UNIVERSITY DEPARTMENTS

ANNA UNIVERSITY CHENNAI : : CHENNAI 600 025

REGULATIONS - 2009

CURRICULUM I TO IV SEMESTERS (FULL TIME)

M.E. INTERNAL COMBUSTION ENGINEERING

SEMESTER I

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	MA9107	Applied Mathematics for Thermal Engineers	3	1	0	4
2	IC9111	Advanced Heat Transfer	3	1	0	4
3	IC9112	Advanced Thermodynamics	3	1	0	4
4	IC9113	Alternative Fuels for I.C. Engines	3	0	0	3
5	IC9114	Combustion and Emission in Engines	3	0	0	3
6	E1	Elective I	3	0	0	3
PRACTICAL						
7	IC9115	I.C. Engines Lab.	0	0	3	1
		TOTAL	18	3	3	22

SEMESTER II

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	IC9121	Electronic Engine Management Systems	3	0	0	3
2	IC9122	Internal Combustion Engine Design	3	0	0	3
3	IC9123	Instrumentation for Thermal Systems	3	0	0	3
4	E2	Elective II	3	0	0	3
5	E3	Elective III	3	0	0	3
6	E4	Elective IV	3	0	0	3
PRACTICAL						
7	IC 9124	Seminar	0	0	0	1
		TOTAL	18	0	0	19

SEMESTER III

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	E5	Elective V	3	0	0	3
2	E6	Elective VI	3	0	0	3
3	E7	Elective VII	3	0	0	3
PRACTICAL						
4.	IC 9131	Project Work – Phase I	0	0	12	6
		TOTAL	9	0	12	15

SEMESTER IV

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
PRACTICAL						
1	IC9141	Project Work - Phase II (Continuation of Phase I)	0	0	24	12
		TOTAL	0	0	24	12

Total number of credits to be earned for award of the degree = 68

This is for Curriculum of University Departments and Affiliated Institutions

ANNA UNIVERSITY CHENNAI :: CHENNAI 600 025

CURRICULUM 2009 (SELF – SUPPORTING PROGRAMME)

M.E. INTERNAL COMBUSTION ENGINEERING

SEMESTER I

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
1	MA9107	Applied Mathematics for Thermal Engineers	3	1	0	4
2	IC9111	Advanced Heat Transfer	3	1	0	4
3	IC9112	Advanced Thermodynamics	3	1	0	4
		TOTAL	**9**	**3**	**0**	**12**

SEMESTER II

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
1	IC9121	Electronic Engine Management Systems	3	0	0	3
2	IC9122	Internal Combustion Engine Design	3	0	0	3
3	IC9123	Instrumentation for Thermal Systems	3	0	0	3
		TOTAL	**9**	**0**	**0**	**9**

SEMESTER III

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
4	IC9113	Alternative Fuels for I.C. Engines	3	0	0	3
5	IC9114	Combustion and Emission in Engines	3	0	0	3
6	E1	Elective I	3	0	0	3
7	IC9115	I.C. Engines Lab.	0	0	3	1
		TOTAL	**9**	**0**	**3**	**10**

SEMESTER IV

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
1	E2	Elective 1	3	0	0	3
2	E3	Elective 2	3	0	0	3
3	E4	Elective 3	3	0	0	3
4	IC9124	Seminar	0	0	0	1
		TOTAL	**9**	**0**	**0**	**10**

SEMESTER V

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
1	E5	Elective 5	3	0	0	3
2	E6	Elective 6	3	0	0	3
3	E7	Elective 7	3	0	0	3
4	IC9131	Project Work Phase – I	0	0	12	6
		TOTAL	**9**	**0**	**12**	**15**

SEMESTER VI

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
1	IC9141	Project Work - Phase II	0	0	24	12
		TOTAL	**0**	**0**	**24**	**12**

Total number of credits to be earned for award of the degree = 68

ELECTIVES FOR M.E. INTERNAL COMBUSTION ENGINEERING

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
1	IC9150	Automotive Engine Systems	3	0	0	3
2	IC9151	Engine Pollution and Control	3	0	0	3
3	IC9152	Engine Auxiliary Systems	3	0	0	3
4	IC9153	Gas Turbine Power Plants	3	0	0	3
5	IC9154	Space Propulsion	3	0	0	3
6	IC9155	Materials, Manufacturing and Testing of Engines	3	0	0	3
7	IC9156	Marine Diesel Engine	3	0	0	3
8	IC9157	Simulation of I.C. Engine Processes	3	0	0	3
9	IC9158	Speciality Engines	3	0	0	3
10	IC9159	Supercharging and Scavenging	3	0	0	3
11	IC9160	Hydrogen as a Fuel in I.C. Engines	0	0	6	3
12	IC9161	Fluid Flow and Heat Transfer in Engines	3	0	0	3

13	IC9162	Computational Fluid Dynamics	3	0	0	3
14	IC9163	Flow Visualisation Techniques for I.C. Engine	3	0	0	3
15	IC9164	Electric and Hybrid Vehicles	3	0	0	3
16	IC9165	Boundary Layer Theory and Turbulence	3	0	0	3
17	IC9166	Microelectronics Application in I.C. Engines	3	0	0	3
18	IC9167	Combustion and Reaction Kinetics in I.C. Engines	3	0	0	3
19	IC9168	Fuel Cell Technology	3	0	0	3
20	EY9150	Advanced Engineering Fluid Mechanics				
		TOTAL	**57**	**0**	**0**	**57**

Note: Students can opt for electives from other streams of thermal Engg. Viz. M.E.I.C Engines and M.E. Energy Engg. which will be also considered as Electives from same Department while exercising **Regulation Clause No:- 3.7.4**

MA9107 APPLIED MATHEMATICS FOR THERMAL ENGINEERS

L	T	P	C
3	1	0	4

UNIT- I APPLICATIONS OF FOURIER TRANSFORM 9

Fourier Transform methods – one-dimensional heat conduction problems in infinite and semi-infinite rod – Laplace Equation – Poisson Equation.

UNIT – II CALCULUS OF VARIATIONS 9

Concept of variation and its properties – Euler's equation – Functionals dependant on first and higher order derivatives – Functionals dependant on functions of several independent variables – Variational problems with moving boundaries – Direct methods – Ritz and Kantorovich methods.

UNIT – III CONFORMAL MAPPING AND APPLICATIONS 9

The Schwarz- Christoffel transformation – Transformation of boundaries in parametric form – Physical applications:Fluid flow and heat flow problems.

UNIT – IV FINITE DIFFERENCE METHODS FOR PARABOLIC EQUATIONS 9

One dimensional parabolic equation – Explicit and Crank-Nicolson Schemes – Thomas Algorithm – Weighted average approximation – Dirichlet and Neumann conditions – Two dimensional parabolic equations – ADI method.

UNIT – V FINITE DIFFERENCE METHODS FOR ELLIPTIC EQUATIONS 9

SOLUTIONS OF LAPLACE AND POISSON EQUATIONS IN A RECTANGULAR REGION – FINITE DIFFERENCE IN POLAR COORDINATES – FORMULAE FOR DERIVATIVES NEAR A CURVED BOUNDARY WHILE USING A SQUARE MESH.

L +T: 45+15 = 60 PERIODS

REFERENCES:

1. Mitchell A.R. and Griffith D.F., The Finite difference method in partial differential equations, John Wiley and sons, New York (1980).
2. Sankara Rao, K., Introduction to Partial Differential Equations, Prentice Hall of India Pvt. Ltd., New Delhi (1997).
3. Gupta, A.S., Calculus of Variations with Applications, Prentice Hall of India Pvt. Ltd., New Delhi (1997).
4. Spiegel, M.R., Theory and Problems of Complex Variables and its Application (Schaum's Outline Series), McGraw Hill Book Co., Singapore (1981).
5. Andrews, L.C. and Shivamoggi, B.K., Integral Transforms for Engineers, Prentice Hall of India Pvt. Ltd., New Delhi (2003).
6. Elsgolts, L., Differential Equations and the Calculus of Variations, MIR Publishers, Moscow (1973).
7. Mathews, J.H. and Howell, R.W., Complex Analysis for Mathematics and Engineering, Narosa Publishing House, New Delhi (1997).
8. Morton, K.W. and Mayers, D.F. Numerical solution of partial differential equations, Cambridge University press, Cambridge (2002).
9. Jain, M. K., Iyengar, S. R. K. and Jain, R. K. " Computational Methods for Partial Differential Equations", New Age International (P) Ltd., 2003.

IC 9111 ADVANCED HEAT TRANSFER L T P C
3 1 0 4

AIM:
The course is intended to build up necessary fundamentals for the understanding of the physical behaviour of conduction and convection

OBJECTIVE:

- To develop the ability to use the heat transfer concepts for various applications like finned systems, turbulence flows, high speed flows.
- To analyse the thermal analysis and sizing of heat exchangers and to learn the heat transfer coefficient for compact heat exchanges.
- To achieve an understanding of the basic concepts of phase change processes and mass transfer.

UNIT - I CONDUCTION AND RADIATION HEAT TRANSFER 10
One dimensional energy equations and boundary condition - three-dimensional heat conduction equations - extended surface heat transfer - conduction with moving boundaries - radiation in gases and vapour.Gas radiation and radiation heat transfer in enclosures containing absorbing and emitting media – interaction of radiation with conduction and convection.

UNIT - II TURBULENT FORCED CONVECTIVE HEAT TRANSFER 10
Momentum and energy equations - turbulent boundary layer heat transfer - mixing length concept - turbulence model – k Є model - analogy between heat and momentum transfer – Reynolds, Colburn, Prandtl turbulent flow in a tube - high speed flows.

UNIT - III PHASE CHANGE HEAT TRANSFER AND HEAT EXCHANGER 8
Condensation with shears edge on bank of tubes - boiling – pool and flow boiling - heat exchanger -Є – NTU approach and design procedure - compact heat exchangers.

UNIT - IV NUMERICAL METHODS IN HEAT TRANSFER 9
Finite difference formulation of steady and transient heat conduction problems – discretization schemes – explicit - Crank Nicolson and fully implicit schemes - control volume formulation -steady one-dimensional convection and diffusion problems - calculation of the flow field – SIMPLER Algorithm.

UNIT – V MASS TRANSFER AND ENGINE HEAT TRANSFER CORRELATION 8
Mass transfer - vaporization of droplets - combined heat and mass transfers - heat transfer correlations in various applications like I.C. engines - compressors and turbines.

TOTAL (L – 45 + T – 15): 60 PERIODS

TEXT BOOKS:

1. Incropera F.P. and DeWitt. D.P., Fundamentals of Heat & Mass Transfer, John Wiley & Sons, 2002.
2. Holman.J.P, Heat Transfer, Tata Mc Graw Hill, 2002.

REFERENCES:

1. Ozisik. M.N., Heat Transfer – A Basic Approach, McGraw-Hill Co., 1985
2. Nag.P.K, Heat Transfer, Tata McGraw-Hill, 2002
3. Ghoshdastidar. P.S., Heat Transfer, Oxford University Press, 2004
4. Yadav, R., Heat and Mass Transfer, Central Publishing House, 1995.

IC 9112 ADVANCED THERMODYNAMICS L T P C
3 1 0 4

AIM

To enrich the knowledge of students in thermodynamics

OBJECTIVE :

- To achieve an understanding of basic principle and scope of thermodynamics.
- To predict the availability and irreversibility associated with the thermodynamic processes.
- To analyse the properties of ideal and real gas mixtures and to understand the basic concepts of fuel and combustions

UNIT – I AVAILABILITY ANALYSIS AND THERMODYNAMIC PROPERTY RELATIONS 10

Reversible work, Availability, Irreversibility and Second-Law Efficiency for a closed System and Steady-State Control Volume. Availability Analysis of Simple Cycles. Thermodynamic Potentials, Maxwell relations, Generalised relations for changes in Entropy, Internal Energy and Enthalpy, Generalised Relations for C_p and C_v, Clausius Clayperon Equation, Joule-Thomson Coefficient, Bridgman Tables for Thermodynamic relations.

UNIT – II REAL GAS BEHAVIOUR AND MULTI-COMPONENT SYSTEMS 10

Different Equations of State, Fugacity, Compressibility, Principle of Corresponding States, Use of generalized charts for enthalpy and entropy departure, fugacity coefficient, Lee-Kesler generalized three parameter tables. Fundamental property relations for systems of variable composition, partial molar properties, Real gas mixtures, Ideal solution of real gases and liquids, Activity, Equilibrium in multi phase systems, Gibbs phase rule for non-reactive components.

UNIT – III CHEMICAL THERMODYNAMICS AND EQUILIBRIUM 10

Thermo chemistry, First Law analysis of reacting systems, Adiabatic Flame temperature, Entropychange of reacting systems, Second Law analysis of reacting systems, Criterion for reaction equilibrium, Equilibrium constant for gaseous mixtures, Evaluation of equilibrium composition.

UNIT – IV STATISTICAL THERMODYNAMICS 8

Microstates and Macrostates, Thermodynamic probability, Degeneracy of energy levels, Maxwell-Boltzman, Fermi-Dirac and Bose-Einstein Statistics, Microscopic Interpretation of heat and work, Evaluation of entropy, Partion function, Calculation of the Macroscopic properties from partition functions.

UNIT – V IRREVERSIBLE THERMODYNAMICS 7

Conjugate Fluxes and Forces, Entropy Production Onsager's Reciprocity relations, Thermo-electric phenomena, formulations.

TOTAL (Tutorial 15 + Lecture 45) 60 PERIODS

REFERENCES :

1. Kenneth Wark Jr., Advanced Thermodynamics for Engineers, McGraw-Hill Inc., 1995.
2. Bejan, A., Advanced Engineering Thermodynamics, John Wiley and Sons, 1988.
3. Holman,J.P., Thermodynamics, Fourth Edition, McGraw-Hill Inc., 1988.
4. Smith, J.M. and Van Ness., H.C., Introduction to Chemical Engineering Thermodynamics, Fourth Edition, McGraw-Hill Inc., 1987.
5. Sonntag, R.E., and Van Wylen, G, Introduction to Thermodynamics, Classical and Statistical, Third Edition, John Wiley and Sons, 1991.
6. Sears, F.W. and Salinger G.I., Thermodynamics, Kinetic Theory and StatisticalThermodynamics, Third Edition, Narosa Publishing House, New Delhi, 1993.
7. DeHotf, R.T., Thermodynamics in Materials Science, McGraw-Hill Inc., 1993.
8. Rao, Y.V.C., Postulational and Statistical Thermodynamics, Allied Publisher Limited, New Delhi, 1994.

IC 9113 ALTERNATIVE FUELS FOR I.C. ENGINES

L	T	P	C
3	0	0	3

AIM

To impart knowledge on various alternative fuels for I.C. Engines

OBJECTIVE:

(i) Gain a working understanding of the engineering issues and perspectives affecting fuel and engine development.

(ii) Examine future trends and development, including hydrogen as an internal combustion engine fuel.

(iii) Explore further fuel specification and performance requirements for advanced combustion systems.

UNIT – I INTRODUCTION **12**

Availability and Suitability and properties of Potential Alternative Fuels – Ethanol, Methanol, DEE, DME, Hydrogen, LPG, Natural Gas, Producer Gas, Bio gas and Bio-diesel, Properties, Merits and Demerits.

UNIT – II LIQUID FUELS FOR S.I. ENGINES **9**

Requirements of fuels for SI engines-Different Techniques of utilizing alternative liquid fuels– Blends, Neat form, Reformed Fuels - Manufacturing, Storage and Safety-Performance and Emission Characteristics of alternative liquid fuels.

UNIT – III LIQUID FUELS IN C.I. ENGINES **8**

Requirements of fuels for CI engines- Different Techniques for their utilization- Blends, Fuel modifications to suit CI engines, Neat fuels, Reformed fuels, Emulsions, Dual fuelling, Ignition accelerators and other additives– Performance and emission characteristics.

UNIT – VI GASEOUS FUELS IN S.I. ENGINES **8**

Use of Hydrogen, CNG, LPG, Natural Gas, Producer gas and Bio gas in SI engines– Safety Precautions – Engine performance and emissions.

UNIT – V GASEOUS FUELS IN C.I. ENGINES 8

Use of Hydrogen, Producer Gas, Biogas, LPG, Natural gas, CNG in CI engines. Dual fuelling, Performance and emission characteristics.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. Osamu Hirao and Richard K.Pefley, Present and Future Automotive Fuels, John Wiley and Sons, 1988.
2 Keith Owen and Trevor Eoley, Automotive Fuels Handbook, SAE Publications, 1990.
3. Richard L.Bechtold, Automotive Fuels Guide Book, SAE Publications, 1997.

REFERENCES :

1 .Automotive Lubricants Reference Book, Second Edition, Roger F. Haycock and John E. Hillier, SAE International Publications, 2004.

IC 9114 COMBUSTION AND EMISSION IN ENGINES

L	T	P	C
3	0	0	3

AIM

To Demonstrate extensive mastery of the fundamental principles which govern the design and operation of internal combustion engines as well as a sound technical framework for understanding real world problems.

OBJECTIVE :

(i) Understand combustion in spark ignition and diesel engines.
(ii) To identify the nature and extent of the problem of pollutant formation and control in internal combustion engines government legislation.

UNIT – I COMBUSTION PRINCIPLES 8

Combustion – Combustion equations, heat of combustion - Theoretical flame temperature - chemical equilibrium and dissociation - Theories of Combustion - Pre-flame reactions - Reaction rates - Laminar and Turbulent Flame Propagation in Engines.

UNIT – II COMBUSTION IN S.I. ENGINE 12

Initiation of combustion, stages of combustion, normal and abnormal combustion, knocking combustion, pre-ignition, knock and engine variables, features and design consideration of combustion chambers. Flame structure and speed, Cycle by cycle variations, Lean burn combustion, stratified charge combustion systems. Heat release correlations. After treatment devices for SI engines.

UNIT – III COMBUSTION IN C.I. ENGINE 10

Stages of combustion, vaporization of fuel droplets and spray formation, air motion, swirl measurement, knock and engine variables, features and design considerations of combustion chambers, delay period correlations, heat release correlations, Influence of the injection system on combustion. Direct and indirect injection systems. Afer treatment devices for diesel enignes.

UNIT – IV COMBUSTION IN GAS TURBINES 5

Flame stability, re-circulation zone and requirements - Combustion chamber configuration, materials.

UNIT – V EMISSIONS 10

Main pollutants in engines, Kinetics of NO formation, NOx formation in SI and CI engines. Unburned hydrocarbons, sources, formation in SI and CI engines, Soot formation and oxidation, Particulates in diesel engines, Emission control measures for SI and CI engines, Effect of emissions on Environment and human beings.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. Ramalingam, K.K., Internal Combustion Engines, Scitech Publications (India) Pvt. Ltd., 2004.
2. Ganesan, V, Internal Combustion Engines, Tata McGraw Hill Book Co., 2003.
3. John B.Heywood, Internal Combustion Engine Fundamentals,McGraw Hill Book, 1998

REFERENCES :

1. Mathur,M.L., and Sharma,R.P., A Course in Internal Combustion Engines, Dhanpat Rai Publications Pvt. New Delhi-2, 1993.
2. Obert,E.F., Internal Combustion Engine and Air Pollution, International Text Book Publishers, 1983.
3. Cohen,H, Rogers,G,E.C, and Saravanamuttoo, H.I.H., Gas Turbine Theory, Longman Group Ltd., 1980.

IC 9115 I.C. ENGINES LAB

L	T	P	C
0	0	3	1

LIST OF EXPERIMENTS

1. Assembly of Engine and its Components
2. Performance, Combustion and Emission Studies on S.I. Engine fueled with alternative fuels
3. Performance, combustion and Emission Studies on C.I. Engines fueled with alternative fuels
4. Study on the effect of varying fuel injection pressure and fuel injection Timing on the engine Performance, Combustion and Emission
5. Study on the effect of preheating air and fuel on the Performance, Combustion and Emission characteristics
6. Study of construction and principle of operation of Emission/Smoke analysers

LABORATORY EQUIPMENTS EQUIREMENTS

1. S.I Engine Components
2. C.I Engine Components
3. Single/ Multicylinder S.I. Engine
4. Single/ Multicylinder C.I. Engine

5. HC/CO Analyser
6. NOx Analyser
7. Smoke Meter
8. Pressure Transducer
9. Charge Amplifier

TOTAL : 45 PERIODS

IC 9121	**ELECTRONIC ENGINE MANAGEMENT**	**L T P C**
		3 0 0 3

AIM:
To teach the students about the various sensors and engine management systems used in petrol and diesel engines

OBJECTIVE :
- To give an in-depth knowledge of various sensors used in engine management
- To give an overview of different types of fuel injection and ignition systems
- To know the latest technological advancements in vehicle power plant

UNIT – I ELECTRONICS 5
Semiconducters , Transistors, Amplifiers – Integrated circuits – Analog and Digital, Logic Gastes, Microcontrollers –Analog Digital / Digital Analog Converters.

UNIT – II SENSORS 8
Sensors for Air flow, Pressure, Temperature, Speed, Exhaust Oxygen, Knock and Position in engine management systems – Principle of operation, construction and characteristics.

UNIT – III GASOLINE INJECTION SYSTEM 12
Open loop and closed loop systems, Mono point, Multi point, Direct injection systems and Air assisted systems – Principles and Features, examples of Bosch injection systems. Idle speed, lambda, knock and spark timing control. Three way catalytic converters, Lean NOx converters.

UNIT – IV DIESEL INJECTION SYSTEM 10
Heat release in the diesel engine and need for control of fuel injection. Inline injection pump - Rotary Pump and injector– Construction and principle of operation, Electronic control of these pumps. Common rail and unit injector system – Construction and principle of operation,

UNIT – V IGNITION SYSTEMS 10
Ignition fundamentals, solid state ignition systems, high energy ignition distributors, Electronic spark timing and control. Combined ignition and fuel management systems. Dwell angle calculation, Ignition timing calculation.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. Robert N.Brady, Automotive Computers and Digital Instrumentation, Prentice Hall, 1988.
2. Bosch Technical Instruction Booklets.
3. Tom Denton, Automotive Electrical and Electronic Systems, Edward Amold, 1995.

REFERENCES :

1. Duffy Smith, Auto Fuel Systems, The Good Heart Willcox Company Inc., Publishers, 1987.
2. Gasoline Engine Management, Second Edition, Robert Bosch GmbH, 2004.
3. Engine Management, Second Edition, Robert Bosch GmbH, 1999.
4. Eric Chowaniety, Automobile Electronics, SAE Publications 1995.
5. William B. Ribbews, Understanding Automotive Electronics, Fifth Edition, SAE Publications1998.

IC 9122 INTERNAL COMBUSTION ENGINE DESIGN

L	T	P	C
3	0	0	3

AIM

To enrich knowledge of the students in the design of engine major components and other subsystems **.**

OBJECTIVE :

To gain knowledge on the principles and procedure for the design of engine components.

- To impart the knowledge on materials and other consideration for engine design.
- To provide knowledge on design of two stroke engines.
- To provide knowledge on design of pollution control equipments.

UNIT – I GENERAL CONSIDERATIONS IN ENGINE DESIGN 5

Principle of similitude, Choice of material, stress and fatigue considerations, design for manufacture, Noise, Vibration and Harshness.

UNIT – II DESIGN OF MAJOR COMPONENTS 12

Piston system, Power cylinder system, connecting rod assembly, crankshaft system, valve gearing, stress analyses.

UNIT – III DESIGN OF OTHER COMPONENTS / SUBSYSTEMS 16

Inlet and exhaust manifolds, cylinder block, cylinder-head, crankcase, engine foundations and mountings, gaskets, bearings, flywheel, turbocharger, supercharger, computer controlled fuel injection system, Basics of ignition, lubrication and cooling system design.

UNIT – IV DESIGN OF TWO-STROKE ENGINES 6

Arrangement and sizing of ports, piston assembly, intake and exhaust system, scavenging, application to automotive gasoline and marine diesel engines.

UNIT –V DESIGN OF POLLUTION CONTROL EQUIPMENT 6

Introduction to design of catalytic converters, particulate traps and EGR systems

UNIT – VI CONCEPTS OF COMPUTER AIDED DESIGN 5

Preparation of working drawings of designed components using CAD system.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. Gordon P.Blair, Basic Design of Two-stroke Engines, S.A.E., 1992.
2. Gordon P.Blair, Advanced Concepts of Two-stroke Engines, S.A.E., 1990.
3. Pounder, C.C., Marine Diesel Engines, Butterworths, 1981.

REFERENCES :

1. A.Kolchin and V.Demidov, Internal Combustion Engine Design, MIR Publishers, Moscow, 1984.
2. Gordon P.Blair, Design and Simulation of Four-Stroke Engines, Society of Automotive Engineers, Inc., USA, 1999.
3. D.E.Winterbone and R.J.Pearson, Design Techniques for Engine Manifolds, Wave action methods for I.C.Engines, Professional Engineering Publishing Ltd., UK, 2000.
4. John Fenton (Editor), Gasoline Engine Analysis for Computer Aided Design, Mechanical Engineering Publishing Ltd., UK, 1986.
5. Rodica Baranescu and Bernard Challen (Editors), Diesel Engine Reference Book, Second Edition, Society of Automotive Engineers, Inc., USA, 1999.
6. SAE Special Publication SP-700, Adiabatic Engines and Systems, Society of Automotive Engineers, Inc., USA, 1987.

IC 9123 INSTRUMENTATION FOR THERMAL SYSTEMS

L	T	P	C
3	0	0	3

AIM: To enhance the knowledge of the students about various measuring instruments, techniques and importance of error and uncertainty analysis.

OBJECTIVE :

(i) To provide knowledge on various measuring instruments.
(ii) To provide knowledge on advance measurement techniques.
(iii) To understand the various steps involved in error analysis and uncertainty analysis**.**

UNIT – I MEASUREMENT CHARACTERISTICS 12

Instrument Classification, Characteristics of Instruments – Static and dynamic, experimental error analysis, Systematic and random errors, Statistical analysis, Uncertainty, Experimental planning and selection of measuring instruments, Reliability of instruments.

UNIT – II MICROPROCESSORS AND COMPUTERS IN MEASUREMENT 5

Data logging and acquisition - use of sensors for error reduction, elements of micro-computer interfacing, intelligent instruments in use.

UNIT – III MEASUREMENT OF PHYSICAL QUANTITIES 10

Measurement of thermo-physical properties, instruments for measuring temperature, pressure and flow, use of sensors for physical variables.

UNIT – IV ADVANCE MEASUREMENT TECHNIQUES 8

Shadowgraph, Schlieren, Interferometer, Laser Doppler Anemometer, Hot wire Anemometer, heat flux sensors, Telemetry in measurement.

UNIT – V MEASUREMENT ANALYSERS 10

Orsat apparatus, Gas Analysers, Smoke meters, gas chromatography, spectrometry.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. Holman, J.P., Experimental methods for engineers, McGraw-Hill, 1988.
2. Barney, Intelligent Instrumentation, Prentice Hall of India, 1988.
3. Prebrashensky, V., Measurements and Instrumentation in Heat Engineering, Vol.1 and 2, MIR Publishers, 1980.

REFERENCES :

1. Raman, C.S., Sharma, G.R., Mani, V.S.V., Instrumentation Devices and Systems, Tata McGraw Hill, New Delhi, 1983.
2. Doeblin, Measurement System Application and Design, McGraw Hill, 1978.
3. Morris.A.S, Principles of Measurements and Instrumentation, Prentice Hall of India, 1998.

IC 9150 AUTOMOTIVE ENGINE SYSTEMS

L	T	P	C
3	0	0	3

AIM: To develop the knowledge of students in various systems of automotive engines.

OBJECTIVE:

(i) To impart knowledge on various automotive engine types and its performance characteristics**.**
(ii) To impart knowledge on fuel and fuel systems.
(iii) To impart knowledge on current trends in engine technology.

UNIT – I TYPES AND CHARACTERISTICS 10

Automotive Engine Types – On-highway, Off-highway, Gasoline, Diesel and Alternate Fueled. Characteristics of Automotive Engines – Power, Torque, Fuel Consumption, Pollutant Emissions, Thermal Efficiency, Life Cycle Cost.

UNIT – II FUEL SYSTEMS 10

Carburetion, fixed venturi and variable venturi and constant vacuum types, Gasoline Injection – TBI, MPFI, GDI and Air-assisted Injection, Engine Management System, Catalytic Conversion of Engine Pollutants, Electrical Catalyst Heaters, Common rail injection, Diesel Particulate Trapping and Trap Regeneration, Gaseous Fuel Injection, Lean NOx catalysts, SCR systems, Dual and Bifueling and Controls.

UNIT – III FUELS 5

Fuel – Quality standards for Automotive Engines – Lead free gasoline, low and ultra – low sulphur diesels, LPG, CNG, Alcohols, Biodiesels, FT diesels, hydrogen.

UNIT – IV COMBUSTION CHAMBERS AND EMISSIONS 5

Ignition, Combustion and knock in SI and CI engines, Control of combustion in SI and CI engines, Importance of control of parameters. Combustion chambers. Emission formation in SI and CI engines. Lean burn, GDI and HCCI systems

UNIT – V DEVELOPMENT TRENDS 15

Current trends in engine technology - Multi-valving, Tuned manifolding, camless valve gearing, variable valve timing, Turbo and supercharging. EGR, Part-load charge stratification in GDI systems, Current materials and production processes for engine components, TS 16949 Certification, performance testing of automotive engines, parasitic losses, standard codes of testing automotive engine components and assemblies, Hybrid electric vehicular piston engines and their characteristics.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. Robert Bosch, GmbH, Automotive Hand Book, Germany, 2000.
2. Tom Denton, Automobile Electrical and Electronic Systems, SAE International USA, 2000.
3. Eric Chowanietz, Automobile Electronics, SAE International, 1995.

REFERENCES :

1. SAE Inc., Advanced Power Plant Concepts, SP – 1325, 1998.
2. Michael Plint and Anthony Martyr, Engine testing Theory and Practice (Second Edition) SAE International, 1999.
3. SAE Inc, Advancements in Electric and Hybrid Electric Vehicle Technology, SP – 1023, 994.

IC 9151 ENGINE POLLUTION AND CONTROL

L	T	P	C
3	0	0	3

AIM

1. To educate the students about pollution formation in engines, and its control.
2. To educate the ways and means to protect the environment from various types of Pollution.

OBJECTIVE :

(i) To create an awareness on the various environmental pollution aspects and issues.
(ii) To give a comprehensive insight into the pollution in engine and gas turbines.
(iii) To impart knowledge on pollutant formation and control.
(iv) To impart knowledge on various emission instruments and techniques.

UNIT – I POLLUTION - ENGINES AND TURBINES 6

Atmospheric pollution from Automotive and Stationary engines and gas turbines, Global warming – Green house effect and effects of I.C. Engine pollution on environment.

UNIT – II POLLUTANT FORMATION 12

Formation of oxides of nitrogen, carbon monoxide, hydrocarbon, aldehydes and Smoke, Particulate emission. Effects of Engine Design - operating variables on Emission formation – Noise pollution.

UNIT – III EMISSION MEASUREMENT 8

Non dispersive infrared gas analyzer, gas chromatography, chemiluminescent analyzer and flame ionization detector, smoke meters – Noise measurement and control

UNIT – IV EMISSION CONTROL 14

Engine Design modifications, fuel modification, evaporative emission control, EGR, air injection, thermal reactors, Water Injection, catalytic converters, application of microprocessor in emission control. Common rail injection system, Particulate traps, NOx converters, SCR systems. GDI and HCCI concepts.

UNIT – V DRIVING CYCLES AND EMISSION STANDARDS 8

Transient dynamometer, Test cells, Driving cycles for emission measurement, chassis dynamometer, CVS system, National and International emission standards.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. Heywood
2. Henien and Patterson
3. Engine emissions by B P Pundir

REFERENCES :

1. Crouse William, Automotive Emission Control, Gregg Division /McGraw-Hill,1980
2. Ernest,S., Starkman, Combustion Generated Air Pollutions, Plenum Press, 1980.
3. George Springer and Donald J.Patterson, Engine emissions, Pollutant Formation and Measurement, Plenum press, 1972.
4. Obert, E.F., Internal Combustion Engines and Air Pollution, Intext Educational Publishers, 1980.

IC 9152 ENGINE AUXILLARY SYSTEMS

L	T	P	C
3	0	0	3

AIM

This course aims to impart the knowledge about carburetion, gasoline and diesel fuel injection, lubrication and cooling systems.

OBJECTIVE:

(i) To provide knowledge on carburetion.
(ii) To provide knowledge Gasoline and diesel fuel injection systems
(iii) To provide knowledge on engine manifolds, lubrication and cooling systems.

UNIT – I CARBURETION 10

Gasoline - air mixtures. Mixture requirements - Mixture formation - Carburetor, Chokes, Effect of altitude on carburation. Carburator systems for emission control.

UNIT – II GASOLINE INJECTION AND IGNITION SYSTEMS 8

Petrol Injection, Pneumatic and Electronic Fuel Injection Systems, Ignition systems-requirements, Timing Systems, breaker mechanism. Energy requirement, Spark plug operation, Electronic Ignition Systems.

UNIT – III DIESEL FUEL INJECTION 8

Atomization, penetration and dispersion, Rate and duration of injection, Fuel line hydraulics, Fuel pump, Injectors. Governors.

UNIT – IV MANIFOLDS AND MIXTURE DISTRIBUTION 8

Intake system components, Air filter, Intake manifold, Exhaust system components, Exhaust manifold and exhaust pipe, Spark arresters, Exhaust mufflers.

UNIT – V LUBRICATION AND COOLING SYSTEMS 10

Lubricants, lubricating systems, Lubrication of piston rings, bearings, oil consumption, Oil cooling - Heat transfer coefficients, liquid and air cooled engines, additives and lubricity improvers.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. Ramalingam,K.K, Internal Combustion Engine, Scitech Publication (India) Pvt.Ltd.2004.
2. Domkundwar, V.M, A Course in Internal Combustion Engines, Dhanpat Rai and Co., 1999.
3. Mathur,M.L., and Sharma,R.P., A Course in Internal Combustion Engines, Dhanpat Rai Publications (P) Ltd., 1998.

REFERENCES :

1. Ganesan, V., Internal Combustion Engines, Tata McGraw-Hill Book Co., 1995.
2. Duffy Smith, Auto Fuel Sytstems, The Good Heart Willcox Company Inc., Publishers, 1987.

IC 9153 GAS TURBINE POWER PLANTS

L	T	P	C
3	0	0	3

OBJECTIVE

To learn the working principle, operations and analysis of gas turbine power plant cycle, components selection or matching.

UNIT – I GAS TURBINE CYCLES 10

Gas turbine cycles – Air Standard Analysis, Different configurations – Re-heater, Intercooler, Heat Exchanger; Component behaviour.

UNIT – II AXIAL FLOW COMPRESSORS 9

Momentum and energy transfer in rotors - Velocity triangles - Stage performance - Degree of reaction - Three-dimensional analysis - Cascade testing - Compressor characteristic curves – Howell's Correlation - Surging and stalling.

UNIT – III AXIAL FLOW TURBINES 8

Stage velocity triangles - impulse and reaction turbines, losses and co-efficient - blade design principles - three-dimensional analysis - testing and performance characteristics – Compounding methods - blade cooling.

UNIT – IV CENTRIFUGAL COMPRESSORS AND RADIAL TURBINES 10

Construction and working principle - velocity triangles - backward, forward and radially swept blades - losses and coefficients- performance characteristics.

Types of inward flow radial (IFR) turbine – velocity triangles – thermodynamics of the 90^0 IFR turbine – optimum design solution of 90^0 IFR turbines – stage losses – performance characteristics.

UNIT – V COMBUSTORS 8

Different types – Annular, Can-annular types - Flow pattern - Cooling methods - Material requirement – Gas turbine pollution and its reduction.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. Cohen, H., Rogers, G.E.C., and Saravanamuttoo, H.I.H., Gas Turbine Theory, Longman Group Ltd, 1989.
2. Gordon C, Dates, Aero-thermodynamics of Gas Turbine and Rocket Propulsion – AIAA Education Series, NY 1984.
3. Kerrebrock, J.L., Aircraft engines and gas turbines, The MIT Press.

REFERENCES:

1. Yahya, S.M., Turbines, Compressors and Fans, Tata McGraw-Hill, 1983.
2. Earl Logan, Jr., Hand book of Turbomachinery, Marcel Dekker, Inc., USA, 1992
3. Dixon, S.L., Fluid Mechanics and Thermodynamics of Turbomachinery, Pergamon Press, 1978.
4. Ganesan, V., Gas Turbines, Tata McGraw-Hill Pub.Co.Ltd., New Delhi, 1999.

IC9154 SPACE PROPULSION L T P C
3 0 0 3

AIM :

OBJECTIVE: To gain insight on the working principle of rocket engines, different feed systems, propellants and their properties and dynamics of rockets.

UNIT – I GAS DYNAMICS 8

Wave motion - Compressible fluid flow through variable area devices – Stagnation state and properties – Normal shock and oblique shock waves – Rayleigh and Fanno Flow.

UNIT - II THERMODYNAMICS OF AIRCRAFT ENGINES 9

Theory of Aircraft propulsion – Thrust – Various efficiencies – Different propulsion systems – Turboprop – Ram Jet – Turbojet, Turbojet with after burner, Turbo fan and Turbo shaft.

UNIT – III PERFORMANCE CHARACTERISTICS OF AIRCRAFT ENGINES 9

Engine - Aircraft matching – Design of inlets and nozzles – Performance characteristics of Ramjet, Turbojet, Scramjet and Turbofan engines.

UNIT – IV ROCKET PROPULSION 9

Theory of rocket propulsion – Rocket equations – Escape and Orbital velocity – Multi-staging of Rockets – Space missions – Performance characteristics – Losses and efficiencies.

UNIT – V ROCKET THRUST CHAMBER 10

Combustion in solid and liquid propellant rockets – Classification of propellants and Propellant Injection systems – Non-equilibrium expansion and supersonic combustion – Propellant feed systems – Reaction Control Systems - Rocket heat transfer.

TOTAL 45 PERIODS

TEXT BOOKS

1. Philip G. Hill and Carl R.Peterson, Mechanics and Thermodynamics of Propulsion, Second Edition, Addition – Wesley Publishing Company, New York, 1992.
2. Zucrow N.J. Principles of Jet Propulsion and Gas Turbines, John Wiley and Sons Inc, New York, 1970.
3. Zucrow N.J. Aircraft and Missile Propulsion , Vol. I and Vol. II, John Wiley and Sons Inc, New York, 1975.

REFERENCES :

1. Bonney E.A. Zucrow N.J. Principles of Guided Missile Design, Van Nostranc Co., 1985.
2. S.M.Yahya, Fundamentals of Compressible Flow.

IC 9155 MATERIALS, MANUFACTURING AND TESTING OF ENGINES

L	T	P	C
3	0	0	3

AIM :

To know the engine materials, manufacturing methodology and testing methodology.

OBJECTIVE :

To provide knowledge on engine materials, manufacturing and testing of engine components.

UNIT – I MATERIALS 7

Selection – types of Materials – Ferrous – Carbon and Low Alloy steels, High Alloy Steels, Cast Irons – Non Ferrous – Aluminium, Magnesium, Titanium, Copper and Nickel alloys.

UNIT – II ENGINE COMPONENTS 15

Cylinder Block, Cylinder Head, Crankcase and Manifolds, Piston Assembly, Connecting Rod, Crankshaft, Camshaft And Valve Train - Production methods – Casting, Forging, Powder Metallurgy – Machining – Testing Methods.

UNIT – III ENGINE AUXILIARIES 7

Carburettors, fuel injection system components, radiators, fans, coolant pumps, ignition System.

UNIT – IV COMPUTER INTEGRATED MANUFACTURING 7

Integration of CAD, CAM and CIM- Networking, CNC programming for machining of Engine Components.

UNIT – V QUALITY AND TESTING 9

TS 16949, BIS codes for testing. Instrumentation, computer aided engine testing, metrology for manufacturing Engine Components.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. Grover, M.P., CAD/CAM, Prentice Hall of India Ltd., 1985.
2. Heldt, P.M., High speed internal combustion engines, Oxford & IBH Publishing Co., 1960.
3. Judge, A.W., Testing of high speed internal combustion engines, Chapman & Hall., 1960.

REFERENCES :

1. Richard, W., Heine Carl R. Loper Jr. and Philip, C., Rosenthal, Principles of Metal Casting, McGraw-Hill Book Co., 1980.
2. IS: 1602 – 1960 Code for testing of variable speed internal Combustion engines for Automobile Purposes, 1966.
3. SAE Handbook, 1994.
4. P.Radhakrishnan and S.Subramaniyan, CAD/CAM/CIM, New Age International (P) Limited, Publishers, 1997.
5. Mikett P.Groover, Automation, production Systems and Computer – Integrated Manufacturing Printice Hall of India Private Limited, 1999.

IC 9156 MARINE DIESEL ENGINES

L	T	P	C
3	0	0	3

AIM

To educate the students about the marine engines, its instrumentation and propulsion systems.

OBJECTIVE

To understand the marine engine fundamentals and mechanics in better way.

UNIT – I ENGINE FUNDAMENTALS 10

Engine Operation; Operating Cycles; Performance factors; Supercharging and Scavenging Systems for two stroke and four stroke cycle engines, Submarine Engine Systems, Fuels and Lubricants, Engine Pollution and Control.

UNIT – II MECHANICS 10

Dynamics of crank gear, Engine Vibration, Design, Engine Systems, Speed governors and Accessory equipments.

UNIT – III INSTRUMENTATION AND CONTROL 10

Automatic instruments and remote control of marine engines, Testing - Standard codes - Rating.

UNIT – IV TYPICAL MODERN MARINE PROPULSION ENGINE SYSTEMS 5

M.A.N, B & W, Pielstick etc.

UNIT – V AUXILIARY SYSTEMS 10

Starting and reversing gears, Fuel systems, cooling system and Lubrication system.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. John Lamb, The Running and Maintenance of the Marine Diesel Engine, Charles Griffin and Company Ltd., U.K., (Sixth Edition), 1976.
2 C.C. Pounder, Marine Diesel Engines, Newnes – Butterworths, UK, (Fifth Edition), 1981.
3. N. Petrovsky, Marine Internal Combustion Engines, Translation from Russian by Horace E Isakson, MIR Publishers, Mascow,1974.

REFERENCES :

1. Doug Woodyard (Editor), Pounder's Marine Diesel Engines, Butterworth-Heinemann,UK (Seventh Edition), 1998
2. C.T.Wilbur and D.A.Wight, Pounder's Marine Diesel Engines, Butterworth-Heinemann,UK (Sixth Edition), 1991.
3. George H.Clark, Industrial and Marine Fuels Reference Book, Butterworth-and Company,(Publishers) Ltd. U.K., 1998.

IC 9157 SIMULATION OF I.C. ENGINE PROCESSES

L	T	P	C
3	0	0	3

AIM : To impart knowledge on simulation of various I.C engine processes.

OBJECTIVE : To learn the simulation of engine combustion based on first and second law of thermodynamics**.**

UNIT – I INTRODUCTION 5

First and second laws of thermodynamics – Estimation of properties of gas mixtures - Structure of engine models – Open and closed cycle models - Cycle studies

UNIT – II SIMULATION PRINCIPLES 8

Chemical Reactions, First law application to combustion, Heat of combustion – Adiabatic flame temperature, Chemical Equilibrium and calculation of equilibrium composition - – Heat transfer in engines – Heat transfer models for engines.

UNIT – III SIMULATION OF COMBUSTION IN SI ENGINES 12

Combustion in SI engines, Flame propagation and velocity, Single zone models – Multi zone models – Mass burning rate, Turbulence models – One dimensional models – Chemical kinetics modeling – Multidimensional models.

UNIT – IV SIMULATION OF COMBUSTION IN CI ENGINES 12

Combustion in CI engines Single zone models – Premixed-Diffusive models – Wiebe' model – Whitehouse way model, Two zone models - Multizone models- Meguerdichian and Watson's model, Hiroyasu's model, Lyn's model – Introduction to Multidimensional and spray modeling

UNIT – V SIMULATION AND GAS EXCHANGE PROCESSES AND ENGINE FRICTION 10

Thermodynamics of the gas exchange process - Flows in engine manifolds – One dimensional and multidimensional models, Flow around valves and through ports Models for scavenging in two stroke engines – Isothermal and non-isothermal models.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. Ashley S. Campbell, Thermodynamic Analysis of Combustion Engines, John Wiley and Sons, 1980.
2. V.Ganesan, Computer Simulation of Spark Ignition Engine Processes, Universities Press, 1995.

References

1. Ashley S. Campbell, Thermodynamic Analysis of Combustion Engines, John Wiley and Sons, 1980.
2. V.Ganesan, Computer Simulation of Spark Ignition Engine Processes, Universities Press, 1995.
3. V.Ganesan, Computer Simulation of Compression Ignition Engine Processes, Universities Press, 2002.
4. Gordon P. Blair, The Basic Design of two-Stroke engines, SAE Publications, 1990.
5. Horlock and Winterbone, The Thermodynamics and Gas Dynamics of Internal Combustion Engines, Vol. I & II, Clarendon Press, 1986.
6. J.I.Ramos, Internal Combustion Engine Modeling, Hemisphere Publishing
7. Corporation, 1989.
8. J.N.Mattavi and C.A.Amann, Combustion Modeling in Reciprocating Engines, Plenum Press, 1980.

IC 9158 SPECIALITY ENGINES

L	T	P	C
3	0	0	3

AIM

To develop the knowledge of students on various engine systems and its special application**.**

OBJECTIVE:

(i) To provide knowledge on SI and CI engine systems.
(ii) To introduce special applications of engines.
(iii) To impart knowledge of lifecycle analyses of engine systems.

UNIT – I INTRODUCTION 10

Design features of Automotive, Locomotive, Marine, Stationary and Generator-set engines.

UNIT – II S.I. ENGINE SYSTEMS 10

Spark ignition engine system variants – Stoichiometric, Lean-burn, port injected/direct injected, carburetted, Air assisted fuel injection engines, HEV Engines. Illustrations – Honda CVCC, Toyota Prius, Orbital Engine etc. Rotary Piston Engines, Dedicated alternative fueled engine systems – CNG, LPG, H_2, Alcohols, Stirling cyle.

UNIT – III C.I. ENGINE SYSTEMS 10

Compression ignition engine system variants – Low, Medium and High speed system characteristics, High pressure fuel injection systems, Homogeneous Charge Compression Ignition systems, Dual and dedicated alternate fueled engine systems, coal and producer gas fueled engine systems, CNG & Landfill gas engine systems, cogeneration system, Total energy engine systems.

UNIT – IV SPECIAL PURPOSE ENGINE SYSTEMS 10

Engines for special applications –Mining Defence, Off-highway – Tractor, Bulldozer etc. Submarines, Race car engine systems, Flexible fueled system, Electric power plant engine systems.

UNIT – V LIFE CYCLE ANALYSES OF ENGINE SYSTEMS 5

Life cycle cost.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. The Wankel Engine, Design, Development, Application,Jan P.Norbye, Chilton Book Company, USA,1971.
2. Introduction to Internal Combustion Engines, Richard Stone, Third Edition, Society of Automotive Engineers, Inc,USA, 1999.
3. Diesel Engine Reference Book, Bernard Challen and Rodica Baranescu (Editors) 2nd Edition, R – 183, SAE International , 1999.

REFERENCES :

1. Some Unusual Engines, L.J.K. Setright, Mechanical Engineering Publication Ltd., UK, 1975.
2. The Wankel R C Engine, R.F.Ansdale, A.S.Barnes & Co.,USA, 1969.
3. Bosch Technical Instruction Booklets, Robert Bosch GmbH, Germany, 1985.

IC 9159 SUPERCHARGING AND SCAVENGING

L	T	P	C
3	0	0	3

AIM

To gain knowledge in the field of turbo charging, supercharging and scavenging.

OBJECTIVE

To understand the supercharging and turbocharging effect on I.C engine performance and emissions. Scavegnging of two stroke engines and design aspects of muffler and port design.

UNIT – I SUPERCHARGING 8

Definition and Engine – modification required. Effects on Engine performance - Thermodynamics Mechanical Supercharging. Types of compressors – Positive displacement blowers – Centrifugal compressors – Performance characteristic curves – Suitability for engine application – Matching of supercharger compressor and Engine.

UNIT – II TURBOCHARGING 8

Turbocharging – Turbocharging methods - Thermodynamics – Engine exhaust manifolds arrangements. – Waste gate, Variable nozzle turbochargers, Variable Geometry Turbocharging – Surging - Matching of compressor, Turbine and Engine.

UNIT – III SCAVENGING OF TWO STROKE ENGINES 12

Features of two stroke cycle engines – Classification of scavenging systems – Charging Processes in two stroke cycle engine – Terminologies – Sankey diagram – Relation between scavenging terms – scavenging modeling – Perfect displacement, Perfect mixing – scavenging models. Mixture control through Reed valve induction.

UNIT – IV PORTS AND MUFFLER DESIGN 8

Porting – Port flow characteristics-Design considerations – Design of Intake and Exhaust Systems – Tuning- Kadenacy system.

UNIT – V EXPERIMENTAL METHODS AND RECENT TRENDS IN TWO STROKE ENGINES 7

Experimental techniques for evaluating scavenging – Firing engine tests – Non firing engine tests —– Development in two stroke engines for improving scavenging. Direct injection two stroke concepts.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. R.S. Benson and N.D. White house, Internal Combustion engines, First edition, Pergamon press, 1979.
2. John B.Heywood, Two Stroke Cycle Engine, SAE Publications, 1997.
3. Schweitzer, P.H., Scavenging of Two Stroke Cycle Diesel Engine, MacMillan Co.,

REFERENCES :

1. G P Blair, Two stroke Cycle Engines Design and Simulation, SAE Publications, 1997.
2. Heinz Heisler, Advanced Engine Techology, Butterworth Heinmann Publishers, 2002.
3. Obert, E.F., Internal Combustion Engines and Air Pollution, Intext Educational Publishers, 1980.Richard Stone, Internal Combustion Engines, SAE, 1992.
4. Vincent,E.T., Supercharging the I.C.Engines, McGraw-Hill.
6. Watson, N. and Janota, M.S., Turbocharging the I.C.Engine, MacMillan Co., 1982.
7. Gordon Blair, Design and Simulation of Two-Stroke Engines.

IC 9160 HYDROGEN AS A FUEL IN I.C. ENGINES

L	T	P	C
3	0	0	3

AIM

To educate the students about the use of hydrogen fuel in I.C engines

OBJECTIVE

To know the use of hydrogen and its role in combustion, performance and emissions in I.C engines.

UNIT – I INTRODUCTION 8

Need, Properties, Pollution, Emission standards, World and Indian Scenario.

UNIT – II PRODUCTION AND STORAGE, SAFETY AND DISTRIBUTION 13

Production Methods – Electrolysis, Steam Reformation and Renewable Energy - Storage Methods - Gaseous, Liquid and Metal Hydrides- Safety aspects and devices - Distribution Types, Hydrogen Refueling Methods.

UNIT – III HYDROGEN IN S.I. ENGINE SYSTEM 8

Engine Modifications, Combustion Characteristics – Dual Fueling, Direct Injection of Gaseous and Liquefied Hydrogen.

UNIT – IV HYDROGEN IN C.I. ENGINE SYSTEM 8

Engine Modification & Combustion Characteristics - Direct Injection – Gaseous and Liquified Hydrogen, Dual Fuel Mode, Hydrogen Enrichment.

UNIT – V RECENT ADVANCES 8

Hybrid Electric Vehicle - On Board Generation and Storage of Hydrogen - Proton Exchange Membrane Fuel Cells.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. International Journal of Hydrogen Energy.
2. Alternative Fuels SP-480, SAE, Feb. 1981, SAE, ISBN O – 89883 – 251-9 , SAE / SP-81 / 480.
3. Alternative Fuels (A decade of success and Promise) edited by Reda Moh.Bata, SAE PT-48, ISBN 1-56091 – 593 – 5.

REFERENCES:

1. Osamu Hirao and Richard K. Pefley, Present and future Automotive Fuels, John Wiley and Sons, 1988.
2. Keith Owen and Trevor Eoley, Automotive Fuels Handbook, SAE Publications, 1990.
3. Richard L. Bechtold, Automotive Fuels Guide Book, SAE Publications, 1997.

IC 9161 FLUID FLOW AND HEAT TRANSFER L T P C
3 0 0 3

OBJECTIVE: To visualize fluid flow in an IC engine, aspects of heat transfer and cooling of components.

UNIT – I INTRODUCTION 9

Basics Laws, Newtonian Fluids, Navier – Stokes Equations, Compressible and Incompressible Flows, Stream Functions and velocity Potential, Vorticity Dynamics.

UNIT – II LOW AND HIGH REYNOLDS NUMBER FLOWS 9

Ideal flows and Boundary layers, Flows at Moderate Reynolds Numbers, Characteristics of High – Reynolds Number Flow, Ideal Flows in a plane, Axi-symmetric and Three dimensional Ideal Flows and Boundary Layers, Low Reynolds Numbers Flows.

UNIT- IV LUBRICATION,SURFACETENSION EFFECTS, MICROSCALE EFFECTS 5

Lubrication approximation, Surface Tension effects, Microscale effects.

UNIT – V COMPRESSIBLE FLOW 10

One dimensional compressible Gas flow, Isentropic Gas Relations, Compressible Flow in Nozzles, Area – velocity Relations, Converging – Diverging Nozzle, Effects of viscous friction and Heat Transfer – Introduction to Multi Dimensional flow.

UNIT – V CONVECTIVE HEAT TRANSFER – MASS TRANSFER AND HEAT TRANSFER IN POROUS MEDIA 12

Convective Heat Transfer – Parallel Flow (Hagen – Poiseuille Flow), Couette Flow, Sudden acceleration of a Flat Plate, Creeping flow, Mass transfer Diffusion and Convection, combined Heat and Mass Transfer, Heat transfer in Porous Media.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. Ronald L. Panton, Incompressible flow, 3rd Edition, Wiley, 2005.
2. K. Muralidhar and G. Biswas, Advanced Engg. Fluid Mechanics, Narosa Publishing House, 1999.
3. Frank M. White, Fluid Mechanics, 4th Edition McGraw Hill, 1999.

REFERENCES :

1. Frank M. White, Viscous Fluid Flow, 2nd Edition, McGraw Hill, 1991.
2. I.G. Currie, Fundamental Mechanics of fluids, 2nd Edition, McGraw Hill 1993.
3. F.P. Incropera and B. Lavine, Fundamentals of Heat and Mass Transfer, 6th Edition, Willey, 2006.
4. J. Welty, C. Wicks, Fundamentals of Momentum, Heat and Mass Transfer, 4th Edition, Wiley 2000.
5. R. Wilson and G. Rorrer, Rehsenow and Choi, Heat and Mass Momentum Transfer, Prentice Hall, 1980.

IC 9162 COMPUTATIONAL FLUID DYNAMICS

L	T	P	C
3	0	0	3

AIM

This course aims to introduce numerical modeling and its role in the field of heat and fluid flow, it will enable the students to understand the various discretisation methods and solving methodologies and to create confidence to solve complex problems in the field of heat transfer and fluid dynamics.

OBJECTIVE :

(i) To develop finite difference and finite volume discretized forms of the CFD equations.

(ii) To formulate explicit & implicit algorithms for solving the Euler Eqns & Navier
Stokes Eqns.

UNIT – I GOVERNING DIFFERENTIAL EQUATION AND FINITE DIFFERENCE METHOD 10

Classification, Initial and Boundary conditions – Initial and Boundary Value problems – Finite difference method, Central, Forward, Backward difference, Uniform and non-uniform Grids, Numerical Errors, Grid Independence Test.

UNIT – II CONDUCTION HEAT TRANSFER 10

Steady one-dimensional conduction, Two and three dimensional steady state problems, Transient one-dimensional problem, Two-dimensional Transient Problems.

UNIT – III INCOMPRESSIBLE FLUID FLOW 10

Governing Equations, Stream Function – Verticity method, Determination of pressure for viscous flow, SIMPLE Procedure of Patankar and Spalding, Computation of Boundary layer flow, finite difference approach.

UNIT – IV CONVECTION HEAT TRANSFER AND FEM 10

Steady One-Dimensional and Two-Dimensional Convection – diffusion, Unsteady one-dimensional convection – diffusion, Unsteady two-dimensional convection – Diffusion – Introduction to finite element method – solution of steady heat conduction by FEM – Incompressible flow – simulation by FEM.

UNIT – V TURBULENCE MODELS 5

Algebraic Models – One equation model, K – ϵ Models, Standard and High and Low Reynolds number models, Prediction of fluid flow and heat transfer using standard codes.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. Muralidhar, K., and Sundararajan, T., "Computational Fluid Flow and Heat Transfer", Narosa Publishing House, New Delhi, 1995.
2. Ghoshdasdidar, P.S., "Computer Simulation of flow and heat transfer" Tata McGraw-Hill Publishing Company Ltd., 1998.
3. Subas, V.Patankar "Numerical heat transfer fluid flow", Hemisphere Publishing Corporation, 1980.

REFERENCES :

1. Taylor, C and Hughes, J.B. "Finite Element Programming of the Navier-Stokes Equation", Pineridge Press Limited, U.K., 1981.
2. Anderson, D.A., Tannehill, J.I., and Pletcher, R.H., "Computational fluid Mechanics and Heat Transfer " Hemisphere Publishing Corporation, New York, USA,1984.
3. Fletcher, C.A.J. "Computational Techniques for Fluid Dynamics 1" Fundamental and General Techniques, Springer – Verlag, 1987.
4. Fletcher, C.A.J. "Computational Techniques for fluid Dynamics 2" Specific Techniques for Different Flow Categories, Springer – Verlag, 1987.
5. Bose, T.X., "Numerical Fluid Dynamics" Narosa Publishing House, 1997.

IC 9163 FLOW VISUALISATION TECHNIQUES FOR I.C. ENGINE FLOW PROCESSES

L	T	P	C
3	0	0	3

AIM :

OBJECTIVE :

UNIT – I INSTRUMENTATION FOR FLOW VISUALIZATION 9

Schilieren photography – Laser Velocimeter – Illuminated Particle Visualisation Hollography – Particle Image velocitymetry.

UNIT – II FLOW VISUALIZATION OF INTAKE PROCESS 9

Engine optical access, Design of optical engine, Thermal properties of materials used for optical engine, processing of materials – Optical techniques.

UNIT – III IN-CYLINDER FLOW 9

Visual Experiment of In-cylinder flow by Laser sheet method. Intake flow visualization by light colour layer examination of principle and photographic measurement techniques.

UNIT – IV COMBUSTION VISUALIZATION 9

Endoscopes, Advanced cameras, Fiber Optic Tools, Laser diagnostics of Flames.

UNIT – V NUMERICAL FLOW VISUALIZATION 9

Direct, Geometric and texture based flow visualization, Dense Geometric Flow visualization – Surface flow visualisation.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. V. Ganesan, Internal Combustion Engines, Tata McGraw Hill Book Co., 1995.
2. J.P. Holman, Experimental Methods for Engineers, McGraw – Hill Inc., 1994.
3. Wolfgang Merzkirch, Flow Visualisation, 2nd Edition, Academic Press, 1987.

REFERENCES:

1. Marshall B. Long, Optical Methods in flow and Particle Diagnosis, Society of Photo Optics, 1989.
2. B.H. Lakshmana Gowda, A Kaleidoscopic view of Fluid Flow Phenomena, Wiley Eastern, 1992.
3. Will Schroeder, Ken Martin and Bill Lorensen, An Object – Oriented Approach to 3D Graphics, 2nd Edition, Prentice Hall, 1998.

IC 9164 ELECTRIC AND HYBRID VEHICLES L T P C
3 0 0 3

AIM :

OBJECTIVE: To understand working of different configurations of electric vehicles, and its components, hybrid vehicle configuration and performance analysis.

UNIT – I ELECTRIC VEHICLES 6

Introduction, Components, vehicle mechanics – Roadway fundamentals, vehicle kinetics, Dynamics of vehicle motion - Propulsion System Design.

UNIT – II BATTERY 7

Basics – Types, Parameters – Capacity, Discharge rate, State of charge, state of Discharge, Depth of Discharge, Technical characteristics, Battery pack Design, Properties of Batteries.

UNIT – III DC & AC ELECTRICAL MACHINES 8

Motor and Engine rating, Requirements, DC machines , Three phase A/c machines, Induction machines, permanent magnet machines, switched reluctance machines.

UNIT – IV ELECTRIC VEHICLE DRIVE TRAIN 12

Transmission configuration, Components – gears, differential, clutch, brakes regenerative braking, motor sizing.

UNIT – V HYBRID ELECTRIC VEHICLES 12

Types – series, parallel and series, parallel configuration – Design – Drive train, sizing of components

TOTAL : 45 PERIODS

REFERENCES :

1. Iqbal Hussain, Electric & Hybrid Vechicles – Design Fundamentals, CRC Press.
2. Rand D.A.J, Woods, R & Dell RM Batteries for Electric vehicles.

IC 9165 BOUNDARY LAYER THEORY AND TURBULENCE L T P C
3 0 0 3

AIM:

OBJECTIVE

To understand the theory of turbulent flow and its modeling, structure types and a detailed insight about turbulence.

UNIT – I FUNDAMENTALS OF BOUNDARY – LAYER THEORY 9

Boundary – Layer Concept, Laminar Boundary Layer on a Flat Plate at zero incidence, Turbulent Boundary Layer on a Flat plate at zero incidence, Fully Developed Turbulent Flow in a pipe, Boundary Layer on an airfoil, Boundary Layer separation.

UNIT – II TURBULENT BOUNDARY LAYERS 9

Internal Flows – Couette flow – Two-Layer Structure of the velocity Field – Universal Laws of the wall – Friction law – Fully developed Internal flows – Channel Flow, Couettee – Poiseuille flows, Pipe Flow.

UNIT – III TURBULENCE AND TURBULENCE MODELS 9

Nature of turbulence – Averaging Procedures – Characteristics of Turbulent Flows – Types of Turbulent Flows – Scales of Turbulence, Prandtl's Mixing length, Two-Equation Models, Low – Reynolds – Number Models, Large – Eddy Simulation.

UNIT – IV STATISTICAL THEORY OF TURBULENCE 9

Ensemble Average – Isotropic Turbulence and Homogeneous Turbulence – Kinematics of Isotropic Turbulence – Taylor's Hypothesis – Dynamics of Isotropic Turbulence -Grid Turbulence and decay – Turbulence in Stirred Tanks.

UNIT – V TURBULENT FLOWS 9

Wall Turbulent shear flows – Structure of wall flow – Turbulence characteristics. of Boundary layer – Free Turbulence shear flows – Jets and wakes – Plane and axi-symmetric flows.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. G. Biswas and E. Eswaran, Turbulent Flows, Fundamentals, Experiments and Modelling,Narosa Publishing House, 2002.
2. H. Schlichting and Klaus Gersten, Boundary Layer Theory, Springer 2000.
3. R.J. Garde,Turbulent Flow, New Age International (p) Limited, Publishers, 2000.

REFERENCES :

1. N. Rajaratnam, Turbulent Jets, Elsevier Scientific Publishing Company, 1976.

IC 9166 MICRO ELECTRONICS APPLICATIONS IN I.C. ENGINES L T P C
3 0 0 3

AIM:

OBJECTIVE: To gain insight about basic electronics devices, their working and application in I.C engines.

UNIT – I INTRODUCTION 6

Analog systems – Characteristics of digital Electronic System – electronic System performance – Signal processing - Digital Signal Processing – Analog Signal processing.

UNIT – II CONTROL SYSTEM 8

Open loop Control – closed loop control – proportional Controller – proportional integral controller – proportional integral differential controller – closed loop limit cycle control.

UNIT – III MICROELECTRONIC FUNDAMENTALS 11

Semi Conductor devices – diodes – Rectifier circuit – Transistors – Transistor model – Transistor amplifiers – operational amplifiers – Digital Circuits – Binary number system – Logic circuits (combinatorial) Logic circuits with memory (Sequential) – Integrated circuits.

UNIT – IV MICRO COMPUTER INSTRUMENTATION AND CONTROL 10

Micro computer fundamentals Tasks and – Operations – CPU Registers Microprocessor Architecture – Micro Computer hardware – Instrumentation applications of Micro Computers – Micro computers in control systems.

UNIT – V MICRO ELECTRONIC ENGINE CONTROL 10

Motivation for Electronic Engine Control – Concept of electronic Engine Control system – control strategy – applications.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. Understanding automotive Electronics, William B. Ribbens Ph.D., Fifth edition, SAE inc. USA, 2005.
2. Robert N.Brady, Automotive Computers and Digital Instrumentation, Prentice Hall, 1988.
3. Bosch Technical Instruction Booklets.

REFERENCES :

1. Tom Denton, Automotive Electrical and Electronic Systems, Edward Amold, 1995.
2. Duffy Smith, Auto Fuel Systems, The Good Heart Willcox Company Inc., Publishers, 1987.
3. Gasoline Engine Management, Second Edition, Robert Bosch GmbH, 2004.
4. Engine Management, Second Edition, Robert Bosch GmbH, 1999.
5. Eric Chowaniety, Automobile Electronics, SAE Publications 1995.
6. William B. Ribbews, Understanding Automotive Electronics, Fifth Edition, SAE Publications 1998.

IC 9167	COMBUSTION AND REACTION KINETICS IN I.C. ENGINES	L T P C 3 0 0 3

AIM

To develop the knowledge about combustion kinetics in SI and CI engines.

OBJECTIVE

To understand the combustion reaction kinetics in SI and CI engines.

UNIT – I INTRODUCTION 8

Gaseous, liquid and solid fuels, Application of the first and second laws of thermodynamics to combustion, – Low temperature reactions – Cool Flames -
High temperature reactions – species concentration and products formation.

UNIT – II GASOLINE ENGINE COMBUSTION 9

Combustion in S.I. Engines , Laminar flame theory, Flame structure, Turbulent premixed flames, Homogeneous Combustion reactions between Gasoline and air – Reaction rate Constants – species determination. Burning rate estimation.

UNIT – III DIESEL ENGINE COMBUSTION 10

Spray formation, Spray dynamics, Spray models, Introduction to diesel engine combustion, Premixed and diffusion combustion reactions – Lean flame Reactions – Lean flame out reactions - Species determination. Emissions and combustion, Combustion rate estimation

UNIT – IV CHEMICAL KINETICS OF COMBUSTION 8

Elementary reactions, Preignition kinetics, Nitric Oxide Kinetics, Soot Kinetics, Calculations, Combustion and Reaction control in SI and CI engines – Reaction control effect on Engine performance and emissions.

UNIT – V MODELLING 10

Calculation of equilibrium composition. Enthalpy and Energy, Coefficients for reactions and adiabatic flame temperature, Modeling of CO, HC NO reactions in SI and CI Engines – Soot Modelling.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. Internal Combustion Engines, J.F. Ferguson, John Wiley and Sons, 2004.
2. Internal Combustion Engines R.S. Benson & N.D. Whitehouse, First edition, Pergamon Press, England 1979.
3. Combustion SR Turns

REFERENCES :

1. Combustion Engineering, Gary L Borman, WCB Mc Graw Hill, 1998.
2. J.B. Heywood, Internal Combustion Engines
3. A.F. Williams combustion in flames, Oxford Press, Second Edition, 1978.
4. S.P. Sharma, Fuels and Combustion, S.P. Chand and Co., Sixth Edition, 1982.

IC 9168 **FUEL CELL TECHNOLOGY** **L T P C**
3 0 0 3

AIM:

OBJECTIVE: To gain insight about fuel cells, their working principle, types of fuel cells and performance analysis.

UNIT – I INTRODUCTION 5

Basic Principles - Classification – Alkaline, Proton Exchange Membrane, Direct Methanol, Phosphoric Acid & Molten Carbonate – Parts - Fuel cell poisoning

UNIT – II THERMODYNAMICS 12

Basic Reactions, Heat of reaction, Enthalpy of formation of substances - Enthalpy change of a reacting system - Gibbs free energy of substances - Gibbs free energy change of a reacting system - Efficiency - Power, heat due to entropy change, and internal ohmic heating

UNIT – III ELECTROCHEMISTRY 13

Nernst equation and open circuit potential, pressure effect, temperature effect - Stoichiometric coefficients and reactants utilization - Mass flow rate calculation - voltage and current in parallel and serial connection - Over-potentials and polarizations - Activation polarization - Tafel equation and exchange current density - Ionic conductivity, catalysts, Temperature and humidification effect, electro-osmotic drag effect

UNIT – IV DESIGN & OPTIMISATION 10

Geometries of fuel cells and fuel cell stacks - Rate of Diffusion of reactants - Water flooding and water management - Gas delivery and current collection - Bipolar plates design - Flow uniformity consideration - Optimization of gas delivery and current collection/asymptotic power density- Heat Removal from Stack

UNIT – V APPLICATIONS 5

Automotive applications & issues - Micro fuel cells & portable power - Distributed & Stationary power.

TOTAL : 45 PERIODS

TEXT BOOKS :

1. Fuel Cell Systems Explained, James Larminie and Andrew Dicks, 2nd Edition, John Wiley & Sons Inc., 2000.
2. PEM Fuel Cells Theory and Practice, Frano Barbir, Elsevier Academic Press, 2005.

EY 9150 ADVANCED ENGINEERING FLUID MECHANICS L T P C
3 0 0 3

AIM:
To introduce the advanced concepts of fluid mechanics and aerodynamics with the emphasis on practical applications.

OBJECTIVES:

- To understand the laws of fluid flow for ideal and viscous fluids.
- To represent the real solid shapes by suitable flow patterns and to analyze the same for aerodynamics performances.
- To understand the changes in properties in compressible flow and shock expansion.

UNIT- I BASIC EQUATIONS OF FLOW 6
Three dimensional continuity equation - differential and integral forms – equations of motion momentum and energy and their engineering applications.

UNIT- II POTENTIAL FLOW THEORY 12
Rotational and irrorational flows - circulation – vorticity - stream and potential functions for standard flows and combined flows – representation of solid bodies by flow patters.Pressure distribution over stationery and rotating cylinders in a uniform flow - magnus effect - Kutta – Zhukovsky theorem.Complex potential functions.Conformal transformation to analyze the flow over flat plate, cylinder, oval body and airfoils.Thin airfoil theory – generalized airfoil theory for cambered and flapped airfoils.

UNIT- III VISCOUS FLOW THEORY 9
Laminar and turbulent Flow - laminar flow between parallel plates - Poiseuille's equation for flow through circular pipes.Turbulent flow - Darcy Weisbach equation for flow through circular pipe - friction factor - smooth and rough Pipes - Moody diagram – losses during flow through pipes.Pipes in series and parallel – transmission of power through pipes.

UNIT- IV BOUNDARY LAYER CONCEPT 9
Boundary Layer - displacement and momentum thickness - laminar and turbulent boundary layers in flat plates - velocity distribution in turbulent flows in smooth and rough boundaries - laminar sub layer.

UNIT- V COMPRESSIBLE FLUID FLOW 9

One dimensional compressible fluid flow – flow through variable area passage – nozzles and diffusers – fundamentals of supersonics – normal and oblique shock waves and calculation of flow and fluid properties over solid bodies (like flat plate, wedge, diamond) using gas tables

TOTAL: 45 PERIODS

TEXT BOOKS:

1.Houghten, E.L. and Carruthers, N.B., Aerodynamics for Engineering Students, Arnold Publishers, 1993.
2. Anderson, J.D., Fundamentals of Aerodynamics, McGraw Hill, Boston, 2001.

REFERENCES:

1.Streeter, V.L., Wylie, E.B., and Bedford, K.W., Fluid Mechanics, WCB McGraw Hill, Boston, 1998.
2.Munson, B.R., Young, D.F. and Okiisi, T.H., Fundamentals of Fluid Mechanics, John Wiley and Sons Inc., NewYork, 1990
3.Kumar, K.L., Engineering Fluid Mechanics, Eurasia Publishing House, New Delhi, 2002
4.Bansal, R.K., Fluid Mechanics, Saurabh and Co., New Delhi, 1985.