UNIVERSITY OF KERALA

B. TECH. DEGREE COURSE

(2013 SCHEME)

SYLLABUS FOR

VII SEMESTER

AERONAUTICAL ENGINEERING

SCHEME -2013

VI SEMESTER
AERONAUTICAL ENGINEERING (S)

Course No	Name of subject	Credits	Weekly load, hours			C A Marks	Exam Duration Hrs	U E Max Mark s	Total Marks
			L	T	D/ P				
13.701	Avionics (S)	3	2	1	-	50	3	100	150
13.702	Mechatronics (MPSU)	4	3	1	-	50	3	100	150
13.703	Combustion Technology (S)	4	3	1	-	50	3	100	150
13.704	Rocket Propulsion (S)	4	3	1	-	50	3	100	150
13.705	Flight Dynamics (S)	4	3	1	-	50	3	100	150
13.706	Propulsion-II (S)	4	3	1	-	50	3	100	150
13.707	Elective III	2	-	-	2	50	3	100	150
13.708	Avionics Lab (S)	2	-	-	2	50	3	100	150
13.709	Project and Project Seminar (MNPSU)	2	-	-	2	100	-		100
	Total	**29**	**17**	**6**	**6**	**500**		**800**	**1300**

13.706 Elective III

13.707.1	Computational Fluid Dynamics (S)
13.707.2	Cryogenics (S)
13.707.3	Experimental Methods (S)
13.707.4	Heat Transfer in Space Applications (S)
13.707.5	Energy Conservation and Management (S)
13.707.6	Research Methodology (S)
13.707.7	Space Mechanics (S)
13.707.8	Gas Turbines (S)

13.701 AVIONICS (S)

Teaching Scheme: 2(L) - 1(T) - 0(P) **Credits**: 3

Course Objective:

- *To introduce the basic of avionics and its need for civil and military aircrafts.*
- *To impart knowledge about the avionic architecture and various avionics data buses.*
- *To gain more knowledge on various avionics subsystems.*

Module – I

INTRODUCTION TO AVIONICS

Need for avionics in civil and military aircraft and space systems – integrated avionics and weapon systems – typical avionics subsystems, design, technologies – Introduction to digital computer and memories.

Module – II

DIGITAL AVIONICS ARCHITECTURE

Avionics system architecture – data buses – MIL-STD-1553B – ARINC – 420 – ARINC – 629.

Module – III

FLIGHT DECKS AND COCKPITS

Control and display technologies: CRT, LED, LCD, EL and plasma panel – Touch screen – Direct voice input (DVI) – Civil and Military Cockpits: MFDS, HUD, MFK, HOTAS.

Module – IV

AIR DATA SYSTEMS AND AUTO PILOT

Air data quantities – Altitude, Air speed, Vertical speed, Mach Number, Total air temperature, Mach warning, Altitude warning – Auto pilot – Basic principles, Longitudinal and lateral auto pilot.

References:

1. Albert Helfrick D., *Principles of Avionics*, Avionics Communications Inc., 2004.
2. Collinson R. P. G. *Introduction to Avionics*, Chapman and Hall, 1996.
3. Middleton D. H., Ed., *Avionics Systems,* Longman Scientific and Technical, Longman Group UK Ltd., England, 1989.
4. Spitzer C.R. *Digital Avionics Systems*, Prentice-Hall, Englewood Cliffs, N.J., U.S.A. 1993.
5. Spitzer C.R. *The Avionics Hand Book*, CRC Press, 2000.
6. Pallet E. H. J., *Aircraft Instruments and Integrated Systems*, Longman Scientific.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Five Short answer questions of 4 marks each. All questions are compulsory. There should be at least one question from each module and not more than two questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course Outcome:

After successful completion of this course, the students will have:

- *Ability to built Digital avionics architecture.*
- *Ability to design and perform analysis on air system.*

13.702 MECHATRONICS (MPSU)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objectives:

The main objectives of this course are

- *To understand the features of various sensors used in CNC machines and robots.*
- *To study the fabrication and functioning of MEMS pressure and inertial sensors.*
- *To develop hydraulic/pneumatic circuit and PLC program for simple applications.*

Module – I

Introduction to Mechatronics: Structure of Mechatronics system. Sensors - Characteristics - Temperature, flow, pressure sensors. Displacement, position and proximity sensing by magnetic, optical, ultrasonic, inductive, capacitive and eddy current methods. Encoders: incremental and absolute, gray coded encoder. Resolvers and synchros. Piezoelectric sensors. Acoustic Emission sensors. Principle and types of vibration sensors.

Module – II

Actuators: Hydraulic and Pneumatic actuators - Directional control valves, pressure control valves, process control valves. Rotary actuators. Development of simple hydraulic and pneumatic circuits using standard Symbols.

Micro Electro Mechanical Systems (MEMS): Fabrication: Deposition, Lithography, Micromachining methods for MEMS, Deep Reactive Ion Etching (DRIE) and LIGA processes. Principle, fabrication and working of MEMS based pressure sensor, accelerometer and gyroscope.

Module – III

Mechatronics in Computer Numerical Control (CNC) machines: Design of modern CNC machines - Mechatronics elements - Machine structure: guide ways, drives. Bearings: anti-friction bearings, hydrostatic bearing and hydrodynamic bearing. Re-circulating ball screws, pre-loading methods. Re-circulating roller screws. Typical elements of open and closed loop control systems. Adaptive controllers for machine tools. Programmable Logic Controllers (PLC) –Basic structure, input/ output processing. Programming: Timers, Internal Relays, Counters and Shift registers. Development of simple ladder programs for specific purposes.

System modeling - Mathematical models and basic building blocks of general mechanical, electrical, fluid and thermal systems.

Module – IV

Mechatronics in Robotics-Electrical drives: DC, AC, brushless, servo and stepper motors. Harmonic drive. Force and tactile sensors. Range finders: ultrasonic and light based range finders. Robotic vision system - Image acquisition: Vidicon, charge coupled device (CCD) and charge injection device (CID) cameras. Image processing techniques: histogram processing: sliding, stretching, equalization and thresholding.

Case studies of Mechatronics systems: Automatic camera, bar code reader, pick and place robot, automatic car park barrier system, automobile engine management system.

References

1. Bolton W., *Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering*, Person Education Limited, New Delhi, 2007
2. HMT, *Mechatronics*, Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2004.
3. Ramachandran K. P., G. K. Vijayaraghavan, M. S. Balasundaram, *Mechatronics: Integrated Mechanical Electronic Systems*, Wiley India Pvt. Ltd., New Delhi, 2008.
4. David G. Aldatore, Michael B. Histand, *Introduction to Mechatronics and Measurement Systems*, McGraw-Hill Inc., USA, 2003.
5. Vijay K. Varadan, K. J. Vinoy, S. Gopalakrishnan, *Smart Material Systems and MEMS: Design and Development Methodologies*, John Wiley & Sons Ltd., England, 2006.
6. Saeed B. Niku, *Introduction to Robotics: Analysis, Systems*, Applications, Person Education, Inc., New Delhi, 2006.
7. Gordon M. Mair, *Industrial Robotics*, Prentice Hall International, UK, 1998.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course outcome:

At the end of the course students will be able:

- *To discuss mechanical systems used in mechatronics*
- *To integrate mechanical, electronics, control and computer engineering in the design of mechatronics systems.*

13.703 COMBUSTION TECHNOLOGY (S)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objectives:

Understanding fundamentals of different combustion processes and its chemistry.

Module – I

Introduction**:** Combustion, Applications of combustion, types of fuels and oxidizers, types of combustion modes and their domain of application, Ideal gas mixtures, partial pressure law, latent heats, Reactant and product mixtures, Enthalpy of formation.

Module – II

Thermo chemistry and kinetics:

Thermodynamics: Stoichiometry, Heat of combustion, adiabatic flame temperature, chemical equilibrium, Equilibrium products of combustion.

Kinetics of Reaction, collision theory, Arrhenius law elementary reactions, chain reaction, Multi step reactions, Global reactions.

Combustion conservation analysis: Mass conservation, momentum conservation, energy conservation, concept of conserved scalar, Transport properties, Transport in turbulent flows.

Module – III

Laminar flames:

Premixed flames: Physical description Detailed analysis, Factors Influencing flame velocity and thickness, Quenching, Flammability and Ignition Flame stabilization.

Diffusion flames: jet flame physical descriptions, flame lengths for circular port and slot burners, Soot formation and destruction.

Module – IV

Combustion and Emissions of Pollutants:

Droplet combustion: Introduction, applications, Droplet evaporation and combustion

Solids burning: Heterogeneous reactions, burning of carbon, particle burning time, coal combustion.

Emissions: Effects of pollutants, Quantification of emissions, emission from premixed combustion, Emissions from non premixed combustion.

References:

1. Stephen R. Turns, *An Introduction to Combustion*, McGraw Hill.
2. Samir Sarkar, *Fuels and Combustion*, Universities Press.

3. Mishra D. P., *Fundamentals of Combustion*, Prentice Hall of India.
4. Strehlow R. A., *Fundamentals of Combustion*, McGraw Hill.
5. Kuo K. K., *Principles of Combustion*, John Wiley and Sons.
6. Kanury A. Murty, *Introduction to Combustion Phenomena*, Gordon & Breach.
7. Michael A. Liberman, Introduction to Physics and Chemistry of Combustion, Springer.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course Outcome:

Students successfully completing this course will have

- *a sound understanding of the principles of combustion;*
- *a basic understanding of the mechanisms of combustion generated air pollution and the techniques that can be used to control them;*
- *a basic understanding of the safety and handling issues associated with combustion;*
- *a sound understanding of the responsibility of engineers to the community in terms of providing a safe healthy environment.*

13.704 ROCKET PROPULSION (S)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objectives :

To impart knowledge in non air-breathing and advanced propulsion methods to students so that they are familiar with various propulsion technologies associated with space launch vehicles, missiles and space probes.

Module – I

Fundamentals of chemical rocket propulsion: Operating principle – specific impulse of a rocket – internal ballistics – performance considerations of rockets – types of igniters-preliminary concepts in nozzle-less propulsion – air augmented rockets –pulse rocket motors – static testing of rockets & instrumentation –safety considerations.

Module – II

Solid rocket propulsion: Salient features of solid propellant rockets – selection criteria of solid propellants – estimation of solid propellant adiabatic flame temperature - propellant grain design considerations – erosive burning in solid propellant rockets – combustion instability – strand burner and T-burner – applications and advantages of solid propellant rockets.

Module – III

Liquid and hybrid rocket propulsion: Salient features of liquid propellant rockets – selection of liquid propellants – various feed systems and injectors for liquid propellant rockets - thrust control and cooling in liquid propellant rockets and the associated heat transfer problems – combustion instability in liquid propellant rockets – peculiar problems associated with operation of cryogenic engines - Introduction to hybrid rocket propulsion – standard and reverse hybrid systems- combustion mechanism in hybrid propellant rockets – applications and limitations.

Module – IV

Electric and advanced propulsion: Electric propulsion**:** Electromagnetic thrusters- magneto plasma dynamic (MPD), pulsed plasma (PPT), Hall effect and variable Current technology of electric propulsion engines, applications.

Nuclear propulsion- Principles, fuel elements, exhaust velocity, operating temperature. Fission fragment propulsion, radioisotope nuclear rocket, fusion propulsion, inertial, electrostatic and magnetic confinement fusion.

Propellant less Propulsion - Photon rocket, beamed energy propulsion, solar, magnetic sails.

References:

1. George P. Sutton and Oscar Biblarz*, Rocket Propulsion Elements*, John Wiley & Sons Inc., New York, 5th Ed., 2010.
2. Mathur M.L., and Sharma, R.P., *Gas Turbine, Jet and Rocket Propulsion*, Standard Publishers and Distributors, Delhi, 1988.
3. James Award, *Aerospace Propulsion System*.
4. Philip Hill and Carl Peterson, *Mechanics and Thermodynamics of Propulsion*, 2nd edition, Pearson Education Ltd, 2009.
5. Gorden C. V., *Aerothermodynamics of Gas Turbine & Rocket Propulsion*, AIAA Education Series, New York, 1997.
6. Cohen H., G. F. C. Rogers, and H. I. H. Saravanamuttoo, *Gas Turbine Theory*, Prentice Hall India Ltd, 2001.
7. Mattingly J. D., W. H. Heiser and D. T. Pratt, *Aircraft Engine Design*, AIAA Education Series, New York, 2002.
8. Saced Farokhi, *Aircraft Propulsion*, Volume 10, John Wiley & sons, 2008.
9. Ahmed F. El-Sayed, *Aircraft Propulsion & Gas Turbine Engine*, CRC Press, 2008.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course Outcome:

- *Understanding various propulsion systems*
- *Knowledge in rocket propulsion systems*
- *Knowing the applications and principles of liquid and solid-liquid propulsion systems*
- *Application of nuclear propulsion in rocketry.*

13.705 FLIGHT DYNAMICS (U)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objective:

To study the performance of airplanes under various operating conditions and the static and dynamic responses of aircraft for both voluntary and involuntary changes in flight conditions.

Module – I

Drag on airplane, international standard atmosphere- forces and moment acting on a flight vehicle- equation of motion of a rigid flight vehicle- different types of drag- drag polars of vehicle from low speeds to high speeds – variation of thrust, power and SFC with velocity and altitude for air breathing engines and rockets- power available and power required curves.

Module – II

Aircraft performance- performance of aircrafts in level flight- maximum speed in level flight- conditions for minimum drag and power required- range and endurance- climbing and gliding flight(maximum rate of climb and steepest angle of climb, minimum rate of sink and shallowest angle of glide)- turning performance(turning rate turn radius). Bank angle and load factor – limitations of pull up and push up diagram and load factor.

Module – III

Static longitudinal stability- degree of freedom of rigid bodies in space- static and dynamic stability- purpose of controls in airplanes- inherently stable and marginal stable airplanes- static, longitudinal stability- stick fixed stability- basic equilibrium equation- stability criterion- effect of fuselage and nacelle- influence of CG location- power effects- stick fixed neutral point- stick free stability- hinge moment coefficient –stick free neutral points- symmetric manoeuvres- stick force gradients- stick force per ‘g’ – aerodynamic balancing – determination of neutral points and manoeuvre points from flight test.

Module – IV

Lateral and directional stability- dihedral effect- lateral control- coupling between rolling and yawning moments- adverse yaw effects – aileron reversal- static directional stability- weather cocking effect- rudder requirements- one engine inoperative condition- rudder lock. Dynamic stability- equation of motion- stability derivative characteristics- brief description of lateral and directional stability. Dynamic stability spiral. Divergence, Dutch roll auto rotation ad spin.

References:

1. Perkins C. D. and R. E. Hage, *Airplane Performance Stability and Control*, John Wiley & Son:,Inc, NY, 1988.
2. Nelson R.C. *Flight Stability and Automatic Control*, McGraw-Hill Book Co., 2004.
3. Mc Cornick W., *Aerodynamics, Aeronautics and Flight Mechanics*, John Wiley, NY, 1979.
4. Etkin B., *Dynamics of Flight Stability and Control*, Edn. 2, John Wiley, NY, 1982.
5. Babister A. W., *Aircraft Dynamic Stability and Response*, Pergamon Press, Oxford, 1980.
6. Dommasch D. O., S. S. Sherby and T. F. Connolly, *Aeroplane Aero dynamics*, Third Edition, Issac Pitman, London, 1981.
7. Mc Cornick B. W, *Aerodynamics, Aeronautics and Flight Mechanics*, John Wiley, NY, 1995.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Note: *Use of approved data book is permitted in the examination hall.*

Course Outcome:

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

- *Understand the static stability of aircraft*
- *Understand the dynamic response of aircraft*
- *Understand the flying qualities of aircraft.*

13.706 PROPULSION – II (S)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objective:

To introduce basic concepts and salient features of engine components of jet propelled engines which are operated in atmosphere. To familiarise with advanced jet propulsion methods like hypersonic propulsion and space propulsion systems.

Module – I

Compressors: Principal of operation of centrifugal compressor - Work done and pressure rise Euler's Turbo machinery equations.
Axial flow compressor analysis, cascade action, flow field. Euler's equation, velocity diagrams, flow annulus area stage parameters. Degree of reaction, cascade airfoil nomenclature and loss coefficient, diffusion factor, stage loading and flow coefficient, stage pressure ratio, Blade Mach No., repeating stage, repeating row.

Module – II

Turbines: Introduction to turbine analysis, mean radius stage calculations, stage parameters, stage loading and flow coefficients degree of reaction, stage temperature ratio and pressure ratio, blade spacing, radial variation, velocity ratio. Axial flow turbine, stage flow path, Dimensional stage analysis. Steps of turbine design: single stage and two stages.
Turbine performance. Blade cooling.

Module – III

Ramjet propulsion: Operating principle – Subcritical, critical and supercritical operation - Combustion in ramjet engine – Ramjet performance - Sample ramjet design calculations - Introduction to scramjet - Preliminary concepts in supersonic combustion - Integral ram rocket - Numerical problems. Introduction to hypersonic propulsion.

Module – IV

Space propulsion systems: Fundamentals of Solid, Liquid and hybrid propulsion- Electric rocket propulsion– types of electric propulsion techniques - Ion propulsion – Nuclear rocket –comparison of performance of these propulsion systems with chemical rocket propulsion systems –future applications of electric propulsion systems - Solar sail.

References:

1. George P. Sutton and Oscar Biblarz, *Rocket Propulsion Elements*, John Wiley & Sons Inc., New York, 5th Ed., 2010.

2. Mathur M.L., and Sharma, R.P., *Gas Turbine, Jet and Rocket Propulsion*, Standard Publishers and Distributors, Delhi, 1988.
3. James Award, *Aerospace Propulsion System*
4. Philip Hill and Carl Peterson, *Mechanics and Thermodynamics of Propulsion*, 2nd edition, Pearson Education Ltd, 2009.
5. Gorden C. V., *Aerothermodynamics of Gas Turbine & Rocket Propulsion*, AIAA Education Series, New York, 1997.
6. Cohen H., Rogers G. F. C. and H. I. H. Saravanamuttoo, , *Gas Turbine Theory*, Prentice Hall India Ltd, 2001.
7. Mattingly J. D., W. H. Heiser and D. T. Pratt, *Aircraft Engine Design*, AIAA Education Series, New York, 2002.
8. Saced Farokhi, *Aircraft Propulsion*, Volume 10, John Wiley & sons, 2008.
9. Ahmed F. El-Sayed, *Aircraft Propulsion & Gas Turbine Engine*, CRC Press, 2008.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, quiz, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course Outcome:

After this programme students are expected to have

- *Ability to identify the engine components of jet propelled engines*
- *Knowledge on the details of advanced Jet propulsion and hypersonic propulsion.*

13.707.1 COMPUTATIONAL FLUID DYNAMICS (S) (Elective III)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objectives:

- *To introduce Governing Equations of viscous fluid flows.*
- *To introduce numerical modeling and its role in the field of fluid flow and heat transfer.*
- *To enable the students to understand the various discretization methods, solution procedures and turbulence modeling.*
- *To create confidence to solve complex problems in the field of fluid flow and heat transfer by using high speed computers.*

Module – I

Basic aspects of computational aerodynamics: why computational Fluid dynamics? What is CFD? - CFD as a research tool- as a design tool. Applications in Various branches of engineering - models of fluid flow- finite control volume, infinitesimal fluid element. Substantial derivative- physical meaning of divergence of velocity.

Governing equations and physical boundary conditions: derivation of continuity, momentum and energy equations- physical boundary conditions significance of conservation and non-conservation forms and their implication on CFD applications- strong and weak conservation forms- shock capturing and shock fitting approaches.

Module – II

Mathematical behavior of partial differential equations and their impact on computational aerodynamics: Classification of quasi-linear partial differential equations by Cramer's rule and Eigen value method. General behavior of different classes of partial differential equations and their importance in understanding physical and CFD aspects of aerodynamic problems at different mach numbers involving hyperbolic, parabolic and elliptic equations- domain of dependence and Range of influence for hyperbolic equations. Well-posed problems.

Module – III

Basic aspects of discretization: Introduction to finite differences- finite difference approximation for first order, second order and mixed derivatives. Pros and cons of higher order difference schemes. Difference equations- explicit and implicit approaches- truncation and round-off errors, consistency, stability, accuracy, convergence, efficiency of numerical solutions-Von Neumann stability analysis. Physical significance of CFL stability condition.

Finite volume methods: Basis of finite volume method- conditions on the finite volume selections- cell-centered and cell-vertex approaches. Definition of finite volume discretization -general formulation of a numerical scheme- two dimensional finite volume methods with example.

Module – IV

Grid types and characteristics: Need for grid generation. Structured grids- Cartesian grids, stretched (compressed) grids, body fitted structured grids, H-mesh, C-mesh, O-mesh, I-mesh, Multi-block grids, C-H mesh, H-O-H mesh, overset grids, adaptive grids. Unstructured grids- triangular/ tetrahedral cells, hybrid grids, quadrilateral/ hexahedra cells.

CFD techniques: Lax-Wendroff technique, MacCormack's technique-Crank Nicholson technique-Relaxation technique - aspects of numerical dissipation and dispersion. Alternating-Direction-Implicit (ADI) Technique. Pressure correction technique- application to incompressible viscous flow- need for staggered grid. Philosophy of pressure correction method- pressure correction formula. Numerical procedures- SIMPLE, SIMPLER, SIMPLEC and PISO algorithms. Boundary conditions for pressure correction method.

References

1. Anderson J. D., Jr., *Computational Fluid Dynamics- The Basics with Applications*, McGraw-Hill Inc., 1995.
2. Anderson D. A., J. C. Tannehill, and R. H. Pletcher, Taylor and Francis, *Computational Fluid Mechanics and Heat Transfer*, Second Edition, 1997.
3. Hirsch C., *Numerical Computation of Internal and External Flows-Fundamentals of Computational Fluid Dynamics*, Second Edition, Elsevier, 2007.
4. Versteeg H. K. and W. Malalasekera, *An Introduction to Computational Fluid Dynamics-The Finite Volume Method*, Second Edition, Pearson Education Ltd, 2010.
5. Tu J., G. H. Yeoh, C. Liu, *Computational Fluid Dynamics-A Practical Approach*,, Butterworth- Heinemann, 2008.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course outcome:

- *Understand and be able to numerically solve the governing equations for fluid flow*
- *Understand and apply finite difference, finite volume and finite element methods to fluid flow problems*
- *Understand how grids are generated*
- *Understand and apply turbulence models to engineering fluid flow problems*
- *Be able to numerically solve a heat transfer problem*

13.707.2 CRYOGENICS (S) (Elective III)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objectives:

- *To know about the cryogenic temperature production, superconductivity and applications*
- *To know about various liquefaction processes*
- *To know about various thermal insulations, properties of cryogenic fluids.*
- *To know about the measuring devices used for cryogenic fluids and storage and transportation of cryogenic fluids.*

Module – I

INTRODUCTION: Historical Background - Introduction to cryogenic propellants - Liquid hydrogen, liquid helium, liquid nitrogen and liquid oxygen, material properties at cryogenic temperatures- mechanical, thermal electrical and magnetic. Application areas of cryogenics, Superconductivity applications

PRODUCTION OF LOW TEMPERATURE: Theory behind the production of low temperature – Joule Thomson expansion, Adiabatic Reversible Turbine Expansion, Discontinuous sudden adiabatic expansion, Philips Refrigerator, Solvay Refrigerator, GM refrigerator, Pulse tube refrigerator, Adiabatic Magnetic Refrigerator, Helium Dilution Refrigerator.

Module – II

CRYOGENIC LIQUEFACTION PROCESSES: Theoretical minimum work for liquefaction, Figure of Merit for actual liquefaction processes.

LIQUEFACTION PROCESSES FOR ARGON, NITROGEN AND OXYGEN: simple Linde-Hampson, Pre-cooled Linde Hampson, Simple Claude, Kapitza, Heylandt processes.

LIQUEFACTION PROCESSES FOR NEON AND HYDROGEN: Pre-cooled Linde Hampson process, Pre-cooled Claude process, Philips Hydrogen liquefaction process.

LIQUEFACTION PROCESSES FOR HELIUM: Pre-cooled Linde Hampson Helium liquefaction process, Collins Helium Liquefaction Process, Philips Helium liquefaction process, Simon Helium liquefaction process.

Module – III

THERMOPHYSICAL PROPERTIES OF CRYOGENIC FLUIDS: thermodynamic properties of cryogenic fluids, vapour liquid equilibrium- oxygen-nitrogen-argon, hydrogen- helium. Virial equation of state, theorem of corresponding states, Peng- Robinson equation of state, prediction of solubility of cryogenic gases. Transport properties of cryogenic fluids, unique properties of noble gases: Helium-3, Helium-4, Neon, Argon, Xenon, hydrogen isotopes.

THERMAL INSULATION OF CRYOGENIC SYSTEMS: Vacuum, Porous and Fibrous, Multilayer, microsphere insulation, Typical insulation system for space propulsion.

Module – IV

MEASUREMENT DEVICES AT CRYOGENIC TEMPERATURES: Temperature- metallic resistance thermometer, constant volume gas thermometer, vapours pressure thermometer, superconducting thermometer, thermocouple, magnetic thermometer.

Sub-atmospheric pressure/ vacuum: McLeod gauge, thermal conductivity gauge, viscosity gauge, ionization gauge. Liquid level measurement: Hydrostatic gauge, electric resistance gauge, capacitance gauge, thermodynamic liquid level probe, magnetic probe, optical level indicator.

Flow Rate: Orifice meter, venturi meter, turbine flow meter, mass flow meter, displacement meter.

STORAGE AND TRANSPORTATION OF CRYOGENIC FLUIDS: Storage vessel, thermal shield and insulation, heat in-leak, factors affecting heat in-leak, transfer and draining of cryogenic liquids, transportation of cryogenic fluids- liquid nitrogen shielded Dewar, helium refrigerated storage vessel, hydrogen refrigerated Dewar, powder insulated Dewar, two phase flow during transfer- cool down time and its calculation. Safety devices for storage and transfer of cryogenic fluids.

References

1. Mamata Mukhopadhyay, *Fundamentals of Cryogenic Engineering*, PHI.
2. Haseldom, G., *Cryogenic Fundamentals*, Academic Press, 1971.
3. Barron, R. F., *Cryogenic Systems*, Oxford University, 1985.
4. Parner, S. F., *Propellant Chemistry*, Reinhold Publishing Corpn., New York, 1985.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course outcome:

- *Having knowledge about the cryogenic temperature production, superconductivity and applications and about various liquefaction processes.*
- *Get acquainted about various thermal insulations, properties of cryogenic fluids.*
- *Get apprehend about the measuring devices used for cryogenic fluids and storage and transportation of cryogenic fluids.*

13.707.3 EXPERIMENTAL METHODS (S) (Elective III)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objectives:

- *To provide details, operating principles and limitations of forces, pressure, velocity and temperature measurements.*
- *To describe flow visualization techniques and to highlight in depth discussion of analog methods.*

Module – I

BASIC MEASUREMENTS IN FLUID MECHANICS: Objective of experimental studies – Fluid mechanics measurements – Properties of fluids – Measuring instruments – Performance terms associated with measurement systems – Direct measurements -Analogue methods – Flow visualization –Components of measuring systems – Importance of model studies.

Module – II

CHARACTERISTICS OF MEASUREMENTS: Characteristic features, operation and performance of low speed, transonic, supersonic and special tunnels - Power losses in a wind tunnel – Instrumentation of wind tunnels – Turbulence- Wind tunnel balance – principles, types and classifications -Balance calibration.

Module – III

FLOW VISUALIZATION AND ANALOGUE METHODS: Principles of Flow Visualization – Hele-Shaw apparatus - Interferometer – Fringe-Displacement method – Schlieren system – Shadowgraph - Hydraulic analogy – Hydraulic jumps – Electrolytic tank.

Module – IV

PRESSURE, VELOCITY AND TEMPERATURE MEASUREMENTS: Measurement of static and total pressures in low and high speed flows- Pitot-Static tube characteristics - Pressure transducers – principle and operation – Velocity measurements - Hot-wire anemometry – LDV – PIV: Temperature measurements.

UNCERTAINTY ANALYSIS: Estimation of measurement errors – External estimate of the error – Internal estimate of the error – Uncertainty calculation - Uses of uncertainty analysis.

References

1. Rathakrishnan, E., *Instrumentation, Measurements, and Experiments in Fluids*, CRC Press –Taylor & Francis, 2007.

2. Robert B Northrop, *Introduction to Instrumentation and Measurements*, Second Edition, CRC Press, Taylor & Francis, 2006.
3. Pope, A., and Goin, L., *High Speed Wind Tunnel Testing*, John Wiley, 1985.Bradsaw
4. Experimental Fluid Mechanics.
5. NAL-UNI Lecture Series 12: *Experimental Aerodynamics*, NAL SP 98 01 April 1998.
6. Lecture course on *Advanced Flow diagnostic techniques* 17-19 September 2008 NAL, Bangalore.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course outcome:

- *Knowledge on measurement techniques in aerodynamic flow.*
- *Acquiring basics of wind tunnel measurement systems*
- *Specific instruments for flow parameter measurement like pressure, velocity, temperature etc.*

13.707.4 HEAT TRANSFER IN SPACE APPLICATIONS (S) (Elective III)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objectives:

- *To know about the thermal environment of space craft*
- *To know about various thermal control techniques*
- *To know about various phase change materials, thermal contact resistance.*

Module – I

SPACE CRAFT THERMAL ENVIRONMENTS: Launch and ascent environments – environment of earth orbit – environments of interplanetary missions.

Module – II

THERMAL CONTROL TECHNIQUES: Passive thermal control techniques: thermal coating materials, thermal insulation, heat sinks, phase change materials – Active thermal control techniques: electrical heaters, thermal louvers, HPR fluid systems, heat pipes, space borne cooling systems.

Insulation-Blanket Design: materials-attachment – high temperature blankets – insulation for in-atmosphere applications.

Module – III

PHASE CHANGE MATERIALS : When to use a PCM -- PCM design. Heat Pipes-Types-Analysis-Testing-heat pipe applications and performances.

Module – IV

THERMAL CONTACT RESISTANCE AND ITS CALCULATION: Parameters influencing thermal joint resistance – effect of oxidation and interstitial effects.

ABLATIVE HEAT TRANSFER: Physical process and calculation of ablation rates – hypersonic ablation of graphite – heat transfer at high velocities – heat transfer in rarefied gases-transpiration and film cooling.

References

1. Gilmore, D. G., *Spacecraft Thermal Control Handbook*, Volume I: Fundamental Technologies, 2nd ed., the Aerospace Press, American Institute of Aeronautics and Astronautics (2002).
2. NASA SP 8105
3. Fortescue P., G. Swinerd and J. Stark (Ed), *Spacecraft Systems Engineering*, 4th ed., John Wiley & Sons (2011).

4. Mayer, R. X., *Elements of Space Technology for Aerospace Engineers*, Academic Press (1999).

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course outcome:

Having knowledge about the thermal environment of space craft, about various thermal control techniques, various phase change materials, thermal contact resistance

13.606.5 ENERGY CONSERVATION AND MANAGEMENT (S) (Elective III)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objectives:

- *To obtain Energy conservation principles*
- *To identify Procedures and Techniques*
- *To know the Energy Policy & Planning*
- *To know to Energy Balance & Energy Audit.*

Module – I

General Aspects:

Energy conservation principles and practices: Energy scenario – Principles and imperatives of energy conservation – Energy consumption pattern – Resource availability – Why save energy – Reasons to save energy – An over view of energy consumption and its effects – Current energy consumption in India – Role of energy managers in industries.

General Philosophy and need of Energy Audit and Management. Definition and Objective of Energy Management, General Principles of Energy Management, Energy Management Skills, Energy Management Strategy. Energy Audit: Need, Types, Methodology and Approach. Energy Management Approach, Understanding Energy Costs, Bench marking, Energy performance, Matching energy usage to requirements, Maximizing system efficiency, Optimizing the input energy requirements, Fuel and Energy substitution.

Module – II

Procedures and Techniques:

Data gathering : Level of responsibilities, energy sources, control of energy and uses of energy get Facts, figures and impression about energy /fuel and system operations, Past and Present operating data, Special tests, Questionnaire for data gathering.

Analytical Techniques: Incremental cost concept, mass and energy balancing techniques, inventory of Energy inputs and rejections, Heat transfer calculations, Evaluation of Electric load characteristics, process and energy system simulation.

Evaluation of saving opportunities: Determining the savings in Rs, Noneconomic factors, Conservation opportunities, estimating cost of implementation.

Energy Audit Reporting: The plant energy study report- Importance, contents, effective organization, report writing and presentation.

Module – III

Energy Policy Planning and Implementation:

Key Elements: Force Field Analysis, Energy Policy-Purpose, Perspective, Contents and Formulation.

Format and Ratification, Organizing: Location of Energy Manager, Top Management Support, Managerial functions, Role and responsibilities of Energy Manager, Accountability. Motivating –Motivation of employees, Requirements for Energy Action Planning. Information Systems: Designing, Barriers, Strategies, Marketing and Communicating Training and Planning.

Module – IV

Energy Balance & MIS: First law of efficiency and Second law of efficiency, Facility as an Energy system, Methods for preparing process flow, Materials and Energy Balance diagram, Identification of losses, Improvements. Energy Balance sheet and Management Information System (MIS) Energy Modeling and Optimization.

Energy Audit Instruments: Instruments for Audit and Monitoring Energy and Energy Savings, Types and Accuracy.

References

1. Murphy W. R., G.Mckay *Energy Management*, Butterworths.
2. Smith C. B., *Energy Management* Principles, Pergamon Press.
3. Dryden I. G. C., *Efficient Use of Energy*, Butterworth Scientific
4. Desai A. V., *Energy Economics*, Wiley Eastern.
5. Reay D. A., *Industrial Energy Conservation* , Pergamon Press
6. Turner W.C., *Energy Management Handbook*, John Wiley and Sons.
7. Witte L. C., P. S. Schmidt and D. R. Brown, *Industrial Energy Management and Utilization,* Hemisphere Publication, Washington.
8. *Industrial Energy Conservation Manuals*, MIT Press, 1982
9. Patrick/Patrick/Fardo *Energy Conservation guide book*, Prentice Hall.
10. *Handbook on Energy efficiency*, *ASHRAEE Energy Use* (4 Volumes).
11. *CRC Handbook of Energy Efficiency*, CRC Press.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course outcome:

Accomplish Energy conservation principles, Procedures and Techniques, Knowing Energy Policy & Planning and Energy Balance & Energy Audit.

13.707.6 RESEARCH METHODOLOGY (S) (Elective II)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objectives:

- *To impart scientific, statistical and analytical knowledge for carrying out research work effectively.*

Module – I

Introduction to Research: The hallmarks of scientific research – Building blocks of science in research – Concept of Applied and Basic research – Quantitative and Qualitative Research Techniques –Need for theoretical frame work – Hypothesis development – Hypothesis testing with quantitative data. Research design – Purpose of the study: Exploratory, Descriptive, Hypothesis Testing.

Module – II

Experimental Design: Laboratory and the Field Experiment – Internal and External Validity – Factors affecting Internal validity. Measurement of variables – Scales and measurements of variables. Developing scales – Rating scale and attitudinal scales – Validity testing of scales – Reliability concept in scales being developed – Stability Measures.

Module – III

Data Collection Methods: Interviewing, Questionnaires, etc. Secondary sources of data collection. Guidelines for Questionnaire Design – Electronic Questionnaire Design and Surveys. Special Data Sources: Focus Groups, Static and Dynamic panels. Review of Advantages and Disadvantages of various Data-Collection Methods and their utility. Sampling Techniques – Probabilistic and non-probabilistic samples. Issues of Precision and Confidence in determining Sample Size. Hypothesis testing, Determination of Optimal sample size.

Module – IV

Multivariate Statistical Techniques: Data Analysis – Factor Analysis – Cluster Analysis – Discriminant Analysis – Multiple Regression and Correlation – Canonical Correlation
Research Report: Purpose of the written report – Concept of audience – Basics of written reports. Integral parts of a report – Title of a report, Table of contents, Abstract, Synopsis, Introduction, Body of a report – Experimental, Results and Discussion – Recommendations and Implementation section – Conclusions and Scope for future work.

References

1. Donald R. Cooper and Ramela S. Schindler, *Business Research Methods*, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2000

2. Uma Sekaran, Research *Methods for Business*, John Wiley and Sons Inc., New York, 2000.
3. C.R.Kothari, *Research Methodology*, Wishva Prakashan, New Delhi, 2001.
4. Donald H.McBurney, *Research Methods*, Thomson Asia Pvt. Ltd. Singapore, 2002.
5. G.W.Ticehurst and A.J.Veal, *Business Research Methods*, Longman, 1999.
6. Ranjit Kumar, *Research Methodology*, Sage Publications, London, New Delhi, 1999.
7. Raymond-Alain Thie'tart, *et.al., Doing Management Research*, Sage Publications, London, 1999.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course outcome:

At the end of this course the students will be able to aaccomplish scientific, statistical and analytical knowledge for carrying out research work effectively.

13.707.7 SPACE MECHANICS (S) (Elective III)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objectives:

- *To introduce concepts of satellite injection and satellite perturbations, trajectory computation for interplanetary travel and flight of ballistic missiles based on the fundamental concepts of orbital mechanics.*

Module – I

SPACE ENVIRONMENT: Peculiarities of space environment and its description– effect of space environment on materials of spacecraft structure and astronauts- manned space missions – effect on satellite life time.

Module – II

BASIC CONCEPTS AND THE GENERAL N- BODY PROBLEM: The solar system – reference frames and coordinate systems – terminology related to the celestial sphere and its associated concepts – Kepler's laws of planetary motion and proof of the laws –Newton's universal law of gravitation - the many body problem - Lagrange-Jacobi identity – the circular restricted three body problem – libration points – the general N-body problem – two body problem – relations between position and time.

Module – III

SATELLITE INJECTION AND SATELLITE PERTURBATIONS: General aspects of satellite injection – satellite orbit transfer – various cases – orbit deviations due to injection errors – special and general perturbations – Cowell's method and Encke's method – method of variations of orbital elements – general perturbations approach.

Module – IV

INTERPLANETARY TRAJECTORIES: Two-dimensional interplanetary trajectories – fast interplanetary trajectories – three dimensional interplanetary trajectories – launch of interplanetary spacecraft – trajectory estimation about the target planet – concept of sphere of influence – Lambert's theorem

BALLISTIC MISSILE TRAJECTORIES: Introduction to ballistic missile trajectories – boost phase – the ballistic phase – trajectory geometry –optimal flights – time of flight – re-entry phase – the position of impact point – influence coefficients.

References

1. Cornelisse, J.W., *Rocket Propulsion and Space Dynamics*, J. W. Freeman & Co. Ltd, London, 1982.
2. Parker, E.R., *Materials for Missiles and Spacecraft*, McGraw Hill Book Co. Inc., 1982.

3. Sutton, G.P., *Rocket Propulsion Elements*, John Wiley & Sons Inc., New York, 5th Edition, 1993.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course outcome:

At the end of this course the students will be able to

- *Perform satellite injection, satellite perturbations and trajectory control.*
- *Apply orbital mechanics to control ballistic missile.*

13.707.8 GAS TURBINES (S) (Elective III)

Teaching Scheme: 3(L) - 1(T) - 0(P) **Credits**: 4

Course Objectives:

- *To familiarize various working principle of Gas Turbine Power plant.*
- *To study basic equation of power cycles*
- *To study flow through centrifugal compressor and axial flow compressor, Turbines and combustion systems*
- *To study Performance predictions.*

Module – I

INTRODUCTION: Open cycle single shaft and twin shaft multi speed arrangement – Closed cycle – Aircraft propulsion – Industrial application – Environmental issues - Future – Possibilities

POWER CYCLES: Ideal cycles method of accounting – Component losses – Design point performance calculations – Comparative performance of practical cycles – Combined cycle – Cognation schemes – Closed cycle - Gas turbine - Reheat –intercooling – Regenerator cycles.

Module – II

CENTRIFUGAL AND AXIAL FLOW COMPRESSORS: Centrifugal compressor – Principle of operation – Work done – Pressure rise – The diffuser – Compressibility effects – Non dimensional quantities - Computerized design procedure. Axial flow compressor basic operation –Elementary theory – Factors effecting stage pressure ratio – Blockage in compressor annulus – Degree of reaction – Blade fixing details - Sealing materials – Material selection for compressor blades – Stage performance – Design and off design performance characteristics.

Module – III

TURBINES AND COMBUSTION SYSTEMS: Operation requirements, type of combustion – Factors affecting combustion process – Combustion chamber performance. Turbine construction – Performance – Impeller blade fixing – Cooling of turbine blades – Blade vibration – Protective coating – Gas turbine turbo chargers - Power expanders – Vortex theory – Estimation of stage performance.

Module – IV

PERFORMANCE PREDICTIONS: Prediction performance of gas turbines component characteristics – Off design operation – Equilibrium running of gas generator – Off design operation of free turbine – Methods of displacing of the equilibrium running line – Incorporation of variable pressure losses – Matching procedure for two spool engines – Principle of control systems.

References

1. Cohen–HEFC Rogers and Saravanamutto, H. W., *Gas turbine theory,* Long man scientific technical, Singapore, 1997.

2. Lefebvre.A.W., Gas *Turbine Propulsion,* McGraw Hill, New York, 1983.

3. Horlock J. H., *Axial flow turbine*, 4th Edition, Butterworth Publishers, London, 1966.

4. Gopalakrishnan, G. and Prithvi Raj D., *Treatise on Turbomachines,* Scitech Publications, Chennai, 2002.

5. Kerrebrock J.C., *Aircraft Engines and Gas Turbines*, Cambridge, Mass MIT Press, 1977.

Internal Continuous Assessment *(Maximum Marks-50)*

50% - Tests (minimum 2)

30% - Assignments (minimum 2) such as home work, problem solving, literature survey, seminar, term-project, software exercises, etc.

20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*

The question paper shall consist of 2 parts.

Part A (20 marks) - Ten Short answer questions of 2 marks each. All questions are compulsory. There should be at least two questions from each module and not more than three questions from any module.

Part B (80 Marks) - Candidates have to answer one full question out of the two from each module. Each question carries 20 marks.

Course outcome:

At the end of this course the students will be familiar to working principle of Gas Turbine Power plant, basic equation of power cycles, flow through centrifugal compressor and axial flow compressor, Turbines and combustion systems and thereby to their Performance predictions.

13.708 LOW SPEED AERODYNAMICS LAB (S)

Teaching Scheme: 0(L) - 0(T) – 2 (P) **Credits**: 2

Course Objective:

This laboratory is divided into three parts to train the students to learn about basic digital electronics circuits, programming with microprocessors, design and implementation of data buses in avionics with MIL – Std. 1553B and remote terminal configuration and their importance in different applications in the field of Avionics.

List of Experiments:

DIGITAL ELECTRONICS

- Addition/Subtraction of binary numbers.
- Multiplexer/Demultiplexer Circuits.
- Encoder/Decoder Circuits.
- Timer Circuits, Shift Registers, Binary Comparator Circuits.

MICROPROCESSORS

- Addition and Subtraction of 8-bit and 16-bit numbers.
- Sorting of Data in Ascending & Descending order.
- Sum of a given series with and without carry.
- Greatest in a given series & Multi-byte addition in BCD mode.
- Interface programming with 4 digit 7 segment Display & Switches & LED’s.
- 16 Channel Analog to Digital Converter & Generation of Ramp, Square, Triangular wave by Digital to Analog Converter.

AVIONICS DATA BUSES

- Study of Different Avionics Data Buses.
- MIL-Std – 1553 Data Buses Configuration with Message transfer.
- MIL-Std – 1553 Remote Terminal Configuration.

Internal Continuous Assessment *(Maximum Marks-50)*

40% - Test
40% - Class work and Record
20% - Regularity in the class

University Examination Pattern:

Examination duration: 3 hours *Maximum Total Marks: 100*
Questions based on the list of experiments prescribed.

80% - Procedure, conducting experiment, results, tabulation and inference

20% - Viva voce

Candidate shall submit the certified fair record for endorsement by the external examiner.

Course Outcome:

Students will get an insight into the use of different experimental techniques used in Avionics.

13 .709 PROJECT AND PROJECT SEMINAR (MNPSU)

Teaching Scheme: 0(L) - 0(T) - 2(P) **Credits**: 2

Course Objective :

- *To identify a problem for the final-year project, outline a solution, and prepare a preliminary design for the solution.*
- *To do a detailed study on the selected topic based on current journals or published papers and present seminars*
- *To improve the ability to perform as an individual as well as a team member in completing a project work.*
- *The seminar based on the project provides students adequate exposure to presentations to improve their communication skills.*

The student shall do a project (project phase 1) in the seventh semester, which shall be continued in the eight semester. He/she shall submit an interim report at the end of the seventh semester and the final project report shall be submitted at the end of the eighth semester. The student shall present two seminars in the seventh semester on the work carried out during project phase 1. The first seminar should highlight the definition of problem, novelty of the project, literature survey and work plan/ methodology. The second seminar should include preliminary results. The students may be assessed individually/ and in groups.

Internal Continuous Assessment *(Maximum Marks-100)*

40% - Assessment by the Guide

40% - Assessment by the Committee.

20% - Regularity in the class

Course Outcome:

At the end of the course, the students would have acquired the basic skills to for performing literature survey and paper presentation. This course shall provide students better communication skills and improve their leadership quality as well as the ability to work in groups, and thus aid them in building a successful career as an engineer.