VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELGAUM

SCHEME OF TEACHING AND EXAMINATION FOR

M.TECH. in AEROSPACE PROPULSION TECHNOLOGY(MAP)

I SEMESTER **CREDIT BASED**

Subject Code	Name of the Subject	Teaching hours/week		Duration of Exam in Hours	Marks for		Total Marks	CREDITS
		Lecture	Practical / Field Work / Assignment/ Tutorials		I.A.	Exam		
14MAP11	APPLIED MATHEMATICS	4	2	3	50	100	150	4
14MAP12	AEROSPACE PROPULSION	4	2	3	50	100	150	4
14MAP13	MEASUREMENTS, INSTRUMENTATION AND CONTROLS	4	2	3	50	100	150	4
14MAP14	HEAT TRANSFER IN PROPULSION SYSTEMS	4	2	3	50	100	150	4
14MAP15X	Elective - I	4	2	3	50	100	150	4
14MAPL16	PROPULSION LAB	--	3	3	25	50	75	2
14MAP17	Seminar	--	3	--	25	--	25	1
	Total	**20**	**16**	**18**	**300**	**550**	**850**	**23**

Elective – I

14MAP151 FINITE ELEMENT METHODS
14MAP152 CONTINUUM MECHANICS
14MAP153 MANAGEMENT OF TECHNOLOGY

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II SEMESTER **CREDIT BASED**

Subject Code	Name of the Subject	Teaching hours/week		Duration of Exam in Hours	Marks for		Total Marks	CREDITS
		Lecture	Practical / Field Work / Assignment/ Tutorials		I.A.	Exam		
14MAP21	AEROSPACE MATERIALS AND PROCESSES.	4	2	3	50	100	150	4
14MAP22	FUELS AND COMBUSTION.	4	2	3	50	100	150	4
14MAP23	MECHANICAL ASPECTS OF ROTATING MACHINERY.	4	2	3	50	100	150	4
14MAP24	COMPUTATIONAL FLUID DYNAMICS.	4	2	3	50	100	150	4
14MAP25X	Elective-II	4	2	3	50	100	150	4
14MAPL26	COMPUTATIONAL FLUID DYNAMICS LAB		3	3	25	50	75	2
14MAP27	Seminar	--	3	--	25	--	25	1
	**Project Phase-I(6 week Duration)	--	--	--	--	--	--	--
	Total	**20**	**16**	**18**	**300**	**550**	**850**	**23**

Elective – II

14MAP251 GAS TURBINE AND ROCKET PROPULSION
14MAP252 ADVANCED GAS TURBINE ENGINES
14MAP253 RAMJET & SCRAMJET

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III SEMESTER: INTERNSHIP **CREDIT BASED**

Course Code	Subject	No. of Hrs./Week		Duration of the Exam in Hours	Marks for		Total Marks	CREDITS
		Lecture	Practical / Field Work		I.A.	Exam		
14MAP31	Seminar / Presentation on Internship (After 8 weeks from the date of commencement)	-	-	-	25	-	25	1
14MAP32	Report on Internship	-	-	-		75	75	15
14MAP33	Evaluation and Viva-voce	-	-	-	–	50	50	4
	Total	**-**	**-**	**-**	**25**	**125**	**150**	**20**

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IV SEMESTER **CREDIT BASED**

Subject Code	Subject	No. of Hrs./Week		Duration of Exam in Hours	Marks for		Total Marks	CREDITS
		Lecture	Field Work / Assignment / Tutorials		I.A.	Exam		
14MAP41	ENGINE PERFORMANCE, CONTROL & SIMULATION	4	--	3	50	100	150	4
14MAP42X	Elective-III	4	-	3	50	100	150	4
14MAP43	Evaluation of Project Phase-II	-	-	-	25	-	25	1
14MAP44	Evaluation of Project Phase-III	-	-	-	25	-	25	1
14MAP45	Evaluation of Project Work and Viva-voce	–	-	3	-	100+100	200	18
Total		**8**	**--**	**09**	**150**	**400**	**550**	**28**
Grand Total (I to IV Sem.) : 2400 Marks; 94 Credits								

Elective-III

14MAP421 FATIGUE AND FRACTURE
14MAP422 ADVANCED BEARINGS AND ROTOR DYNAMICS
14MAP423 ADVANCED MANUFACTURING PROCESSES

Note:

1) Project Phase – I : 6 weeks duration shall be carried out between II and III Semesters. Candidates in consultation with the guides shall carryout literature survey / visit to Industries to finalise the topic of dissertation. .
2) Project Phase – II : 16 weeks duration. 3 days for project work in a week during III Semester. Evaluation shall be taken during the first two weeks of the IV Semester. Total Marks shall be 25.
3) Project Phase – III : 24 weeks duration in IV Semester. Evaluation shall be taken up during the middle of IV Semester. At the end of the Semester Project Work Evaluation and Viva-Voce Examinations shall be conducted. Total Marks shall be 250 (Phase I Evaluation:25 Marks, Phase –II Evaluation: 25 Marks, Project Evaluation marks by Internal Examiner(guide): 50, Project Evaluation marks by External Examiner: 50, marks for external and 100 for viva-voce).

   Marks of Evaluation of Project:

   - The I.A. Marks of Project Phase – II & III shall be sent to the University along with Project Work report at the end of the Semester.
4) During the final viva, students have to submit all the reports.
5) The Project Valuation and Viva-Voce will be conducted by a committee consisting of the following:

   a) Head of the Department (Chairman)
   b) Guide
   c) Two Examiners appointed by the university. (out of two external examiners at least one should be present).

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I SEMESTER

Applied Mathematics

Sub Code	**: 14MAP11**	**IA Marks**	**: 50**
Hrs/week	**: 04**	**Exam Hours**	**: 03**
Total Lecture Hrs	**: 50**	**Exam Marks**	**: 100**
Practical/Field work/Assignment hrs per week	**: 02**	**First Semester: 18 Weeks**	

Same as **Subject Code: 14 MAE11**

AEROSPACE PROPULSION

Sub Code : 14 MAP12	**IA Marks : 50**
No. of Lecture Hrs/week : 04	**Exam Hrs : 03**
Total Lecture Hrs : 50	**Exam Marks : 100**

Unit-I

Introduction to Propulsive Devices and Gas Turbine Engines: Atmospheric Properties. Turbojet, Turbofan, Turboprop, Turbo-shaft Engine Construction and Nomenclature, theory and performance, introduction to compressors, turbines, combustors and after burners for aircraft engines.

10 Hours

Unit-II

Gas Turbine Engine Fuel and Fuel Systems: Fuel specification, fuel properties, liquid fuel handling and treatment, heavy fuels, fuel gas handling and treatment, equipment for removal of particulate and liquids from fuel gas systems, fuel heating, cleaning of turbine components, fuel economics, operating experience, heat tracing of piping systems. Types of heat tracing systems, storage of liquids.

10 Hours

Unit-III

Engine Performance and Health Monitoring: Performance and Matching of modules of gas turbines-turbomachine aerothermodynamics, aerothermal equations, efficiencies, dimensional analysis, compressor performance characteristic, turbine performance characteristics, Engine health monitoring techniques.

10 Hours

Unit-IV

Engine Air Frame Integration: Engine Performance theory, Propeller theory – pusher and tractor mode. Thrust vectoring nozzles. Introduction to Rocket Propulsion and Space Mission, Classification and fundamentals. Fuels and propellants. Rocket combustion processes. Introduction to Space mission. Fuel cells for space mission.

10 Hours

Unit-V

Solid Propellant Rocket Description: Performance Estimation, Flame spread and Ignition transient. Mechanical characterization of propellants. Grain design. Burn rate estimation.

Liquid Propellant Rocket Description: Performance estimation. Injectors. Cooling systems. Combustion instabilities.

Hybrid Propellant Rocket Description: Performance estimation, Mission requirements and Power plant selection. Cryogenic engines. Ramjet and Scramjet engines.

10 Hours

Text Books:

1. Dennis G Shepherd, **"Aerospace Propulsion"** American Elsovier Publishing Co Inc NY.

2. George P Sutton and Donald M Ross, **"Rocket Propulsion Elements",** John Wiley & Sons NY.

Reference Books:

1. Michael J Kroes and Thomas W Wild, "Aircraft power plants", Macmillan/McGraw Hill NY.

2. E. Irwin Treager, "**Aircraft Gas Turbine Engine Technology",** 3rd Edition, 1995, 'ISBN-002018281

3. Hill, P.G. , Peterson, C.R. Addison , **"Mechanics & Thermodynamics of Propulsion",** Wesley Longman INC, 1999.

4. Huzel and Houng, **"Design of Liquid Propellant Rocket Engines',** NASA SP 125, 1971.

5. Barrere et al., **"Rocket Propulsion",** Elsevier Co., 1960

6. Williams F A. et al., **"Fundamental Aspects of Solid Propellant Rockets",** Agardograph, 116 Technivision, 1970.

7. Meherwan P. Boyce, “Gas turbine engineering handbook”, Gulf professional publisher, Elsevier, 2006

MEASUREMENTS, INSTRUMENTATION AND CONTROLS

Sub Code : 14 MAP13	**IA Marks : 50**
No. of Lecture Hrs/week : 04	**Exam Hrs : 03**
Total Lecture Hrs : 50	**Exam Marks : 100**

Unit-I

Motion - Force - Torque - Power - Pressure Measurements: Relative and absolute motion measurement. Force measurement- balance, hydraulic and pneumatic load cell, elastic force device. Torque and Power measurement- transmission, driving, absorption dynamometers. Pressure measurement- Low, moderate and high pressure measurement.

Temperature – Flow- Acoustics measurement: Temperature measurement – non electrical, electrical, radiation method. Flow measurement- primary, positive displacement, secondary or rate meter. Acoustics measurement- characteristics of sound, sound pressure, power and intensity levels, loudness, typical sound measuring systems, microphones.

10 Hours

Unit-II

Instrumentation and their Representation: Introduction, functional elements of a measurement system, classification of instruments, microprocessor based instrumentation, standard and calibration. Static and Dynamic characteristic of instruments – error and uncertainties in performance parameters, propagation of uncertainties in compound quantities, static performance parameter, impedance loading and matching, specification and selection of instrument. Dynamic characteristics – formulation of system equation, dynamic response, compensation.

10 Hours

Unit-III

Transducer, Intermediate, Indicating, Recording and Display Elements: Transducer elements–analog and digital transducers. Intermediate elements – amplifiers, differentiating and integrating elements, filters, A-D and D-A converters, terminology and conversions, data transmission elements. Digital voltmeter, cathode ray oscilloscopes, galvanometric recorder, servo type potentiometric recorders, magnetic tape recorders, digital recorder of memory type, data acquisition systems, data displace and storage.

10 Hours

Unit-IV

Introduction to Automatic Controls: Introduction, closed loop and open loop control systems, mathematical modeling of mechanical, electrical, hydraulic and pneumatic systems, Types of control actions. State-Space Methods - Introduction, Vector matrix representation of State-Space equations, State Transition Matrix and equations, Characteristics equations,

Controllability and observeability of control systems: General concept of controlability, definition of state controllability, alternate tests on controlability, Definition of observability, alternate tests on observability, relationship among controllability, observability and transfer functions.

10 Hours

Unit-V

Design of control systems in state space: Pole placement, Design of servo systems, state observers, design of regulator systems with observers, design of control systems with observers, quadratic optimal regulator systems.
Design of discrete data control systems: Digital implementation of analog controllers, digital controllers, design in frequency domain and z plane.

10 Hours

Text Books:

1. Nakra and Chaudhry, B C Nakra K K Chaudhry, "**Instrumentation, Measurement and Analysis"** Tata McGraw-Hill Companies, Inc, New York, Seventh Edition 2006.

2. R. S. Sirohi, H. C. Radha Krishna, **"Mechanical measurements"** New Age International Pvt. Ltd., New Delhi, 2004.

Reference:

1. B.C. Kuo, "Automatic Control Systems" Prentice Hall Inc.
2. K. Ogata, "Modern Control Engineering" Prentice Hall Inc
3. Arun K. Ghosh, **"Introduction to Measurements and Instrumentation",** Prentice-Hall of India Ltd, New Delhi, 2nd Edition 2007.

4. Harrison & Bollinger, "**Automatic Control Systems"** International Text Book Company.
5. Francis H. Raven, **"Automatic Control Engineering"**, McGraw- Hill International

HEAT TRANSFER IN PROPULSION SYSTEMS

Sub Code : 14 MAP14 **IA Marks : 50**
No. of Lecture Hrs/week : 04 **Exam Hrs : 03**
Total Lecture Hrs : 50 **Exam Marks : 100**

Unit-I

Fundamentals: Conduction, Convection, Radiation, Concept of boundary layers - velocity / thermal. Need for turbine blade cooling, turbine cooling technology, turbine heat transfer and cooling issues.

Turbine-Stage Heat Transfer: Introduction, Real engine turbine stage, simulated turbine stage, time-resolved heat-transfer measurement on a rotor blade. Cascade blade heat transfer. Airfoil end wall heat transfer. Turbine rotor blade tip heat transfer. Leading edge region heat transfer. Flat surface heat transfer.

10 Hours

Unit-II

Turbine Film Cooling: Fundamentals of film cooling. Film cooling on rotating turbine blades. Film cooling on cascade vane simulations, Film cooling on cascade blade simulations, Film cooling on airfoil endwalls. Turbine blade tip film cooling. Leading edge region film cooling. Flat surface film cooling. Film cooling effectiveness. Discharge coefficient of turbine cooling holes. Film cooling effect on aerodynamic losses.

Jet Impingement Cooling: Heat transfer enhancement by a single jet, Impingement heat transfer in the mid-chord region by jet array, Impingement cooling of leading edge.

10 Hours

Unit-III

Rib Turbulated Cooling: Effect of rib layouts and flow parameters on ribbed channel heat transfer, heat transfer coefficient and friction factor correlation, high performance ribs, effect of surface heating conditions, nonrectangular cross section channels, effect of high blockage ratio ribs, effect of rib profile effect of number of ribbed walls, effect of a 180^o sharp turn, detailed heat transfer coefficient measurements in ribbed channel, effect of film cooling hole on ribbed channel heat transfer.

10 Hours

Unit-IV

Pin Fin Cooling: Flow and heat transfer analysis with single pin, pin array and correlation, effect of pin shape on heat transfer, effect of non-uniform array and flow convergence, effect of skewed pin array, partial pin arrangements, effect of turning flow, pin fin cooling with ejection, effect of missing pin on heat transfer coefficient.

Temperature Measurement Techniques: Infra red thermography, Thermocouples, Heat flux gauges, Liquid crystal thermography, Temperature sensitive paints. Engine Temperature and Health Monitoring- Thermal barrier coatings, Engine temperature monitoring, Engine safety and health monitoring

10 Hours

Unit-V

Compound and new cooling techniques: Impingement on ribbed walls, impingement on pinned and dimpled walls, combined effect of ribbed wall with grooves, combined effect of ribbed walls with pins and impingement inlet conditions, combined effect of swirl flow and ribs, impingement heat transfer with perforated baffles, combined effect of swirl and impingement. Concept of heat pipe for turbine cooling, new cooling concepts.

10 Hours

Text Books:

1. Technology Je Chin Han, Sandip Dutta & Srinath V Ekkad. Taylor and Francis, **"Gas Turbine Heat Transfer and Cooling",** New York- 2000

2. JP Holman, **"Heat Transfer",** McGraw – Hill Book Company

References:

1. Anthony Giampaolo, **"Gas Turbine Handbook",**

2. NAL, Bangalore, **"Engine health monitoring as applied to gas turbine engines",** 1983

3. Eckert, E R G and Goldstern R J Ed., **"Measurement techniques in heat transfer" ,**

4. Hill P., and Peterson, C., "**Mechanics and Thermodynamics of Propulsion",** Addison-Wesley Publishing Company, 2nd Edition, 1992.

FINITE ELEMENT METHODS

Sub Code : 14 MAP151	**IA Marks : 50**
No. of Lecture Hrs/week : 04	**Exam Hrs : 03**
Total Lecture Hrs : 50	**Exam Marks : 100**

Unit-I

Introduction to Finite Element Method: Basic Steps in Finite Element Method to solve mechanical engineering (Solid, Fluid and Heat Transfer) problems: Functional approach and Galerkin approach.

Displacement Approach: Admissible Functions, Convergence Criteria: Conforming and Non Conforming elements, C_o C_1 and C_n Continuity Elements. Basic Equations, Element Characteristic Equations, Assembly Procedure, Boundary and Constraint Conditions.

10 Hours

Unit-II

Solid Mechanics I : One-Dimensional Finite Element Formulations and Analysis – Bars- uniform, varying and stepped cross section-Basic(Linear) and Higher Order Elements Formulations for Axial, Torsional and Temperature Loads with problems. Beams- Basic (Linear) Element Formulation-for uniform, varying and stepped cross section- for different loading and boundary conditions with problems.

10 Hours

Unit-III

One-Dimensional Finite Element Formulations in Two and Three Dimension: Trusses, Plane Frames and Space Frame Basic (Linear) Elements Formulations for different boundary condition -Axial, Bending, Torsional, and Temperature Loads with problems.

Two Dimensional Finite Element Formulations for Solid Mechanics Problems: Triangular Membrane (TRIA 3, TRIA 6, TRIA 10) Element, Four-Noded Quadrilateral Membrane (QUAD 4, QUAD 8) Element Formulations for in-plane loading with sample problems. Triangular and Quadrilateral Axi-symmetric basic and higher order Elements formulation for axi-symmetric loading only with sample problems

10 Hours

Unit-IV

Three Dimensional Finite Element Formulations for Solid Mechanics Problems: Finite Element Formulation of Tetrahedral Element (TET 4, TET 10), Hexahedral Element (HEXA 8, HEXA 20), for different loading conditions. Serendipity and Lagrange family Elements.

Finite Element Formulations for Structural Mechanics Problems: Basics of plates and shell theories: Classical thin plate Theory, Shear deformation Theory and Thick Plate theory. Finite Element Formulations for triangular and quadrilateral Plate elements. Finite element formulation of flat, curved, cylindrical and conical Shell elements.

10 Hours

Unit-V

Dynamic Analysis: Finite Element Formulation for point/lumped mass and distributed masses system, Finite Element Formulation of one dimensional dynamic analysis: bar, truss, frame and beam element. Evaluation of eigen values and eigen vectors applicable to bars, shaft, beams, plane and space frame

10 Hours

Text Books:

1. Chandrupatla T. R, **"Finite Elements in Engineering",** 2nd Edition, PHI, 2007.

2. Lakshminarayana H. V., "**Finite Elements Analysis – Procedures in Engineering,"** Universities Press,

Reference Books:

1. Rao S. S., **"Finite Elements Method in Engineering,"** 4th Edition, Elsevier, 2006

2. P.Seshu, **"Textbook of Finite Element Analysis"** PHI, 2004.

3. J.N.Reddy, **"Finite Element Method",** McGraw -Hill International Edition.

4. Cook R. D., et al., **“Concepts and Application of Finite Elements Analysis”,** 4th Edition, Wiley & Sons, 2003.

5. Daryl L Logan, **“A first course in Finite Element Method”,** Thomson, Third Edition

6. Hutton. **“Fundamentals of FEM”,** McGraw –Hill, 2004

CONTINUUM MECHANICS

Sub Code : 14 MAP152	**IA Marks : 50**
No. of Lecture Hrs/week : 04	**Exam Hrs : 03**
Total Lecture Hrs : 50	**Exam Marks : 100**

Unit-I

Analysis of Stress: Continuum concept, homogeneity, isotropy, mass density, body force, surface force Cauchy’s stress principle-stress vector, State of stress at a point- stress tensor, stress tensor –stress vector relationship, Force and moment, equilibrium, stress tensor symmetry. Stress transformation laws, stress quadric of Cauchy. Principal stresses, Stress invariants, stress ellipsoid, maximum and minimum shear stress, Mohr’s circle for stress, plane stress, deviator and spherical stress tensors.

10 Hours

Unit-II

Deformation and Strain: Particles and points, continuum configuration-deformation and flow concepts. Position vector, displacement vector-Lagrangian and Eulerian description, deformation gradient, displacement gradient. Deformation tensors, finite strain tensors,small deformation theory, infinitesimal strain tensors. Relative displacement- linear, rotation tensors. Transformation properties of strain tensors. Principal strains, strain invariants, cubical dilatation, spherical and deviator strain tensors, plane strain, Mohr’s circle, and compatibility equations.

Motion and Flow: Motion, flow, material derivative. Velocity, acceleration, instantaneous velocity field. Path line, stream line, steady motion. Rate of deformation, Vorticity, natural strain –physical interpretation. Material derivatives of volume, area and line element, material derivatives of volume, surface and line integrals.

10 Hours

Unit-III

Fundamental Laws of Continuum Mechanics: Conservation of mass, continuity equation. Linear momentum principle, equation of motion, equilibrium equations. Moment of momentum principle. Conservation of energy- first law of thermodynamics energy equation. Equation of state, entropy, second law of thermodynamics. Clausius-Duhem inequality, dissipation function. Constitutive equations-thermomechanical and mechanical continua.

Linear Elasticity: Generalized Hooke's law, Strain energy function, isotropy, anisotropy, elastic symmetry. Isotropic media-elastic constants. Elastostatic and Elastodynamic problems. Theorem of superposition, uniqueness of solutions, St. Venant's principle. Two dimensional elasticity- plane stress, plane strain, Airy's stress function. Two dimensional elastostatic problems in polar coordinates. Hyperelasticity, Hypoelasticity, linear thermoelasticity.

10 Hours

Unit-IV

Fluids: Fluid pressure, viscous stress tensor, barotropic flow. Constitutive equations-Stokesian, Newtonian fluids. Basic equation for Newtonian fluid, Nevier-Strokes-Duhum equations. Steady flow, hydrostatic, irrotational flow. Perfect fluids- Bernoulli's equation, circulation, potential flow, plane potential flow.

10 Hours

Unit-V

Plasticity: Basic concept and definitions, idealized plastic behavior. Yield condition- Tresca and Von-Mises criteria. Stress space-?-plane, yield surface. Post yield behavior-isotropic and kinematic hardening. Plastic stress-strain equations, plastic potential theory. Equivalent stress, equivalent plastic strain increment. Plastic work, strain hardening hypothesis. Total deformation theory-elastoplastic problems. Elementary slip line theory for plane plastic strain

Viscoelasticity: Linear viscoelastic behavior. Simple viscoelastic models-generalized models, linear differential operator equation. Creep and Relaxation- creep function, relaxation function, hereditary integrals. Complex moduli and compliances. Three dimensional theory- viscoelastic stress analysis, correspondence principles.

10 Hours

Text Books:

1. J. N. Reddy, **"Introduction to Continuum Mechanics with Applications",** Cambridge University Press, New York-2008

2. W. Michael Lai, David Rubin, Erhard Krempl **"Introduction to Continuum Mechanics",** Fourth edition, 2010, Butterworth-Heinemann -Elsevier Inc. USA

References:

1. George. E. Mase, "Continuum Mechanics", Schaum's outline series, 'McGraw Hill Book Company inc, USA.
2. Batra, R. C. **"Elements of Continuum Mechanics"** , (2006) Reston, VA: AIAA.
3. Mase, George E, **"Continuum Mechanics",** (1970), McGraw-Hill Professional
4. Dill, Ellis Harold, **"Continuum Mechanics: Elasticity, Plasticity, Viscoelasticity",** Germany: CRC Press, (2006).
5. Fung, Y. C, **"A First Course in Continuum Mechanics"**, (2nd edition), Prentice-Hall, Inc.. (1977).
6. Gurtin, M. E, **"An Introduction to Continuum Mechanics"**, New York: Academic Press, (1981).
7. Mase, G. Thomas, George E. Mase, **"Continuum Mechanics for Engineers"**, (Second Edition), CRC Press, (1999).

MANAGEMENT OF TECHNOLOGY

Sub Code : 14 MAP153	**IA Marks : 50**
No. of Lecture Hrs/week : 04	**Exam Hrs : 03**
Total Lecture Hrs : 50	**Exam Marks : 100**

Unit-I

Management of Technological Innovation: Importance, new growth theory, general issues to be managed, changing nature of industry, business and innovation systems and networks, changing nature of management-innovation process, globalization.

Management of Research and Development: What is Research and Development, Centralized and decentralized Research and Development, managing research teams, balancing research portfolios, managing international Research and Development.

10 Hours

Unit-II

Management of New Product Development: New product, innovative new product development, development of new services, flexibility in design, innovation across the board.

Management of Operation and Production: Techniques of operation and production management, lean production, automation, investment appraisal techniques, role of engineers in industry, internal and external integration of operation and production, manufacturing strategy.

10 Hours

Unit-III

Technology Strategy : Strategic management issue, technology strategy, technological competencies, balancing investments in resources and innovative capabilities, learning and technology strategy, technology strategies in small and medium sized enterprise.

Technological Collaboration: Extent of technological collaboration, Challenges of managing, organizational learning and technological collaboration, trust and technological collaboration, international technological collaboration.

10 Hours

Unit-IV

Commercialization Process: Introduction to commercialization process, marketing technology products, industrial intellectual property rights, licensing, technology pricing, technical standards, and technology transfer.

10 Hours

Unit-V

Future Challenges for Management of Technological Innovation: Five future challenges for management of technological innovation- managing technology based competition in the knowledge economy, managing the new innovation process, managing relationship with government, managing global science and technology.

10 Hours

Text Books:

1. Mark Dodgson, **"The management of technological innovation: An international and strategic approach"**, Oxford university press, New York, 2002
2. Ravinder Kumar Jain, Harry Charalambos Triandis, **"Management of research and development organizations: managing the unmanageable"** John Wiley and sons, Inc, Canada, 1997

Reference Books:

1. Ravi Jain, Harry C. Triandis, Cynthia W. Weick, **"Managing Research, Development and Innovation: Managing the Unmanageable"** John Wiley and sons, Inc, New York, 2010
2. Thomas W. Jackson, Jack Marion Spurlock**, "Research and development management"** Dow Jones-Irwin, University of Minnesota, 2009
3. Paul Lowe, **"The management of technology: perception and opportunities"** Champman and Hall,1995
4. Khalil, **"Management Of Technology"** Tat McGraw-Hill-2009

PROPULSION LAB

Sub Code : 14 MAPL16 **IA Marks : 25**
No. of Lecture Hrs/week : 03 **Exam Hrs : 03**
Total Lecture Hrs : 50 **Exam Marks : 50**

List of Experiments

1. Cascade testing of a model of turbine blade row and study of wake survey.
2. Estimation of propeller performance
3. Forced Convective heat transfer on a flat surface
4. Measurement of Burning Velocity of a Premixed Flame
5. Determination of heat of combustion of aviation fuels
6. Fuel - injection characteristics (spray cone geometry; spray speed etc. for various type of injectors)
7. Measurement of an static overall pressure rise & rotor static pressure rise & fan overall efficiency through axial flow fan unit
8. Investigation of relationship between flame speed and air-fuel ratio for a slow burning gaseous fuel.
9. Construction of flame stability diagram through flame propagation & stability unit
10. Measurement of Ram Jet Engine characteristics (thrust, static and total pressures, temperatures, exhaust velocity & fuel consumption)
11. Measurement of PulseJet Engine characteristics (thrust, static and total pressures, temperatures, exhaust velocity & fuel consumption)
12. Study of Jet Engine characteristics (thrust, static and total pressures, temperatures, exhaust velocity & fuel consumption)

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II SEMESTER

AEROSPACE MATERIALS AND PROCESSES

Sub Code : 14 MAP21	**IA Marks : 50**
No. of Lecture Hrs/week : 04	**Exam Hrs : 03**
Total Lecture Hrs : 50	**Exam Marks : 100**

Unit-I

Introduction

The Gas Turbine Engine: Major engine components, material trends, component operating environments and material requirements, compressor and turbine discs, blades. Combustion chambers, shafts, bearings.

Steels: Compressor and turbine discs, processing of steel to billets, future trends in disc materials, compressor and turbine blading, transmission materials-bearings, shafts and gears

10 Hours

Unit-II

Titanium Alloys: Classification of alloys, development of titanium alloys, production of titanium, Future development

Nickel Base Alloys: Metallurgy of Nickel base alloys, Phases present in Nickel base alloys, Strengthening mechanism, Heat treatment of Nickel base alloys, application of Nickel base alloys for turbine discs and blades, powder metallurgy discs, sheet materials, dispersion strengthened alloys.

Composite materials: Glass fibre reinforced plastics, high temperature glass fibre composites, carbon fiber reinforced plastics, pressure resisted resin injection, autoclave moulding resin system, future developments like organic resins, reinforcing fibres, high temperature materials. Ceramic materials,properties and their applications in rotating parts.

10Hours

Unit-III

Casting Technology: Light alloy casting, moulding practice, melting practice, precision investment casting, effect of casting parameters on properties, techniques for special or small quantity castings, titanium casting, directional solidification, hot isostatic pressing, future trends in casting technology, Processing of ceramics like slip casting, powder metallurgy technique.

10Hours

Unit-IV

Forging of Gas Turbine components: Historical back ground, forging equipment, press, recent trends, quality control aspects of thermo mechanical processing, processing to improve mechanical properties, Incoloy 901, titanium 6-4 alloy,12% chromium steels, super alloy powder metallurgy. Forging of compressor and turbine blades.

10Hours

Unit-V

Sheet Materials fabrication and joining: Alloy requirements, sheet materials, steels, titanium alloys, high temperature super alloys, heat treatment and de-scaling, forming, chemical machining, electron beam welding, brazing of super alloys, ultrasonic machining, water jet cutting, electrochemical processing, laser cutting for rotating machinery components, Joining technologies like plasma technique, laser welding, use of rapid prototyping machines in manufacturing components.

Surface degradation and protective treatments: Corrosion behavior, coatings and surface treatments, erosion behavior of compressor components, surface degradation and protection of combustor and turbine components, hot corrosion, high temperature coating technology.

10 Hours

Text Books:

1. G. W. Meetham, Developemnt of Gas Turbine Materials, Applied Science Publications, London
2. K. U. Krainer, Metal Matrix Composites, Wiley-VCH, Verlag GmbH & Co., 2006

Reference Books:

1. Mikell P. Groover, Fundamentals of Modern Manufacturing: Materials, Processes, and Systems, 2nd Edition, Wiley, 2005

2. G. W. Meetham and M. H. Van de Voorde, Materials for High Temperature Engineering Applications, Springer, 2006

3. George E. Dieter, Mechanical Metallurgy, SI Metric Edition, McGraw-Hill, 1988

4. William D. Callister, Materials Science and Engineering: an Introduction, 6th edition, John Wiley and sons, 2005

5. Serope Kalpakjian, Steven R Schmid, Manufacturing Engineering and Technology, Pearson Education, 2003

FUELS AND COMBUSTION

Sub Code : 14 MAP22	**IA Marks : 50**
No. of Lecture Hrs/week : 04	**Exam Hrs : 03**
Total Lecture Hrs : 50	**Exam Marks : 100**

Unit-I

Fuel Properties: Fuel Properties, Relative Density, API Gravity, Molecular Mass, Distillation Range, Vapor Pressure, Flash Point, Volatility Point, Viscosity, Surface Tension, Freezing Point, Specific Heat, Latent Heat, Thermal Conductivity, Combustion Properties of Fuels, Calorific Value, Enthalpy, Spontaneous-Ignition temperature, Limits of Flammability, Smoke Point, Luminometer Number, Smoke Volatility Index, Pressure and Temperature Effects, Sub atmospheric Pressure, Low Temperature, High Temperature

10 Hours

Unit-II

Fuel Treatment: Introduction, Types of Hydrocarbons, Paraffins, Olefins, Naphthenes, Aromatics, Production of Liquid Fuels, Removal of Sulfur Compounds, Contaminants, Asphaltenes, Gum, Sediment, Ash, Water, Sodium, Vanadium, Additives, Gum Prevention, Corrosion Inhibition/Lubricity Improvers, Anti-Icing, Antistatic–Static Dissipators, Metal Deactivators, Antismoke

Alternative Fuels aerospace applications: Hydrogen, Methane, Propane, Ammonia, Alcohols, Slurry fuels, Synthetic fuels, Fuels Produced by Fischer–Tropsch Synthesis of Coal/Biomass, Biofuels, Alternative fuel Properties, Combustion and Emissions Performance, Fischer–Tropsch Fuels, Biodiesel Fuels, Highly Aromatic (Broad Specification)

10 Hours

Unit-III

Basic Considerations: Introduction to Gas turbine Combustor, Basic Design Features, Combustor Requirements, Combustor Types and parts, Fuel Preparation, Atomizers, liner wall-cooling Techniques, combustor stability limits, combustor exit temperature traverse quality (pattern factors), Combustors for Low Emissions.

Combustion Fundamentals: Deflagration, Detonation, Classification of Flames, Physics of combustion Chemistry, Flammability Limits, Global Reaction-Rate Theory, Weak Mixtures, Rich Mixtures, Laminar Premixed Flames, laminar and turbulent flame burning velocity, measurement techniques for flame velocity, Factors Influencing Laminar Flame Speed, Equivalence Ratio, Initial Temperature, Pressure, Laminar Diffusion Flames, Turbulent Premixed Flames, Flame Propagation in Heterogeneous Mixtures of Fuel Drops, Fuel Vapor and Air.

10 hours

Unit-IV

Combustion flame characterization: Droplet and Spray Evaporation, Heat-Up Period, Evaporation Constant, Convective Effects, Effective Evaporation Constant, Spray Evaporation, Ignition Theory, Gaseous Mixtures, Heterogeneous Mixtures, Spontaneous Ignition, Flashback, Stoichiometry, Adiabatic Flame Temperature, Factors Influencing the Adiabatic Flame Temperature, Fuel/Air Ratio, Initial Air Temperature, Pressure.

Combustion Performance: Combustion Efficiency, The Combustion Process, Reaction-Controlled Systems, Burning Velocity Model, Stirred Reactor Model, Mixing-Controlled Systems, Evaporation-Controlled Systems, Reaction- and Evaporation-Controlled Systems.

10 Hours

Unit-V

Flame Stabilization & Fuel Classification: Definition of Stability Performance, Measurement of Stability Performance, Bluff-Body Flame holders, Stabilization, Mechanisms of Flame Stabilization, Flame Stabilization in Combustion Chambers, Classification of Liquid Fuels, Aircraft Gas Turbine Fuels, Engine Fuel System, Aircraft Fuel Specifications, Classification of Gaseous Fuels.

10 Hours

Text Books:

1. Arthur H.Lefebvre & Dilip R. Ballal, Gas Turbine Combustion, Alternative fuels and Emissions CRC Press, 3rd Edition, 2010
2. Samir Sarkar, Fuels & Combustion, Orient Long man 1996.

Reference Books:

1. Minkoff, G.J., and C.F.H. Tipper, Chemistry of Combustion Reaction, London Butterworths, 1962.
2. Wilson, P.J. and J.H. Wells, Coal, Coke and Coal Chemicals, New York, McGraw-Hill, 1960.
3. Williams, D.A. and G. James, Liquid Fuels, London Pergamon, 1963.
4. Gas Engineers Handbook, New York, Industrial Press, 1966.

Mechanical Aspects of Rotating Machinery

Sub Code	:	11MAP23	IA Marks	:	50
Hrs/ Week	:	04	Exam Hours	:	03
Total Hours	:	50	Exam Marks	:	100

Unit-I

Introduction: Definition of a rotating machinery, parts of a rotating machinery w.r.t different aero engine configurations namely like turboprop, turbo shaft, turbojet and turbo fan. Basic issues in rotating machinery like vibrations, unbalance, casing rub and oil debris.

Vibration: An overview of basics of vibrations and their significance in rotating machinery, Sources of vibrations in rotating machinery and its characterization. Vibration isolators, vibration measurement, sensors and analysis, industrial standards for vibration.

10 Hours

Unit-II

Analytical modeling and solution for vibration: Single DOF systems, free vibration, un-damped and viscously damped cases. Forced vibration, impulse and Fourier excitation. Response spectra, and modal frequency response, one & two degrees of freedom system. General multi-DOF systems including stiffness, flexibility and mass matrices. Natural frequencies and mode shapes (Eigen values and Eigen vectors), Coupled modes.

Energy methods: Lagrange's equations, Application to rotor- shaft systems, Branched gear- shaft systems, Rigid body modes, Continuous (distributed parameter) systems. Critical Speeds and Response to Imbalance: Classical whirl, Coriolis effects, Euler angles, Coriolis matrix, Quadratic Eigen value problem solution, Campbell diagrams.

10 Hours

Unit-III

Fatigue and creep: Definition of fatigue and creep, creep and fatigue in gas turbine components, low and high cycle fatigue, life estimation of turbine blades estimation for creep, typical examples of gas turbine components failure due to creep and fatigue.

10 Hours

Unit-IV

Imbalance characterization in engines: Rigid and flexible rotors, impact of unbalance on aero engine performance, sources of unbalance, single and multi-plane balancing , Shaft Alignment , Balancing standards for rotating machinery in industries.

Bearings, Lubrication and Seals**:** Types of bearings in aero engines, Load and life evaluation of aircraft engine bearings, lubrication and its characterization. Application of magnetic and foil bearings in aero engines, Different types of seals used in aero engines.

10 Hours

Unit-V

Engine noise and Inspection: Shaft and casing stiffness measurement and methods for control, Measurement of noise, sources of noise generation and methods for noise reduction, Various methods for inspecting Engine rotating component including non-destructive methods and CMM. Engine fault diagnosis and tools

10 Hours

Text Books:

1. W.T. Thomson, Mechanical Vibration, 5th Edition, Prentice- Hall, 1997.
2. Michell Lalanne and Ferraris, Rotordynamics Prediction in Engineering, John Wiley, 1998.

Reference Books:

1. Daniel J. Inman, Engineering Vibration, Prentice Hall, 2007.
2. S.P. Timoshenko et al, Vibration problems in Engineering, Wolfenden Press, 2008.
3. John M. Vance, Rotor dynamics of Turbomachinery, Wiley-Interscience, 1988.
4. Maurice L Adams, Rotating Machinery Vibration, CRC Press, 2000.

COMPUTATIONAL FLUID DYNAMICS

Subject Code	**: 14 MAP24**	**IA Marks**	**: 50**
No of Lectures Hours/Week	**: 04**	**Exam Hours**	**: 03**
Total No. of Lecture Hours	**: 50**	**Exam Marks**	**:100**

Unit-I

Introduction-CFD ideas to understand, CFD Application, Governing Equations**,** The Flow and its Mathematical Description, Conservative vs non conservative forms, Integral vs. differential forms , Conservation Laws, Continuity Equation, Momentum Equation, Energy Equation, Viscous Stresses ,Complete System of the Navier-Stokes Equations, Formulation for a Perfect Gas, Formulation for a Real **Gas,** Simplifications to the Navier-Stokes Equations.

Mathematical Behavior of Partial Differential Equations and Discretization- Classification of partial differential equations and its` Impact on physical and computational fluid dynamics; case studies,Essence of discritisation, Higher order Difference quotients, Explicit & Implicit Schemes, Consistency Requirements, Accuracy of Discretisation, Von Neumann Stability Analysis, Fourier Symbol and Amplification Factor, Derivation of the CFL Condition.

10 Hours

Unit-II

Principles of Solution of the Governing Equations-Spatial Discretisation, Finite Difference Method, Finite Volume Method, Finite Element Method, Other Discretisation Methods. Central versus Upwind Schemes, Temporal Discretisation, Explicit Schemes, Implicit Schemes. Turbulence Modelling, **Initial** and Boundary Conditions, Aspects of Numerical dissipation & dispersion, artificial viscosity.

Grid Generation-Structured Grid Generation, Algebraic Methods, PDE methods, Surface grid generation, Multi Block Structured grid generation, Unstructured Grid Generation, Delaunay-Vuronoi Method, advancing front methods (AFM Modified for Quadrilaterals, iterative paving method, Quadtree & Octree method), **AdMAPive Grid Methods-** Multi Block AdMAPive Structured Grid Generation, Unstructured AdMAPive Methods, Mesh refinement methods, Mesh movement Methods and Mesh enrichment method.

Approximate Transformation. Matrices & Jacobian. Generic form of governing Flow Equations with strong conservative form in transformed space. Transformation of Equation from physical plane into computational Plane -examples. Control function methods.

10 Hours

Unit-III

Spatial Discretisation- Structured Finite Volume Scheme, Geometrical Quantities of a Control Volume, Two-Dimensional Case, Three-Dimensional Case, General Discretisation Methodologies-Cell-Centred Scheme, Cell-Vertex Scheme: Overlapping Control Volumes, Cell-Vertex Scheme: Dual Control Volumes, Cell-Centred versus Cell-Vertex Schemes. Discretisation of Convective Fluxes- Central Scheme with Artificial Dissipation, Flux-Vector Splitting Schemes, Flux-Difference Splitting Schemes, Total Variation Diminishing Schemes, Limiter Functions. Discretisation of Viscous Fluxes-Cell-Centred Scheme, Cell-Vertex Scheme.

Temporal Discretisation-Explicit Time-Stepping Schemes-Multistage Schemes (Runge-Kutta), Hybrid Multistage Schemes, Implicit Time-Stepping Schemes, Treatment of the Source Term, Determination of the Maximum Time Step

10 Hours

Unit-IV

Turbulence Modelling-Basic Equations of Turbulence, Reynolds Averaging, Favre (Mass) Averaging, Favre- and Reynolds-Averaged Navier-Stokes Equations, Reynolds-Averaged Navier-Stokes Equations and turbulence models, Large-Eddy Simulation (LES), Wall Models, DES, Direct Numerical Simulation(DNS)

Boundary Conditions-Concept of Dummy Cells-Solid Wall, Inviscid Flow, Viscous Flow, Fafield . Concept of Characteristic Variables- Inlet/Outlet Boundary, Symmetry Plane, Coordinate Cut, Periodic Boundaries, Interface Between Grid Blocks, Flow Gradients at Boundaries of Unstructured Grids.

10 Hours

Unit-V

CFD Application to Some Problems-Flow over a flat plate, airfoil, Convergent & Convergent Divergent nozzle, Flow in a cascade, Flow in a compressor/turbine stage, 1D heat conduction,1D conduction-convection, Quasi-Steady Rotor-Stator Interaction, Industrial examples, Basic concepts in multiphase and combustion modelling.

10 Hours

TEXT BOOKS:

1. **John D Anderson Jr. -** Computational Fluid Dynamics, `The Basics with Applications`, McGraw Hill International Edn;1995.
2. **T J Chung** - Computational Fluid Dynamics, Cambridge University Press, 2008.

REFERENCE BOOKS:

3. **F. Wendt (Editor),** “Computational Fluid Dynamics - An Introduction”, Springer – Verlag, Berlin; 1992.

4. **Charles Hirsch**, "Numerical Computation of Internal and External Flows", Vols. I and II. John Wiley & Sons, New York; 1988.
5. **Jiyuan Tu, Guan Heng Yeoh, and Chaoqun Liu**, Computational Fluid Dynamics- A Practical Approach, Elsevier Inc; 2008

ELECTIVES-II

GAS TURBINES AND ROCKET PROPULSION

Subject Code	**: 14 MAP251**	**IA Marks**	**: 50**
No of Lectures Hours/Week	**: 04**	**Exam Hours**	**: 03**
Total No. of Lecture Hours	**: 50**	**Exam Marks**	**:100**

Unit-I

Introduction and Categories: Categories of propulsion system, air breathing engines, non-air breathing engines, thrust of turbojet, turbofan, ramjet and rockets, Performance parameters of propulsion systems.

10 Hours

Unit-II

Components and Performance: Gas turbine components, flow through gas turbine components like inlets, compressor, combustor, turbine and nozzles, Gas turbine component characteristics, propeller, propeller performance

10 Hours

Unit-III

Basic Cycles, Performance and matching: Gas turbine engine basic cycle, ideal and real cycle, T-S diagram, turbo jet, turbofan and turboprop engines, turbofan with mixed and un mixed jets, Concept of spooling, Engine rating, concept of flat rating Thrust and SFC variation with flight Mach number and altitude, Commercial gas turbine engines.

Single and two spool engine matching, matching of turbojet and turbo fan engines, Design point optimization of gas turbine engine, Engine sizing, Installed performance and uninstalled performance, Gas turbine engine evaluation in test beds .

10 Hours

Unit-IV

Velocity increment and mass ratio, burnout velocity and distance, specific impulse, trajectory and gravity turn, coasting height, multi staging, satellite and escape velocity.

Aero-thermo chemistry, Chemical rockets, internal ballistics of solid propellant rockets, performance parameters, Liquid propellant rockets, components and its performance, propellant-general, liquid and solid propellant.

10 Hours

Unit-V

Hybrid rockets, status and development of chemical rockets, Electro thermal rocket engines, performance parameters, propellants, resistance heating, arc heating, electrode less discharge, Electromagnetic propulsion, principle of operation, pulse plasma accelerators, travelling wave accelerators, propellants, performance of E-M accelerators.

Ion Propulsion: Performance parameters, efficiency of ions, acceleration of the beam, beam neutralization, optimum specific impulse, acceleration – deceleration system, heavy ion.

10 Hours

Text Books:

1. Sutton, G.P., "Rocket Propulsion Elements", John Wiley & sons Inc., New York, 5th Edition, 1993
2. D.G.Shepherd, "Aerospace Propulsion", American Elsevier Publishing Company, Inc.

Reference Books:

1. Jack D. Mattingly ," Elements of Gas Turbine Propulsion" Tata McGraw-Hill Publishing Company Limited, New Delhi, 1996
2. Jack. D. Mattingly, William H. Heiser and David. T. Pratt ,"Aircraft Engine Design", AIAA Education Series
3. Gordon C. Oates "Aerothermodynamics of Gas Turbine and Rocket Propulsion", AIAA Education Series
4. William W. Bathe, "Fundamentals of Gas Turbines", John Wiley and Sons
5. HIH Sarvanamuttoo, GFC Rogers, H.Cohen "Gas Turbine Theory" , 5th Edition, Pearson Education, Asia
6. Hill, P.G and Peterson, CR "Mechanics & Thermodynamics of Propulsion" Addition-Wesley Longman INC, 1999.

ADVANCED GAS TURBINE ENGINES

Subject Code	**: 14 MAP252**	**IA Marks**	**: 50**
No of Lectures Hours/Week	**: 04**	**Exam Hours**	**: 03**
Total No. of Lecture Hours	**: 50**	**Exam Marks**	**:100**

Unit-I

Compressor and turbine: theory, 3-D Flow analysis in turbo machines, -Loss mechanism and classification and correlations, Rotating stall and surge and its characterisation, active and passive control, Methods of stall margin improvements, Turbine end wall contouring, Tip clearance control, Rim seals for leakage improvements, Comparison of swept propeller blades with conventional propeller blades.

Dry low emission combustion systems, Variable geometry combustor, Staged combustion, Rich burn, quick quench-lean burn (RQL) combustor, lean premixed (LPM)combustor, Catalytic combustion, Flame stabilization in combustor and after burner, Correlation for prediction of components of emission, emission standards, alternate fuels for aerospace applications.

10 Hours

Unit-II

Gas Turbine Engine Cooling: Turbine film cooling, Film cooling effectiveness, turbine blade tip film cooling, leading edge film cooling, effects on aerodynamic losses, internal blade cooling, jet impingement cooling, rib turbulated cooling, pin-fin cooling, compound and new cooling techniques, turbine internal cooling with rotation, effects of rotation number, model orientation, wall heating, channel cross section, empirical correlations.

10 Hours

Unit-III

Methods and techniques: Experimental methods in heat transfer, measurement techniques, mass transfer analogy techniques, optical techniques, liquid crystal thermograph, flow and thermal field measurement techniques

Engine thrust augmentation, engine thrust reverser concept and devices, thrust vectoring methods, fluidic thrust reverser.

10 Hours

Unit-IV

Performance: Gas turbine performance deterioration, Intake distortion and quantification, compressor fouling, variable inlet guide vane (VIGV) and variable stator vane (VSV) problems, hot end damage, tip rubs and seal damage, quantifying faults, quantifying performance deterioration.

10 Hours

Unit-V

Engines: Grouping of engine systems, bare engine, nacelle, engine mounts, inlet anti icing system, electrical power generation systems, pneumatic system, hydraulic systems, fuel supply system, fire detection and extinguishing system, FADEC, sensors, Engine Starting system.

Classification of turbofan engines, Schematic of High speed turbofan, Geared Turbofan, Ducted contra rotating fan, open rotors, comparison in terms of fuel burn, intercooled and recuperated engine, Some examples of the above from literature, emission and noise, Noise quantification and suppression, Standards for engine noise.

10 Hours

Text Books:

1. Jack D. Mattingly ," Elements of Gas Turbine Propulsion" Tata McGraw-Hill Publishing Company Limited, New Delhi, 1996
2. Andreas Linke-Diesinger, " Systems of commercial turbo fan engines", Springer Publication

Reference Books:

1. Je-Chin Han, Sandip Dutta, Srinath kkad, " Gas turbine Heat Transfer and cooling technology" , Taylor and Francis, 2000
2. Razak, A.M.Y., "Industrial Gas Turbines-Performance and Operability", Woodhead Publishing Limited
3. NASA-SP-36
4. Philip P. Walsh and Paul Fletcher, "Gas Turbine Performance", 1998, Blackwell Science Ltd, Blackwell Publishing company
5. Charles E. Otis and Peter A. Vosbury ,"Aircraft Gas Turbine Power plants"

6. Arthur H.Lefebvre and Dilip R. Ballal, " Gas Turbine Combustion- Alternate Fuels and emissions", CRC Press, Taylor and Francis Group
7. Budugur Lakshminarayana,"Fluid Mechanics and Heat Transfer of Turbomachinery", John Wiley and Sons, Inc.

RAMJET AND SCRAMJET

Subject Code	**: 14 MAP253**	**IA Marks**	**: 50**
No of Lectures Hours/Week	**: 04**	**Exam Hours**	**: 03**
Total No. of Lecture Hours	**: 50**	**Exam Marks**	**:100**

Unit-I

Introduction: Background Description, Fundamentals of Propulsion, Motivation to Study Ramjet and Scramjet, Thrust, Modes of Thrust Generation, Hypersonic Air breathing propulsion Ramjet. Basics of compressible one dimensional flows, Compressibility of Fluid, Mach number, T-S diagram of Compressible flow, Types of Ramjet Engines, Analysis of Ramjet Engines, performance, Thrust Equation.

10 Hours

Unit-II

The ramjet engine: concept and performance. Different kinds of ramjets: the ram-rocket, the scramjet, Ram jet engine components like inlet, combustion chamber, nozzle, fuel control system and their design. Influence of component performance on the ram jet engine Supersonic intakes, internal compression intake, Normal shock diffuser, converging diverging diffuser, external compression intakes, flow distortion, mixed compression intake, axi-symmetric intake.

10 Hours

Unit-III

Ramjet Operating principle : Sub critical, 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. Types of Scramjet Engines, Analysis of Scramjet Engines, performance, Thrust Equation, Problem, TS Diagram, Loss coefficient, Combustion Chamber, Types of Injection

10 Hours

Unit-IV

Scramjet Propulsion: Practical Progress, Heat addition in duct with Area variations, Isolators, Aerothermodynamics of dual mode combustion system, Real H-K diagram, Interoperation of Experimental Data, Fuel-air mixing processes, Measures of local goodness of mixing, Mixing in a Turbulent shear layer

10 Hours

Unit-V

Hypersonic Air breathing Engine: Performance Analysis, Thermodynamics Closed Cycle Analysis ,Maximum Allowable Compression Temperature, First Law Analysis Results, Stream Thrust Analysis, Compression Components, Influence of Boundary Layer Friction, Burner Entry Pressure, Leading-Edge Oblique Shock Wave geometry

10 Hours

Text Books:

1. Hypersonic air-breathing propulsion by William H. Heiser, David T. Pratt
2. Scramjet Propulsion –edited by ET Curran and S N B Murthy , Progress in Astronautics and Aeronautics, AIAA

References:

1. Ramjet Technology, EA Bunt and others
2. RAMJETS, AIAA ,
3. AGARD, Advisory Group For Aerospace Research and Development

COMPUTATIONAL FLUID DYNAMICS LAB

Subject Code :14MAPL26 **IA Marks : 25**
No of Lab Hrs/Week :03 **Exam hrs : 03**
Total No. of Lab Hrs :50 **Exam Marks : 50**

List of Experiments

1. Laminar Flow over a flat plate and determination of flow variables.
2. Turbulent Flow over a flat plate and determination of flow variables.
3. Flow over an airfoil and computation of basic flow variables (velocities and pressure).
4. Computation of flow parameter in a Convergent & Convergent- Divergent nozzle using commercially available software.
5. Computation of Fluid Flow variables in a cascade of blades using commercially available software.
6. Computations of Flow variables in a compressor/turbine stage using commercially available software.
7. Experiment on One-dimensional heat conduction and computation of different parameters.
8. Computation of one dimensional conduction-convection mode of heat transfer using commercially available software.
9. Computation in a quasi-steady Rotor-Stator Interaction using commercially available software.
10. Computational Fluid dynamics in any one Industrial example relevant to aerospace propulsion technology using commercially available software..
11. Basic concepts and computation in multiphase flow in propulsion using commercially available software.
12. Computations of flow variables in combustion modeling in a gas turbine propulsion system using commercially available software.

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELGAUM
SYLLABUS OF TEACHING AND EXAMINATION FOR
M.TECH. AEROSPACE PROPULSION TECHNOLOGY(MAP)

IV SEMESTER

ENGINE PERFORMANCE, CONTROL AND SIMULATION

Sub Code : 14 MAP41	**IA Marks : 50**
No. of Lecture Hrs/week : 04	**Exam Hrs : 03**
Total Lecture Hrs : 50	**Exam Marks : 100**

UNIT-I: Gas turbine engine, Turbojet, turbofan, turboprop schematic, identification of components flow properties along gas path, Definition of Engine Performance parameters specific thrust and specific fuel consumption, installed and uninstalled performance, Importance of by-pass ratio and afterburning, concept of multi spooling, importance of bleed and power off-take, engine systems and accessories.

Component performance, atmospheric model, correlations for variation of gas properties, inlet and diffuser pressure recovery, compressor and turbine isentropic and polytrophic efficiencies, Burner efficiency, pressure loss and pattern factor. Exit nozzle loss, propeller performance parameters, variable and constant pitch propellers, component performance with variable gas properties.

10 Hours

UNIT-II: Parametric cycle analysis of real engine, turbojet, turbo jet with after burner, turbofan with separate exhaust streams, turbofan with after burning separate exhaust streams, turbofan with after burning mixed exhaust streams, turbo prop engine.

Engine operating line on compressor characteristics, Equilibrium running of gas generator, matching procedure for twin spool engines, behaviour of twin spool engines, Method of displacing equilibrium running line, matching procedure for turbofan engine, performance deterioration.

10 Hours

UNIT-III: Aero engine evaluation, engine test bed types, schematic layout of test beds, instrumentation on test beds, engine and component performance from gas path data, engine health monitoring parameters, sensors, analysis of vibration and blade tip gap signals, high temperature sensors, oil debris monitoring, engine trend analysis for engine diagnostics and prognostics.

Noise characterization, Measurement of noise, sources of noise generation in aero engine components, noise propagation due to propellers, comparative noise characteristics for turbojet, turbofan, turbo shaft and turbo prop, active and passive methods for noise reduction, International standards for aero engine noise.

10 Hours

UNIT-IV: Aircraft engine integration, configuration of engine locations in aircrafts, types of nacelles and pylon. Engine mounts, basic loads on engine mounts. Nacelle-pylon-wing integration, Types of thrust reverser and its mechanism. Drag due to nacelle, engine installed performance.

8 Hours

UNIT-V: Aero engine control, FADEC architecture, Digital electronic control unit for aero engine, Gas generator control, engine limit protection, engine automatic and manual starting, power management, engine data for cockpit indication, engine condition parameters display in the cockpit, thrust reverser control and feedback, fuel control and computation, fuel recirculation control, cooling of FADEC, management of engine subsystems like lubrication, on board power, fuel scavenge, starting system, Engine gas path data in FADEC, Engine health management from flight data recorder.

10 Hours

TEXT BOOKS:

1. Jack D. Mattingly ,” Elements of Gas Turbine Propulsion” Tata McGraw-Hill Publishing Company Limited, New Delhi, 1996
2. Gordon C. Oates “Aerothermodynamics of Gas Turbine and Rocket Propulsion”, AIAA Education Series

REFERENCES:

1. Jack. D. Mattingly, William H. Heiser, David.T.Pratt ,”Aircraft Engine Design”, AIAA Education Series
2. Nicholas Cumpsty,” Jet Propulsion”, Cambridge University Press, 1997
3. Saeed Farokhi, “ Aircraft Propulsion”, John Wiley & Sons, Inc
4. Ahmed F. E1-Sayed, “ Aircraft Propulsion and Gas Turbine Engines”, CRC Press, Taylor and Francis Group
5. Philip P. Walsh and Paul Fletcher, ”Gas Turbine Performance”, 1998, Blackwell Science Ltd, Blackwell Publishing company
6. Andreas Linke-Diesinger, Systems of Commercial Turbo Fan Engines-An Introduction to System Functions, Springer Publications

IV SEMESTER ELECTIVES

FATIGUE AND FRACTURE

Sub Code : 14 MAP421 **IA Marks : 50**
No. of Lecture Hrs/week : 04 **Exam Hrs : 03**
Total Lecture Hrs : 50 **Exam Marks : 100**

UNIT-I: Fracture Mechanics Principles: Introduction, Mechanisms of Fracture, a crack in a structure, the Graffiti's criterion, modern design, - strength, stiffness and toughness. Stress intensity approach.

Stress Analysis for Members with Cracks: Linear elastic fracture mechanics, Crack tip stress and deformations; Relation between stress intensity factor and fracture toughness, Stress intensity based solutions. Crack tip elastic zone estimation, Plane stress and Plane strain concepts, the Dugdale approach and the thickness effect.

10 Hours

UNIT-II: Elastic - Plastic Fracture Mechanics: Introduction, Elasto-plastic factor criteria, crack resistance curve, I-integral, Crack opening displacement, crack tip opening displacement, Importance of R-curve in fracture mechanics, Experimental determination of I-integral, COD and CTOD.

Dynamic and Crack Arrest: Introduction, the dynamic stress intensity and elastic energy release rate, crack branching, the principles of crack arrest, and the dynamic fracture toughness.

12 Hours

UNIT-III: Fatigue and Fatigue Crack Growth Rate: Fatigue loading, various stages of crack propagation, the load spectrum, approximation of the stress spectrum, the crack growth integration, fatigue crack growth laws.

Fracture Resistance of Materials: Fracture criteria, fatigue cracking criteria, effect of alloying and second phase particles, effect of processing and anisotropy, effect of temperature, closure.

10 Hours

UNIT-IV: Computational Fracture Mechanics: Overview of numerical methods, traditional methods in computational fracture mechanics – stress and displacement marching, elemental crack advance, virtual crack extension, the energy domain integral, finite element implementation. Limitations of numerical fracture analysis.

10 Hours

UNIT-V: Fracture Toughness testing of metals: Specimen size requirements, various test procedures, effects of temperature, loading rate and plate thickness on fracture toughness. Fracture testing in shear modes, fatigue testing, NDT methods.

8 Hours

TEXT BOOKS:

1. Introduction to Fracture Mechanics - Karen Helen, McGraw Hill Pub 2000.
2. Fracture of Engineering Brittle Materials - Jayatilake, Applied Science, London. 2001.

REFERENCES:

1. Elementary Engineering Fracture of Mechanics - David Broek, Artinus Nijhoff, London 1999
2. Fracture Mechanics Application - T. L. Anderson, CRC press 1998

ADVANCED BEARINGS AND ROTOR DYNAMICS

Sub Code : 14 MAP422 | **IA Marks : 50**
No. of Lecture Hrs/week : 04 | **Exam Hrs : 03**
Total Lecture Hrs : 50 | **Exam Marks : 100**

UNIT-I: Introduction to Fluid Film Bearings, Anti friction bearings, Advanced Bearings and Rotor dynamics.
Variable geometry tilted pad bearings, Fluid film bearing dynamic coefficients & load bearing capability and methods of obtaining them, Influence of preload on the dynamic coefficients of journal bearings.

10 Hours

UNIT-II: Objective of Rotor dynamic Analysis, Concept of rigid and flexural critical speeds and mode shapes, External Dampers, Single degree spring-mass-damper system analysis as applied to Jeffcott rotors.

Bending Critical Speeds of Simple Shafts, whirling of an unbalanced simple elastic rotor, Transfer Matrix Analysis for bending Critical Speeds, , Effect of axial stiffness.

10 Hours

UNIT-III: Torsional vibrations in rotating machinery, modeling of rotating machinery shafting, Transfer matrix analysis for free vibration, equivalent discrete system, transient response in torsional vibration.

Hydrodynamic Bearings, Viscosity, mechanism of pressure development in the film, a simple rotor in fluid film bearing, optimum design of bearings, Shafts with dissimilar moment of inertia.

10 Hours

UNIT-IV: Introduction to Smart Materials, Structures and Products Technologies. Overview of application of smart materials to rotor dynamics. Shape Memory Materials, Fiber-Optic Sensors.

10 Hours

UNIT-V: Case study, Ball and Rolling element bearing, Bearing support design for a typical aero engine, FEM methods, Different Types of Models, Bearing and Seal Metrics, Torsional and Axial Models, Transient response using FEM software.

10 Hours

Text Books:

1. Rotor dynamics by JS Rao , New Age International Publishers
2. Machinery Vibration and rotor Dynamics by John Vance, Fouad Zeidan and Brian Murphy

References:

1. Rotor Dynamics by Agnieszka Muszyńska
2. Rotor Dynamics of Turbo machinery by John M. Vance

ADVANCED MANUFACTURING PROCESSES

Sub Code : 14 MAP423	**IA Marks : 50**
No. of Lecture Hrs/week : 04	**Exam Hrs : 03**
Total Lecture Hrs : 50	**Exam Marks : 100**

UNIT-I: Advanced machining theory & practices, mechanisms of chip formation, shear angle relations, and theoretical determination of cutting forces in orthogonal cutting; analysis of turning, drilling, and milling operations.
Mechanics of grinding; dynamometry; thermal aspects of machining; tool wear; economics of machining; processing of polymers, ceramics, and composites;

10 Hours

UNIT-II: Advanced foundry processes - metal mould, continuous, squeeze, vacuum mould, evaporative pattern, and ceramic shell casting.
Advanced Machining Processes: Introduction, Process principle, Material removal mechanism, Parametric analysis and applications of processes such as ultrasonic machining (USM),Abrasive jet machining (AJM),Water jet machining (WJM),Abrasive water jet machining (AWJM), Electrochemical machining (ECM),Electro discharge machining (EDM),Electron beam machining (EBM),Laser beam machining (LBM) processes.

12 Hours

UNIT-III: Advanced Casting Processes: Metal mould casting, Continuous casting, Squeeze casting, vacuum mould casting, Evaporative pattern casting, Ceramic shell casting.
Advanced Welding Processes: Details of electron beam welding (EBW), laser beam welding (LBW), ultrasonic welding (USW).

10 Hours

UNIT-IV: Advanced Metal Forming Processes: Principles, advantages and applications of high energy rate forming (HERF) process, Electro-magnetic forming, explosive forming, Electro-hydraulic forming, Stretch forming, Contour roll forming.

8 Hours

UNIT-V: Powder metallurgy: Basic steps in Powder metallurgy brief description of methods of production of metal powders, conditioning and blending powders, compaction and sintering application of powder metallurgy components, advantages and limitations.

10 Hours

Text Books:

1. "Materials and Processes in Manufacturing" (8th Edition), E. P. DeGarmo, J. T Black, R. A. Kohser, Prentice Hall of India, New Delhi (ISBN 0-02-978760).

2. "Manufacturing Science" A. Ghosh, and A. K. Mallik, Affiliated East-West Press Pvt. Ltd. New Delhi.

References:

1. "Nontraditional Manufacturing Processes", G.F. Benedict, Marcel Dekker, Inc. New York (ISBN 0-8247-7352-7).

2. Mechanical metallurgy (SI units), by G.E. Dieter, Mc Graw Hill pub.2001

3. Manufacturing Engineering and Technology by Serope Kalpakjian and Stevan R.