VISVESVARAYA TECHNOLOGICAL UNIVERSITY
BELAGAVI

Scheme of Teaching and Examination and Syllabus

M.Tech Aerospace Propulsion Technology(APT)

Outcome Based Education(OBE) and Choice Based Credit System (CBCS)

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI
Scheme of Teaching and Examination – 2018-19
M.Tech Aerospace Propulsion Technology(APT)
Outcome Based Education(OBE) and Choice Based Credit System (CBCS)

I SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching Hours /Week		Examination				Credits
				Theory	Practical/ Field work/ Assignment	Duration in hours	CIE Marks	SEE Marks	Total Marks	
1	PCC	18MAP11	Applied Mathematics	04	--	03	40	60	100	4
2	PCC	18MAP12	Aerospace Propulsion	04	--	03	40	60	100	4
3	PCC	18MAP13	Finite Element Methods	04	--	03	40	60	100	4
4	PCC	18MAP14	Aerospace Materials and processes	04	--	03	40	60	100	4
5	PCC	18MAP15	Introduction to Space Technology	04	--	03	40	60	100	4
6	PCC	18MAPL16	Propulsion Lab	-	04	03	40	60	100	2
7	PCC	18RMI17	Research Methodology and IPR	02	--	03	40	60	100	2
			TOTAL	**22**	**04**	**21**	**280**	**420**	**700**	**24**

Note: PCC: Professional Core Course.

Internship: All the students shall have to undergo mandatory internship of 6 weeks during the vacation of I and II semesters and /or II and III semesters. A University examination will be conducted during III semester and prescribed credit shall be included in the III semester. Internship shall be considered as a head of passing and shall be considered for the award of degree. Those, who do not take-up/complete the internship shall be declared as failed and have to complete during subsequent University examination after satisfy the internship requirements.

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI
Scheme of Teaching and Examination – 2018-19
M.Tech Aerospace Propulsion Technology(APT)
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II SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching Hours /Week		Examination				Credits
				Theory	Practical/ Field work/ Assignment	Duration in hours	CIE Marks	SEE Marks	Total Marks	
1	PCC	18MAP21	Computational Fluid Dynamics	04	--	03	40	60	100	4
2	PCC	18MAP22	Fuels and Combustion	04	--	03	40	60	100	4
3	PCC	18MAP23	Heat Transfer in Propulsion Systems	04	--	03	40	60	100	4
4	PEC	18MAP24X	Professional elective 1	04	--	03	40	60	100	4
5	PEC	18MAP25X	Professional elective 2	04	--	03	40	60	100	4
6	PCC	18MAPL26	Computational Fluid Dynamics Lab	--	04	03	40	60	100	2
7	PCC	18MAP27	Technical Seminar	--	02	--	100	--	100	2
TOTAL				**20**	**06**	**18**	**340**	**360**	**700**	**24**

Note: PCC: Professional core Course, PEC: Professional Elective Course,

Professional Elective 1		**Professional Elective 2**	
Course Code under 18MAP24X	**Course title**	**Course Code under 18MAP25X**	**Course title**
18MAP241	Fatigue and Fracture Mechanics	18MAP251	Ramjet and Scramjet
18MAP242	Engine Performance Control & Simulation	18MAP252	Mechanical Aspects of Rotating Machinery
18MAP243	Aerospace Structures	18MAP253	Advanced Composite Materials

Note:

1.Technical Seminar:CIE marks shall be awarded by a committee comprising of HoD as Chairman, Guide/co-guide in any and a senior faculty of the department. Participation in seminar by all postgraduate students of the same and other semesters of the programme shall be mandatory.

The CIE marks awarded for Technical Seminar, shall be based on the evaluation of Seminar Report, Presentation skill and Question and Answer session in the ratio 50:25:25.

2. Internship: All the students shall have to undergo mandatory internship of 6 weeks during the vacation of I and II semesters and /or II and III semesters. A University examination will be conducted during III semester and prescribed credit shall be included in the III semester. Internship shall be considered as a head of passing and shall be considered for the award of degree. Those, who do not take-up/complete the internship shall be declared as failed and have to complete during subsequent University examination after satisfy the internship requirements.

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III SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching Hours /Week		Examination				Credits
				Theory	Practical/ Field work/ Assignment	Duration in hours	CIE Marks	SEE Marks	Total Marks	
1	PCC	18MAP31	Aerospace Instrumentation and Control	04	--	03	40	60	100	4
2	PEC	18MAP32X	Professional Elective 3	04	--	03	40	60	100	4
3	PEC	18MAP33X	Professional Elective 4	04	--	03	40	60	100	4
4	Project	18MAP34	Evaluation of Project phase -1	--	02	--	100	--	100	2
5	Internship	18MAPI35	Internship	(Completed during the intervening vacation of I and II semesters and /or II and III semesters.)		03	40	60	100	6
		TOTAL		12	02	12	**260**	**240**	**500**	**20**

Note: PCC: Professional Core Course, PEC: Professional Elective Course

Professional Elective 3		Professional Elective 4	
Course Code under 18MAP32X	**Course title**	**Course Code under 18MAP33X**	**Course title**
18MAP321	Advanced Bearings and Rotor Dynamics	18MAP331	Missile and Launch Vehicles
18MAP322	Hypersonic Aerodynamics	18MAP332	Advanced Propulsion Systems
18MAP323	Advanced Gas Turbines	18MAP333	Gas Turbine and Rocket Propulsion

Note:

1. Project Phase-1: Students in consultation with the guide/co-guide if any, shall pursue literature survey and complete the preliminary requirements of selected Project work. Each student shall prepare relevant introductory project document, and present a seminar.

CIE marks shall be awarded by a committee comprising of HoD as Chairman, Guide and a senior faculty of the department.The CIE marks awarded for project work phase -1, shall be based on the evaluation of Project Report, Project Presentation skill and Question and Answer session in the ratio 50:25:25.

SEE (University examination) shall be as per the University norms.

2. Internship: Those, who have not pursued /completed the internship, shall be declared as failed and have to complete during subsequent University examinations after satisfy the internship requirements.

Internship SEE (University examination) shall be as per the University norms.

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI
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IV SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching Hours /Week		Examination				Credits
				Theory	Practical/ Field work/ Assignment	Duration in hours	CIE Marks	SEE Marks Viva voce	Total Marks	
1	Project	18MAP41	Project work phase -2	--	04	03	40	60	100	20
			TOTAL	--	**04**	**03**	**40**	**60**	**100**	**20**

Note:

1. Project Phase-2:

CIE marks shall be awarded by a committee comprising of HoD as Chairman, Guide/co-guide, if any and a Senior faculty of the department. The CIE marks awarded for project work phase -2, shall be based on the evaluation of Project Report subjected to plagiarism check, Project Presentation skill and Question and Answer session in the ratio 50:25:25.

SEE shall be at the end of IV semester. Project work evaluation and Viva-Voce examination (SEE), after satisfying the plagiarism check, shall be as per the University norms.

I SEMESTER

M.Tech Aerospace Propulsion Technology (APT)

M.Tech Aerospace Propulsion Technology(APT) Outcome Based Education(OBE) and Choice Based Credit System (CBCS) SEMESTER -I			
APPLIED MATHEMATICS (**Professional Core Course**)			
Subject Code	18MAP11	CIE Marks	40
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	SEE Marks	60
CREDITS – 04			

Course objectives: This course will enable students to

1. Understand principles of vector operations
2. Analyze integrals
3. Find numerical solutions to equations
4. Determine finite difference approximate in various forms

Modules	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
Module -1 Review of Fourier series and Applications, Review of Laplace Transforms and Applications. Classification of second order linear partial differential equations, Canonical forms for hyperbolic, parabolic and elliptic equations, Homogeneous and Non-Homogeneous equations with constant coefficients. Applications.	**10 Hours**	**L1, L2**
Module -2 Vector Functions, General rules for differentiation, Velocity and Acceleration, Gradient of a scalar field, Directional Derivative, Properties of Gradient, Divergence of vector point function, Curl of a vector point function, Properties of Divergence and Curl. Applications Integration of vector functions, Line integral, Circulation, Work done by a force, Surface integrals, Volume integrals, Divergence Theorem of Gauss, Green's Theorem in the plane, Stoke's Theorem, problems on all the three theorems and Applications	**10 Hours**	**L1, L2**
Module -3 Review of Complex analysis, Complex analysis applied to potential theory, Electrostatic fields, conformal mapping, Heat problems, Fluid flow, General properties of Harmonic functions, Complex Integration, Cauchy's Theorem, Cauchy's Integral Formula, Cauchy's Integral Formula for Derivatives, Taylor's and	**10 Hours**	**L1, L2, L3**

Laurent's series. Applications. Singular point, Residue, Method of finding Resides, Residue Theorem, Contour Integration, Integration round the unit circle, Rectangular contour. Applications.		
Module -4 Numerical Solutions algebraic and transcendental equations: False position method, Newton –Raphson method, Iteration method, Aitken's method, Solution of linear simultaneous equations. Gauss elimination method, Inverse of a matrix , Gauss-Seidal method, Crout's method. Solution of Ordinary Differential Equations: Taylor's Series method, Picard's method, Euler's method, Euler's Mo dified method, Runge-Kutta 4^{th}order method. Predictor and corrector method (Milen's and Adams-Bashfourth)Applications.	**10 Hours**	**L1, L2, L3**
Module -5 Finite differences, Interpolation, Newton's Forward & Backward Interpolation formulae, Lagrange's formula, Newton's Divided difference, Central difference formulae (all formulae with proof). Numerical Differentiation, Numerical Integration (all rules with proof).Applications.	**10 Hours**	**L1, L2, L3**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying

Course outcomes:
After studying this course, students will be able to:

1. Apply principles of vector operations to engineering problems
2. Solve close form solutions
3. Apply finite difference approximate to solve elliptic, hyperbolic and parabolic form of equations

Graduate Attributes:
- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions
- Interpretation of data

Question paper pattern:
- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

Text Books:

1. Erwin Kreyszing: " Advanced Engineering Mathematics"- John Wiley &Sons(Asia) Pvt. Ltd. 8th edition
2. H K Dass:" Advanced Engineering Mathematics"- S Chand and Company Ltd. 12thedition.

Reference Books:

1. Bali and Iyengar: "Engineering Mathematics"- Laxmi Publications (P) Ltd. 6th edition.
2. C. Ray Wylie and Louis C Barret: "Advanced Engineering". Mathematics Tata McGraw Hill Publishing Co. Ltd. 6th edition.
3. Michael D Greenberg: "Advanced Engineering Mathematics"- Pearsons India Ltd. 2nd edition.
4. B S Grewal: " Higher Engineering Mathematics"- 12th edition.

M.Tech Aerospace Propulsion Technology(APT) **Outcome Based Education(OBE) and Choice Based Credit System (CBCS)** **SEMESTER -I**			
AEROSPACE PROPULSION (**Professional Core Course**)			
Subject Code	**18MAP12**	CIE Marks	40
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	SEE Marks	60
CREDITS – 04			

Course objectives: This course will enable students to

1. Understand the construction and operation of turbojet, turboprop and reciprocating engines
2. Acquire knowledge of chemical rocket propulsion
3. Acquire knowledge on space mission propulsion requirement

Modules	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
Module -1 **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.	**8 Hours**	**L1, L2**
Module -2 **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**	**L1, L2**
Module -3 **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**	**L1, L2, L3,L4**

Module -4 **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**	**L1, L2, L3**
Module -5 **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.	**12 Hours**	**L1, L2, L3**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying,L4-Analysing

Course outcomes:

After studying this course, students will be able to:

1. Explain construction and operation of various propulsion devices
2. Solve problems related to combustion
3. Specify space mission propulsion requirements

Graduate Attributes:

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions
- Interpretation of data

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

Text Books:

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

NY.
2. Michael J Kroes and Thomas W Wild, “Aircraft power plants”, Macmillan/McGraw Hill NY.
3. George P Sutton and Donald M Ross, “Rocket Propulsion Elements”, John Wiley & Sons NY.

Reference Books:

1. E. Irwin Treager, “Aircraft Gas Turbine Engine Technology”, 3rd Edition, 1995, 'ISBN-002018281
2. Hill, P.G. , Peterson, C.R. Addison , “Mechanics & Thermodynamics of Propulsion”, Wesley Longman INC, 1999.
3. Huzel and Houng, “Design of Liquid Propellant Rocket Engines’, NASA SP 125, 1971.
4. Barrere et al., “Rocket Propulsion”, Elsevier Co., 1960
5. Williams F A. et al., “Fundamental Aspects of Solid Propellant Rockets”, Agardograph, 116 Technivision, 1970.
6. Meherwan P. Boyce, “Gas turbine engineering handbook”, Gulf professional publisher, Elsevier, 2006

M.Tech Aerospace Propulsion Technology(APT) **Outcome Based Education(OBE) and Choice Based Credit System (CBCS)** **SEMESTER -I**			
FINITE ELEMENT METHODS **(Professional Core Course)**			
Subject Code	**18MAP13**	CIE Marks	40
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	SEE Marks	60
CREDITS – 04			

Course objectives: This course will enable students to

1. Understand Finite Element Method (FEM)
2. Acquire the knowledge on two and three dimensional finite element analysis
3. Gain knowledge on FEM in aero structure analysis of beams and trusses.
4. Acquire foundations of FEM for fluid flow, heat transfer and dynamics problems.

Modules	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
Module -1 **Introduction to Finite Element Method, One-Dimensional Elements-Analysis of Bars:** Engineering Analysis, History, Advantages, Classification, Basic steps, Convergence criteria, Role of finite element analysis in computer-aided design., Mathematical Preliminaries, Differential equations formulations, Variational formulations, weighted residual methods. Basic Equations and Potential Energy Functional, 1-0 Bar Element, Strain matrix, Element equations, Stiffness matrix, Consistent nodal force vector: Body force, Initial strain, Assembly Procedure, Boundary and Constraint Conditions, Single point constraint, Multi-point constraint, 2-D Bar Element.	**10 Hours**	**L1, L2, L3, L4**

Module -2 **Two-Dimensional Elements-Analysis, Three-Dimensional Elements-Applications and Problems:** Three-Noded Triangular Element (TRIA 3), Four-Noded Quadrilateral Element (QUAD 4), Shape functions for Higher Order Elements (TRIA 6, QUAD 8) . Basic Equations and Potential Energy Functional, Four-Noded Tetrahedral Element (TET 4), Eight-Noded Hexahedral Element (HEXA 8), Tetrahedral elements, Hexahedral elements: Serendipity family, Hexahedral elements: Lagrange family. Shape functions for Higher Order Elements.	**10 Hours**	**L1, L2, L3, L4**
Module -3 **Aero Structural analysis through FEM for Beams and Trusses:** 1–D Beam Element, 2–D Beam Element, shape functions and stiffness matrixes, Problems, trusses with one, two, three and four bar elements.	**10 Hours**	**L1, L2, L3, L4**
Module -4 **FEM analysis of Heat Transfer and Fluid Flow:** Steady state heat transfer, 1 D heat conduction governing equation, boundary conditions, One dimensional element, Functional approach for heat conduction, Galerkin approach for heat conduction, heat flux boundary condition, 1 D heat transfer in thin fins. Basic differential equation for fluid flow in pipes, around solid bodies, porous media.	**10 Hours**	**L1, L2, L3. L4**
Module -5 **FEM for Dynamic:** Formulation for point mass and distributed masses, Consistent element mass matrix of one dimensional bar element, truss element, axisymmetric triangular element, quadrilatateral element, beam element. Lumped mass matrix, Evaluation of eigen values and eigen vectors, Applications to bars, stepped bars and beams.	**10 Hours**	**L3,L4,L5**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying ,L4-Analysing,L5-Evaluation

Course outcomes:
After studying this course, students will be able to:

1. Apply Finite Element Method (FEM)
2. Apply the knowledge on two and three dimensional finite element analysis.
3. Apply FEM in aero structure analysis of beams and trusses.
4. Apply FEM for fluid flow, heat transfer and dynamics problems.

Graduate Attributes:
- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions

o Interpretation of data
Question paper pattern: • The question paper will have ten questions. • Each full question consists of 20 marks. • There will be 2 full questions (with a maximum of four sub questions) from each module. • Each full question will have sub questions covering all the topics under a module. • The students will have to answer 5 full questions, selecting one full question from each module.
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, 2004.
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. Bathe K. J. "Finite Elements Procedures"- PHI. 5. Cook R. D., et al., "Concepts and Application.

M.Tech Aerospace Propulsion Technology(APT) Outcome Based Education(OBE) and Choice Based Credit System (CBCS) SEMESTER -I			
AEROSPACE MATERIALS AND PROCESSES **(Professional Core Course)**			
Subject Code	**18MAP14**	CIE Marks	40
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	SEE Marks	60
CREDITS – 04			

Course objectives: This course will enable students to

1. Understand materials for Gas Turbine engines.
2. Acquire the knowledge of alloys like Titanium, Nickel, Composite materials and their to technologies.
3. Understand the casting and forging technology for Gas Turbine components.
4. Gain knowledge on sheet metal making process.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module -1 **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	**8 Hours**	**L1, L2**
Module -2 **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	**12 Hours**	**L1, L2**

resin system, future developments like organic resins, reinforcing fibres, high temperature materials. Ceramic materials, properties and their applications in rotating parts.		
Module -3 **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.	**10 Hours**	**L1, L2, L3**
Module -4 **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.	**8 Hours**	**L1, L2, L3**
Module -5 **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.	**12 Hours**	**L1, L2, L3**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying

Course outcomes:
After studying this course, students will be able to:

1. Apply materials for Gas Turbine Engines.
2. Distinguish and apply the alloys for Titanium, Nickel, Composite materials and their technologies.
3. Use casting and forging technology for Gas turbine components.
4. Apply sheet metal making process.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions
- Interpretation of data

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

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

Reference Books:

1. G. W. Meetham and M. H. Van de Voorde, Materials for High Temperature Engineering Applications, Springer, 2006
2. George E. Dieter, Mechanical Metallurgy, SI Metric Edition, McGraw-Hill, 1988
3. William D. Callister, Materials Science and Engineering: an Introduction, 6th edition, John Wiley and sons, 2005
4. Serope Kalpakjian, Steven R Schmid, Manufacturing Engineering and Technology, Pearson Education, 2003

M.Tech Aerospace Propulsion Technology(APT) Outcome Based Education(OBE) and Choice Based Credit System (CBCS) SEMESTER -I			
INTRODUCTION TO SPACE TECHNOLOGY **(Professional Core Course)**			
Subject Code	**18MAP15**	CIE Marks	40
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	SEE Marks	60
CREDITS – 04			

Course objectives: This course will enable students to

1. Understand the fundamentals of rocket propulsion and reentry vehicles.
2. Acquire knowledge on orbit mechanics and satellite dynamics
3. Acquire knowledge on space mission operation.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module -1 **Fundamentals of Rocket Propulsio**n: Space Mission-Types-Space Environment-Launch Vehicle Selection. Introduction to rocket propulsion-fundamentals of solid propellant rockets-Fundamentals of liquid propellant rockets-Rocket equation. Two-dimensional trajectories of rockets and missiles-Multi-stage rockets-Vehicle sizing-Two stage Multi-stage Rockets-Trade-off Ratios-Single Stage to Orbit-Sounding Rocket-Aerospace Plane-Gravity Turn Trajectories-Impact point calculation-injection conditions-Flight dispersions.	**12 Hours**	**L1, L2**
Module -2 **Atmospheric Reentry:** Introduction-Steep Ballistic Reentry-Ballistic Orbital Reentry-Skip Reentry-"Double-Dip" Reentry - Aero-braking - Lifting Body Reentry.	**08 Hours**	**L1, L2**
Module -3 **Fundamentals of Orbit Mechanics, Orbit Maneuvers**: Two-body motion-Circular, elliptic, hyperbolic, and parabolic orbits-Basic Orbital Elements-Ground trace In-Plane Orbit changes-Hohmann Transfer-Bielliptical Transfer-Plane Changes - Combined Maneuvers - Propulsion for Maneuvers.	**10 Hours**	**L1, L2, L3**

Module -4 **Satellite Attitude Dynamics:** Torque free Axi-symmetric rigid body-Attitude Control for Spining Spacecraft - Attitude Control for Non-spinning Spacecraft - The Yo-Yo Mechanism - Gravity - Gradient Satellite-Dual Spin Spacecraft- Attitude Determination.	**10 Hours**	**L1, L2, L3**
Module -5 **Space Mission Operations:** Supporting Ground Systems Architecture and Team interfaces - Mission phases and Core operations - Team Responsibilities - Mission Diversity - Standard Operations Practices.	**10 Hours**	**L1, L2, L3**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying

Course outcomes:

After studying this course, students will be able to:

1. Apply the fundamentals of rocket propulsion and reentry vehicles.
2. Apply knowledge on orbit mechanics and satellite dynamics.
3. Solve space mission operation.

Graduate Attributes:

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions
- Interpretation of data

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

Text Books:

1. "Spaceflight Dynamics", W.E. Wiesel, McGraw Hill, 1997.
2. "Rocket Propulsion and Space flight dynamics", Cornelisse, Schoyer HFR and Wakker KF, Pitman, 1984.

Reference Books:

1. Vincet L. Pisacane, "Fundamentals of Space Systems", Oxford University Press, 2005.
2. "Understanding Space: An Introduction to Astronautics", J.Sellers, McGraw Hill, 2000.
3. "Introduction to Space Flight", Francis J Hale, Prentice-Hall, 1994.
4. "Spacecraft Mission Design", Charies D. Brown, AIAA education Series, 1998.
5. "Elements of Space Technology for aerospace Engineers", Meyer Rudolph X, Academic Press, 1999.

<table>
<tr><td colspan="4">M.Tech Aerospace Propulsion Technology(APT)
Outcome Based Education(OBE) and Choice Based Credit System (CBCS)
SEMESTER -I</td></tr>
<tr><td colspan="4">PROPULSION LAB
(Professional Core Course)</td></tr>
<tr><td>Subject Code</td><td>18MAPL16</td><td>CIE Marks</td><td>40</td></tr>
<tr><td>Number of Lecture Hours/Week</td><td>04</td><td>Exam Hours</td><td>03</td></tr>
<tr><td>Total Number of Lecture Hours</td><td>56</td><td>SEE Marks</td><td>60</td></tr>
<tr><td colspan="4">CREDITS – 02</td></tr>
<tr><td colspan="4">Course objectives: This course will enable students to
1. Familiarization with various propulsion experimental facilities
2. Familiarize with different propulsion experiments and measurement techniques
3. Conduct the test, acquire the data and analyse and document</td></tr>
</table>

Experiments	Revised Bloom's Taxonomy (RBT) Level
1. Cascade testing of a model of turbine blade row and study of wake survey.	**L1, L2, L3, L4**
2. Estimation of propeller performance	**L1, L2, L3, L4**
3. Forced Convective heat transfer on a flat surface	**L1, L2, L3, L4**
4. Measurement of Burning Velocity of a Premixed Flame	**L1, L2, L3, L4**
5. Determination of heat of combustion of aviation fuels	**L1, L2, L3, L4,**
6. Fuel - injection characteristics (spray cone geometry; spray speed etc. for various types of injectors)	**L1, L2, L3, L4**
7. Measurement of static overall pressure rise & rotor static pressure rise & fan overall efficiency through axial flow fan unit	**L1, L2, L3, L4**
8. Effect of inlet flow distortion on measurement of static overall pressure rise & rotor static pressure rise & fan overall efficiency through axial flow fan unit .	**L3, L4, L5**
9. Investigation of relationship between flame speed and air-fuel ratio for a	**L1, L2, L3**

slow burning gaseous fuel.	
10. Construction of flame stability diagram through flame lift up and flame fall back	**L1, L2, L3**
11. Measurement of static overall pressure rise & rotor static pressure rise & fan overall efficiency through counter rotating axial flow fan unit	**L1, L2, L3**
12. Effect of inlet flow distortion on measurement of static overall pressure rise & rotor static pressure rise & fan overall efficiency through contra rotating axial flow fan unit .	**L3, L4, L5**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding, L3 – Applying, L4-Analysing, L5 – Evaluating.

Course outcomes:

After studying this course, students will be able to:

1. Demonstrate various experimental facilities
2. Explain the use of different sensors and measurement techniques
3. Perform the test, acquire the data and analyse and document

.

Conduct of Practical Examination:

1. Demonstrate various experimental facilities
2. Explain the use of different measurement techniques
3. Perform the test, acquire the data and analyse and document

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly)
- Interpretation of data.

<table>
<tr><td colspan="4" align="center">M.Tech Aerospace Propulsion Technology(APT)
Outcome Based Education(OBE) and Choice Based Credit System (CBCS)
SEMESTER -I</td></tr>
<tr><td colspan="4" align="center">RESEARCH METHODOLOGY AND IPR
(Professional Core Course) and (Common to all M.Tech Programmes)</td></tr>
<tr><td>Course Code</td><td>18RMI17</td><td>CIE Marks</td><td>40</td></tr>
<tr><td>Number of Lecture Hours/Week</td><td>02</td><td>Exam Hours</td><td>03</td></tr>
<tr><td>Total Number of Lecture Hours</td><td>25</td><td>SEE Marks</td><td>60</td></tr>
<tr><td colspan="4" align="center">CREDITS – 02</td></tr>
<tr><td colspan="4">Course objectives:

To give an overview of the research methodology and explain the technique of defining a research problem
To explain the functions of the literature review in research.
To explain carrying out a literature search, its review, developing theoretical and conceptual frameworks and writing a review.
To explain various research designs and their characteristics.
To explain the details of sampling designs, measurement and scaling techniques and also different methods of data collections.
To explain several parametric tests of hypotheses and Chi-square test.
To explain the art of interpretation and the art of writing research reports.
To explain various forms of the intellectual property, its relevance and business impact in the changing global business environment.
To discuss leading International Instruments concerning Intellectual Property Rights.
</td></tr>
</table>

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module -1 **Research Methodology:** Introduction, Meaning of Research, Objectives of Research, Motivation in Research, Types of Research, Research Approaches, Significance of Research, Research Methods versus Methodology, Research and Scientific Method, Importance of Knowing How Research is Done, Research Process, Criteria of Good Research, and Problems Encountered by Researchers in India. **Defining the Research Problem:** Research Problem, Selecting the Problem, Necessity of Defining the Problem, Technique Involved in Defining a Problem, An Illustration	**5 Hours**	**L1, L2**
Module -2 **Reviewing the literature:** Place of the literature review in research, Bringing clarity and focus to your research problem, Improving research methodology, Broadening knowledge base in	**5 Hours**	**L1, L2**

research area, Enabling contextual findings, How to review the literature, searching the existing literature, reviewing the selected literature, Developing a theoretical framework, Developing a conceptual framework, Writing about the literature reviewed. **Research Design:** Meaning of Research Design, Need for Research Design, Features of a Good Design, Important Concepts Relating to Research Design, Different Research Designs, Basic Principles of Experimental Designs, Important Experimental Designs.		
Module -3 **Design of Sampling:** Introduction, Sample Design, Sampling and Non-sampling Errors, Sample Survey versus Census Survey, Types of Sampling Designs. **Measurement and Scaling:** Qualitative and Quantitative Data, Classifications of Measurement Scales, Goodness of Measurement Scales, Sources of Error in Measurement Tools, Scaling, Scale Classification Bases, Scaling Technics, Multidimensional Scaling, Deciding the Scale. **Data Collection**: Experimental and Surveys, Collection of Primary Data, Collection of Secondary Data, Selection of Appropriate Method for Data Collection, Case Study Method	**5 Hours**	**L1, L2**
Module -4 Testing of Hypotheses: Hypothesis, Basic Concepts Concerning Testing of Hypotheses, Testing of Hypothesis, Test Statistics and Critical Region, Critical Value and Decision Rule, Procedure for Hypothesis Testing, Hypothesis Testing for Mean, Proportion, Variance, for Difference of Two Mean, for Difference of Two Proportions, for Difference of Two Variances, P-Value approach, Power of Test, Limitations of the Tests of Hypothesis. Chi-square Test: Test of Difference of more than Two Proportions, Test of Independence of Attributes, Test of Goodness of Fit, Cautions in Using Chi Square Tests. .	**5 Hours**	**L1,L2, L3,L4**
Module -5 **Interpretation and Report Writing:** Meaning of Interpretation, Technique of Interpretation, Precaution in Interpretation, Significance of Report Writing, Different Steps in Writing Report, Layout of the Research Report, Types of Reports, Oral Presentation, Mechanics of Writing a Research Report, Precautions for Writing Research Reports. **Intellectual Property:** The Concept, Intellectual Property System in India, Development of TRIPS Complied Regime in India, Patents Act, 1970, Trade Mark Act, 1999,The Designs Act, 2000, The Geographical Indications of Goods (Registration and Protection) Act1999, Copyright Act,1957,The Protection of Plant Varieties and Farmers' Rights Act, 2001,The Semi-Conductor Integrated Circuits Layout Design Act, 2000, Trade Secrets, Utility Models, IPR and Biodiversity, The Convention on Biological Diversity (CBD) 1992, Competing Rationales for Protection of IPRs, Leading International Instruments Concerning IPR, World Intellectual Property Organisation (WIPO),WIPO and	**5 Hours**	**L1,L2, L3,L4**

WTO, Paris Convention for the Protection of Industrial Property, National Treatment, Right of Priority, Common Rules, Patents, Marks, Industrial Designs, Trade Names, Indications of Source, Unfair Competition, Patent Cooperation Treaty (PCT), Advantages of PCT Filing, Berne Convention for the Protection of Literary and Artistic Works, Basic Principles, Duration of Protection, Trade Related Aspects of Intellectual Property Rights(TRIPS) Agreement, Covered under TRIPS Agreement, Features of the Agreement, Protection of Intellectual Property under TRIPS, Copyright and Related Rights, Trademarks, Geographical indications, Industrial Designs, Patents, Patentable Subject Matter, Rights Conferred, Exceptions, Term of protection, Conditions on Patent Applicants, Process Patents, Other Use without Authorization of the Right Holder, Layout-Designs of Integrated Circuits, Protection of Undisclosed Information, Enforcement of Intellectual Property		
Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying , L4 – Analysing.	

Course outcomes:
At the end of the course the student will be able to:

- Discuss research methodology and the technique of defining a research problem
- Explain the functions of the literature review in research, carrying out a literature search, developing theoretical and conceptual frameworks and writing a review.
- Explain various research designs and their characteristics.
- Explain the details of sampling designs, measurement and scaling techniques and also different methods of data collections
- Explain several parametric tests of hypotheses and Chi-square test.
- Explain the art of interpretation and the art of writing research reports
- Discuss various forms of the intellectual property, its relevance and business impact in the changing global business environment and leading International Instruments concerning IPR

Graduate Attributes (As per NBA): Problem analysis, Investigation, Design, Individual and teamwork, Communication skills, Professionalism.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

Text Books:

1. Research methodology: Methods and Techniques, C.R. Kothari, Gaurav Garg, New Age International,4th Edition, 2018.
2. ResearchMethodologyastep-by-stepguideforbeginners. (For the topic Reviewing

the literature under module 2) , Ranjit Kumar, SAGE Publications Ltd.,3rd Edition, 2011 3. Study Material (For the topic Intellectual Property under module 5), Professional Programme Intellectual Property Rights, Law and Practice, The Institute of Company Secretaries of India, Statutory Body Under an Act of Parliament, September 2013.
Reference Books: 1.An introduction to Research Methodology, Garg B.L et al ,RBSA Publishers 2002 2.An Introduction to Multivariate Statistical Analysis Anderson T.W,Wiley 3rd Edition, 2003 3.Research Methodology, Sinha, S.C, Dhiman ,EssEss Publications2002 4.Research Methods: the concise knowledge base ,Trochim ,Atomic Dog Publishing ,2005 5.How to Write and Publish a Scientific Paper, Day R.A ,Cambridge University Press ,1992 6.Conducting Research Literature Reviews: From the Internet to Paper ,Fink A ,Sage Publications ,2009 7.Proposal Writing ,Coley S.M. Scheinberg, C.A ,Sage Publications ,1990 8.Intellectual Property Rights in the Global Economy ,Keith Eugene Maskus ,Institute for International Economics ,2000

II SEMESTER
M.Tech Aerospace Propulsion Technology (APT)

M.Tech Aerospace Propulsion Technology(APT) Outcome Based Education(OBE) and Choice Based Credit System (CBCS) SEMESTER -II			
COMPUTATIONAL FLUID DYNAMICS **(Professional Core Course)**			
Subject Code	**18MAP21**	CIE Marks	40
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	SEE Marks	60
CREDITS – 04			

Course objectives: This course will enable students to

1. Understand CFD ideas and Mathematical behaviour of PDEs
2. Acquire the knowledge to solve CFD problems through finite difference discritisation
3. Gain knowledge for grid generation and optimize grids
4. Transform the grids to computational domain
5. Acquire the knowledge to solve CFD problems through finite volume technique

Modules	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
Module -1 **Introduction:** CFD ideas to understand, CFD Application, Governing Equations (no derivation) of flow; continuity, momentum, energy. Conservative & Non-conservative forms of equations, Integral vrs Differential Forms of Equations. Form of Equations particularly suitable for CFD work. Shock capturing, Shock fitting, Physical Boundary conditions. **Mathematical Behavior of Partial Differential Equations and Discretization:** Classification of partial differential equations and its Impact on computational fluid dynamics; case studies. Essence of discritization, order of accuracy and consistency of numerical schemes, Lax's Theorem, convergence, Reflection Boundary condition.	**10 Hours**	**L1, L2**
Module -2 **Mathematical Behavior of Partial Differential Equations and Discretization:** Higher order Difference quotients. Explicit & Implicit Schemes. Error and analysis of stability, Error Propagation. Stability properties of Explicit & Implicit schemes. **Solution Methods of Finite Difference Equations:** Time & Space Marching. Alternating Direction Implicit (ADI) Schemes. Relaxation scheme, Jacobi and Gauss-Seidel techniques, SLOR	**10 Hours**	**L1, L2**

technique. Lax-Wendroff first order scheme, Lax-Wendroff with artificial viscosity, upwind scheme, midpoint leap frog method**.**		
Module -3 **Grid Generation:** Structured Grid Generation: Algebraic Methods, PDE mapping methods, use of grid control functions, Surface grid generation, Multi Block Structured grid generation, overlapping and Chimera grids. Unstructured Grid Generation: Delaunay-Voronoi Method, advancing front methods (AFM Modified for Quadrilaterals, iterative paving method, Quadtree & Octree method).	**10 Hours**	**L1, L2, L3**
Module -4 **Adaptive Grid Methods:** Multi Block Adaptive Structured Grid Generation, Unstructured adaptive Methods. Mesh refinement methods, and Mesh enrichment method. Unstructured Finite Difference mesh refinement. **Approximate Transformation & Computing Techniques:** 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. Variation Methods. Domain decomposition. Parallel Processing.	**10 Hours**	**L1, L2, L3**
Module -5 **Finite Volume Techniques:** Finite volume Discritisation-Cell Centered Formulation. High resolution finite volume upwind scheme Runge-Kutta stepping, Multi-Step Integration scheme. Cell vertex Formulation. Numerical Dispersion. **CFD Application to Some Problems:** Aspects of numerical dissipation & dispersion. Approximate factorization, Flux Vector splitting. Application to Turbulence-Models. Large eddy simulation, Direct Numerical Solution. Post-processing and visualization, contour plots, vector plots etc.	**10 Hours**	**L1, L2, L3,L4,L5**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying , L4-Analysing, L5-Evaluation

Course outcomes:
After studying this course, students will be able to:

1. Develop grids around given shapes and transform the physical domain in to computational domain
2. Develop adaptive structured and unstructured grids
3. Apply knowledge to solve CFD problems through finite difference and finite volume

techniques

Graduate Attributes:

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions
- Interpretation of data

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

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:

1. F. Wendt (Editor), Computational Fluid Dynamics - An Introduction, Springer – Verlag, Berlin; 1992.
2. Charles Hirsch, Numerical Computation of Internal and External Flows, Vols. I and II. John Wiley & Sons, New York; 1988.
3. JiyuanTu, Guan HengYeoh, and Chaoqun Liu, Computational Fluid Dynamics- A Practical Approach, Elsevier Inc; 2008.

M.Tech Aerospace Propulsion Technology(APT) Outcome Based Education(OBE) and Choice Based Credit System (CBCS) SEMESTER -II			
FUELS AND COMBUSTION **(Professional Core Course)**			
Subject Code	**18MAP22**	CIE Marks	40
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	SEE Marks	60
CREDITS – 04			

Course objectives: This course will enable students to

1. Understand fuels their properties their treatment for aerospace applications.
2. Acquire the knowledge on fundamentals of combustion.
3. Gain knowledge on combustion flame characterization, combustion performance, fuel stabilization and classification.

Modules	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
Module -1 **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.	**8 Hours**	**L1, L2**
Module -2 **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	**12 Hours**	**L1, L2**

Coal/Biomass, Biofuels, Alternative fuel Properties, Combustion and Emissions Performance, Fischer–Tropsch Fuels, Biodiesel Fuels, Highly Aromatic (Broad Specification).		
Module -3 **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**	**L1, L2, L3**
Module -4 **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.	**12 Hours**	**L1, L2, L3**
Module -5 **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.	**8 Hours**	**L1, L2, L3**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying

Course outcomes:
After studying this course, students will be able to:

1. Distinguish fuels their properties their treatment for aerospace applications.
2. Use the knowledge on fundamentals of combustion.
3. Apply the combustion flame characterization, combustion performance, fuel stabilization and classification.

Graduate Attributes:

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions
- Interpretation of data

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

Text Books:

1. Arthur H.Lefebvre&Dilip R. Ballal, Gas Turbine Combustion, Alternative fuels and Emissions CRC Press, 3rd Edition, 2010
2. Minkoff, G.J., and C.F.H. Tipper, Chemistry of Combustion Reaction, London Butterworths, 1962.
3. Samir Sarkar, Fuels & Combustion, Orient Long man 1996.

Reference Books:

1. Wilson, P.J. and J.H. Wells, Coal, Coke and Coal Chemicals, New York, McGraw-Hill, 1960.
2. Williams, D.A. and G. James, Liquid Fuels, London Pergamon, 1963.
3. Gas Engineers Handbook, New York, Industrial Press, 1966.

M.Tech Aerospace Propulsion Technology(APT) Outcome Based Education(OBE) and Choice Based Credit System (CBCS) SEMESTER -II			
HEAT TRANSFER IN PROPULSION SYSTEMS **(Professional Core Course)**			
Subject Code	**18MAP23**	CIE Marks	40
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	SEE Marks	60
CREDITS – 04			

Course objectives: This course will enable students to

1. Understand fundamentals of heat transfer in aero engines.
2. Acquire the knowledge on turbine film cooling, jet impingement cooling.
3. Gain knowledge on cooling and their techniques (such as Rib turbulated cooling, pin fin cooling and temperature measurement techniques)

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module -1 **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**	**L1, L2**
Module -2 **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 end walls. 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	**10 Hours**	**L1, L2**

jet array, Impingement cooling of leading edge.		
Module -3 **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**	**L1, L2, L3**
Module -4 **Pin Fin Cooling:** Flow and heat transfer analysis with single pin, pin array and correlation,effect of pin shape on heat transfer, effect of nonuniform 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:** Infrared 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.	**12 Hours**	**L1, L2, L3**
Module -5 **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.	**8 Hours**	**L1, L2, L3**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying

Course outcomes:

After studying this course, students will be able to:

1. Apply fundamentals of heat transfer in aero engines.
2. Distinguish turbine film cooling, jet impingement cooling.
3. Apply cooling and their techniques (such as Rib turbulated cooling, pin fin cooling and temperature measurement techniques)

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions
- Interpretation of data

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

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

Reference Books:

1. Anthony Giampaolo, "Gas Turbine Handbook", Fairmont Pr, 1997.
2. NAL, Bangalore, "Engine health monitoring as applied to gas turbine engines", 1983
3. Eckert, E R G and Goldstein R J Ed., "Measurement techniques in heat transfer", Washington: Hemisphere Pub. Corp.

M.Tech Aerospace Propulsion Technology(APT) Outcome Based Education(OBE) and Choice Based Credit System (CBCS) SEMESTER -II			
FATIGUE AND FRACTURE MECHANICS **(Professional elective 1)**			
Subject Code	**18MAP241**	CIE Marks	40
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	SEE Marks	60
CREDITS – 04			

Course objectives: This course will enable students to

1. Understand the principles of fracture mechanics
2. Acquire knowledge of plastic fracture mechanics
3. Know the computational fracture mechanics

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module -1 **Fracture Mechanics Principles:** Introduction, Mechanisms of Fracture, a crack in a structure, the Graffiti's criterion, modem 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 plastic zone estimation, Plane stress and plane strain concepts. The Dugdale approach, the thickness effect.	**10 Hours**	**L1, L2.L3,L4**
Module -2 **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.	**10 Hours**	**L1, L2**
Module -3 **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.	**10 Hours**	**L1, L2, L3**
Module -4 **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.	**10 Hours**	**L1, L2, L3**

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.		
Module -5 **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. **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.	**10 Hours**	**L1, L2, L3**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying, L4-Analysing

Course outcomes:

After studying this course, students will be able to:

1. Apply principles of fracture mechanics
2. Solve problems related to plastic fracture mechanics
3. Model Computational fracture mechanics

Graduate Attributes:

- o Engineering Knowledge.
- o Problem Analysis.
- o Design / development of solutions
- o Interpretation of data

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

Text Books:

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

Reference Books:

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

M.Tech Aerospace Propulsion Technology(APT)
Outcome Based Education(OBE) and Choice Based Credit System (CBCS)
SEMESTER -II

ENGINE PERFORMANCE, CONTROL AND SIMULATION
(Professional elective 1)

Subject Code	**18MAP242**	CIE Marks	40
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	SEE Marks	60

CREDITS – 04

Course objectives: This course will enable students to

1. Understand the basics of aero engine performance and evaluation, control and simulation.
2. Know different performance parameters and characteristics.
3. Know aero-engine component performance and engine integration.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module -1 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**	**L1, L2**
Module -2 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	**10 Hours**	**L3, L4**

of displacing equilibrium running line, matching procedure for turbofan engine, performance deterioration.		
Module -3 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**	**L3, L4, L5**
Module -4 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.	**10 Hours**	**L1, L2, L3**
Module -5 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**	**L1, L2, L3**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analysing, L5- Evaluating

Course outcomes:
After studying this course, students will be able to:

1. Apply the basics of aero engine performance and evaluation, control and simulation.
2. Distinguish different performance parameters and characteristics.
3. Evaluate aero-engine component performance and engine integration.

Graduate Attributes (as per NBA):
- Engineering Knowledge.

- Problem Analysis.
- Design / development of solutions
- Interpretation of data

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

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

Reference Books:

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.

M.Tech Aerospace Propulsion Technology(APT) Outcome Based Education(OBE) and Choice Based Credit System (CBCS) SEMESTER -II			
AEROSPACE STRUCTURES **(Professional elective 1)**			
Subject Code	**18MAP243**	CIE Marks	40
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	SEE Marks	60
CREDITS – 04			

Course objectives: The student will be exposed to advanced topics in Aerospace structural analysis. Outcome: The student shall be able to solve Aerospace structural problems can participate structural design.

1. Describe the roles that structures and structural materials play in aerospace vehicles;
2. Explain the general design concepts for aerospace structures: vehicles, components, and materials;
3. Demonstrate the tools and skills needed to analyze the static and dynamic performance of aero structures;
4. Analyzing, formulating, and solving aerospace structural engineering problems.

Modules	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
Module -1 **Structural Components and Loads of Aerospace components:** Loads on Structural components, Function of structural components, Fabrication of structural components, Connections; Airworthiness: Factors of Safety- flight envelope, Load factor determination, Airframe loads: Aircraft inertia loads, Symmetric maneuver loads, Normal accelerations associated with various types of maneuvers, Gust loads	**10 Hours**	**L1, L2**
Module -2 **Shear Flow and Shear Center in Open and Closed Thin Wall Sections Open Sections:** Shear center and elastic axis, Concept of shear flow, Beams with one axis of symmetry; Closed Sections: Bradt-Batho formula, Single and multi-cell closed box structures, Semi monocoque and mono cocque structures, Shear flow in single and multi-cell monocoque and semimonocoque box beams subject to torsion.	**10 Hours**	**L1, L2**
Module -3 **Thin Plate Theory Bending of thin plates:** Pure bending of	**10 Hours**	**L1, L2, L3,L4**

thin plates, Plates subjected to bending and twisting, Plates subject to distributed transverse load, Combined bending and in-plane loading of a thin rectangular plate, Bending of thin plates having a small initial curvature, Energy method for bending of thin plates structural instability in thin plates Buckling of thin plates, Inelastic buckling of plates, Experimental determination of critical loads for a flat plate, Local instability, Instability of stiffened panels, Failure stress in plates and stiffened panels, Tension field beams.		
Module -4 **Bending, Shear and Torsion of Thin-Walled Beams-I Bending and Open Thin-Walled Beams:** Symmetrical bending, Unsymmetrical bending, Deflections due to bending, Calculation of section properties, Applicability of bending theory, Temperature effects bending, shear and torsion of thin-walled beams-II Shear of Beams: General stress, strain and displacement relationships for open and single cell closed section thin-walled beams, Shear of open and closed section beams; Torsion of Beams: Torsion of closed and open section beams; Combined Open and Closed Section Beams: Bending, Shear, Torsion	**10 Hours**	**L1, L2, L3**
Module -5 Stress Analysis of Aircraft Components Wing spars, Fuselages, Wings, Fuselage frames and wing ribs, Laminated composite structures smart materials and adaptive structures Smart Materials Technologies and Control Applications: Control requirements, Smart Materials Piezoelectric elements, Electrostrictive elements, Magentostrictive transducers, Electrorheological fluids, Shape memory alloys, Fiber optic sensors, Applications of smart materials, Adaptive Structures: Adaptive aerospace structures-Structural Health Monitoring.	**10 Hours**	**L1, L2, L3, L4**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying , L4-Analysing

Course outcomes:

After studying this course, students will be able to:

1. Identify the solve problems of beam that satisfies the given engineering requirements.
2. Describe the necessary assumptions in designing aircraft structural systems.
3. Apply proper engineering principles and theories to solve open-ended structural problems.
4. Understand the concepts of composite materials for aircraft structures for both stiffness and strength requirements.
5. Recognize the need for proper fabrication processes via discussions of current, news worthy, design-related incidents
6. Explain the failure criteria in the design of aircraft structures on environment including safety.

Graduate Attributes:

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions
- Interpretation of data

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

Text Books:

1. E.F. Bruhn, "Analysis & Design of Flight Vehicle Structures", Tristate Offset Co., 1980.
2. Megson, T.M.G; Aircraft Structures for Engineering Students, Edward Arnold, 1995.
3. Autar K. Kaw, Mechanics of Composite Materials, CRC Press LLC, 1997

Reference Books:

1. Peery, D.J. and Azar, J.J., Aircraft Structures, 2nd Edition, McGraw-Hill, New York, 1993
2. Rivello, R.M., Theory and Analysis of Flight structures, McGraw-Hill, N.Y., 1993
3. B.D. Agarwal and L.J. Broutman, "Analysis and Performance of fiber composites", John-Wiley and Sons, 1990.

M.Tech Aerospace Propulsion Technology(APT) Outcome Based Education(OBE) and Choice Based Credit System (CBCS) SEMESTER -II			
RAMJET AND SCRAMJET **(Professional elective 2)**			
Subject Code	**18MAP251**	CIE Marks	40
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	SEE Marks	60
CREDITS – 04			

Course objectives: This course will enable students to

1. Understand the basics of ramjet and scramjet engines.
2. Acquire knowledge of principles of operation and engine performance.
3. Know the different progresses in ramjet and scramjet propulsions.

Modules	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
Module -1 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**	**L1, L2, L3,L4**
Module -2 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**	**L1, L2**
Module -3 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 –	**10 Hours**	**L1, L2, L3,L4**

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.		
Module -4 **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**	**L1, L2, L3**
Module -5 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**	**L1, L2, L3,L4**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying, L4- Analysing

Course outcomes:

After studying this course, students will be able to:

1. Use the basics of ramjet and scramjet engines.
2. Apply principles of operation and engine performance.
3. Distinguish different progresses in ramjet and scramjet propulsions.

Graduate Attributes :

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions
- Interpretation of data

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

Text Books:

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

Reference Books:

1. AGARD, Advisory Group for Aerospace Research and Development.
2. Ramjet Technology, EA Bunt and others

3. RAMJETS, AIAA.

M.Tech Aerospace Propulsion Technology(APT)
Outcome Based Education(OBE) and Choice Based Credit System (CBCS)
SEMESTER -II

MECHANICAL ASPECTS OF ROTATING MACHINERY
(Professional elective 2)

Subject Code	**18MAP252**	CIE Marks	40
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	SEE Marks	60

CREDITS – 04

Course Objectives: This course will enable students to

1. Understand the basics of vibration loads in Rotating Machinery systems.
2. Acquire knowledge systems in use.
3. Know the background of systems and optimization of their designs.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module -1 **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**	**L1, L2**
Module -2 **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.	**12Hours**	**L1, L2,L3,L4**

Module -3 **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	**08 Hours**	**L1, L2, L3**
Module -4 **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**	**L1, L2, L3**
Module -5 **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**	**L1, L2, L3**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying, L4-Analysing

Course Outcomes:

After studying this course, students will be able to:

1. Distinguish the basics of concept and different kind of loads in rotating components of systems.
2. Apply knowledge systems in use.
3. Appreciate different systems and do optimization of their designs.

Graduate Attributes :

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions
- Interpretation of data

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

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.

M.Tech Aerospace Propulsion Technology(APT) Outcome Based Education(OBE) and Choice Based Credit System (CBCS) SEMESTER -II			
ADVANCED COMPOSITES MATERIALS **(Professional elective 2)**			
Subject Code	**18MAP253**	CIE Marks	40
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	SEE Marks	60
CREDITS – 04			

Course objectives: This course will enable students to

1. Understand the science of composite materials and micro and macro behaviour of a lamina.
2. Understand the composite materials for thermal, electrical/electro-magnetic applications.
3. Gain knowledge on composites for thermoelectric, dielectric and smart structure applications.

Modules	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
Module -1 **Science of composite materials:** Polymer-matrix composites, Carbon-matrix, Metal-matrix, Ceramic-matrix. Advance processing techniques: Filament winding, pultrusion, pulforming, thermoforming, injection, injection molding, liquid molding, blow molding. Application to aircraft, missiles & spacecraft.	**10 Hours**	**L1, L2**
Module -2 **Macro& Microbehavior of a lamina:** Stress strain relationship for an orthotropic Lamina- Restriction on elastic constants-Strengths of an orthotropic lamina and failure theories for an orthotropic lamina. Determination of elastic constants-Rule of mixtures, Macro-mechanical behavior of a laminate: Classical plate theory-stress and strain variation in laminate. Strength analysis of a laminate.	**10 Hours**	**L1, L2,L3,L4**
Module -3 **Composite materials for thermal application, electrical/electro- magnetic application:** Materials for high thermal conductivity, thermal interface materials, materials for thermal insulation, materials for heat retention Application to micro-electronics, resistance heating Mechanism behind electromagnetic application, materials for electromagnetic application.	**10 Hours**	**L1, L2, L3**
Module -4 **Materials for thermoelectric, dielectric application, optical**	**10 Hours**	**L1, L2, L3**

& magnetic application: Non-structural & Structural composites, dielectric behavior, piezoelectric behavior, Piezoelectric/ferroelectric composite principles. Pyroelectric behavior. Materials for optical wave guide, materials for lasers. Metal-matrix composites for magnetic application.		
Module -5 **Smart structure application:** Polymer matrix composites for damage sensing, temperatures Sensing & vibration reduction. Introduction to testing: Environmental effects testing, Design allowable & Damage tolerance Testing. Test Techniques.	**10 Hours**	**L1, L2, L3**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying , L4-Analysing

Course outcomes:

After studying this course, students will be able to:

1. Use the science of composite materials and micro and macro behaviour of a lamina.
2. Distinguish and apply the composite materials for thermal, electrical/electro-magnetic applications.
3. Apply composites for thermoelectric, dielectric and smart structure applications.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions
- Interpretation of data

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

Text Books:

1. Composite Materials-Functional Material for modern Technologies-Deborah D. L. Chung, Springer-Verlag London Ltd., 2004.
2. Mechanics of Composite Materials-R M Chawla, Springer Verlag,1998.

Reference Books:

1. Composite materials-Testing & Design-Ravi B Deo& Charles R, Editor, ASTM STP Publication, 1996.
2. Composite materials-Properties as Influenced by Phase geometry- Nielson, Springer-Verlag Berlin Heidelberg 2005.

III SEMESTER
M.Tech Aerospace Propulsion Technology (APT)

<table>
<tr><td colspan="4">M.Tech Aerospace Propulsion Technology(APT)
Outcome Based Education(OBE) and Choice Based Credit System (CBCS)
SEMESTER -III</td></tr>
<tr><td colspan="4">AEROSPACE INSTRUMENTATION AND CONTROLS
(Professional Core Course)</td></tr>
<tr><td>Subject Code</td><td>18MAP31</td><td>CIE Marks</td><td>40</td></tr>
<tr><td>Number of Lecture Hours/Week</td><td>04</td><td>Exam Hours</td><td>03</td></tr>
<tr><td>Total Number of Lecture Hours</td><td>50</td><td>SEE Marks</td><td>60</td></tr>
<tr><td colspan="4">CREDITS – 04</td></tr>
<tr><td colspan="4">Course objectives: This course will enable students to
1. Understand the basics of aerospace instrumentations for force, torque, power, pressure , flow and acoustic measurements
2. Know the transducers and controls
3. Understand the designs of control systems</td></tr>
</table>

Modules	Teaching Hours	Revised Bloom’s Taxonomy (RBT) Level
Module -1 **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**	**L1, L2**
Module -2 **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**	**L1, L2**
Module -3	**10 Hours**	**L1, L2, L3**

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.		
Module -4 **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, eigen values and eigen vectors, similarities transformations, decomposition of transfer functions. **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**	**L1, L2, L3**
Module -5 **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**	**L1, L2, L3**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying

Course outcomes: After studying this course, students will be able to:

1. Use the basics of aerospace instrumentations for force, torque, power, pressure , flow and acoustic measurements
2. Apply and Distinguish the transducers and controls
3. Apply the concepts of designs of control systems

.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions
- Interpretation of data

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

Text Books:

1. Nakra and Chaudhry, B C Nakra K KChaudhry, ―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.
3. B.C. Kuo, ―Automatic Control Systems‖ Prentice Hall Inc.
4. K. Ogata, ―Modern Control Engineering‖ Prentice Hall Inc.

Reference Books:

1. Arun K. Ghosh, ―Introduction to Measurements and Instrumentation‖, Prentice-Hall of India Ltd, New Delhi, 2nd Edition 2007.
2. Harrison & Bollinger, ―Automatic Control Systems‖ International Text Book Company.
3. Francis H. Raven, ―Automatic Control Engineering‖, McGraw- Hill International

M.Tech Aerospace Propulsion Technology(APT) Outcome Based Education(OBE) and Choice Based Credit System (CBCS) SEMESTER -III			
ADVANCED BEARINGS AND ROTOR DYNAMICS (Professional elective 3)			
Subject Code	**18MAP321**	CIE Marks	40
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	SEE Marks	60
CREDITS – 04			

Course objectives: This course will enable students to
1. Understand the fundamentals of bearings and rotor dynamics
2. Acquire knowledge of vibration related phenomenon in bearings and their challenges
3. Know the bearing materials, sensors and measurements

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module -1 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 capabilityand methods of obtaining them, Influence of preload on the dynamic coefficients of journal bearings.	**10 Hours**	**L1, L2**
Module -2 Objective of Rotor dynamic Analysis, Concept of rigid and flexural critical speeds and modeshapes, 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 MatrixAnalysis for bending Critical Speeds, Effect of axial stiffness.	**10 Hours**	**L1, L2**
Module -3 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**	**L1, L2, L3**
Module -4 Introduction to Smart Materials, Structures and Products Technologies. Overview of application of smart materials to rotor	**10 Hours**	**L1, L2, L3**

dynamics. Shape Memory Materials, Fiber-Optic Sensors.		
Module -5 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**	**L1, L2, L3, L4**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying , L4- Analysing

Course outcomes: After studying this course, students will be able to:
1. Apply the fundamentals of bearings and rotor dynamics
2. Distinguish vibration related phenomenon in bearings and their challenges
3. Apply bearing materials, sensors and measurements

Graduate Attributes (as per NBA):
- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions
- Interpretation of data

Question paper pattern:
- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

Text Books:
1. Rotor dynamics by JS Rao , New Age International Publishers
2. Machinery Vibration and rotor Dynamics by John Vance, FouadZeidan and Brian Murphy

Reference Books:

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

M.Tech Aerospace Propulsion Technology(APT) Outcome Based Education(OBE) and Choice Based Credit System (CBCS) SEMESTER -III			
HYPERSONIC AERODYNAMICS (Professional elective 3)			
Subject Code	**18MAP322**	IA Marks	40
Number of Lecture Hours/Week	04	CIE Hours	03
Total Number of Lecture Hours	50	SEE Marks	60
CREDITS – 04			
Course objectives: This course will enable students to 1. Understand oblique and curved shock waves and shock wave structure 2. Acquire knowledge of hypersonic viscous effects 3. Know the hypersonic wind tunnel test techniques			

Modules	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
Module -1 **General Considerations.** Characteristics General features of hypersonic flow field. Assumptions underlying inviscid hypersonic theory. Normal shock waves, oblique & curved shocks. Mach number independence principles. General strip theory. **Small Disturbance Theory.** Introduction to basic equations. Hypersonic Similitude, United supersonic-hypersonic similitude. Slender – body strip theory.	**10 Hours**	**L1, L2**
Module -2 **Small Disturbance Theory.** Slightly blunted slender bodies, large incidence & correlation of Similitude. Unsteady flow theory. Non equilibrium effects. **Newtonian Theory.** Two-dimensional axis symmetric bodies, simple shapes & free layers. Optimum shapes, shock layer structure.	**10 Hours**	**L1, L2**
Module -3 **Newtonian Theory.** Shock layer structure with cross flow. Conical flow, bodies of revolution at small incidences. **Theory of Thin Shock Layers.** Basic concepts, successive approximation schemes. Constant stream tube-area approximation. Two-dimensional axis symmetric blunt faced bodies.	**10 Hours**	**L1, L2, L3**
Module -4	**10 Hours**	**L1, L2, L3**

Viscous Flows. Hypersonic Viscous effects, Boundary Layer equations . Similar laminar boundary layer solutions. Local similarity concept. Viscous interactions - flow models and interaction parameters. Weak pressure interaction. Strong pressure interaction. General features of rarified gas flows.		
Module -5 **Hypersonic Testing.** Hypersonic Scaling, high enthalpy & high speed, types of hypersonic facilities. Shock tunnels & expansion tubes. Features of Hypersonic wind tunnel design. Instrumentation to hypersonic vehicle testing. Test model similarity laws.	**10 Hours**	**L1, L2, L3**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying

Course outcomes: After studying this course, students will be able to:
1. Apply knowledge of oblique and curved shock waves and shock wave structure
2. Solve problems related to hypersonic viscous effects
3. Model hypersonic wind tunnel testing

Graduate Attributes (as per NBA):
- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions
- Interpretation of data

Question paper pattern:
- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

Text Books:
1. Wallace D Hayes & Ronald F Probstein,`Hypersonic Invisicd Flows`, Dover Publication 2004.
2. Wallace Hayes,` Hypersonic Flow Theory`, Academic Press Inc., 1959.

Reference Books:
1. John D Anderson Jr. `Hypersonic and High Temperature Gas Dynamics`, AIAA, 2000.
2. Frank K.Lu and Dart E. Marran,` Advanced Hypersonic Test Facilities, AIAA 2002.
3. Cherynl C.G.,` Introduction to Hypersonic Flow`, Academic Press,1961.

M.Tech Aerospace Propulsion Technology(APT) Outcome Based Education(OBE) and Choice Based Credit System (CBCS) SEMESTER -III			
ADVANCED GAS TURBINES (Professional elective 3)			
Subject Code	**18MAP323**	CIE Marks	40
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	SEE Marks	60
CREDITS – 04			

Course objectives: This course will enable students to
1. Understand jet propulsion cycles and thermodynamics of each component of a turbine engine
2. know the materials for various components and the manufacturing techniques of various parts
3. Gain knowledge on the performance of compressors and turbines

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module -1 **Jet propulsion cycles and analysis:** Introduction, Prime movers, simple gas turbine, energy equation, Dimensional analysis of rotating machine, Ram jet engine, pulse jet engine, turboprop engine, turbojet engine, thrust and thrust equation, specific thrust of turbojet engine, efficiencies, parameters affecting performance, thrust augmentation, problems	**10 Hours**	**L1,L2, L3,L4**
Module -2 **Ideal cycles and their analysis:** Introduction, assumptions, Brayton Cycle, reheat cycle, reheat and regenerator, inter cooled cycle with heat exchanger, inter cooled and reheat cycle, comparison of varies cycles, Ericsson cycle, compressor and turbine efficiency, performance of actual cycle.	**10 Hours**	**L1, L2,L3,L4**
Module -3 **Centrifugal and axial flow compressors:** Essential parts of centrifugal and axial flow compressors, principles of operation, blade shape and velocity triangles, performance characteristics, surging and chocking, degree of reaction, compressor stage efficiency, and mechanical loses, problems.	**10 Hours**	**L1, L2, L3,L4.L5**
Module -4 **Impulse and reaction turbine:** single impulse stage and reaction stage, velocity triangles of a single stage machines, expression for work output, blade and stage efficiencies, velocity and pressure	**10 Hours**	**L1, L2, L3**

compounding, multi stage reaction turbines, performance graphs, losses and efficiencies.		
Module -5 **Blade materials, cooling and environmental consideration:** Blade materials, manufacturing techniques, blade fixing, blade cooling, liquid cooling, air cooling, practical air cooled blades, NOX formation, noise standards, noise reduction, aircraft emission standards	**10 Hours**	**L1, L2, L3**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying , L4-Analysing,L5-Evaluation

Course outcomes: After studying this course, students will be able to:
1. Model jet propulsion cycles
2. Select the materials for various components and involve in manufacturing of various parts
3. Solve problems related to performance of compressors and turbines

Graduate Attributes (as per NBA):
- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions
- Interpretation of data

Question paper pattern:
- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

Text Books:

1. Gas turbines - V Ganesan Tata McGraw-Hill Publishing company limited.
2. Gas turbine theory - H.I.H Saravanamuttoo, G.F.C. Rogers and H. Cohen PV Straznicky, Publisher: Pearson Education Canada.

Reference Books:
1. Mechanics & Thermodynamics of Propulsion - Hill, P.G. & Peterson, C.R. Addison – Wesley Longman INC, 1999.
2. Aerospace Propulsion - Dennis G Shepherd, American Elsevier Publishing Co Inc NY.
3. Aircraft Gas Turbine Engine Technology, 3rd Edition - E. Irwin Treager, 1995 ISBN-002018281.

M.Tech Aerospace Propulsion Technology(APT) Outcome Based Education(OBE) and Choice Based Credit System (CBCS) SEMESTER -III			
MISSILES AND LAUNCH VEHICLES (Professional elective 4)			
Subject Code	**18MAP331**	CIE Marks	40
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	SEE Marks	60
CREDITS – 04			

Course objective:
This course will enable students to
1. Understand the types of space launch vehicles and missiles.
2. Study the solid and liquid rocket motors.
3. Acquire the knowledge on launch vehicle dynamics, attitude control, rocket testing and materials.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module -1 **Introduction:** Space launch Vehicles and military missiles, function, types, role, mission, mission profile, thrust profile, propulsion system, payload, staging, control and guidance requirements, performance measures, design, construction, operation, similarities and differences. Some famous space launch vehicles and strategic missiles.	**8 Hours**	**L1, L2**
Module -2 **Solid Propellant Rocket Motor Systems:** Solid Propellant rocket motors, principal features, applications. Solid propellants, types, composition, properties, performance. Propellant grain, desirable properties, grain configuration, preparation, loading, structural design of grain. Liners, insulators and inhibitors, function, requirements, materials. Rocket motor casing – materials. Nozzles, types, design, construction, thermal protection. Igniters, types, construction. Description of modern solid boosters I) Space Shuttle SRB, II)the Arienne SRB **Liquid Propellant Rocket Motor Systems:** Liquid propellants, types, composition, properties, performance. Propellant tanks, feed systems, pressurization, turbo-pumps, valves and feed lines, injectors, starting and ignition. Engine cooling, support structure. Control of engine starting and thrust build up, system calibration, integration and optimisation – safety and environmental concerns. Description of the space	**12 Hours**	**L1, L2**

shuttle main engine. Propellant slosh, propellant hammer, geysering effect in cryogenic rocket engines.		
Module -3 **Aerodynamics Of Rockets And Missiles:** Classification of missiles. Airframe components of rockets and missiles, Forces acting on a missile while passing through atmosphere, method of describing aerodynamic forces and moments, lateral aerodynamic moment, lateral damping moment, longitudinal moment of a rocket, lift and drag forces, drag estimation, body upwash and downwash in missiles. Rocket dispersion, re-entry body design considerations.	**8 Hours**	**L1, L2, L3**
Module -4 **Launch Vehicle Dynamics:** Tsiolskovsky's rocket equation, range in the absence of gravity, vertical motion in the earth's gravitational field, inclined motion, flight path at constant pitch angle, motion in the atmosphere, the gravity turn – the culmination altitude, multi staging. Earth launch trajectories – vertical segment, the gravity turn, constant pitch trajectory, orbital injection. Actual launch vehicle trajectories, types. Examples, the Mu 3-S-II, Ariane, Pegasus launchers. Reusable launch vehicles, future launchers, launch assist technologies. **Attitude Control Of Rockets And Missiles:** Rocket Thrust Vector Control – Methods of Thrusts Vector Control for solid and liquid propulsion systems, thrust magnitude control, thrust termination; stage separation dynamics, separation techniques.	**12 Hours**	**L1, L2**
Module -5 **Rocket Testing:** Ground Testing and Flight Testing, Types of Tests facilities and safeguards, monitoring and control of toxic materials, instrumentation and data management. Ground Testing, Flight Testing, Trajectory monitoring, post -accident procedures. Description of a typical space launch vehicle launch procedure. **Materials:** Criteria for selection of materials for rockets and missiles, requirements for choice of materials for propellant tanks, liners, insulators, inhibitors, at cryogenic temperatures, requirements of materials at extremely high temperatures, requirements of materials for thermal protection and for pressure vessels.	**10 Hours**	**L1, L2**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying

Course outcomes:

After studying this course, students will be able to:

1. Identify the types of space launch vehicles and missiles.
2. Distinguish the solid and liquid propellant motors.
3. Classify different types of materials used for rockets and missies.

Graduate Attributes:

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions
- Interpretation of data

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

Text Books:

1. George P Sutton and Oscar Biblarz, 'Rocket Propulsion Element', John Wiley and Sons Inc,7th edition, 2010,ISBN-13: 978-8126525775.
2. Jack N Neilson, 'Missile Aerodynamics', AIAA,1st edition, 1988,ISBN-13: 978-0962062902.

Reference Books:

1. S S Chin, 'Missile Configuration Design'.
2. Cornelisse, J.W., Schoyer H.F.R. and Wakker,. K.F., Rocket Propulsion and Space-Flight Dynamics, Pitman, 1979,ISBN-13: 978-0273011415
3. Turner, M.J.L., Rocket and Spacecraft propulsion, Springer,3rd edition,2010,ISBN-13: 978-3642088698.
4. Ball, K.J., Osborne, G.F., Space Vehicle Dynamics, Oxford University Press, 1967,ISBN-13: 978-0198561071
5. Parker, E.R., Materials for Missiles and Spacecraft, McGraw Hill, 1982.

<table>
<tr><td colspan="4">M.Tech Aerospace Propulsion Technology(APT)
Outcome Based Education(OBE) and Choice Based Credit System (CBCS)
SEMESTER -III</td></tr>
<tr><td colspan="4">ADVANCED PROPULSION SYSTEMS
(Professional elective 4)</td></tr>
<tr><td>Subject Code</td><td>18MAP332</td><td>CIE Marks</td><td>40</td></tr>
<tr><td>Number of Lecture Hours/Week</td><td>04</td><td>Exam Hours</td><td>03</td></tr>
<tr><td>Total Number of Lecture Hours</td><td>50</td><td>SEE Marks</td><td>60</td></tr>
<tr><td colspan="4">CREDITS – 04</td></tr>
<tr><td colspan="4">Course objectives: This course will enable students to
1. Familiarization with cryogenic, environmental effects of space propulsion, and green propellants
2. Acquire knowledge of miniaturise propulsion
3. Understand some advance propulsion technologies</td></tr>
</table>

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module -1 **Advanced Cryogenic & LOX-HC Engines -** Introduction to cryogenics and its applications, Properties of Cryogenic fluids, Engine cycles, system level analysis, testing, thrust chamber, turbo pumps, cryotanks. HC Engines. Engines for booster and upper stages. LOX Kerosene & LOX-Methane engines. Liquid Oxygen and Hydrocarbon, liquid rocket engine (LRE) for application as main engines & booster stages of Launchers-Different LRE cycles.	**10 Hours**	**L1, L2**
Module -2 **Green Propellants Propellant-less Propulsion.** Environmental effects of space propellants (toxicity, pollution, performance aspects). Liquid bio-propellant (H2-O2, N2O4-, etc.) for main engines. Solid propellant (NH4ClO4) for the booster. Momentum exchange tether, electro-dynamic tether, Solar thermal propulsion for upper stages, solar sails, magnetic sails. Beamed energy -Earth to Orbit Propulsion.	**10 Hours**	**L1, L2**
Module -3 **Miniaturised Propulsion & Electrical Propulsion Systems.** Classification of mission requirement. Micro- propulsion technologies; solid micro thruster, micro bi-propellant thruster, cold gas thruster, Integration aspects in micro-spacecraft. Electrical Propulsion Systems. State-of-the-art in electrical propulsion system, high-power gridded ion thruster (GIT), high	**10 Hours**	**L1, L2, L3**

– power Hall Effect thruster (HET), high- power applied-field magnetoplasmadynamic thruster (MPDT), and double stage HET. Micro Ion thruster, Microchip laser thruster. Colloid thruster. Fundamentals of ion propulsion body design considerations.		
Module -4 **Nuclear Propulsion.** Nuclear rocket engine design and performance, nuclear rocket reactors, nuclear rocket nozzles, nuclear rocket engine control, radioisotope propulsion, basic thrusters configuration, thrusters technology, heat source development, nozzle development, nozzle performance of radio isotope propulsion systems. Testing of Nuclear rocket engines.	**10 Hours**	**L1, L2**
Module -5 **Other Advance Propulsion Technologies.** Super Conductivity-Property of material-super conductivity state, conduction, electrons propagation. Effect of temperature on material conductivity. Type-I and type-II materials. **Chemical propellant system -** advanced propellants, high energy density matter (HEDM), alternative design-pulse detonation rocket. **Laser Propulsion System-** General Concept. Laser accelerated Plasma Propellant. Test Techniques and safety for Advance Propulsion Technologies.	**10 Hours**	**L1, L2**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying

Course outcomes: After studying this course, students will be able to:
1. Other Advance Propulsion Technologies. Super Conductivity-Property of material-super conductivity state, conduction, electrons propagation. Effect of temperature on material conductivity . Type-I and type-II materials.
2. Chemical propellant system - advanced propellants, high energy density matter (HEDM), alternative design-pulse detonation rocket.
3. Laser Propulsion System- General Concept. Laser accelerated Plasma Propellant. Test Techniques and safety for Advance Propulsion Technologies.

Graduate Attributes:
- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions
- Interpretation of data

Question paper pattern:
- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

Text Books:

1. Claudio Bruno, and Antonio Accettura, ` Advance Propulsion Systems & Technologies: Today to 2020, AIAA 2008.
2. G P Sutton,` Rocket Propulsion Elements`, John Wiley & Sons Inc., New York, 1998 978-0962062902.

Reference Books:

1. Martin Tajmar,` Advanced Space Propellant Systems `, Springer 2003.
2. William H. Heiser and David T. Pratt,` Hypersonic Airbreathing Propulsion, AIAA Education Series, 2001
3. Fortescue and Stark, `Spacecraft Systems Engineering`,1999.

M.Tech Aerospace Propulsion Technology(APT) Outcome Based Education(OBE) and Choice Based Credit System (CBCS) SEMESTER -III			
GAS TURBINES AND ROCKET PROPULSION (Professional elective 4)			
Subject Code	**18MAP333**	CIE Marks	40
Number of Lecture Hours/Week	04	Exam Hours	03
Total Number of Lecture Hours	50	SEE Marks	60
CREDITS – 04			

Course objectives: This course will enable students to

1. Understand the fundamentals of gas turbines and rocket propulsion.
2. Understand the basic cycles and theory of propulsion.
3. Gain knowledge on types of propulsion and types of rocket fuels.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module -1 Categories of propulsion system, air breathing engines, non-air breathing engines, thrust of turbojet, turbofan, ramjet and rockets, Performance parameters of propulsion systems.	**8 Hours**	**L1, L2, L3,L4**
Module -2 Gas turbine components, flow through gas turbine components like inlets, compressor, combustor, turbine and nozzles, Gas turbine component characteristics, propeller, propeller performance.	**8 Hours**	**L1, L2, L3,L4**
Module -3 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 .	**12 Hours**	**L1, L2, L3,L4, L5**

Module -4	10 Hours	L1, L2, L3, L4,
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.		
Module -5 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.	**12 Hours**	**L1, L2, L3,L4**

Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding ,L3 – Applying , L4-Analysing, L5-Evaluation

Course outcomes:

After studying this course, students will be able to:

1. Use the fundamentals of gas turbines and rocket propulsion.
2. Apply the basic cycles and theory of propulsion.
3. Distinguish types of propulsion and types of rocket fuels.

Graduate Attributes:

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions
- Interpretation of data

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

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.
3. Jack D. Mattingly ," Elements of Gas Turbine Propulsion" Tata McGraw-Hill

Publishing Company Limited, New Delhi, 1996.

Reference Books:

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