question from each module.
Each question carries 10 Marks

11. If a mercury barometer reads 700 mm and a Bourdon gauge at a point in a flow system reads 500 kN/m^2. What is the absolute pressure at the point ?

OR

12. A horizontal venturimeter with inlet dia 200 mm and throat dia 100 mm is used to measure the flow of water. The inlet pressure is 0.18 N/mm^2 and the vacuum, pressure at the throat is 280 mm of mercury. Find the rate of flow. Take cd =0.98.

13. In a circular pipe of dia 100 mm a fluid of viscosity 7 poise and sp. gr. 1.5 is flowing. If the maximum shear stress at the wall of the pipe is 196.2 N/m^2 find (i) the pressure gradient ; (ii) the average velocity ; (iii) Reynold's number.

OR

14. A crude oil of viscosity 0.9 paise and relative density 0.9 is flowing through s horizontal pipe of dia 100 mm length 12 m. Calculate the difference of pressure at the two ends of the pipe, if 785 N of the oil is collected in a tank in 25 seconds.
15. A pelton wheel has a mean bucket speed of 12 m/s and is supplied with water at the rate of

0.7 m^3/s under a head of 3 over. If the bucket deflect the jet through an angle of 160° find the power and efficiency of the turbine.

OR

16. A turbine is to operate under a head of 25 m at 200 r.p.m. The discharge is 9 m^3/s. If the overall efficiency is 90% determine :Power generated, Specific speed of turbine, Type of turbine.
17. A single acting reciprocating pump has a piston dia of 150 mm and stroke length 350 mm. The
centre of the pump is 3.5 m above the water surface in the sump and 22 m below the delivery water level. Both the suction and delivery pipes have same dia of 100 mm and are 5 m and 30 m long respectively. If the pump is working at 30 r.p.m. determine (i) the pressure heads on the piston at the beginning, middle and end of both suction and delivery strokes ; (ii) the power required to drive the pump. Take H_{atm} as 10.3 m of water.

OR

18. The bore and stroke of a double-acting single-cylinder reciprocating pump running at 30 r.p.m. are 200 mm and 400 mm respectively. The sump is 1.2 m below the pump axis and draws water thru a suction pipe of 100 mm dia and 3 m long. The water delivers to a tank at 28 m and thru a 100 mm dia pipe and 38 m long. Determine the net force due to fluid pressure on the piston when it has moved thru a distance of 100 m from the IDC. Take 0.006 for both suction and delivery pipes.
19. It is required to pump water out of a deep well under a total head of 90 m. A number of pumps with a design speed of 1000 rpm specific speed 30 and rated capacity of .015 m^3 per second are available. How many pumps are required and how should they be connected whether in series or parallel.

OR

20. A centrifugal pump in which water enters radially has an impeller dia. 360 mm and width 180 mm at the inlet delivers water to a head of 165 mm. At the outlet impeller dia. Is 720 mmand width is 90 mm. The blades are curved backwards at 30^o to the tangent at the exit and the discharge is 0.389 m^3 per second. Speed of pump is 1200 rpm. Determine (i) Theoretical head developed (ii) Manometric efficiency (iii) Vane angle at inlet. Take overall efficiency as 70%

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Fundamental concepts**	
1.1	Properties of fluid - density, specific weight	1
1.2	Viscosity, surface tension, capillarity	1
1.3	Capillarity, vapour pressure	1
1.4	Bulk modulus, compressibility	1
1.5	Velocity, rate of shear strain	1
1.6	Newton's law of viscosity	1
1.7	Newtonian and non-Newtonian fluids	1
1.8	Real and ideal fluids	1
1.9	Incompressible and compressible fluids	1
2	**Fluid statics, kinematics and dynamics**	
2.1	Atmospheric pressure, gauge pressure and absolute pressure	1
2.2	Pascal's Law	1
2.3	Measurement of pressure - piezo meter, manometers, pressure gauges.	1
2.4	Types of flow, path line, streak line and stream line	1
2..5	Continuity equation, Euler's equation	1
2.6	Bernoulli's equation. Reynolds experiment, Reynold's number	1
2.7	Hagen- Poiseuille equation, head loss due to friction, friction	1
2.8	Darcy- Weisbach equation, Chezy's formula (No derivations)	1
2.9	Compounding pipes, branching of pipes, siphon effect	1
2.10	Water hammer transmission of power through pipes (simple problems)	1
3	**Boundary layer theory & Flow rate measurements**	
3.1	Boundary layer theory: Basic concepts	1
3.2	Laminar and turbulent boundary layer displacement, momentum, energy thickness	1
3.3	Drag and lift, separation of boundary layer	1
3.4	Flow rate measurements- venturi and orifice meters	1
3.5	Notches and weirs, practical applications	1
3.6	Velocity measurements- Pitot tube	1
3.7	Pitot –static tube	1
4	**Hydraulic turbines**	
4.1	Impact of jets on vanes - flat, curved, stationary vanes	1
	Impact of jets on vanes - moving vanes	1
4.2	Impact of jets on vanes -radial flow over vanes	1
4.3	Impulse and Reaction Turbines- Introduction	1

4.4	Pelton Wheel constructional features - speed ratio, jet ratio & work done, losses and efficiencies	1
4.5	Francis turbine constructional features, work done and efficiencies	2
4.6	Axial flow turbine (Kaplan) constructional features, work done and efficiencies	2
5	**Positive displacement pumps & Rotary motion of liquids**	
5.1	Positive displacement pumps: reciprocating pump, indicator diagram	1
5.2	Air vessels and their purposes, slip, negative slip and work required and efficiency	2
5.3	Effect of acceleration and friction on indicator diagram	1
5.4	Multi cylinder pumps	1
5.5	Rotary motion of liquids: – free, forced and spiral vortex flows	1
5.6	Centrifugal pump, working principle, impeller, casings	1
5.7	Manometric head, work, efficiency and losses	1
5.8	Priming, specific speed, multistage pumps	1
5.9	Selection of pumps, pump characteristics	1

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MUT203	AUTO CHASSIS	PCC	4	0	0	4

Preamble: This course aims at providing

- ✓ **an in-sight in the area of a vehicle chassis, its different components and arrangements**
- ✓ **a deeper knowledge on the functional sub systems in the chassis except the power pack.**
- ✓ **Basic understanding on the hybrid and electric vehicle arrangements**

Prerequisite: NIL

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

CO 1	Distinguish between the different types of chassis frame construction and its arrangements
CO 2	Evaluate the different types of front axles and steering systems used in vehicles
CO 3	Identify the suspension system and different classes of wheels used in a vehicle
CO 4	Understand the braking systems and its testing methods
CO 5	Comparing the different types of rear axles and adjoining components

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

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**		**End Semester Examination**
	1	**2**	
Remember	10	10	10
Understand	10	10	20
Apply	20	20	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. Are you able to identify the different automobile chassis frame constructions and its merits?

Course Outcome 2 (CO2)

1. Can you identify the different type of steering and front axle used in the vehicle?

Course Outcome 3(CO3):

1. Can you decide on the suspension and wheels which are best suited for the vehicle you are making?

Course Outcome 4 (CO4):

1. Are you able to identify the importance of speed and its relation with the braking system of a vehicle?

Course Outcome 5 (CO5):

1. Can you identify the working of differential and type of rear axle being employed in a vehicle?

Model Question paper

QP CODE: **PAGES:…**

Reg. No: _______________ **Name :_______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

THIRD SEMESTER B.TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: MUT 203

Course Name: AUTO CHASSIS

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

Part A

(Answer all questions. Each question carry 5 marks)

1. List down the different chassis layouts used in automobiles according to the position of the prime mover. Explain any one of them
2. What are the different types of stresses coming on the chassis frame? Explain them.
3. Explain the front wheel alignment geometry with neat sketches.
4. With a neat diagram, explain the steering linkage system used for an independent suspension from steering wheel to front wheels.
5. Why do we require a suspension system? Explain the functions of a suspension system.

6. Explain the constructional details of a radial tyre with a cross sectional sketch.
7. What are the differences between disc brakes and drum brakes? Which one is superior and why?
8. Explain the components and working of brake-by-wire system.
9. Why do we need a differential? Explain the working principle of differential with a sketch.
10. Why is axle shaft made of solid bar and propeller shaft made of hollow tube?

Part B

Answer any one full question from each module.

Each question carries 10 Marks

11. (a) List down the material composition used for the frame material (5)

    (b) Explain the different cross sections of the frame (5)

OR

12. (a) Explain ladder frame and X-frame with suitable sketches (6)

    (b)What is the difference between fully forward and semi forward type of heavy-duty chassis construction? Give two examples for both types. (4)

13. Explain Ackermann steering mechanism with a neat sketch and derive the condition for true rolling (10)

OR

14. Explain the working of Davis steering mechanism and state its advantage and disadvantage with Ackermann steering. Why is Davis mechanism not in use now? (10)

15. (a) Explain the most commonly used independent suspension system for cars. (5)

    (b) Explain the construction and working of leaf springs. Why do we require helper springs? (5)

OR

16. Explain the different types of rims used in an automobile with suitable sketches. (10)

17. (a)Why do we have vehicles with disc brakes at front and drum at rear and not vice versa? (5)

    (b)Explain the term leading shoe and trailing shoe in drum brake. Which is more effective in braking based on the equations of brake torque? (5)

OR

18. Explain the term ESP. Explain its working and different types of controls (10)
19. Explain the different types of gears used in final drive for a front engine rear wheel drive vehicle with neat sketches (10)

OR

20. Explain the constructional details of semi floating and fully floating axles with suitable sketches. (10)

Syllabus

Module	Contents	Hours	Sem.Exam Marks
Module 1: INTRODUCTION	Classification of automobiles and their layout with reference to prime mover location and drive, Frame types, Constructional details –Materials – Testing of frames chassis defects., Integrated body construction- loads, moments and stresses on frame members (basics), Types of chassis layout of hybrid and electric vehicles, Types of chassis- fully forward, semi forward, Truck or bus chassis, two & three wheeler chassis layout,	9	20%
Module 2: FRONT AXLE AND STEERING	Front Axle types. Construction details. Materials. Front wheel geometry viz. Camber, kingpin inclination, included angle, caster, toe-in and toe-out. Conditions for true rolling motion of road wheels during steering. Steering mechanisms, Ackermann and Davis steering, Constructional details of steering linkages, Steering linkage layout for conventional and independent suspensions. Different types of steering gear boxes. Turning radius, wheel wobble and shimmy. Power and power assisted steering – Electric steering – Steer by wire	9	20%
Module 3: SUSPENSION SYSTEM, WHEELS AND TYRES	Types of suspension. Factors influencing ride comfort, Suspension springs – leaf spring types, shackle and mounting brackets, coil and torsion bar springs. Spring materials, Independent front and rear suspension systems, inter connected suspension, Rubber, pneumatic, hydro-elasitc, hydro-gas suspension, Active suspension system. Hydraulic dampers, Gas filled dampers, Magneto Rheological fluids. Types of wheels, Construction of wheel assembly, aspect ratio, tyre specifications, Types of tyres and constructional details. Static and rolling properties of pneumatic tyres, Wheel balancing and wheel alignment.	9	20%
Module 4: BRAKES	Types of brakes, Principles of shoe brakes- Constructional details, materials. Braking torque developed by leading and trailing shoes, self energising brakes, Disc brake theory, types, constructional details, advantages. Brake actuating system – mechanical, hydraulic, pneumatic brakes, brake compensation. Factors affecting brake performance viz. operating temperature, area of brake	9	20%

	lining, brake clearance. Exhaust brakes. Power and power assisted brakes - Antilock braking system (ABS) and Electronic stability program(ESP), Retarded engine brakes, eddy retarders ,Regenerative braking system – Brake by wire- Testing of brakes – Road tests, brake bleeding, garage tests and tests for Type Approval under IS:11852		
Module 5: FINAL DRIVE & REAR AXLE:	Purpose of final drive & drive ratio, Different types of final drives, need of differential, Constructional details and working of differential unit, Non-slip differential, Differential lock, Differential housing, Function of rear axle, Construction, Types of loads acting on rear axle, Axle casings, Axle types - semi-floating, three quarter and full floating axle shafts, Final drive lubrication. Twin Speed final drive. Final drive for multi-axle vehicles.	9	20%

Text Books

1. Kripal Singh, Automobile Engineering, ADW Vol II, Standard Publisher, New Delhi , 2006
2. N.K. Giri, Automotive Mechanics, Kanna Publishers, 2007

Reference Books

1. Heldt P.M., Automotive Chassis, Chilton Co., New York, 1990
2. Newton Steeds and Garret, Motor Vehicles, 13th Edition, Butterworth, London, 2005.
3. Heinz Haisler, Advanced Vehicle Technology, Butterworth, London, 2005.
4. Stuart Mills and Julie Wilson, How to Design and Build an Electric Car or Vehicle,
5. Seith Leitman, Build your own electric vehicle, 3rd edition, McGraw Hill education, 2013

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Introduction - Discussion on syllabus, Cos and POs**	
1.1	Classification of automobiles	1
1.2	Layouts based on the location of engine and drive	1
1.3	Frames, Constructional details –Materials	1
1.4	Integrated body construction	1
1.5	Study of loads, moments and stresses on frame members (basics)	1
1.6	Types of chassis layout of hybrid and electric vehicles	1
1.7	Types of chassis- fully forward, semi forward,	1
1.8	Truck or bus chassis,	1
1.9	Two & three wheeler chassis layout.	1

2	**Front axle and Steering**	
2.1	Front Axle types. Construction details. Materials.	1
2.2	Front wheel geometry viz. Camber, kingpin inclination, caster, toe-in and toe-out.	1
2.3	Conditions for true rolling motion of road wheels during steering	1
2.4	Steering geometry. Ackermann and Davis steering	1
2..5	Constructional details of steering linkages	1
2.6	Steering linkage layout for conventional and independent suspensions	1
2.7	Different types of steering gear boxes	1
2.8	Turning radius, wheel wobble and shimmy	1
2.9	Power and power assisted steering – Electric steering – Steer by wire	1
3	**Suspension System, Wheels and Tyres**	
3.1	Types of suspension. Factors influencing ride comfort	1
3.2	Suspension springs – leaf spring, shackle and mounting brackets, coil and torsion bar springs, Spring materials	1
3.3	Independent suspension – front and rear	1
3.4	Rubber, pneumatic, hydro-elasitc, hydro-gas suspension	1
3.5	Hydraulic dampers, Magneto Rheological fluids	1
3.6	Design of leaf springs	1
3.7	Types of wheels. Construction of wheel assembly	1
3.8	Types of tyres and constructional details.	1
3.9	Static and rolling properties of pneumatic tyres, Wheel balancing and alignment	1
4	**Brakes**	
4.1	Types of brakes. Principles of shoe brakes. Constructional details, materials	1
4.2	Braking torque developed by leading and trailing shoes	1
4.3	Disc brake theory, constructional details, advantages	1
4.4	Brake actuating system – mechanical, hydraulic, pneumatic. brake compensation	1
4.5	Factors affecting brake performance viz. operating temperature, area of brake lining, brake clearance.	1
4.6	Exhaust brakes. Power and power assisted brakes	1
4.7	Antilock braking system	1
4.8	Retarded engine brakes, eddy retarders ,Regenerative braking system – Brake by wire	1
4.9	Testing of brakes – Road tests, garage tests and tests for Type Approval under IS:11852	1

5	**Final drive and rear axle**	
5.1	Purpose of final drive & drive ratio	1
5.2	Different types of final drives	1
5.3	Need of differential, Constructional details of differential unit,	1
5.4	Non-slip differential, Differential lock, Differential housing	1
5.5	Function of rear axle, Construction, Types of loads acting on rear axle	2
5.6	Axle types - semi-floating, full floating	1
5.7	Axle shafts, Final drive lubrication	1
5.8	Twin Speed final drive. Final drive for multi-axle vehicles	1

MET 205	METALLURGY & MATERIAL SCIENCE	CATEGORY	L	T	P	Credits	Year of Introduction
		PCC	3	1	0	4	2019

Preamble:

Understanding of the correlation between the chemical bonds and crystal structure of metallic materials to their mechanical properties.

Recognize the importance of crystal imperfections including dislocations in plastic deformation.

Learning about different phases and heat treatment methods to tailor the properties of Fe-C alloys.

Examine the mechanisms of materials failure through fatigue and creep.

To determine properties of unknown materials and develop an awareness to apply this knowledge in material design

Prerequisite: PHT 110 Engineering Physics and CYT 100 Engineering Chemistry

Course Outcomes - At the end of the course students will be able to

CO 1	Understand the basic chemical bonds, crystal structures (BCC, FCC, and HCP), and their relationship with the properties.
CO 2	Analyze the microstructure of metallic materials using phase diagrams and modify the microstructure and properties using different heat treatments.
CO 3	How to quantify mechanical integrity and failure in materials.
CO 4	Apply the basic principles of ferrous and non-ferrous metallurgy for selecting materials for specific applications.
CO 5	Define and differentiate engineering materials on the basis of structure and properties for engineering applications.

Mapping of course outcomes with program outcomes (Minimum requirements)

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

ASSESSMENT PATTERN

Bloom's taxonomy	Continuous Assessment Tests		End Semester Examination (Marks)
	Test 1 (Marks)	Test 11 (Marks)	
Remember	25	25	25
Understand	15	15	15
Apply	30	25	30
Analyze	10	10	10
Evaluate	10	15	10
Create	10	10	10

Mark distribution

Total Marks	CIE marks	ESE marks	ESE duration
150	50	100	3 Hours

Continuous Internal Evaluation (CIE) Pattern:

Attendance	10 marks
Regular class work/tutorials/assignments	15 marks
Continuous Assessment Test (Minimum 2 numbers)	25 marks

End semester 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

Part -A

Course Outcome 1 (CO1): Understand the basic chemical bonds, crystal structures (BCC, FCC, and HCP), and their relationship with the properties.

1. What are the attributes of atomic and crystalline structures into the stress - strain curve?
2. Explain the significance of long range and short range order of atomic arrangement on mechanical strength.
3. What is the difference between an allotrope and a polymorphism?
4. Draw the (112) and (111) planes in simple cubic cell.

Course Outcome 2 (CO2): Analyze the microstructure of metallic materials using phase diagrams and modify the microstructure and properties using different heat treatments.

1. What is the driving force for recrystallisation and grain growth of metallic crystals?
2. What is the driving force for the formation of spheroidite.
3. What is tempered martensite?
4. Why 100 % pure metals are weak in strength?

Part -B

Course Outcome 3 (CO3): How to quantify mechanical integrity and failure in materials

1. A small hole is drilled through a steel plate ahead of a crack, whether it can stop the crack's progress until repairs can be made. Explain in detail and derive the equation for the principle.
2. Draw and explain S-N curves for ferrous and non-ferrous metals. Explain different methods to improve fatigue resistance.
3. Explain different stages of creep; Give an application of creep phenomenon. What is superplasticity?

Course Outcome 4 (CO4): Apply the basic principles of ferrous and non-ferrous metallurgy for selecting materials for specific applications.

1. What are the classification, compositions and applications of high speed steel? identify 18:4:1
2. Describe the composition, properties, and use of Bronze and Gun metal.
3. Explain the importance of all the non-ferrous alloys in automotive applications. Elaborate on the composition, properties and typical applications of any five non-ferrous alloys.

Course Outcome 5 (CO5): Define and differentiate engineering materials on the basis of structure and properties for engineering applications.

1. Carbon is allowed to diffuse through a steel plate 15 mm thick. The concentrations of carbon at the two faces are 0.65 and 0.30kgC/m^3Fe, which are maintained constant. If the pre-exponential and activation energy are $6.2 x 10^{-}7 m^2$/s and 80,000 J/mol, respectively, compute the temperature at which the diffusion flux is $1.43 \times 10^{-}9$ kg/m^2-s.
2. Explain the fundamental effects of alloying elements in steel on polymorphic transformation temperatures, grain growth, eutectoid point, retardation of the transformation rates, formation and stability of carbides.
3. Describe the kind of fracture which may occur as a result of a loose fitting key on a shaft.

SYLLABUS

MODULE - 1

Earlier and present development of atomic structure - Primary bonds: - characteristics of covalent, ionic and metallic bond - properties based on atomic bonding: - Secondary bonds: - classification, application. *(Brief review only).*

Crystallography: - SC, BCC, FCC, HCP structures, APF - theoretical density simple problems - Miller Indices: - crystal plane and direction - Modes of plastic deformation: - Slip and twinning -Schmid's law - Crystallization: Effects of grain size, Hall - Petch theory, simple problems.

MODULE - II

Classification of crystal imperfections - forest of dislocation, role of surface defects on crack initiation- Burgers vector –Frank Read source - Correlation of dislocation density with strength and nano concept - high and low angle grain boundaries– driving force for grain growth and applications - Polishing and etching - X – ray diffraction, simple problems –SEM and TEM - Diffusion in solids, fick's laws, mechanisms, applications of diffusion in mechanical engineering, simple problems.

MODULE - III

Phase diagrams: - need of alloying - classification of alloys - Hume Rothery`s rule - equilibrium diagram of common types of binary systems: five types - Coring - lever rule and Gibb`s phase rule - Reactions- Detailed discussion on Iron-Carbon equilibrium diagram with microstructure and properties -Heat treatment: - TTT, CCT diagram, applications - Tempering- Hardenability, Jominy end quench test, applications- Surface hardening methods.

MODULE - IV

Strengthening mechanisms - cold and hot working - alloy steels: how alloying elements affecting properties of steel - nickel steels - chromium steels - high speed steels -cast irons - principal non ferrous alloys.

MODULE - V

Fatigue: - creep -DBTT - super plasticity - need, properties and applications of composites, super alloy, intermetallics, maraging steel, Titanium - Ceramics:- structures, applications.

Text Books

1. Callister William. D., Material Science and Engineering, John Wiley, 2014
2. Higgins R.A. - Engineering Metallurgy part - I – ELBS,1998

Reference

1. Avner H Sidney, Introduction to Physical Metallurgy, Tata McGraw Hill,2009
2. Anderson J.C. *et.al*., Material Science for Engineers, Chapman and Hall,1990
3. Clark and Varney, Physical metallurgy for Engineers, Van Nostrand,1964
4. Dieter George E, Mechanical Metallurgy, Tata McGraw Hill, 1976
5. Raghavan V, Material Science and Engineering, Prentice Hall,2004
6. Reed Hill E. Robert, Physical metallurgy principles, 4th edition, Cengage Learning,2009
7. Myers Marc and Krishna Kumar Chawla, Mechanical behavior of materials, Cambridge University press,2008
8. Van Vlack -Elements of Material Science - Addison Wesley,1989
9. https://nptel.ac.in/courses/113/106/113106032

MODEL QUESTION PAPER

METALLURGY & MATERIAL SCIENCE - MET 205

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

Part – A

Answer all questions.

Answer all questions, each question carries 3 marks

1. What is a slip system? Describe the slip systems in FCC, BCC and HCP metals
2. NASA's *Parker Solar Probe* will be the first-ever mission to "touch" the Sun. The spacecraft, about the size of a small car, will travel directly into the Sun's atmosphere about 4 million miles from the earth surface. Postulate the coolant used in the parker solar probe with chemical bonds.
3. What is the driving force for grain growth during heat treatment
4. What are the roles of surface imperfections on crack initiation
5. Explain the difference between hardness and hardenability.
6. What is tempered martensite? Explain its structure with sketch.
7. Postulate, why cast irons are brittle?
8. How are properties of aluminum affected by the inclusion of (a) copper and (b) silicon as alloying elements?
9. What is the grain size preferred for creep applications? Why. Explain thermal fatigue?
10. Explain fracture toughness and its attributes into a screw jack?

PART -B

Answer one full question from each module.

MODULE – 1

11. **a.** Calculate the APF of SC, BCC and FCC (7 marks).

    b. What is slip system and explain why FCC materials exhibit ductility and BCC and HCP exhibit brittle nature with details of slip systems (7 marks).

OR

12. Explain the effect of: (i) Grain size; (ii) Grain size distribution and (iii) Grain orientation (iv) Grain shape on strength and creep resistance with neat sketches. Attributes of Hall-Petch equation and grain boundaries (14 marks).

MODULE – 2

13. **a**. Describe step by step procedure for metallographic specimen preparation? Name different types etchants used for specific metals and methods to determine grain size (7 marks).

b. Carbon is allowed to diffuse through a steel plate 15 mm thick. The concentrations of carbon at the two faces are 0.65 and 0.30 kgC/m^3Fe, which are maintained constant. If the pre-exponential and activation energy are 6.2x10^{-}7m^2/s and 80,000 J/mol, respectively, compute the temperature at which the diffusion flux is 1.43 x 10^{-}9 kg/m^2-s (7 marks).

OR

14. a**.** Explain the fundamental differences of SEM and TEM with neat sketches (7 marks).

b**.** A beam of X-rays wavelength 1.54Å is incident on a crystal at a glancing angle of 8º35' when the first order Bragg's reflection occurs calculate the glancing angle for third order reflection (7 marks).

MODULE – 3

15. Postulate with neat sketches, why 100% pure metals are weaker? What are the primary functions of alloying? Explain the fundamental rules governing the alloying with neat sketches and how is it accomplished in substitution and interstitial solid solutions (14 marks).

OR

16. Draw the isothermal transformation diagram of eutectoid steel and then sketch and label (1) A time temperature path that will produce 100% pure coarse and fine pearlite (2) A time temperature path that will produce 50% martensite and 50% bainite (3) A time temperature path that will produce 100% martensite (4) A time temperature path that will produce 100% bainite (14 marks).

MODULE – 4

17. Explain the effect of, polymorphic transformation temperature, formation and stability of carbides, grain growth, displacement of the eutectoid point, retardation of the transformation rates, improvement of corrosion resistance on adding alloy elements to steel (14 marks).

OR

18. Give the composition, microstructure, properties and applications of (i) Gray iron and SG iron. (ii) White iron and Gray iron. (iii) Malleable iron and Gray iron. (iv) Gray iron and Mottled iron, (v) SG iron and Vermicullar Graphite Iron (14 marks).

MODULE – 5

19. a A small hole is drilled through a steel plate ahead of a crack, whether it can stop the crack's progress until repairs can be made or not? Explain in detail and derive the equation (7 marks).

b What is ductile to brittle transition in steel DBTT? What are the factors affecting ductile to brittle transition? Narrate with neat sketch (7 marks).

OR

20. Classify ceramics with radius ratio with neat sketches. Explain with an example for each of the AX, AmXp, AmBmXp type structures in ceramics with neat sketch (14 marks).

COURSE CONTENT AND LECTURE SCHEDULES.

Module	TOPIC	No. of hours	Course outcomes
1.1	Earlier and present development of atomic structure; attributes of ionization energy and conductivity, electronegativity; correlation of atomic radius to strength; electron configurations; - Primary bonds: - characteristics of covalent, ionic and metallic bond: attributes of bond energy, cohesive force, density, directional and non-directional - properties based on atomic bonding:- attributes of deeper energy well and shallow energy well to melting temperature, coefficient of thermal expansion - attributes of modulus of elasticity in metal cutting process -Secondary bonds:- classification- hydrogen bond and anomalous behavior of ice float on water, application- specific heat, applications. (Brief review only).	2	CO1
1.2	Crystallography:- Crystal, space lattice, unit cell- SC, BCC, FCC, atomic packing factor and HCP structures - short and long range order - effects of crystalline and amorphous structure on mechanical properties.	2	CO1 CO2
1.3	Coordination number and radius ratio; theoretical density; simple problems - Polymorphism and allotropy.	1	
1.4	Miller Indices: - crystal plane and direction - Attributes of miller indices for slip system, brittleness of BCC, HCP and ductility of FCC - Modes of plastic deformation: - Slip and twinning.	1	CO5
1.5	Schmid's law, equation, critical resolved shear stress, correlation of slip system with plastic deformation in metals and applications.	1	
1.6	Mechanism of crystallization: Homogeneous and heterogeneous nuclei formation, under cooling, dendritic growth, grain boundary irregularity - Effects of grain size, grain size distribution, grain shape, grain orientation on dislocation/strength and creep resistance - Hall - Petch theory, simple problems.	2	CO2
2.1	Classification of crystal imperfections: - types of point and dislocations.	1	CO2
2.2	Effect of point defects on mechanical properties - forest of dislocation, role of surface defects on crack initiation - Burgers vector.	1	
2.3	Dislocation source, significance of Frank-Read source in metals deformation - Correlation of dislocation density with strength and nano concept, applications.	3	CO2
2.4	Significance high and low angle grain boundaries on dislocation – driving force for grain growth and applications during heat treatment.		
2.5	Polishing and etching to determine the microstructure and grain size- Fundamentals and crystal structure determination by X – ray diffraction, simple problems –SEM and TEM.	2	CO2 CO5
2.6	Diffusion in solids, fick's laws, mechanisms, applications of diffusion in mechanical engineering, simple problems.	1	

3.1	Phase diagrams: - Limitations of pure metals and need of alloying - classification of alloys, solid solutions, Hume Rothery`s rule - equilibrium diagram of common types of binary systems: five types.	2	CO2 CO5
3.2	Coring - lever rule and Gibb`s phase rule - Reactions: - monotectic, eutectic, eutectoid, peritectic, peritectoid.	1	
3.3	Detailed discussion on Iron-Carbon equilibrium diagram with microstructure and properties changes in austenite, ledeburite, ferrite, cementite, special features of martensite transformation, bainite, spheroidite etc.	3	CO2 CO5
3.4	Heat treatment: - Definition and necessity – TTT for a eutectoid iron–carbon alloy, CCT diagram, applications - annealing, normalizing, hardening, spheroidizing.		
3.5	Tempering:- austermpering, martempering and ausforming - Comparative study on ductility and strength with structure of pearlite, bainite, spherodite, martensite, tempered martensite and ausforming.	1	CO2
3.6	Hardenability, Jominy end quench test, applications- Surface hardening methods:- no change in surface composition methods :- Flame, induction, laser and electron beam hardening processes- change in surface composition methods :carburizing and Nitriding; applications.	2	CO2
4.1	Cold working: Detailed discussion on strain hardening; recovery; re-crystallization, effect of stored energy; re- crystallization temperature - hot working, Bauschinger effect and attributes in metal forming.	1	
4.2	Alloy steels:- Effects of alloying elements on steel: dislocation movement, polymorphic transformation temperature, alpha and beta stabilizers, formation and stability of carbides, grain growth, displacement of the eutectoid point, retardation of the transformation rates, improvement in corrosion resistance, mechanical properties	1	CO4
4.3	Nickel steels, Chromium steels etc. – change of steel properties by adding alloying elements: - Molybdenum, Nickel, Chromium, Vanadium, Tungsten, Cobalt, Silicon, Copper and Lead - High speed steels - Cast irons: Classifications; grey, white, malleable and spheroidal graphite cast iron etc, composition, microstructure, properties and applications - Principal Non ferrous Alloys: - Aluminum, Copper, Magnesium, Nickel, study of composition, properties, applications, reference shall be made to the phase diagrams whenever necessary.(Topic 4.3 may be considered as a assignment).	4	CO4 CO5
4.4	Fatigue: - Stress cycles – Primary and secondary stress raisers - Characteristics of fatigue failure, fatigue tests, S-N curve.	1	CO3
4.5	Factors affecting fatigue strength: stress concentration, size effect, surface roughness, change in surface properties, surface residual stress - Ways to improve fatigue life – effect of temperature on fatigue, thermal fatigue and its applications in metal cutting.	2	

5.1	Fracture: – Brittle and ductile fracture – Griffith theory of brittle fracture – Stress concentration, stress raiser – Effect of plastic deformation on crack propagation - transgranular, intergranular fracture - Effect of impact loading on ductile material and its application in forging, applications - Mechanism of fatigue failure.	2	CO3
5.2	Structural features of fatigue: - crack initiation, growth, propagation - Fracture toughness (definition only), applications - Ductile to brittle transition temperature (DBTT) in steels and structural changes during DBTT, applications.	1	
5.3	Creep: - Creep curves – creep tests - Structural change:- deformation by slip, sub-grain formation, grain boundary sliding - Mechanism of creep deformation - threshold for creep, prevention against creep - Super plasticity: need and applications	2	CO3
5.4	Composites: - Need of development of composites; fiber phase; matrix phase; only need and characteristics of PMC, MMC, and CMC.	2	CO3 CO5
5.5	Modern engineering materials: - only fundamentals, need, properties and applications of, intermetallics, maraging steel, super alloys, Titanium-Ceramics:-coordination number and radius ratios- AX, A_mX_p, $A_mB_mX_p$ type structures – applications.	3	

MEL201	COMPUTER AIDED MACHINE DRAWING	CATEGORY	L	T	P	Credits	Year of Introduction
		PCC	0	0	3	2	2019

Preamble: To introduce students to the basics and standards of engineering drawing related to machines and components.

To make studentsfamiliarize with different types of riveted and welded joints, surface roughness symbols; limits, fits and tolerances.

To convey the principles and requirements of machine and production drawings.

To introduce the preparation ofdrawings of assembled and disassembled view of important valves and machine components used in mechanical engineering applications.

To introduce standard CAD packages for drafting andmodelingof engineering components.

Prerequisite: EST 110 - Engineering Graphics

Course Outcomes - At the end of the course students will be able to

CO1	Apply the knowledge of engineering drawings and standards to prepare standard dimensioned drawings of machine parts and other engineering components.
CO2	Preparestandard assembly drawings of machine components and valvesusing part drawings and bill of materials.
CO3	Apply limits and tolerances to components and choose appropriate fits for given assemblies
CO 4	Interpret the symbols of welded, machining and surface roughness on the component drawings.
CO 5	Prepare part and assembly drawings and Bill of Materials of machine components and valves using CAD software.

Mapping of course outcomes with program outcomes (Minimum requirements)

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

Assessment Pattern

Bloom's taxonomy	Continuous Assessment Tests	
	Test 1 PART A Sketching and Manual Drawing	Test 2 PART B CAD Drawing
Remember	25	20
Understand	15	15
Apply	30	20
Analyse	10	10
Evaluate	10	15
Create	10	20

Mark Distribution

Total Marks	CIE Marks	ESE marks	ESE duration
150	75	75	2.5 hours

Continuous Internal Evaluation (CIE) Pattern:

Attendance	15 marks
Regular class work/Drawing/Workshop Record/Lab Record and Class Performance	30 marks
Continuous Assessment Test (minimum two tests)	30 marks

End semester examination pattern

End semester examination shall be conducted on Sketching and CAD drawing on based complete syllabus

The following general guidelines should be maintained for the award of marks

Part A Sketching – 15 marks
Part B CAD drawing – 50marks
Viva Voce – 10 marks.

Conduct of University Practical Examinations

The Principals of the concerned Engineering Colleges with the help of the Chairmen/Chairperson will conduct the practical examination with the approval from the University and bonafide work / laboratory record, hall ticket, identity card issued by college are mandatory for appearing practical University examinations. No practical examination should be conducted without the presence of an external examiner appointed by the University.

END SEMSTER EXAMINATION

MODEL QUESTION PAPER

MEL 201: COMPUTER AIDED MACHINE DRAWING

Duration : 2.5 hours Marks : 75

Note :

1. All dimensions in mm
2. Assume missing dimensions appropriately
3. A4 size answer booklet shall be supplied
4. Viva Voce shall be conducted for 10 marks

PART A (SKETCHING)

(Answer any TWO questions). 15 marks

1. Sketch two views of a single riveted single strap butt joint. Take dimensions of the plate as 10mm. Mark the proportions in the drawing.

2. Show by means of neat sketches, any three methods employed for preventing nuts from getting loose on account of vibrations

3. Compute the limit dimensions of the shaft and the hole for a clearance fit based on shaft basis system if:

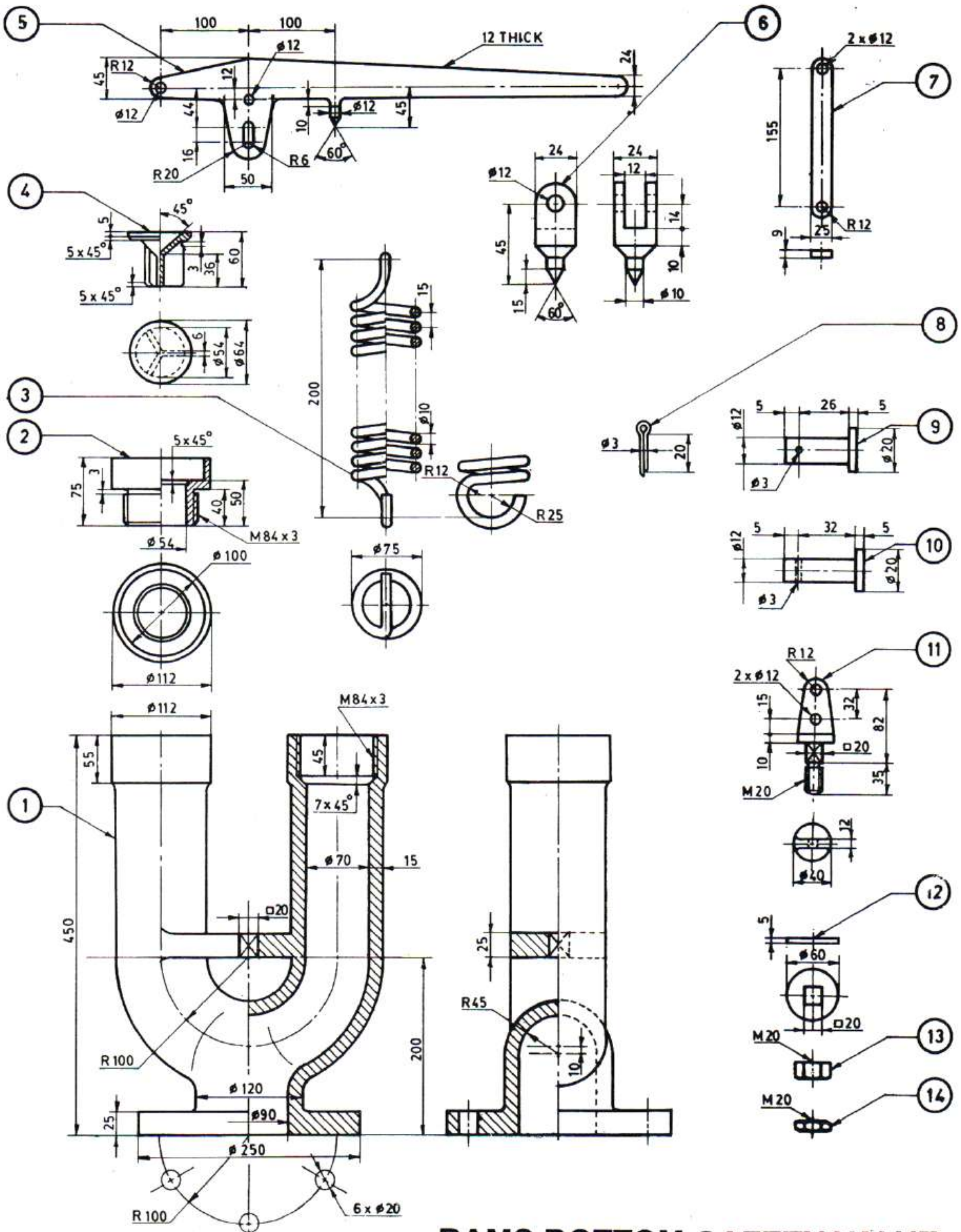
   Basic size= ϕ30 mm
   Minimum clearance = 0.007 mm
   Tolerance on hole = 0.021 mm
   Tolerance on shaft= 0.021 mm

   Check the calculated dimensions. Represent the limit dimensions schematically.

PART B (CAD DRAWING) 50 marks

4. Draw any two assembled views of the Rams Bottom Safety Valve as per the details given in the figure using any suitable CAD software. Also prepare bill of materials and tolerance data sheet.

Item	Description	Qty	Material	Item	Description	Qty	Material
1	Body	1	C.I.	**8**	Split Pin	3	M.S.
2	Valve Seat	2	G.M.	**9**	Pin for Link	2	M.S.
3	Spring	1	Steel	**10**	Pin for Pivot	1	M.S.
4	Valve	2	G.M.	**11**	Shackle	1	M.S.
5	Lever	1	M.S.	**12**	Washer	1	M.S.
6	Pivot	1	M.S.	**13**	Nut	1	M.S.
7	Link	2	M.S.	**14**	Lock Nut	1	M.S.



RAMS BOTTOM SAFETY VALVE

SYLLABUS

Introduction to machine drawing, drawing standards, fits, tolerances, surface roughness, assembly and part drawings of simple assemblies and subassemblies of machine parts viz., couplings, clutches, bearings, I.C. engine components, valves, machine tools, etc; introduction to CAD etc.

Text Books:
1. N. D. Bhatt and V.M. Panchal, Machine Drawing, Charotar Publishing House.
2. P I Varghese and K C John, Machine Drawing, VIP Publishers.

Reference Books
1. Ajeet Singh, Machine Drawing Includes AutoCAD, Tata McGraw-hill.
2. P S Gill, Machine Drawing, Kataria& Sons.

Course content and drawing schedules.

No:	List of Exercises	Course outcomes	No. of hours
	PART –A (Manual drawing) *(Minimum 6 drawings compulsory)*		
1	**Temporary Joint:** Principles of drawing, free hand sketching, Importance of machine Drawing. BIScode of practice for Engineering Drawing, lines, types of lines, dimensioning, scales of drawing, sectional views, **Riveted joints.**	CO 1	**3**
2	**Fasteners:** Sketching of conventional representation of welded joints,Bolts and Nuts **or** Keys and Foundation Bolts.	CO 1	**3**
3	**Fits and Tolerances:** Limits, Fits – Tolerances of individual dimensions – Specification of Fits – basic principles of geometric & dimensional tolerances. **Surface Roughness:** Preparation of production drawings and reading of part and assembly drawings, surface roughness, indication of surface roughness, etc.	CO 2	**3**
4	Detailed drawing of Cotter joints, Knuckle joint and Pipe joints	CO 2	**3**
5	**Assembly drawings(2D):** Stuffing box and Screw jack	CO 1 CO3 CO4	**3**

	PART –B **(CAD drawing)** *(Minimum 6 drawings compulsory)*		
6	Introduction to drafting software like Auto CAD, basic commands, keyboard shortcuts. Coordinate and unit setting, Drawing, Editing, Measuring, Dimensioning, Plotting Commands, Layering Concepts, Matching, Detailing, Detailed drawings.	CO 1 CO 2 CO 3 CO5	**3**
7	Drawing of Shaft couplings and Oldham's coupling	CO 1 CO 2 CO 3 CO5	**3**
8	**Assembly drawings(2D)with Bill of materials:** Lathe Tailstock and Universal joint	CO 1 CO3 CO5	**3**
9	**Assembly drawings(2D)with Bill of materials:** Connecting rod and Plummer block	CO 1 CO3 CO5	**3**
10	**Assembly drawings(2D)with Bill of materials:** Rams Bottom Safety Valve **OR** steam stop valve	CO 1 CO3 CO5	**3**

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MUL203	FM & HM LAB	PCC	0	0	3	2

Preamble:

This lab is mainly focussed to develop a platform where the students can enhance their engineering knowledge in the fluid mechanics domain by applying their theoretical knowledge acquired.

Prerequisite: MET203 Mechanics of Fluids

Course Outcomes:

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

CO 1	Determine the coefficient of discharge of flow measuring devices (notches, orifice meter and Venturi meter)
CO 2	Calibrate flow measuring devices (notches, orifice meter and Venturi meter)
CO 3	Evaluate the losses in pipes
CO 4	Determine the metacentric height and stability of floating bodies
CO 5	Determine the efficiency and plot the characteristic curves of different types of pumps and turbines

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

SYLLABUS

LIST OF EXPERIMENTS

1. Determination of coefficient of discharge and calibration of Notches.

2. Determination of coefficient of discharge and calibration of Orifice meter.

3. Determination of coefficient of discharge and calibration of Venturi meter.

4. Determination of hydraulic coefficients of orifices.

5. Determination of Chezy’s constant and Darcy’s coefficient on pipe friction apparatus.

6. Determine the minor losses in pipe.

7. Experiments on hydraulic ram.

8. Reynolds experiment.

9. Bernoulli’s experiment.

10. Determination of metacentric height and radius of gyration of floating bodies.

11. Performance test on positive displacement pumps.

12. Performance test on centrifugal pumps, determination of operating point and efficiency.

13. Performance test on gear pump.

14. Performance test on Impulse turbines.

15. Performance test on reaction turbines (Francis and Kaplan Turbines).

16. Speed variation test on Impulse turbine.

17. Determination of best guide vane opening for Reaction turbine.

18. Impact of jet.

Note: 12 experiments are mandatory

Reference Books

1. Yunus A. Cenegel, John M. Cimbala; Fluid Mechanics- Fundamentals and Applications (in SI Units); McGraw Hill, 2010.
2. Bansal R.K, Fluid Mechanics and Hydraulic Machines (SI Units); Laxmi Publications, 2011.
3. Modi P.N and Seth S.M, “Hydraulics and Fluid Mechanics Including Hydraulic Machines” Standard Book House, New Delhi, 20th Edition, 2015
4. Graebel. W. P, "Engineering Fluid Mechanics", Taylor & Francis, Indian Reprint, 2011
5. Robert W. Fox, Alan T. McDonald, Philip J. Pritchard, “Fluid Mechanics and Machinery”, John Wiley and sons, 2015.
6. J. Frabzini, 'Fluid Mechanics with Engineering Applications', McGraw Hill, 1997.

SEMESTER -3

MINOR

MUT 281	FUNDAMENTALS OF AUTOMOBILE ENGINEERING	CATEGORY	L	T	P	CREDIT
		VAC	4	0	0	4

Preamble: The aim of this subject is to offer the students a general understanding of the anatomy of automobile and

- ✓ To get basic idea about the basics of Automobile engineering.
- ✓ To understand the working of different automotive systems and subsystems
- ✓ To understand the importance of electronics in automobiles
- ✓ To update the latest developments in automobiles

Prerequisite:

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

CO 1	Explain the basics of Automobiles and IC engines
CO 2	Categorize the fuel supply system and ignition system
CO 3	Illustrate and identify starting, braking and steering systems
CO 4	Categorize the comfort and electrical components in automobile
CO 5	Illustrate the latest developments in automobiles

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

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	25	25	50
Understand	25	25	50
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 5 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 10 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define operating cycles for SI and CI engines

2. Identify the combustion characteristics of IC engines

3. Explain the various alternate fuels for SI and CI engines

Course Outcome 2 (CO2)

1. Distinguish between CI and SI fuel injection system

2. Classify the fuel injection systems

3. Classify and identify the ignition systems in SI engines

Course Outcome 3(CO3):

1. To illustrate the working of starting system

2. Explain and identify the alternator and its working

3. Describe about the function of braking system

4 .Explain the various steering parameters

Course Outcome 4 (CO4):

1. To illustrate the working of electrical accessories

2. Describe the working principle of automotive air conditioner ?

3. Explain the principle of automobile illumination

Course Outcome 5 (CO5):

1. Categorize the electronics and microprocessors in automobile.

2. To illustrate the latest developments in automobiles .

3. Discuss the details of onboard diagnosis and security systems in automobile.

Model Question paper

QP CODE: **PAGES: 02**

Reg. No: _______________ **Name :_______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

THIRD SEMESTER B.TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: MUT 281

Course Name: FUNDAMENTALS OF AUTOMOBILES ENGINEERING

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

PART A

Answer all Questions.
Each question carries 5 Marks

1. Enumerate the history of automobile.

2. Differentiate between SI and CI engines.

3. With the help of neat figure explain the working of CRDI.

4. Explain the working principle of TAC (transistor assisted contact) ignition system.

5. Explain the various types of fire tenders used in firefighting.

6. Discuss about the starting system in automobile

7. With the aid of neat figure explain the working of hydraulic braking system.

8. What you mean by electronic fuel gauge differentiate it from analog gauges?

9. Explain 1) Throttle position sensor 2) fuel flow sensor

10. Discuss about the need for electric and hybrid vehicles

PART B

Answer any one full question from each module.
Each question carries 10 Marks

Module 1

11. a) With the aid of neat sketch explain the constructional details of IC engine . (5)

b) Differentiate between Cetane and octane number (5)

12. a) Discuss about the thermodynamic cycles for IC engines. (5)

b) Explain in detail the factors contributing the combustion chamber design. (5)

Module 2

13. Describe the fuel supply systems in CI engines (10)

14. a) With the aid of neat sketch explain DTSI,Electronic, solid state ignition system (5)

b) With neat sketch explain distributor less ignition system (5)

Module 3

15. Discuss salient features of Antilock Brake Systems. (10)

16. a) Explain the working principle of DC generators used in automobiles. (5)

b) Enumerate on the working of pneumatic brakes (5)

Module 4

17. Explain the Principle and constructional details of automobile illumination. (10)

18. Discuss on the design factors and concepts related to air conditioning system (10)

Module 5

19. What are the common Electronic / Microprocessor control systems used in automobiles? (10)

20. a) What are the components an electric vehicle and also explain salient features of hybrid vehicles (5)

b) Write a note Limitations of electric vehicles. (5)

SYLLABUS

Module 1

Fundamentals of Automobiles - Automobile history and development. Introduction to IC engines. Thermodynamic cycle" of spark ignition (SI) and compression ignition (CI) engines. Construction and working principles SI and CI engines. Four stroke and two stroke engines. Comparison of SI and CI engines. Introduction to combustion in SI and CI engines, Stages of combustion, Combustion chambers for SI and CI engines, Importance of Swirl, squish and turbulence. Factors controlling the combustion. Conventional and alternate fuels for IC engines: desirable characteristics of gasoline, desirable characteristics of diesel fuel alternative fuels for SI engines and CI engines. Cetane and octane number.

Module 2

Fuel supply system in IC engines : Quantity & hit and miss governing. Working of a carburetor, Introduction and fuel system circuit. Air fuel ratio requirements. Types of gasoline fuel injection system, MPFI - L Jetronic and D jetronic systems, GDI, electrical fuel pump, electronically controlled fuel supply system, electronically controlled exhaust gas re-circulation system, Diesel fuel injection systems- Engine governor, Jerk pumps, distributor pumps, types of nozzles, Electronic fuel supply system in diesel engines - CRDI.

Components of Ignition systems. Ignition system: Types of ignition, spark plug, firing order, magneto and coil ignition, constructional details, distributor, spark plugs, ignition coil, ignition timing, TAC (transistor assisted contact) ignition system, CD Ignition system, DTSi, Electronic / solid state ignition system,. Microprocessor controlled ignition system, advantages, simplified operational diagram of a distributor less ignition system, automatic ignition advance methods, ignition timing, spark plugs-construction, principle of electronic ignition and ignition advance.

Module 3

Starting and charging systems: Starter motor- Principle, condition at starting, series motor and its characteristics, types of drives, types of starter switches. Principle of generation of DC generator, constructional details, armature reaction, third bush control, voltage & current regulators, construction and working, construction of A.C. generators (alternators), advantages.

Steering and braking system: -Basic principle of a steering system: - swinging beam system Ackermann, over steer and under steer, slip angle, camber, caster etc. Brakes: - mechanical and hydraulic brakes- layout, master cylinder, wheel cylinder, Pneumatic brakes, properties of friction lining and pad materials, efficiency, stopping distance, theory of internal shoe brake, Braking efficiency and stopping distance. components, power brakes, Antilock Brake Systems, parking brake.

Module 4

Lighting and electrical accessories: Principle of automobile illumination, head lamp, mounting and construction, sealed beam, composite headlights, auxiliary lighting, horn, wind screen wipers, signalling devices, electrical gauges - analog fuel gauge, oil gauge, temperature gauges, electronic speedometers, electronic fuel gauge.

Terminology, design factors and concepts related to air conditioning system - Construction and working principles of Thermostatic Expansion valve and Orifice tube based system- Heating system types -detailed study of HVAC components like compressor, evaporator, condenser, TXV, orifice tube , Receiver-drier, heater core etc. Location of air conditioning components in a vehicle, refrigerants & air management systems and automatic climate control system

Module 5

Electronic / Microprocessor control systems: Concept of CPU and computer memory used in automobiles, sensors- Pressure sensor, Throttle position sensor, fuel flow sensor, thermistor sensor, oxygen sensor, speed sensors, knock detecting sensor, actuators solenoids and stepper motor. Electronic dash board instruments - Onboard diagnosis system, security and warning system.

Introduction to Electric Vehicles: Need of electric vehicles hybrid vehicles comparative study of diesel, petrol, pure electric and hybrid vehicles. Hybrid and Electric vehicle –. Layout, Merits, demerits and components, various modes of operation of hybrid vehicles, Electronic control system – Different configurations of Hybrid vehicles. Power split device. Energy regeneration. High energy and power density batteries – Introduction to fuel cell vehicles, PEM Fuel cell. Limitations of electric vehicles. Specification of some electric and hybrid vehicles

Text Books

1. Crouse W. H. and D. L. Anglin, Automotive Mechanics, Tata McGraw Hill, 2003.

2. Kirpal Singh, Automobile Engineering- Vol. I & II, Standard Publishers, 2008.

3. Kohli P. L., Automotive Electrical Equipment, Tata McGraw Hill, New Delhi, 2004.

4. Narang G. B., Automobile Engineering, Khanna Publishers, New Delhi,

5. Joseph Hietner, Automotive Mechanics, East- West Press Pvt. Ltd, Madras, 2006.

6. Jain K. K. and R. B. Asthana, Automobile Engineering, Tata McGraw Hill, 1999.

7. . Giri N.K, Automobile Mechanics, 8/e, Khanna Publishers

Reference Books

1. Gupta R.B. Auto design , Satya Prakash, New Delhi, 2015
2. Heinz Heisler, Advanced engine technology, Butterworth-Heinemann,1995

3. Heinz Heisler, Advanced vehicle technology, Society of Automotive Engineers Inc, 2002
4. Hillier and Peter Coobes, Fundamentals of motor vehicle technology, Nelson Thornes, 2004
5. Tom Denton, Automobile mechanical and electrical systems, Butterworth-Heinemann, 2011

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1	**Module 1 (11 hours)**	
1.1	Automobile history and development. Introduction to IC engines.	1
1.2	Thermodynamic cycle‟s and constructional details of spark ignition (SI) and compression ignition (CI) engines. Working principles.	3
1.3	Two stroke SI engines – construction and working. Valve timing and port timing diagram. Comparison of SI and CI engines and four stroke and two stroke engines. Introduction to combustion in SI and CI engines, Stages of combustion, Combustion chambers for SI and CI engines, Importance of Swirl, squish and turbulence.	3
1.4	Factors controlling combustion chamber design. Conventional and alternate fuels for IC engines: desirable characteristics of gasoline desirable characteristics of diesel fuel alternative fuels for SI engines and CI engines	2
2	**Module 2 (10 hours)**	
2.1	Fuel supply system in IC engines : Quantity & hit and miss governing. Working of a carburetor, Introduction and fuel system circuit. Air fuel ratio requirements. Types of gasoline fuel injection system, TBI, MPFI - L Jetronic and D jetronic systems.	2
2.2	GDI, electrical fuel pump, electronically controlled fuel supply system, electronically controlled exhaust gas re-circulation system, Diesel fuel injection systems- Engine governor, Jerk pumps, distributor pumps, types of nozzles, Electronic fuel supply system in diesel engines - CRDI.	2
2.3	Components of Ignition systems. Ignition system: Types of ignition, spark plug, firing order, magneto and coil ignition, constructional details, distributor, spark plugs, ignition coil, ignition timing, TAC (transistor assisted contact) ignition system.	3
2.4	CD Ignition system, DTSi, Electronic / solid state ignition system,. Microprocessor controlled ignition system, advantages, simplified operational diagram of a distributor less ignition system, automatic ignition advance methods, ignition timing, spark plugs-	3

	construction, principle of electronic ignition and ignition advance	
3	**Module 3 (9 hours)**	
3.1	Starting and charging systems: Starter motor- Principle, condition at starting, series motor and its characteristics, types of drives, types of starter switches. Principle of generation of DC generator, constructional details, armature reaction, third bush control, voltage & current regulators, construction and working, construction of A.C. generators (alternators), advantages.	3
3.2	Steering and braking system: -Basic principle of a steering system: -swinging beam system Ackermann, over steer and under steer, slip angle, camber, caster etc. Brakes: - mechanical and hydraulic brakes-layout, master cylinder, wheel cylinder,	3
3.3	Pneumatic brakes, properties of friction lining and pad materials, efficiency, stopping distance, theory of internal shoe brake, Braking efficiency and stopping distance. components, power brakes, Antilock Brake Systems, parking brake.	3
4	**Module 4 (8hours)**	
4.1	Lighting and electrical accessories: Principle of automobile illumination, head lamp, mounting and construction, sealed beam, composite headlights, auxiliary lighting, horn, wind screen wipers, signalling devices, electrical gauges - analog fuel gauge, oil gauge, temperature gauges, electronic speedometers, electronic fuel gauge.	4
4.2	Terminology, design factors and concepts related to air conditioning system - Construction and working principles of Thermostatic Expansion valve and Orifice tube based system-Heating system types -detailed study of HVAC components like compressor, evaporator, condenser, TXV, orifice tube , Receiver-drier, heater core etc. Location of air conditioning components in a vehicle, refrigerants & air management systems and automatic climate control system	4
5	**Fire Fighting and Investigation (10 hours)**	
5.1	Electronic / Microprocessor control systems: Concept of CPU and computer memory used in automobiles, sensors- Pressure sensor, Throttle position sensor, fuel flow sensor, thermistor sensor, oxygen sensor, speed sensors, knock detecting sensor, actuators solenoids and stepper motor. Electronic dash board instruments - Onboard diagnosis system, security and warning system.	4
5.2	Introduction to Electric Vehicles: Need of electric vehicles hybrid vehicles comparative study of diesel, petrol, pure electric and hybrid vehicles. Hybrid and Electric vehicle –. Layout, Merits, demerits and components, various modes of operation of hybrid vehicles.	3

5.3	Electronic control system – Different configurations of Hybrid vehicles. Power split device. Energy regeneration. High energy and power density batteries – Introduction to fuel cell vehicles, PEM Fuel cell. Limitations of electric vehicles. Specification of some electric and hybrid vehicles	3

SEMESTER -4

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET202	ENGINEERING THERMODYNAMICS	PCC	3	1	-	4

Preamble :

Thermodynamics is the study of energy . Without energy life cannot exist. Activities from breathing to the launching of rockets involves energy transactions and are subject to thermodynamic analysis. Engineering devices like engines, turbines, refrigeration and air conditioning systems, propulsion systems etc., work on energy transformations and must be analysed using principles of thermodynamics. So, a thorough knowledge of thermodynamic concepts is essential for a mechanical engineer. This course offers an introduction to the basic concepts and laws of thermodynamics.

Prerequisite : NIL

Course Outcomes :

After completion of the course the student will be able to

CO1	Understand basic concepts and laws of thermodynamics
CO2	Conduct first law analysis of open and closed systems
CO3	Determine entropy and availability changes associated with different processes
CO4	Understand the application and limitations of different equations of state
CO5	Determine change in properties of pure substances during phase change processes
CO6	Evaluate properties of ideal gas mixtures

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Blooms Category	CA			ESA
	Assignment	Test - 1	Test - 2	
Remember	25	20	20	10
Understand	25	40	40	20
Apply	25	40	40	70
Analyse	25			
Evaluate				
Create				

Continuous Internal Evaluation Pattern:

Attendance : 10 marks

Continuous Assessment Test (2 numbers) : 25 marks

Assignment/Quiz/Course project : 15 marks

Mark distribution & Duration of Examination :

Total Marks	CA	ESE	ESE Duration
150	50	100	3 Hours

End semester 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

1. Discuss the limitations of first law of thermodynamics.

2. Second law of thermodynamics is often called a directional law . Why?

3. Explain Joule-Kelvin effect. What is the significance of the inversion curve ?

Course Outcome 2

1. A mass of 2.4 kg of air at 150 kPa and 12°C is contained in a gas – tight, frictionless piston – cylinder device. The air is now compressed to a final pressure of 600 kPa . During this process, heat is transferred from the air such that the temperature inside the cylinder remains constant. Calculate the work input during this process.

2. Carbon dioxide enters an adiabatic nozzle steadily at 1 MPa and 500°C with a mass flow rate of 600 kg/hr and leaves at 100 kPa and 450 m/s. The inlet area of the nozzle is 40 cm^2. Determine (a) the inlet velocity and (b) the exit temperature

3. A vertical piston – cylinder device initially contains 0.25 m^3 of air at 600 kPa and 300°C. A valve connected to the cylinder is now opened and air is allowed to escape until three-quarters of the mass leave the cylinder at which point the volume is 0.05 m^3. Determine the final temperature in the cylinder and the boundary work during this process.

Course Outcome 3

1.An adiabatic vessel contains 2 kg of water at 25˚C. B paddle – wheel work transfer, the temperature of water is increased to 30˚C.   If the specific heat of water is assumed to be constant at 4.186 kJ/kg.K, find the entropy change of the universe.

2. Two kilograms of water at 80°C is mixed adiabatically with 3 kg of water at 30°C in a constant pressure process at 1 atm. Find the increase in entropy of the total mass of water due to the mixing process.

3. Argon enters an insulated turbine operating under steady state at 1000˚C and 2 MPa and exhausts at 350 kPa. The mass flow rate is 0.5 kg/s and the turbine develops power at the rate of 120 kW. Determine (a)the temperature of the argon at the turbine exit, (b) the irreversibility of the turbine and (c) the second law efficiency. Neglect KE and PE effects. Take T_o = 20˚C and P_o = 1 bar

Course Outcome 4

1. What are the limitations of ideal gas equation and how does Van der Waals equation overcome these limitations ?

2. Discuss law of corresponding states and its role in the construction of compressibility chart.

3. A rigid tank contains 2 kmol of N_2 and 6 kmol of CH_4 gases at 200 K and 12 MPa. Estimate the volume of the tank, using (a) ideal gas equation of state (b) the compressibility chart and Amagat's law

Course Outcome 5

1.Steam is throttled from 3 MPa and 600˚C to 2.5 MPa. Determine the temperature of the steam at the end of the throttling process.

2. Determine the change in specific volume, specific enthalpy and quality of steam as saturated steam at 15 bar expands isentropically to 1 bar. Use steam tables

3. Estimate the enthalpy of vapourization of steam at 500 kPa, using the Clapeyron equation and compare it with the tabulated value

Course Outcome 6

1. A gaseous mixture contains , by volume, 21%nitrogen, 50% hydrogen and 29 % carbon dioxide. Calculate the molecular weight of the mixture, the characteristic gas constant of the mixture and the value of the reversible adiabatic expansion index - γ. At 10˚C, the C_p values of nitrogen, hydrogen and carbon dioxide are 1.039, 14.235 and 0.828 kJ/kg.K respectively.

2. A mixture of 2 kmol of CO_2 and 3 kmol of air is contained in a tank at 199 kPa and 20˚C. Treating air to be a mixture of 79% N_2 and 21% O_2 by volume , calculate (a) the individual mass of CO_2 , N_2 and O_2, (b) the percentage content of carbon by mass in the mixture and (c) the molar mass , characteristic gas constant and the specific volume of the mixture

3. A gas mixture in an engine cylinder has 12% CO_2, 11.5 % O_2 and 76.5% N_2 by volume. The mixture at 1000˚C expands reversibly, according to the law $PV^{1.25}$ = constant, to 7 times its initial volume. Determine the work transfer and heat transfer per unit mass of the mixture.

SYLLABUS

Module 1: Role of Thermodynamics and it's applications in Engineering and Science –Basic Concepts Macroscopic and Microscopic viewpoints, Concept of Continuum, Thermodynamic System and Control Volume, Surrounding, Boundaries, Types of Systems, Universe, Thermodynamic properties, Process, Cycle, Thermodynamic Equilibrium, Quasi – static Process, State, Point and Path function. Zeroth Law of Thermodynamics, Measurement of Temperature, reference Points, Temperature Scales.

Module 2: Energy - Work - Pdv work and other types of work transfer, free expansion work, heat and heat capacity. Joule's Experiment- First law of Thermodynamics - First law applied to Non flow Process- Enthalpy- specific heats- PMM1, First law applied to Flow Process, Mass and Energy balance in simple steady flow process. Applications of SFEE, Transient flow –Filling and Emptying Process, Limitations of the First Law.

Module 3: Second Law of Thermodynamics, Thermal Reservoir, Heat Engine, Heat pump – Kelvin-Planck and Clausius Statements, Equivalence of two statements, Reversibility, Irreversible Process, Causes of Irreversibility, PMM2, Carnot's theorem and its corollaries, Absolute Thermodynamic Temperature scale. Clausius Inequality, Entropy- Entropy changes in various thermodynamic processes, principle of increase of entropy and its applications, Entropy generation, Entropy and Disorder, Reversible adiabatic process- isentropic process, Third law of thermodynamics, Available Energy, Availability and Irreversibility- Second law efficiency.

Module 4: Pure Substances, Phase Transformations, Triple point, properties during change of phase, T-v, p-v and p-T diagram of pure substance, p-v-T surface, Saturation pressure and Temperature, T-h and T-s diagrams, h-s diagrams or Mollier Charts, Dryness Fraction, steam tables. Property calculations using steam tables. The ideal Gas Equation, Characteristic and Universal Gas constants, Deviations from ideal Gas Model: Equation of state of real substances, Vander Waals Equation of State, Virial Expansion, Compressibility factor, Law of corresponding state, Compressibility charts.

Module 5: Mixtures of ideal Gases – Mole Fraction, Mass fraction, Gravimetric and volumetric Analysis, Dalton's Law of partial pressure, Amagat's Laws of additive volumes, Gibbs-Dalton's law Equivalent Gas constant and Molecular Weight, Properties of gas mixtures: Internal Energy, Enthalpy, specific heats and Entropy, Introduction to real gas mixtures- Kay's rule. General Thermodynamic Relations – Combined First and Second law equations – Helmholtz and Gibb's functions - Maxwell's Relations, Tds Equations. The Clapeyron Equation, equations for internal energy, enthalpy and entropy, specific heats, Throttling process, Joule Thomson Coefficient, inversion curve.

Text Books

1. P. K. Nag, Engineering Thermodynamics, McGraw Hill, 2013

2. E. Rathakrishnan Fundamentals of Engineering Thermodynamics, PHI, 2005

3. Y. A. Cengel and M. A. Boles, Thermodynamics an Engineering Approach, McGraw Hill, 2011

Reference Books:

1. Moran J., Shapiro N. M., Fundamentals of Engineering Thermodynamics, Wiley, 2006

2. R. E. Sonntag and C. Borgnakke, Fundamentals of Thermodynamics, Wiley, 2009

3. Holman J. P. Thermodynamics, McGraw Hill, 2004

4. M. Achuthan, Engineering Thermodynamics, PHI, 2004

COURSE PLAN

Module	Topics	Hours Allotted
1	Role of Thermodynamics and it's applications in Engineering and Science – Basic Concepts Macroscopic and Microscopic viewpoints, Concept of Continuum, Thermodynamic System and Control Volume, Surrounding, Boundaries, Types of Systems, Universe	1L
	Thermodynamic properties, Process, Cycle, Thermodynamic Equilibrium, Quasi – static Process, State, Point and Path function.	1L
	Zeroth Law of Thermodynamics, Measurement of Temperature, reference Points, Temperature Scales.	2L + 1T
2	Energy - Work - Pdv work and other types of work transfer, free expansion work, heat and heat capacity.	2L + 1T
	Joule's Experiment- First law of Thermodynamics - First law applied to Non flow Process- Enthalpy- specific heats- PMM1	2L + 1T
	First law applied to Flow Process, Mass and Energy balance in simple steady flow process. Applications of SFEE	2L + 1T
	Transient flow –Filling and Emptying Process, Limitations of the First Law.	1L + 1T
3	Second Law of Thermodynamics, Thermal Reservoir, Heat Engine, Heat pump – Kelvin-Planck and Clausius Statements, Equivalence of two statements	2L
	Reversibility, Irreversible Process, Causes of Irreversibility, PMM2, Carnot's theorem and its corollaries, Absolute Thermodynamic Temperature scale.	2L + 1T
	Clausius Inequality, Entropy- Entropy changes in various thermodynamic processes, principle of increase of entropy and its applications, Entropy generation, Entropy and Disorder, Reversible adiabatic process- isentropic process, Third law of thermodynamics	2L + 1T
	Available Energy, Availability and Irreversibility- Second law efficiency.	2L + 1T
	Pure Substances, Phase Transformations, Triple point, properties during change of phase, T-v, p-v and p-T diagram of pure substance, p-v-T surface,	2L

4	Saturation pressure and Temperature, T-h and T-s diagrams, h-s diagrams or Mollier Charts, Dryness Fraction, steam tables. Property calculations using steam tables	2L + 1T
	The ideal Gas Equation, Characteristic and Universal Gas constants, Deviations from ideal Gas Model: Equation of state of real substances, Vander Waals Equation of State, Virial Expansion, Compressibility factor, Law of corresponding state, Compressibility charts.	2L +1T
5	Mixtures of ideal Gases – Mole Fraction, Mass fraction, Gravimetric and volumetric Analysis, Dalton's Law of partial pressure, Amagat's Laws of additive volumes, Gibbs-Dalton's law.	2L
	Equivalent Gas constant and Molecular Weight, Properties of gas mixtures: Internal Energy, Enthalpy, specific heats and Entropy	1L +1T
	Introduction to real gas mixtures- Kay's rule	1L
	General Thermodynamic Relations – Combined First and Second law equations – Helmholtz and Gibb's functions - Maxwell's Relations	2L
	Tds Equations. The Clapeyron Equation, equations for internal energy, enthalpy and entropy, specific heats, Throttling process, Joule Thomson Coefficient, inversion curve.	2L + 1T

MODEL QUESTION PAPER

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FOURTH SEMESTER B.TECH DEGREE EXAMINATION

Course Code : MET202

Course Name : ENGINEERING THERMODYNAMICS

(Permitted to use Steam Tables and Mollier Chart)

Max. Marks : 100 Duration : 3 Hours

Part – A

Answer all questions.

1. Define thermodynamics. List a few of its applications

2.Differentiate between intensive and extensive properties.

3. Differentiate between heat and work.

4. Explain system approach and control volume approach as applied in the analysis of a flow process.

5. An inventor claims to have developed an engine that delivers 26 kJ of work using 82 kJ of heat while operating between temperatures 120°C and 30°C. Is his claim valid ? Give the reason for your answer.

6. Show that two reversible adiabatics cannot intersect

7.Define (i)critical point and (ii) triple point, with respect to water

8. Why do real gases deviate from ideal gas behaviour? When do they approach ideal behaviour?

9. Define Helmholtz function and Gibbs function and state their significance

10. Explain Kay's rule of real gas mixtures

(3 x 10 = 30 marks)

Part – B

Answer one full question from each module.

Module - 1

11.a] Explain macroscopic and microscopic approach to thermodynamics . (7 marks) b] With the aid of a suitable diagram, explain the working of constant volume gas thermometer. (7 marks)

OR

12.a] What is meant by thermodynamic equilibrium ? What are the essential conditions for a system to be in thermodynamic equilibrium ? (7 marks)

b] Express the temperature of 91^{o}C in (i) Farenhiet (ii) Kelvin (iii) Rankine. (7 marks)

Module – 2

13.a] A mass of 2.4 kg of air at 150 kPa and 12°C is contained in a gas – tight, frictionless piston – cylinder device. The air is now compressed to a final pressure of 600 kPa . During this process, heat is transferred from the air such that the temperature inside the cylinder remains constant. Calculate the work input during this process. (7 marks)

b] A 2 m^3 rigid tank initially contains air at 100 kPa and 22^{o}C. The tank is connected to a supply line through a valve. Air is flowing in the supply line at 600 kPa and 22^{o}C. The valve is opened, and air is allowed to enter the tank until the pressure in the tank reaches the line pressure, at which point the valve is closed. A thermometer placed in the tank indicates that the air temperature at the final state is 77^{o}C. Determine, (i) the mass of air that has entered the tank and (ii) the amount of heat transfer. (7 marks)

OR

14.a] A turbine operates under steady flow conditions, receiving steam at the following conditions : pressure 1.2 MPa, temperature 188°C, enthalpy 2785 kJ/kg, velocity 33.3 m/s and elevation 3m. The steam leaves the turbine at the following conditions : pressure 20 kPa, enthalpy 25kJ/kg, velocity 100 m/s, and elevation 0 m. Heat is lost to the surroundings at the rate of 0.29 kJ/s. If the rate of steam flow through the turbine is 0.42 kg/s, what is the power output of the turbine in kW ? (7 marks)

b] State the general energy balance equation for an unsteady flow system and from it, derive the energy balance equation for a bottle filling process, stating all assumptions. (7 marks)

Module – 3

15.a]State the Kelvin-Planck and Clausisus statements of the second law of thermodynamics and prove their equivalence. (7 marks)

b]A heat engine operating between two reservoirs at 1000 K and 300 K is used to drive a heat pump which extracts heat from the reservoir at 300 K at a rate twice that at which the engine rejects heat to it. If the efficiency of the engine is 40 % of the maximum possible and the COP of the heat pump is 50 % of the maximum possible, what is the temperature of the reservoir to which the heat pump rejects heat ? What is the rate of heat rejection from the heat pump, if the rate of heat supply to the engine is 50kW ? (7 marks)

OR

16.a] A house is to be maintained at 21°C during winter and at 26°C during summer. Heat leakage through the walls, windows and roof is about 3000 kJ/hr per degree temperature difference between the interior of the house and the environment. A reversible heat pump is proposed for realising the desired heating and cooling. What is the minimum power required to run the heat pump in the reverse, if the outside temperature during summer is 36°C? Also find the lowest environment temperature during winter for which the inside of the house can be maintained at 21°C consuming the same power. (7 marks)

b] Air enters a compressor in steady flow at 140 kPa, 17°C and 70 m/s and leaves at 350 kPa, 127°C and 110 m/s. The environment is at 100 kPa and 7°C. Calculate per kg of air (a) the actual work required (b) the minimum work required and (c) the irreversibility of the process. (7 marks)

Module – 4

17.a]Show the constant pressure transformation of unit mass of ice at atmospheric pressure and -20°C to superheated steam at 220°C on P-v , T-v and P-T coordinate systems and explain their salient features . (7 marks)

b] A rigid vessel of volume 0.3 m^3 contains 10 kg of oxygen at 300 K. Using (i) the perfect gas equation and (ii) the Van der Waal's equation of state, determine the pressure of oxygen in the vessel. Take the Van der Waal's constants for oxygen as a =0.1382 m^6 Pa/ mol^2 and b=0.03186 m^3/ kmol . (7 marks)

OR

18.a]Steam at 25 bar and 300°C expands isentropically to 5 bar. Calculate the change in enthalpy, volume and temperature of unit mass of steam during this process using steam tables and Mollier chart and compare the values (7 marks)

b]Explain law of corresponding states and its significance to the generalized compressibility chart. (7 marks)

Module – 5

19.a] Derive the expressions for the equivalent molecular weight and characteristic gas constant for a mixture of ideal gases. (6 marks)

b] 0.5 kg of Helium and 0.5 kg of Nitrogen are mixed at 20°C and at a total pressure of 100 kPa. Find (i) volume of the mixture (ii) partial volumes of the components (iii) partial pressures of the components (iv) the specific heats of the mixture and (v) the gas constant of the mixture. Take ratio of specific heats for Helium and Nitrogen to be 1.667 and 1.4 respectively. (8 marks)

OR

20.a] 2 kg of carbon dioxide at 38°C and 1.4 bar is mixed with 5 kg of nitrogen at 150°C and 1.03 bar to form a mixture at a final pressure of 70 kPa. The process occurs adiabatically in a steady flow apparatus. Calculate the final temperature of the mixture and the change in entropy during the mixing process. Take specific heat at constant pressure for CO_2 and N_2 as 0.85 kJ/kg.K and 1.04 kJ/kg respectively. (7 marks)

b]Derive the Maxwell relations. Explain their significance ? (7 marks)

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MUT204	AUTO POWERPLANT	PCC	3	1	0	4

Preamble: This course aims at providing

- ✓ **an in-sight in the area of AN IC Engine, its different components and arrangements**
- ✓ **a deeper knowledge in the area of combustion.**
- ✓ **Testing of performance of an IC Engine and conformity to the requirements**

Prerequisite: NIL

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

CO 1	Understand various types of IC engines and components of the engine and its functions.
CO 2	Understand the Engine cooling and lubrication systems
CO 3	Gain knowledge on the fuel system components and their working in an SI Engine
CO 4	Gain knowledge on the fuel system components and their working in a CI Engine
CO 5	Evaluate and test the performance of an IC engine based on different parameters

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

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**		**End Semester Examination**
	1	**2**	
Remember	10	10	10
Understand	10	10	20
Apply	20	20	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. Are you able to classify and identify the different components of an IC engine?

Course Outcome 2 (CO2)
1. Are you able to understand the working of cooling and lubrication systems in an IC engine?

Course Outcome 3(CO3):
1. Are you able to identify the different components and working of a modern SI Engine?

Course Outcome 4 (CO4):
1. Are you able to identify the different components and working of a modern CI Engine?

Course Outcome 5 (CO5):
1. Are you able to test and trouble shoot an engine to meet the requirements?

Model Question paper

QP CODE:
PAGES:…

Reg. No: _______________ **Name :_______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FOURTH SEMESTER B.TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: MUT 204

Course Name: AUTO POWERPLANT

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

Part A
(Answer all questions. Each question carry 5 marks)

1. List down the different types of power plant used in automobiles

2. What are the different types of cam operating mechanisms .
3. Explain the functions of cooling system in an automobile.
4. With a neat diagram, explain the components of lubrication system
5. Why do we require a fuel supply system in an automobile? Explain the functions of a fuel supply system.
6. Explain the constructional details of Flex Fuel Vehicles.
7. What are the requirements of diesel injection system?
8. Explain the components and working CRDI system.
9. Explain in detail the procedure for measuring the of brake power.
10. What are the components of a heat balance sheet?

Part B

Answer any one full question from each module.

Each question carries 10 Marks

11. (a) Differentiate between otto cycle & diesel cycle (5)
    (b) Explain octane and cetane number (5)

OR

12. (a) Explain different types of cylinder head suitable sketches (5)
    (b)With neat diagram explain difference Types of valve and valve seats (5)
13. Explain dry sump and mist lubrication systems in detail (10)

OR

14. With neat diagram explain the components of components of water cooling system (10)
15. (a) With the aid of a diagram, explain the different circuits in carburetor. (5)
    (b) Explain the construction and working of GDI engines? (5)

OR

16. Explain with suitable sketch, the components of fuel feed systems. (10)

17. (a)Explain the components of diesel injection system . (5) (b)Discuss Quadra Jet and Multijet principles ? (5)

OR

18. Explain C-AV Bosch pump. Explain its working with neat figure 10)
19. Explain the different performance curves also highlight the effect of various parameters on the performance of the engines. (10)

OR

20. Discuss in detail the procedure of OBD tool for trouble shooting in automobiles (10)

Syllabus

Module	Contents	Hours	Sem.Exam Marks
I	Introduction: Types of power plant, Basic engine nomenclature, classification of IC engines (Classification by cylinder arrangement, Valve arrangement and Type of valves), Engine cycles-Otto cycle & Diesel cycle, Comparison of SI and CI engines, working of 2 -stroke and 4 stroke engines with relative merits and demerits, Numbering of cylinders, firing order. SI and CI engine fuel requirement, Octane and Cetane number, Air-fuel ratio, stages of combustion in SI engines and CI engines, abnormal combustion- detonation and diesel knock. ***Constructional details of engine components:*** Moving parts and stationary parts, Cylinder block and crank case-types, cylinder liners, types of cylinder head, piston & piston rings, piston pins, connecting rod, crank shaft, flywheel-dual mass flywheel, Main Bearings, camshaft, camshaft drives-DOHC, Types of valve and valve seats, hydraulic tappets, valve actuating mechanisms (mechanisms with side camshaft and overhead camshaft), inlet and exhaust manifold construction, Components of intake and exhaust systems in modern engines	9	20%
II	Lubrication system: lubrication principles, classification of lubricants, properties of lubricants, service ratings of oils, oil additives, specification of lubricants, crankcase ventilation, wet sump, dry sump and mist lubrication systems, pre-lubrication systems, effect of engine conditions on lubricating oil, consumption of lubricating oil, Components of lubrication system (oil strainers, oil filters, oil pumps, oil coolers), chassis lubrication. Cooling system: Necessity of engine cooling and correct operating temperatures, types of cooling systems like Direct air cooling, Indirect or water cooling, Liquid cooling, Pressure sealed cooling, Evaporative cooling or steam cooling, oil coolers, components of water cooling system (thermostat, water pump, radiator, cooling fan etc), coolants and antifreeze solution, temperature gauges.	9	20%
III	Fuel supply system in petrol engines: Types of fuel feed systems, fuel tank, fuel pumps and fuel filters (types and construction), air filter types and construction, combustion and ignition limits in SI engines, carburetion, properties of air-petrol mixtures, mixture requirements for steady state operation, transient mixture requirements, simple carburetor, different circuits in carburetor, type of carburetors like Solex, SU, Carter	9	20%

	etc, Electronically controlled engines- sensors & actuators, injectors, ECU, MPFI engines, GDI engines, TSI, Flex Fuel Vehicles, EGR, SCR & other emission control in SI engines.		
IV	Fuel supply system in diesel engines: Requirements of diesel injection system, combustion chambers, swirl types, Components of diesel injection system, Diesel filters, fuel feed pump, hand pump, heavy duty air filters, Diesel injection pump types - simple and multiple unit pump, C-AV Bosch pump, Modem distributor type pumps, injection nozzles, governors (mechanical, pneumatic and hydraulic governors), cold starting devices., Electronically controlled engines-CRDI, and types of injectors, multiple injection, UPCR, Quadra Jet and Multijet principles, DPF, DOC & other emission control in CI engines.	9	20%
V	Performance test- Engine Dynamometers, chassis dynamometer, Standard testing procedure of IC engines – Performance curves, effect of various parameters on the performance of the engines, Measurement of brake power, Indicated power, Fuel consumption, Air consumption, Heat balance test – heat carried away by exhaust gases, Morse test on IC engines, CAFE standard, star labelling, Drive cycles-MIDC, emission standards. Use of OBD tool for trouble shooting, DLC, MIL, DTC, engine scan tools-types. Brake testing and fuel economy test of vehicles.	9	20%

Text Books

1. 1 Ganesan V, “Internal combustion engines”, 4th edition, Tata McGraw Hill Education, 2012.
2. 2 Rajput R. K, “A textbook of Internal Combustion Engines”, 2nd edition, Laxmi Publications (P) Ltd, 2007.
3. Mathur and Sharma, “A course on Internal combustion Engines”, Dhanpat Rai & Sons, 1985.

Reference Books

1. John. B, Heywood, “Internal Combustion Engine Fundamentals”, McGraw Hill Publishing Co., New York,1900 .
2. Ramalingam K. K, “Internal Combustion Engines”, Second Edition, Scitech Publications,2009
3. Edward F, Obert, “Internal Combustion Engines and Air Pollution”, Intext Education Publishers, 1980.

Course Contents and Lecture Schedule

N0	Topics	No of lectures
I	Introduction: Types of power plant, Basic engine nomenclature, classification of IC engines (Classification by cylinder arrangement, Valve arrangement and Type of valves), Engine cycles-Otto cycle & Diesel cycle, Comparison of SI and CI	1
1.1	engines, working of 2 -stroke and 4 stroke engines with relative merits and demerits, Numbering of cylinders, firing order. SI and CI engine fuel requirement, Octane and Cetane number, Air-fuel ratio, stages of combustion in SI engines and CI engines, abnormal combustion- detonation and diesel knock.	2
1.2	***Constructional details of engine components:*** Moving parts and stationary parts, Cylinder block and crank case-types, cylinder liners, types of cylinder head, piston & piston rings, piston pins, connecting rod, crank shaft, flywheel-dual mass flywheel, Main Bearings, camshaft, camshaft drives-DOHC,	3
1.3	Types of valve and valve seats, hydraulic tappets, valve actuating mechanisms (mechanisms with side camshaft and overhead camshaft), inlet and exhaust manifold construction, Components of intake and exhaust systems in modern engines	3
2	Lubrication system: lubrication principles, classification of lubricants, properties of lubricants, service ratings of oils, oil additives, specification of lubricants, crankcase ventilation, wet sump, dry sump and mist lubrication systems, pre-lubrication systems, effect of engine conditions on lubricating oil,	3
2.1	consumption of lubricating oil, Components of lubrication system (oil strainers, oil filters, oil pumps, oil coolers), chassis lubrication. Cooling system: Necessity of engine cooling and correct	3
2.3	operating temperatures, types of cooling systems like Direct air cooling, Indirect or water cooling, Liquid cooling, Pressure sealed cooling, Evaporative cooling or steam cooling, oil coolers, components of water cooling system (thermostat, water pump, radiator, cooling fan etc), coolants and antifreeze solution, temperature gauges.	3

3	Fuel supply system in petrol engines: Types of fuel feed systems, fuel tank, fuel pumps and fuel filters (types and construction), air filter types and construction, combustion and ignition limits in SI engines, carburetion, properties of air-petrol mixtures, mixture requirements for steady state operation,	6
3.1	transient mixture requirements, simple carburetor, different circuits in carburetor, type of carburetors like Solex, SU, Carter etc, Electronically controlled engines- sensors & actuators, injectors, ECU, MPFI engines, GDI engines, TSI, Flex Fuel Vehicles, EGR, SCR & other emission control in SI engines.	3
4	Fuel supply system in diesel engines: Requirements of diesel injection system, combustion chambers, swirl types, Components of diesel injection system, Diesel filters, fuel feed pump, hand pump, heavy duty air filters, Diesel injection pump types - simple and multiple unit pump, C-AV Bosch pump,	6
4.1	Modem distributor type pumps, injection nozzles, governors (mechanical, pneumatic and hydraulic governors), cold starting devices., Electronically controlled engines-CRDI, and types of injectors, multiple injection, UPCR, Quadra Jet and Multijet principles, DPF, DOC & other emission control in CI engines.	3
5	Performance test- Engine Dynamometers, chassis dynamometer, Standard testing procedure of IC engines – Performance curves, effect of various parameters on the performance of the engines, Measurement of brake power, Indicated power, Fuel consumption, Air consumption, Heat balance test – heat carried away by exhaust gases, Morse test on	5
5.1	IC engines, CAFE standard, star labelling, Drive cycles-MIDC, emission standards. Use of OBD tool for trouble shooting, DLC, MIL, DTC, engine scan tools-types. Brake testing and fuel economy test of vehicles.	4

CODE MUT206	COURSE NAME MECHANICS OF SOLIDS	CATEGORY	L	T	P	CREDIT
		PCC	3	1	0	4

Preamble:

This course helps the students to understand the concept of stress and strain in different types of structure/machine under various loading conditions. The course also covers simple and compound stresses due to forces, stresses and deflection in beams due to bending, torsion in circular section, strain energy, different theories of failure, stress in thin cylinder thick cylinder and spheres due to external and internal pressure.

Prerequisite: EST100 ENGINEERING MECHANICS

Course Outcomes:

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

CO 1	Analyse the stresses, strains and deformations of structures under 2- and 3-dimensional loading by tensorial and graphical (Mohr's circle) approaches
CO 2	Analyse the strength of materials using stress-strain relationships for structural and thermal loading
CO 3	Use Shear Force and Bending Moment diagrams to estimate the deflection of beams, and strain energy methods to determine the deformation of structures subjected to various loading conditions
CO 4	Apply the theory of pure bending to study the structural behaviour of beams and perform basic design of shafts subjected to torsional loading
CO 5	Estimate the strength of thin cylinders, spherical vessels and columns, and appreciate the theories of failures and its relevance in mechanical design

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

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember			
Understand	10	10	20
Apply	20	20	30
Analyse	20	20	50
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 a maximum of 2 subdivisions and carry 14 marks.

COURSE LEVEL ASSESSMENT QUESTIONS

Course Outcome 1 (CO1):

1. Determine the resultant traction at a point in a plane using the stress tensor.

2. Evaluate the principal stresses, principal strains and their directions from a given state of stress or strain.

3. Write the stress tensor and strain tensor.

Course Outcome 2 (CO2)

1. Write the generalized Hooke's law for stress-strain relations.

2. Estimate the state of strain from a given state of stress.

3. Analyse the strength of a structure subjected to thermal loading.

Course Outcome 3(CO3):

1. Draw the shear force and bending moment diagrams.

2. Apply strain energy method to estimate the deformation of a structure.

3. Use strain energy method to estimate the loads acting on a structure for a maximum deflection.

Course Outcome 4 (CO4):

1. Determine the bending stress on a beam subjected to pure bending.

2. Design a shaft to transmit power and torque.

3. Analyse the stress and deflection of a structure subjected to bending and twisting.

Course Outcome 5 (CO5):

1. Estimate the stresses on a thin cylinder or spherical vessel.

2. Analyse a column for buckling load.

3. A bolt is subjected to a direct tensile load of 20 kN and a shear load of 15 kN. Suggest suitable size of this bolt according to various theories of elastic failure, if the yield stress in simple tension is 360 MPa. A factor of safety 2 should be used. Assume poisson's ratio as 0.3.

SYLLABUS

Module 1: Analysis of deformable bodies: stress, stress at a point using Cartesian stress tensor, Cauchy's equation for stress on a given plane, normal stress & shear stress; Strain, deformation and displacement (in Cartesian coordinates), strain components, 2D plane stress and plane strain problems, principal stresses (2D & 3D), stress invariants, Mohr's circle representation for stress in 2D and problems, representation 3D stress in Mohr's circle using principal stresses as input.

Module 2: Stress-strain relations for isotropic materials (3D, 2D plane stress, 2D plain strain), Elastic constants (μ, λ, E, G, ν and K), Relation between elastic constants; Calculation of stress and strain in axially loaded members (single and composite materials). Concept of thermal strain and stress, Simple problems on thermal stress in axially loaded members.

Module 3: Bending moment and shear force. Shear force and bending moment diagrams for cantilever, and simply supported beams. Strain energy, Equations for strain energy due to axial load, transverse shear, bending moment and torque. Expressions in terms of load & deflection. Expressions in terms of elastic constants and dimensions of the body. Simple problems to solve elastic deformations. Second theorem of Castigliano and simple problems to solve deflection of beams.

Module 4: Theory of pure bending and bending stresses, Derivation of bending equation (Flexural formula), Section modulus, Flexural rigidity, problems to calculate bending stress, solving the deflection of beams using Macaulay's method, Torsion of circular shafts, Derivation of torsion equation, simple problems. Simple problems on combined torsion and bending.

Module 5: Thin cylinders and spherical vessels. Introduction to buckling of columns, Euler's theory and Rankine's formula for columns. Theories of failure: Rankine theory, Guest's theory, Saint-Venant's theory, Hencky-von Mises theory and Haigh's theory

Text Books

1. Mechanics of materials in S.I.units, R .C. Hibbeler, Pearson Higher Education 2018

2. Advanced Mechanics of Solids, L. S. Srinath, TMH

3. Design of Machine Elements, V. B Bhandari

Reference Books

1. Strength of Materials, Surendra Singh, S. K. Kataria& Sons

2. Engineering Mechanics of Solids, Popov E., PHI 2002

3. Mechanics of Materials S. I. units, Beer, Johnston, Dewolf, McGraw Hills 2017

4. Strength of Materials, Rattan, McGraw Hills 2011

COURSE PLAN

No	Topic	No. of Lectures
1	**Module 1: Stress and Strain Analysis**	**9 hrs**
1.1	Describe the deformation behaviour of elastic solids in equilibrium under the action of a system of forces. Describe method of sections to illustrate stress as resisting force per unit area. Stress vectors on Cartesian coordinate planes passing through a point and writing stress at a point in the form of a matrix.	1 hr
1.2	Direction cosines of a plane. Equality of cross shear (Derivation not required). Write Cauchy's equation (Derivation not required) for stress on a plane as the product of stress tensor and direction cosine vector. Normal and tangential (shear) components of stress on a plane.	1 hr
1.3	Deformation, displacement, gradient of deformation and strains in elastic solids. Cartesian components of strain and Cauchy's strain-displacement relationships (small-strain only). Strain tensor in 2D and 3D. Write the stress tensor and strain tensor for Plane stress and Plane Strain analysis.	1 hr
1.4	Stress on an oblique plane under axial loading, Discuss principal planes, characteristic equation to find principal stresses for 2D and 3D state of stress, stress invariants. Evaluate principal stresses in 2D and 3D using characteristic equations.	2 hrs
1.5	Discuss the order of principal stress and maximum shear stress. Compare the principal stresses in 2D and 3D state of stress. Represent the state of stress using principal stress tensor. Determine the direction of principal stresses as eigenvectors of the principal stress tensor.	2 hrs
1.6	Represent the 2D and 3D state of stress using principal stress graphically (Mohr's circle). Determine the maximum shear stress by Mohr's circle method and compare with the theoretical relations.	2 hrs
2	**Module 2: Stress - Strain Relationships**	**8 hrs**
2.1	Stress-strain diagram, normal strain under axial loading, deformations of members under axial loading, Stress and strain distribution under axial loading (Saint Venant's principle of end loads). Stress–Strain Behavior of Ductile and Brittle Materials.	2 hr
2.2	Constitutive equations-generalized Hooke's law, equations for linear elastic isotropic solids in 3D and 2D. Hooke's law for Plane stress and plane strain conditions in terms of Young's Modulus and Poisson's ratio. Numerical problems.	2 hrs
2.3	Lame's constants (λ and μ), other elastic constants (E, G, v and K) and the relation between them. Generalized Hooke's law in terms of Lame's constants. Calculation of stress and strain in axially loaded members with single and composite materials	2 hrs

2.4	Effects of thermal loading – thermal stress and thermal strain. Thermal stress on a prismatic bar held between fixed supports. Numerical problems.	2 hrs
3	**Shear Force-Bending Moment Diagrams and Strain Energy Principles**	**9 hrs**
3.1	Shear force and bending moment diagrams for cantilever and simply supported beams with UDL, point load and varying load	2 hrs
3.2	Load-deflection diagram, concept of strain energy, strain energy density, modulus of resilience	1 hr
3.3	Linear elastic loading, elastic strain energy and Complementary strain energy. Elastic strain energy for axial loading, transverse shear, bending and torsional loads (short derivations in terms of loads and deflections).	1 hr
3.4	Strain energy due to impact loading, simple numerical problems	1 hr
3.5	Expressions for strain energy in terms of load, geometry and material properties of the body for axial, shearing, bending and torsional loads. Simple problems to solve elastic deformations	2 hrs
3.6	Castigliano's second theorem to find displacements, reciprocal relation, proof for Castigliano's second theorem.	1 hr
3.7	Simple problems to find the deflections of beams due to various loads	1 hr
4	**Pure Bending and Torsion of shafts**	**9 hrs**
4.1	Fundamentals of beam bending including sign conventions, pure bending, curvature of a beam, normal stresses in beams, moment-curvature formula	2 hrs
4.2	Derivation of flexural formula, section modulus, flexural rigidity, numerical problems to evaluate bending stress	2 hrs
4.3	Deflection of beams using Macauley's method (procedure and problems with multiple loads)	2 hrs
4.4	Torsional deformation of circular shafts, assumptions for shafts subjected to torsion within elastic deformation range, derivation of torsion formula	1 hr
4.5	Torsional rigidity, Polar moment of inertia, basic design of transmission shafts. Simple problems to estimate the stress in a solid and hollow shafts	1 hr
4.6	Numerical problems for basic design of circular shafts subjected to externally applied torques	1 hr
5	**Combined loadings and Theories of Failure**	**8 hrs**
5.1	Circumferential and Longitudinal stress in a thin cylindrical vessel, stresses in a thin spherical vessel (short derivations) and numerical problems	2 hrs
5.2	Fundamentals of bucking and stability, critical load, equilibrium diagram for buckling of an idealized structure	1 hr
5.3	Buckling of columns with pinned ends, Euler's buckling theory for long columns	2 hrs

5.4	Critical stress, slenderness ratio, Rankine's formula for short columns	1 hr
5.5	Introduction to Theories of Failure. Rankine's theory for maximum normal stress, Guest's theory for maximum shear stress, Saint-Venant's theory for maximum normal strain	1 hr
5.6	Hencky-von Mises theory for maximum distortion energy, Haigh's theory for maximum strain energy	1 hr

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
KTU
Estd.
2014

MODEL QUESTION PAPER

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FOURTH SEMESTER B.TECH DEGREE EXAMINATION

Course Code : MUT206

Course Name : MECHANICS OF SOLIDS

Max. Marks : 100 Duration : 3 Hours

PART – A

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

1. Express the stress invariants in terms of Cartesian components of stress and principal stress.
2. Write down the Cauchy's strain displacement relationships in 3D polar form.
3. Distinguish between the states of plane stress and plane strain.
4. Represent the generalized Hooke's law for an isotropic material in terms of Lame's constants.
5. Discuss reciprocal relation for multiple loads on a structure.
6. Express the strain energy for a cantilever beam subjected to a transverse point load at free end.
7. List any three important assumptions in the theory of torsion.
8. Write the significance of flexural rigidity and section modulus in the analysis of beams.
9. Compare the strength of a thin spherical vessel and a thin cylindrical vessel on the basis of hoop stress.
10. Discuss Saint-Venant's theory of failure.

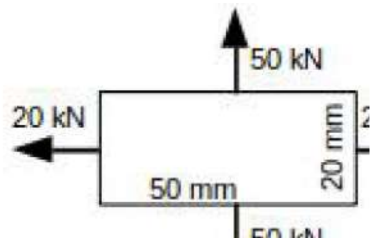
PART – B

(*ANSWER ONE FULL QUESTION FROM EACH MODULE*)

MODULE – 1

11. a) The state of stress at a point is given by σ_{xx} = 12.31 MPa, σ_{yy} = 8.96 MPa, σ_{zz} = 4.34 MPa, τ_{xy} = 4.2 MPa, τ_{yz} = 5.27 MPa, τ_{xz} = 0.84 MPa. Determine the principal stresses. (7 marks)

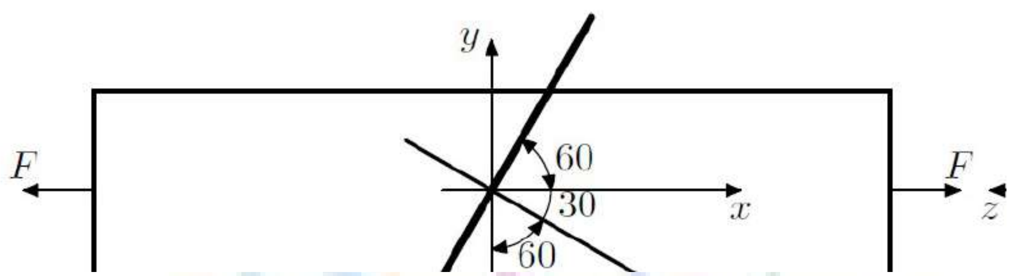
    b) An aluminum alloy plate of size 50 mm × 20 mm with thickness 5 mm is loaded as shown. Find the change in thickness? What must be the load to be applied to have the same change in thickness if load is applied only along thickness direction? Take Young's Modulus as 60 GPa and Poisson's ratio as 0.3. (7 marks)



OR

12. a) The displacement field for a body is given by **u**= $(x^2 + y)\boldsymbol{i} + (3 + z)\,\boldsymbol{j} + (x^2 + 2y)\boldsymbol{k}$. What is the deformed position of a point originally at (3,1,–2)? Write the strain tensor at the point (−3,−1,2).
(7 marks)

b) An axially loaded square bar of cross sectional area 10 mm^2 is subjected to an average force of F = 10 N as shown in figure. Write down the stress tensor. For a plane parallel to z axis and inclined at 60 degree with the x-axis, determine for any point on the plane, the resisting traction normal stress and shear stress. (7 marks)



MODULE – 2

13. a) A 2.5m long steel pipe of 300 mm outer diameter and 15 mm wall thickness is used as a column to carry a 700 kN axial centric load. Take E = 200 GPa and ν = 0.3, determine the change in length of the pipe, change in outer diameter, and the change in wall thickness.
(7 marks)

b) A copper strip 20 × 2.5 mm^2 in section is held between two strips of steel of the same size. Find the stresses in steel and copper due to temperature rise of 6°C. Take $\alpha_s = 1.2 \times 10^{-5}$ / °C, $\alpha_c = 1.85 \times 10^{-5}$ / °C, $E_s = 2 \times 10^5$ N/mm^2 and $E_c = 1.2 \times 10^5$ N/mm^2.
(7 marks)

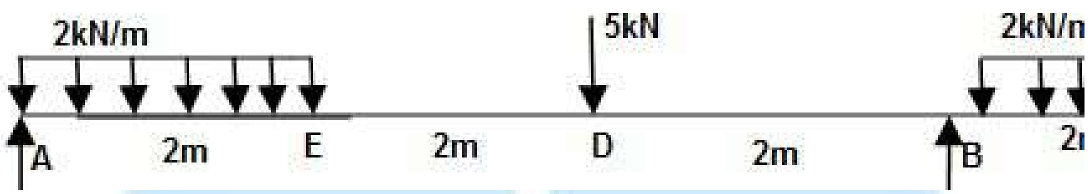
OR

14. a) A brass bar 20mm diameter is enclosed in a steel tube of 25mm internal diameter and 50mm external diameter. Both bar and tube is of same length and fastened rigidly at their ends. The composite bar is free of stress at 20°C. To what temperature the assembly must be heated to generate a compressive stress of 48MPa in brass bar? Also determine the stress in steel tube. E_{steel} = 200GPa and E_{brass} = 84GPa, $\alpha_{steel} = 12 \times 10^{-6}$ / °C and $\alpha_{brass} = 18 \times 10^{-6}$ / °C.
(9 marks)

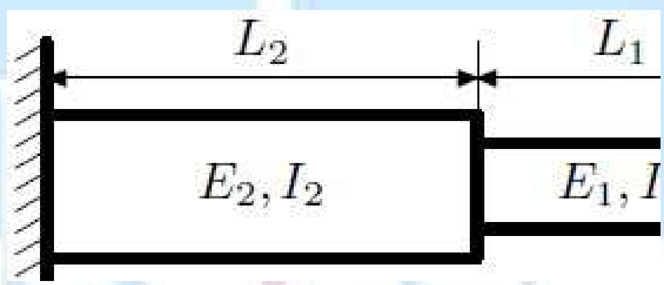
b) Draw the stress-strain diagram for a ductile material and explain the salient points. (5 marks)

MODULE – 3

15. a) Draw shear force and bending moment diagram for the beam given in the figure and mark all the salient points. 9 marks)



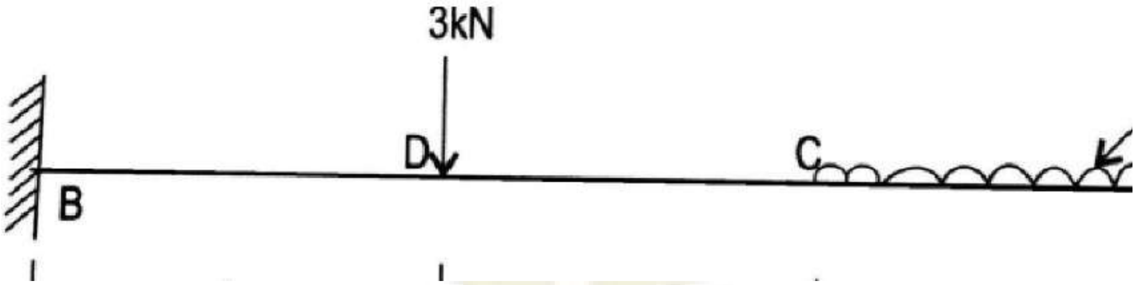
b) Determine the deflection at the free end of the stepped beam using strain energy method.



(5 marks)

OR

16. a) Draw the SFD and BMD of a cantilever beam loaded as shown in figure. (5 marks)



b) The displacement field of a body is $\vec{u} = [(x^2 + y)\,\hat{i} + (3 + z)\,\hat{j} + (x^2 + 2y)$. Use the small strain theory to compute the strain energy per unit volume at the point (2,3,1). Given that G = 80×10^6 kPa and E = 207×10^6 kPa.
(9 marks)

MODULE – 4

17. a) A horizontal girder of steel having uniform section is 14 m long and is simply supported at its ends. It carries concentrated loads of 120 kN and 80 kN at two points 3 m and 4.5 m from the two ends respectively. Moment of inertia for the section of the girder is 16×10^8 mm^4 and E_s = 210 kN/mm^2. Calculate the deflection of the girder at points under the two loads and maximum deflection using Macaulay's method. (10 marks)

b) Compare the strength of a hollow shaft of diameter ratio 0.75 to that of a solid shaft by considering the permissible shear stress. Both the shafts are of same material, of same length and weight. (4 marks)

OR

18. a) A solid aluminium shaft 1 m long and 50 mm diameter is to be replaced by a tubular steel shaft of the same length and the same outside diameter such that each of the two shafts could have the same angle of twist per unit torsional moment over the total length. What must the inner diameter of the tubular steel shaft be? Modulus of rigidity of the steel is three times that of aluminium.
(9 marks)

b) Derive the equation for the theory of pure bending. (5 marks)

MODULE – 5

19. a) Find the crippling load for a hollow steel column 50mm internal diameter and 5mm thick. The column is 5m long with one end fixed and other end hinged. Use Rankine's formula and Rankine's constant as 1/7500 and σ_c = 335 N/mm^2.
(8 marks)

b) Explain the maximum normal stress theory, maximum strain energy theory and maximum shear stress theory of failure.
(6 marks)

OR

20. a) A cylindrical shell 3m long closed at the ends has an internal diameter of 1m and wall thickness 15mm. Calculate the circumferential and longitudinal stresses induced and also the change in dimensions of the shell, if it is subjected to an internal pressure of 1.5MPa. Take E = 2×10^5 N/mm^2 and ν = 0.3.
(9 marks)

b) Derive Euler's formula for a column with one end is hinged and the other end fixed. (5 marks)

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Estd. 2014

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MUL202	MATERIALS TESTING LAB	PCC	0	0	3	2

Preamble:

The objective of this course is to give a broad understanding of common materials related to mechanical engineering with an emphasis on the fundamentals of structure-property-application and its relationships. A group of 6/7 students can conduct experiment effectively. A total of six experiments for the duration of 2 hours each is proposed for this course.

Prerequisite: A course on Engineering Mechanics is required

Course Outcomes:

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

CO 1	To understand the basic concepts of analysis of circular shafts subjected to torsion.
CO 2	To understand the behaviour of engineering component subjected to cyclic loading and failure concepts
CO 3	Evaluate the strength of ductile and brittle materials subjected to compressive, Tensile shear and bending forces
CO 4	Evaluate the microstructural morphology of ductile or brittle materials and its fracture modes (ductile /brittle fracture) during tension test
CO 5	To specify suitable material for applications in the field of design and manufacturing.

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		3				3	2	2	1
CO 3	3	3	3	1	3				3	2	3	2
CO 4	3	3	3	3	3	2	2	1	3	2	3	2
CO 5	3	3	3	1	3	2	2	1	3	2	3	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 troubleshooting)	: 25 Marks
(d) Viva voce	: 20 marks
(e) Record	: 5 Marks

General instructions:

Practical examination to be conducted immediately after the second series test covering 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.

SYLLABUS

LIST OF EXPERIMENTS

1. To conduct tension test on ductile material (mild steel/ tor-steel/ high strength steel) using Universal tension testing machine and Extensometer.
2. To conduct compression test on ductile material (mild steel/ tor-steel/ high strength steel) using Universal tension testing machine and Extensometer.
3. To conduct tension test on Brittle material (cast iron) using Universal tension testing machine and Extensometer.
4. To conduct shear test on mild steel rod.
5. To conduct microstructure features of mild steel/copper/ brass/aluminium using optical microscope, double disc polishing machine, emery papers and etchent.
6. To conduct fractography study of ductile or brittle material using optical microscope.
7. To conduct Hardness test of a given material. (Brinell, Vickers and Rockwell)

8. To determine torsional rigidity of mild steel/copper/brass rod.
9. To determine flexural rigidity of mild steel/ copper/brass material using universal testing machine.
10. To determine fracture toughness of the given material using Universal tension testing machine.
11. To study the procedure for plotting S-N curve using Fatigue testing machine.
12. To conduct a Toughness test of the given material using Izod and Charpy Machine.
13. To determine spring stiffness of close coiled/open coiled/series/parallel arrangements.
14. To conduct bending test on wooden beam.
15. To conduct stress measurements using Photo elastic methods.
16. To conduct strain measurements using strain gauges.
17. To determine moment of inertia of rotating bodies.
18. To conduct an experiment to Verify Clerk Maxwell's law of reciprocal deflection and determine young's Modulus of steel.
19. To determine the surface roughness of a polished specimen using surface profilometer.

Note: 12 experiments are mandatory

Reference Books

1. G E Dieter. Mechanical Metallurgy, McGraw Hill,2013

2. Dally J W, Railey W P, Experimental Stress analysis , McGarw Hill,1991

3. Baldev Raj, Jayakumar T, Thavasimuthu M., Practical Non destructive testing, Narosa Book

Distributors,2015

MUL204	VEHICLE SYSTEMS LAB	CATEGORY	L	T	P	CREDIT
		PCC	0	0	3	2

Preamble: The aim of this course is to make the students gain practical knowledge about various systems in automobile and after this course the student will be able to handle any maintenance issue in a vehicle and also identify the troubles of the vehicles from the symptoms shown.

Prerequisite: NIL

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

CO 1	**To study about hand tools, special purpose tools, and their uses in automobile maintenance workshop**
CO 2	**Rectifying and trouble shooting in various system in automobiles** **Disassembling and inspection of various components of automobiles**
CO 3	**Utilize one's ability as an individual or in a team for the effective communication, practical skill and document design.**

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	-	-	2	-	-	2	2	-	-
CO 2	3	2	2	2	1	2	-	-	2	2	-	-
CO 3	3	2	2	2	1	2	-	-	3	3	-	-

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.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. To study about hand tools, special purpose tools, and their uses.

Course Outcome 2 (CO2)

1. Rectifying and trouble shooting in engines
2. Rectifying and trouble shooting in ignition systems
3. Rectifying and trouble shooting in braking system in automobiles
4. Rectifying and trouble shooting in Fuel supply system in automobiles

Course Outcome 3 (CO3):

1. Disassembling of clutch and gear box and to explain the condition of gear box and clutch assembly
2. Dismantle and assembly of various joints in the suspension, steering gear box and transmission systems

LIST OF EXPERIMENTS

List of Exercises/Experiments (Minimum 12 exercises/experiments are mandatory)

1. Servicing of clutch assembly, checking the spring tension of coil springs in spring tester.
2. Dismantling of gear box, inspecting components, servicing, checking the gear ratios.
3. Dismantling of differential assembly, servicing, backlash adjustments, check for drive axis ratio.
4. Servicing master and wheel cylinders in hydraulic brake system & bleeding of brakes.
5. Valve timing setting including valve clearance adjustment.
6. Servicing of steering gear box, checking for end play in shafts.
7. Overhauling of a complete strut type suspension system.

8. Disassembling and servicing of Leaf Spring Assembly
9. Dismantle and assemble C.V joint. Also examine a slip joint, U.J cross in propeller shaft.
10. Compression test of petrol and diesel engine.
11. Disassembling cylinder head, decarbonising, Valve Seat Grinding
12. Disassembling of engine: inspection of engine components, servicing of components, measurement of dimensions of different components of engine, compare with standard specifications, piston ring setting, assembling using special tools.
13. Rectifying the troubles in ignition system, adjusting spark plug and C. B. Point gap, checking ignition timing.
14. Servicing of tire and tube - Tyre removing, inspection, check for cuts, bulges and excessive tread wear, resetting using pneumatic tyre changer, vulcanizing or puncturing of tubes.
15. Testing the injector – testing the pressure of mechanical diesel injector, spray pattern, adjusting of injection pressure

Note: 12 experiments are mandatory

Reference Books

Text Book:

1. Boyce Dwiggins – Automobile Repair guide, Theodor Audel and Co., Indiana – 1978.
2. A. W. Judge – Maintenance of high speed diesel engine, Chapmann Hall Ltd.
3. A. W. Judge – Motor vehicle engine servicing 3rd edition, Pitman paper mark, London, 1969.
4. Vehicle service manuals and reputed manufacturers

SEMESTER -4

MINOR

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MUT282	AUTOMOTIVE CHASSIS AND ENGINE COMPONENTS	VAC	4	0	0	4

Preamble: This course aims at providing

- ✓ **an in-sight in the area of constructional details of engine ,lubrication system and cooling system**
- ✓ **a deeper knowledge on the function and types of the chassis.**
- ✓ **Basic understanding on the functional sub systems in the chassis.**

Prerequisite: NIL

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

CO 1	Identifying the **constructional details of engine components and lubrication system**
CO 2	Evaluate the different types of cooling system and chassis framework
CO 3	Understand the front axle and steering system
CO 4	Identify the suspension system and different classes of wheels used in a vehicle
CO 5	Comparing the different types of rear axles and adjoining components

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

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**		**End Semester Examination**
	1	**2**	
Remember	30	30	60
Understand	20	20	40
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. Are you able to Identify the constructional details of engine components and lubrication system

Course Outcome 2 (CO2)

1. Are you able to identify the importance of the different types of cooling system and chassis framework

Course Outcome 3(CO3):

1 Can you identify the type of steering and front axle used in the vehicle?

Course Outcome 4 (CO4):

1. . Can you decide on the suspension and wheels which are best suited for the vehicle you are making?

Course Outcome 5 (CO5):

1. Can you identify the working of differential and type of rear axle being employed in a vehicle?

Model Question paper

QP CODE: **PAGES:…**

Reg. No: _______________ **Name :_______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

THIRD SEMESTER B.TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: MUT282

Course Name: AUTOMOTIVE CHASSIS AND ENGINE COMPONENTS

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

Part A

(Answer all questions. Each question carry 5 marks)

1. List down the different layouts used in an automobile according to the position of the prime mover? Explain any one of them
2. What are the different types of vibration damper used in engines.
3. Explain the front wheel geometries with neat sketches

4. With a neat diagram, explain the steering linkage system used for independent suspension front axle from steering wheel to wheels
5. Why do we require a suspension system? Explain the functions of a suspension system
6. Explain the construction details of engine cooling system
7. What are the differences between Wet sump Dry sump lubrication systems)
8. Explain the mechanism of Power and power assisted steering
9. Why do we need a differential? Explain the working of differential
10. Why is axle shaft made of solid bar and propeller shaft made of hollow tube?

Part B

Answer any one full question from each module.

Each question carries 10 Marks

11. (a) List down the types of cylinder head (5)

    (b) Explain the different lubrication systems (5)

OR

12. (a) With neat sketch explain the different types of valve operating mechanisms (10)
13. Explain ackermann steering mechanism with a neat sketch. Derive the condition for true rolling (10)

OR

14. Explain the working of Davis steering mechanism. Compare its advantage and disadvantage with Ackermann steering. Why is Davis mechanism not in use now (10)
15. (a) Explain the most commonly used independent suspension system (5)

    (b) Explain the construction and working of leafsprings. Why do we require helper springs (5)

OR

16. Explain the different types of rims used in an automobile with neat sketch (10)
17. What is necessity of engine cooling and correct operating temperatures, also explain the different types of engine cooling methods. (10)

OR

18. With the aid of neat sketch explain the different layout of chassis & its main components (10)
19. Explain the different types of gears used in final drive for a front engine rear wheel drive vehicle with neat sketches (10)

OR

20. Explain semi floating and fully floating axles with neat sketches (10)

Syllabus

Module	Contents	Hours	Sem.Exam Marks
I	**Constructional details of engine and Lubrication system** **Constructional details of engine components:** Types, components and layout of an automobile. Classification of automotive engines, multi-cylinder reciprocating engine, construction details- main parts: cylinder head, cylinder, crank case, cylinder liners, types of cylinder head, gasket materials pistons, piston rings, connecting rod, flywheel, vibration damper, Main Bearings, crank shaft, cam shaft, different types of valve operating mechanisms- side cam and overhead camshaft mechanisms. Inlet and exhaust manifold construction, hydraulic tappets **Lubrication system**: Function of lubrication system, lubrication principles, classification of lubricants, types of lubricants, properties of lubricants, , crankcase ventilation, lubrication systems (Mist, Wet sump Dry sump lubrication systems), effect of engine conditions on lubricating oil, Components of lubrication system (oil strainers, oil filters, oil pumps, oil coolers), chassis lubrication.	9	20%
II	**Cooling system and introduction to Chassis and Frame** **Cooling system**: Necessity of engine cooling and correct operating temperatures, types of cooling systems like Direct air cooling, Indirect or water cooling, Liquid cooling, Pressure sealed cooling, Evaporative cooling or steam cooling, components of water cooling system (thermostat, water pump, radiator, cooling fan etc), antifreeze solution, temperature gauges. **Chassis and Frame:** Layout of chassis & its main components. Types of frames, conventional frames and unitized chassis, articulated, rigid vehicles, prime movers, hybrid car & electric car.	9	20%
III	**Front Axle and Steering :Front Axle types.** Construction details.Materials. Front wheel geometry viz. Camber, kingpininclination, caster, toe-in and toe-out. Conditions for true rolling motion of road wheels duringsteering. Steering geometry. Ackermann and Davis steering. Constructional details of steeringlinkages. Steering linkage layout for conventional and independent suspensions.Different types of steering gear boxes.Turning radius, wheel wobble and shimmy. Power and power assisted steering – Electric steering – Steer by wire.	9	20%

IV	**Suspension System, Wheels and Tyres** Types of suspension. Factors influencing ride comfort, Suspension springs – leaf spring, shackle and mounting brackets, coil and torsion bar springs. Spring materials, Independent suspension – front and rear. Rubber, pneumatic, hydroelasitc suspension – Active suspension system. Hydraulic dampers, Magneto Rheological fluids . Design of leaf springs, Types of wheels. Construction of wheel assembly. Types of tyres and constructional details. Static and rolling properties of pneumatic tyres, Wheel balancing and alignment.	**9**	**20%**
V	**Final Drive & Rear Axle:** Purpose of final drive & drive ratio, Different types of final drives, need of differential, Constructional details of differential unit, Non-slip differential, Differential lock, Differential housing, Function of rear axle, Construction, Types of loads acting on rear axle, Axle types - semi-floating, full floating, Axle shafts, Final drive lubrication. Twin Speed final drive. Final drive for multiaxle vehicles.	**9**	**20%**

Text Books

1. Kripal Singh, Automobile Engineering, ADWVol II, Standard Publisher, New Delhi , 2006
2. N.K. Giri, Automotive Mechanics, Kanna Publishers, 2007
3. M. L. Mathur, R. P. Sharma - Internal Combustion Engines, Dhanpat Rai Publications
4. R.K. Rajput, Internal Combustion Engines, Laxmi Publications.
5. V Ganesan, Internal Combustion Engine Tata McGraw Hill Publishing Company Ltd., New Delhi 2006.

Reference Books

1. Heldt P.M., Automotive Chassis, Chilton Co., New York, 1990
2. Newton Steeds and Garret, Motor Vehicles, 13th Edition, Butterworth, London, 2005.
3. Heinz Haisler,Advanced Vehicle Technology, Butterworth, London, 2005.
4. Stuart Mills and Julie Wilson, How to Design and Build an Electric Car or Vehicle,
5.SeithLeitman, Build your own electric vehicle, 3rd edition, McGraw Hill education, 2013

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Introduction**	
1.1	Types, components and layout of an automobile. Classification of automotive engines, multi-cylinder reciprocating engine,	1
1.2	construction details- main parts: cylinder head, cylinder, crank case, cylinder liners, types of cylinder head, gasket materials pistons, piston rings, connecting rod, flywheel, vibration damper,	2
1.3	Main Bearings, crank shaft, cam shaft, different types of valve operating mechanisms- side cam and overhead camshaft	2

	mechanisms. Inlet and exhaust manifold construction, hydraulic tappets	
1.4	: Function of lubrication system, lubrication principles, classification of lubricants, types of lubricants, properties of lubricants, , crankcase ventilation	2
1.5	lubrication systems (Mist, Wet sump Dry sump lubrication systems), effect of engine conditions on lubricating oil, Components of lubrication system (oil strainers, oil filters, oil pumps, oil coolers), chassis lubrication.	2
2	**Cooling system and introduction to Chassis and Frame**	
2.1	Necessity of engine cooling and correct operating temperatures, types of cooling systems like Direct air cooling, Indirect or water cooling, Liquid cooling, Pressure sealed cooling	3
2.2	, Evaporative cooling or steam cooling, components of water cooling system (thermostat, water pump, radiator, cooling fan etc), antifreeze solution, temperature gauges.	3
2.3	**Chassis and Frame:** Layout of chassis & its main components. Types of frames, conventional frames and unitized chassis, articulated, rigid vehicles, prime movers, hybrid car & electric car.	3
3	**Front axle and Steering**	
3.1	Front Axle types. Construction details. Materials.	1
3.2	Front wheel geometry viz. Camber, kingpin inclination, caster, toe-in and toe-out.	1
3.3	Conditions for true rolling motion of road wheels during steering	1
3.4	Steering geometry. Ackermann and Davis steering	1
3..5	Constructional details of steering linkages	1
3.6	Steering linkage layout for conventional and independent suspensions	1
3.7	Different types of steering gear boxes	1
3.8	Turning radius, wheel wobble and shimmy	1
3.9	Power and power assisted steering – Electric steering – Steer by wire	1
4	**Suspension System, Wheels and Tyres**	
4.1	Types of suspension. Factors influencing ride comfort	1
4.2	Suspension springs – leaf spring, shackleand mounting brackets, coil and torsion bar springs, Spring materials	1
4.3	Independent suspension –front and rear	1
4.4	Rubber, pneumatic, hydroelasitc suspension	1

4.5	Hydraulic dampers, Magneto Rheological fluids	1
4.6	Design of leaf springs	1
4.7	Types of wheels. Construction of wheel assembly	1
4.8	Types of tyres and constructional details.	1
4.9	Static and rolling properties of pneumatic tyres, Wheel balancing and alignment	1
5	**FINAL DRIVE AND REAR AXLE**	
5.1	Purpose of final drive & drive ratio	1
5.2	Different types of final drives	1
5.3	Need of differential, Constructional details of differential unit,	1
5.4	Non-slip differential, Differential lock, Differential housing	1
5.5	Function of rear axle, Construction, Types of loads acting on rear axle	2
5.6	Axle types - semi-floating, full floating	1
5.7	Axle shafts, Final drive lubrication	1
5.8	Twin Speed final drive. Final drive for multiaxle vehicles	1

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SEMESTER -4 HONOURS

KTU Estd. 2014

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MUT 292	Incompressible and compressible Flows	VAC	3	1	0	4

Code	Description
T	Theory based courses (other the lecture hours, these courses can have tutorial and practical hours, e.g., L-T-P structures 3-0-0, 3-1-2, 3-0-2 etc.)
L	Laboratory based courses (where performance is evaluated primarily on the basis of practical or laboratory work with LTP structures like 0-0-3, 1-0-3, 0-1-3 etc.)
N	Non-credit courses

Preamble: The objective of learning Compressible and Incompressible fluid flow is to understand, the fundamental concepts of Compressible Incompressible fluid flow, various governing equations and their applications. By learning the course, one must be able to analyse various problems on compressible and incompressible flow and the various types of flow measurement techniques

Prerequisite: Fluid Mechanics and Machinery

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

CO 1	Examine and identify the fundamentals of basic conservation equations, governing equations and vorticity
CO 2	Conduct the differential analysis of fluid flow for incompressible fluids
CO 3	Understand the basics of compressible fluid flow
CO 4	Analyse the various conditions for Fanno flow and Rayleigh flow for compressible fluids
CO 5	Understand the governing equations for normal shock
CO 6	Apply the various measuring techniques learned for Compressible flow field visualization and measurement

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

Assessment Pattern

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the Reynolds transport theorem

Course Outcome 2 (CO2)

1. Derive Navier- Stokes equations for various conditions

Course Outcome 3(CO3):

1.State the physical difference between incompressible, subsonic, sonic and supersonic flows

2. List the basic problems on isentropic flow.

3. Describe the Isentropic duct flow of an ideal gas

Course Outcome 4 (CO4)

1. Illustrate flow in constant area duct with friction only (Fanno flow).

2. Explain the flow in constant area duct with heat transfer only (Rayleigh flow)

Course Outcome 5 (CO5):

1.Describe the governing equations prevailing normal shocks

2. Explain the property changes across shocks

Course Outcome 6 (CO6):

1.Explain the various techniques for Compressible flow field visualization and measurement

2.List the various instruments used for the compressible flow measurement

Syllabus

Module 1

Fluid Kinematics- Lagrangian and Eulerian Descriptions- Flow patterns and flow visualisations- Plots of fluid flow data- Vorticity and Rotationality- Reynolds transport theorem

Module 2

Differential Analysis of Fluid Flow- Introduction-Conservation of mass- The continuity equation- The stream function-Caushy's equation- Navier-Stokes equations- Differential analysis of fluid flow problems

Module 3

Compressible fluid flows: Introduction and review: Concept of continuum-system and control volume approach- conservation of mass, momentum and energy- stagnation state-compressibility-Entropy relations - Acoustic velocity-Mach number - physical difference between incompressible, subsonic, sonic and supersonic flows

Isentropic duct flow of an ideal gas: Governing equations - 1D compressible adiabatic duct flow, variation of properties with Mach number and critical properties; Converging nozzles, choking, converging-diverging nozzles, basic problems on isentropic flow.

Module 4

Flow in constant area duct with friction only (Fanno flow): Governing equations – Fanno line - significance of maximum entropy point on Fanno line – choking in Fanno flow – relations of properties with Mach number - basic problems.

Flow in constant area duct with heat transfer only (Rayleigh flow): Governing equations – Rayleigh line - significance of maximum entropy and maximum enthalpy points on Rayleigh line – choking in Rayleigh flow – relations of properties with Mach number – basic problems.

Module 5

Normal shocks: Governing equations - Prandtl Meyer relation - property changes across shocks, shocks in isentropic, Fanno and Rayleigh flows, problems of normal shock in those flows – introduction to oblique shock.

Measurement techniques: Compressible flow field visualization and measurement - Shadowgraph - interferometer- subsonic compressible flow field - measurement (Pressure, Velocity and Temperature) – compressibility - correction factor- hot wire anemometer-supersonic flow measurement -Rayleigh Pitot tube - wedge probe - stagnation temperature probe- temperature recovery factor –Kiel probe - Wind tunnels – closed and open type

Model Question paper

QP CODE:
PAGES:3

Reg. No: _______________ **Name :_______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

THIRD SEMESTER B.TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: MUT 292

Course Name: Incompressible and compressible Flows

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

PART A

Answer all Questions.
Each question carries 5 Marks

1. Differentiate between stream lines and stream tubes
2. What does the word kinematics mean? Explain what the study of fluid kinematics involve
3. Differentiate between Newtonian and Non- Newtonian fluids
4. Explain the significance of Navier- Stokes equations
5. What is Mach number? Explain its significance in analyzing flow.
6. Derive the governing equation for isentropic flow through duct with varying area.
7. Explain choking in Fanno flow.
8. Plot Rayleigh curve on HS diagram and explain the salient points.
9. Explain why shock is impossible in subsonic flow.
10. Compare open and closed wind tunnels

Part B

11. Derive the expression for acceleration field of a fluid particle through a nozzle

or

12. Derive and prove the Reynold Transport theorem
13. Derive continuity equation using an infinitesimal control volume

or

14. Derive the Navier- Stokes equation for incompressible, isothermal flow
15. Derive the expression to prove conservation of momentum in compressible flow.

or

16. A supersonic nozzle expands air from po = 25 bar and To = 1050 K to an exit pressure of 4.35 bar; the exit area of the nozzle is 100 cm2. Determine (a) throat area (b) pressure and temperature at the throat (c) temperature at exit (d) exit velocity as fraction of the maximum attainable velocity and (e) mass flow rate.
17. The stagnation temperature of air in a combustion chamber is increased 3.5 times its initial value. If the air at entry is at 5 bar and 105 °C and a Mach number of 0.25, determine i) Mach number, pressure and temperature at exit ii) stagnation pressure loss iii) heat supplied per kg of air.

or

18. A convergent-divergent nozzle having a throat diameter of 7.5 mm supplies air to an insulated duct of diameter 15 mm. The stagnation properties of air at entry to the nozzle are 7.5 bar and 300 K. The flow through nozzle is isentropic. The mean coefficient of friction for the duct is 0.005. Calculate the maximum length of the duct that can be provided without discontinuity in the nozzle or duct. Find the condition of air at the exit, for the duct length.
19. Derive Prandtl Meyer relation

or

20. Explain the working of (a) hot wire anemometer (b) Kiel Probe

Text Books

1. *Fluid Mechanics and Hydraulic Machines* by Dr.R.K.Bansal. Revided Ninth Edition. Modi P. N. and S. M. Seth, *Hydraulics & Fluid Mechanics*, S.B.H Publishers, New Delhi, 2002.
2. Kumar D. S., *Fluid Mechanics and Fluid Power Engineering,* S. K. Kataria & Sons, New Delhi, 1998.
3. Cengel Y. A. and J. M. Cimbala, Fluid Mechanics, Tata McGraw Hill, 2013
4. Balachandran P., Fundamentals of Compressible Fluid Dynamics, PHI Learning. 2006
5. Rathakrishnan E., Gas Dynamics, PHI Learning, 2014
6. Yahya S. M., Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion, New Age International Publishers, 2003

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2. Balachandran P., Gas Tables, Prentice-Hall of India Pvt. Limited, 2011

Reference Books

1. J. F. Douglas, "Fluid Mechanics", Pearson education.
2. Robert W. Fox and Mc Donald, "Introduction to fluid dynamics", John Wiley and sons
3. Turbulence in Fluids, 3rd edition M. Lesieur Dordrecht; Boston: Kluwer Academic Publishers, 1997
4. Anderson, Modern compressible flow, 3e McGraw Hill Education, 2012
5. Shapiro, Dynamics and Thermodynamics of Compressible Flow – Vol 1., John Wiley & Sons,1953
6. Fundamental Mechanics of Fluids, Fourth Edition I.G.Currie CRC Press (Taylor and Francis Group

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Fluid Kinematics**	
1.1	Lagrangian and Eulerian Descriptions	2
1.2	Flow patterns and flow visualisations	2
1.3	Plots of fluid flow data	2
1.4	Vorticity and Rotationality	2
1.5	Reynolds transport theorem	1
2	**Differential Analysis of Fluid Flow**	
2.1	Introduction-Conservation of mass	1
2.2	The continuity equation	1
2.3	The stream function	1
2.4	Caushy's equation	2
2..5	Navier-Stokes equations	2
2.6	Differential analysis of fluid flow problems	2
3	**Compressible fluid flows**	
3.1	Introduction and review: Concept of continuum	1
3.2	System and control volume approach	1
3.3	Conservation of mass, momentum and energy	1
3.4	Stagnation state- compressibility	2
3.5	Entropy relations	1
3.6	Acoustic velocity-Mach number	1
3.7	Physical difference between incompressible, subsonic, sonic and supersonic flows	1
4	**Flow in constant area duct with friction only (Fanno flow) & Flow in constant area duct with heat transfer only (Rayleigh flow)**	
4.1	Flow in constant area duct with friction only (Fanno flow): Governing equations	1

4.2	Fanno line - significance of maximum entropy point on Fanno line	1
4.3	Choking in Fanno flow	1
4.4	Relations of properties with Mach number - basic problems	1
4.5	Flow in constant area duct with heat transfer only (Rayleigh flow): Governing equations	1
4.6	Rayleigh line - significance of maximum entropy and maximum enthalpy points on Rayleigh line	1
4.7	Choking in Rayleigh flow – relations of properties with Mach number – basic problems.	1
5	**Normal shocks & Measurement techniques**	
5.1	Normal shocks: Governing equations - Prandtl Meyer relation	1
5.2	Property changes across shocks	1
5.3	Shocks in isentropic, Fanno and Rayleigh flows	1
5.4	Problems of normal shock in those flows	1
5.5	Introduction to oblique shock.	1
5.6	Measurement techniques: Compressible flow field visualization and measurement	1
5.7	Shadowgraph - interferometer	1
5.8	Subsonic compressible flow field - measurement (Pressure, Velocity and Temperature)	1
5.9	Compressibility - correction factor	1
5.10	Hot wire anemometer- supersonic flow measurement	1
5.11	Rayleigh Pitot tube - wedge probe - stagnation temperature probe- temperature recovery factor	1
5.12	Kiel probe - Wind tunnels – closed and open type	1