Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

Group: 1		
Sl. No.	**Course Code**	**Course Name**
1	16MAE12	Aerodynamics
2	16MAE422	Missile Aerodynamics
3	16MAP422	Hypersonic Aerodynamics

Group: 2		
Sl. No.	**Course Code**	**Sub/ Course Name**
1	16MAP421	Advanced Gas Turbine
2	16MAE154	Aero Engine Testing & Performance Evaluation
3	16MAP12	Aerospace Propulsion
4	16MAE423	Theory of Combustion
5	16MAE424	Rockets and Space Propulsion
6	16MAP22	Fuels and Combustion
7	16MAP23	Heat Transfer in Propulsion Systems
8	16MAP24	Gas Turbine and Rocket Propulsion
9	16MAP253	Ramjet and Scramjet
10	16MAP424	Advanced Propulsion

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Group: 3		
Sl. No.	**Course Code**	**Course Name**
1	16MAE23	Airframe Structures and Structural Design
2	16MAE252	Theory of Aero-elasticity
3	16MAE421	Fatigue and Fracture Mechanics
4	16MAE24	Flight Vehicle Design
5	16MAP154	Aerospace Structures
6	16MAP423	Advanced Bearings and Rotor Dynamics

Group: 4		
Sl. No.	**Course Code**	**Sub/ Course Name**
1	16MAE13	Introduction to Aerospace Vehicles and Systems
2	16MAE21	Aircraft Performance and Flight Mechanics
3	16MAE251	Aircraft Navigation Systems
4	16MAE253	Flight Testing
5	16MAE41	Aircraft Flight Dynamics and Automatic Flight Control
6	16MAP13	Introduction to Space Technology
7	16MAP252	Engine Performance Control & Simulation
8	16MAP254	Space Transportation Systems
9	16MAP41	Aerospace Instrumentation and controls

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Group: 5		
Sl. No.	**Course Code**	**Course Name**
1	16MAP21	Computational Fluid Dynamics
2	16MAP14	Finite Element Methods
3	16MAE254	State Space Methods
4	16MAP152	Continuum Mechanics

Group: 6		
Sl. No.	**Course Code**	**Course Name**
1	16MAE151	Introduction to Avanced Composites
2	16MAP151	Aerospace Materials and Processes
3	16MAP153	Advanced Composite Materials

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As per 2017 Regulation

01	16MAE12	Group-1	AERODYNAMICS
Exam Hours:03		**Exam Marks:100**	

Modules

Module -1 Basics of Aerodynamics: Properties of fluids, Characteristics of Atmosphere, Type of fluid flows, Generation of Lift, Drag and Moment, Incompressible flows over airfoils, calculation of lift and drag from measured pressure distribution, Streamlined and bluff-body, Reynolds number and Mach number, Conservation law of mass and momentum, Euler and Bernoulli‟s equations, pitot-tube measurement of airspeed .Pressure coefficient. Streamlines, path lines and streak lines. Angular velocity, vorticity, circulation Stream function, velocity potential and their relationship. Governing equation for irrotational and incompressible fluid flow.

Module -2 Aerodynamics of airfoils and wings: Airfoil nomenclature and classification, Low speed aerodynamic characteristics of symmetric and cambered airfoils, Centre of pressure, aerodynamic centre and aerodynamic moment, Concept of point vortex, line vortex and vortex sheet, Kutta condition, Kelvins circulation theorem and starting vortex, Classical thin airfoil theory and symmetric airfoil. Finite wing nomenclature. Incompressible flow over wing, vortex filament, bound vortex, horse shoe vortex, downwash, induce angle of attack and drag. Type of drag. Biot-Savart law and Helmholtzs vortex theorem. Prandtls lifting line theory and limitations. Elliptic lift distributions, expression for induced angle of attack and induce drag. Two dimensional and three dimensional wings lift curve slope and effect of aspect ratio. High lift devices.

Module -3
High speed Aerodynamics: Fundamentals of thermodynamic concepts, conservation of energy. Speed of sound, Mach wave and Mach angle. Normal shock wave, Oblique shock wave, Expansion fan, Prandtl-Meyer expansion. Family of shocks. Flow through convergent divergent nozzle. Hodograph and pressure turning angle. Rankine- Hugoniot relation.

Module -4 Compressible flow over airfoil: Full velocity potential equation. Small perturbation theory. Linearized velocity potential equation and boundary conditions. Pressure coefficient for small perturbation. Prandtl- Glauret compressibility correction. Critical Mach number, Drag Divergence Mach Number, Sound barrier. Transonic area rule, supercritical airfoil, swept wing and delta wing.

Module -5 One dimensional flow through constant area duct: Fanno flow and fanno line, Rayleigh flow and Rayleigh line. Method of characteristics and its application. Flow past Wedge and cone.

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. Fundamentals of Aerodynamics: John D. Anderson, McGraw-Hill publication.
2. Modern compressible flow: John D. Anderson, McGraw-Hill publication.

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As per 2017 Regulation

02	16MAE422	Group-1	MISSILE AERODYNAMICS
Exam Hours:03		**Exam Marks:100**	

Modules

Module -1 Introduction: Theory of bodies of revolution. Lift and moment of slender bodies of revolution..Planar W-B Interference. Classes of missiles, Types of design and control; Wing, Canard, Tail, Tailless control; Dorsal, Jet control, Monowing, Triform, and Cruciform.

Module -2 Aerodynamic Characteristics of Airframe Components & Missile Performance: Forebody: conical, ogival, hemi-spherical, etc. Midsection: boat-tail. Characteristics of bodies of revolution. Aerodynamics of airfoil, Aspect-ratio, Wing Planform, Aerodynamic control: wing, canard and tail. **Missile Performance:** Introduction. Drag: Friction, pressure, interference, induced and boat tail drag. Boost glide trajectory: graphical and iterative method. Long range cruise trajectory; Maximum speed, rate of climb, time to climb, stall speed, maximum range. Long range ballistic trajectory: powered and unpowered flight and design consideration.

Module -3 Longitudinal Stability and Control, Maneuvering Flight: Introduction, Two-degree of freedom analysis, Complete missile aerodynamics: static stability margin, load factor capability for forward control and rear control, Flat turn: Cruciform, Triform, Pull ups; Relation between Maneuverability and load factor. Stability margin.

Module -4 Directional & Lateral Stability and Control: Introduction, Cruciform configuration: wing, body and tail contribution, Directional Control. Introduction to lateral stability and control, Induced roll - cruciform, Lateral Control cruciform, Special design consideration, Damping in roll. Induced roll; Mono wing, Lateral Control- Mono wing.

Module -5 Air loads: Design criteria: Forward Control, Rear control. Component Air loads: Body, Aerodynamic surfaces. Component load distribution: Body and lifting surfaces. Aerodynamic Hinge moments and Aerodynamic heating.

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. S S Chin, “Missile Configuration Design”, McGraw Hill, 1961
2. Jack N Neilson, `Missile Aerodynamics`, McGraw hill Book Company, Inc 1960

Reference Books:

1. M.J. Hemsch, and J.N. Nielsen,” Tactical Missile Aerodynamics”, AIAA , 2006
2. J.H. Blacklock,” Automatic Control of Aircraft and Missiles”, John Wiley & Sons, II Edition, 1991.

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PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

03	16MAP422	Group-1	HYPERSONIC AERODYNAMICS
Exam Hours:03			**Exam Marks:100**

Modules

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.

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.

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.

Module -4

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.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 16 marks.
- There will be 2full 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.

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PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)
As per 2017 Regulation

01	16MAP421	Grop-2	ADVANCED GAS TURBINE
Exam Hours:03			**Exam Marks:100**

Modules

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.

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.

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.

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 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.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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

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PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

02	16MAE154	Group-2	AERO-ENGINE TESTING AND PERFORMANCE EVALUATION
Exam Hours:03			**Exam Marks:100**

Modules

Module -1 Introduction: Need For Gas Turbine Engine Testing And Evaluation, Philosophy Of Testing, Rationale Of Testing. Types of tests: Proof of Concepts, Design Verification, Design Validation, and Formal Tests.
Aero Thermodynamic Tests: Compressor: Compressor scaling parameter Groups, Compressor MAP. Inlet distortions. Surge margin stack up. Testing and Performance Evaluation, Test rig.

Module -2 Combustor: Combustor MAP, Pressure loss, combustion light up test. Testing and Performance Evaluation. **Aero Thermodynamic Tests: Turbines:** Turbine MAP. Turbine Testing And Performance Evaluation. Component model scaling. **Inlet duct & nozzles:** Ram pressure recovery of inlet duct. Propelling nozzles, after burner, maximum mass flow conditions. Testing and Performance Evaluation.

Module -3 Engine performance: Design & off-design Performance. Transient performance. Qualitative characteristics quantities. Transient working lines .Starring process & Wind milling of Engines. Thrust engine start envelope. Calculations for design and off-design performance from given test data – (case study for a Jet Engine).

Module -4
Qualification Tests: Tests used to evaluate a design. Environment ingestion capability. Preliminary flight rating tests, Qualification testing, acceptance tests, Reliability figure of merit. Structural integrity tests: Design Verification Tests, Durability and Life Assessment Tests, Reliability Tests, Failure Simulation Tests, Functional And Operability Tests. **Types of engine tests:** Normally Aspirated Testing, Ram Air Testing, Altitude Testing, Flying Test Bed, Mission Oriented Tests, Open Air Test Bed, Ground Testing of Engine Installed in Aircraft, Flight testing.

Module -5 Test cell: Air breathing engine test facility. Direct connect altitude cell, propulsion wind tunnels. Types of engine test beds. Factors for design of engine test beds. Altitude test facility. Steps in test bed cross calibration. Engine testing with simulated inlet distortions. Surge test. Cell Calibration and Correction. Performance Reduction Methodology. Instrumentation: Data Acquisition, Measurement of Thrust, Pressure, Temperature, Vibration, etc. Accuracy and Uncertainty in Measurements. Experimental Stress Analysis.

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. P.P Walsh and P. Pletcher, Gas Turbine Performance, Blackwell Science, 1998, ISBN 0632047843.
2. J P Holman, Experimental methods for Engineers, Tata McGraw –Hill Publishing Co. Ltd ., 2007

Reference Books:

1. Advance Aero-Engine Testing, AGARD-59 Publication
2. NASA CR-1875,`An inventory of Aeronautical Ground Research Facilities.

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PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

03	16MAP12	Group-2	AEROSPACE PROPULSION
Exam Hours :03		Exam Marks:100	

Modules

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.

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.

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.

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.

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.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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‖ AmericanElsovier 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

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PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

04	16MAE423	Group-2	THEORY OF COMBUSTION
Exam Hours :03			**Exam Marks:100**

Modules

Module -1 Basics of Combustion theory: Combustion Stochiometry and Thermo chemical Calculation, Chemical Kinetics and Equilibrium, Transport Phenomena-Theory of Viscosity, conductivity and diffusivity.

Module -2 Pre-Mixed Flames: Description of premixed flames, Burning velocity and parametric dependences, Experimental methods of measuring burning velocity, Simple one-dimensional thermal theory of flame, concepts of minimum ignition energy, quenching distance, stability limits and flame stabilization. Turbulent premixed flame.

Module -3 Diffusion Flame: Jet flame physical description, theoretical analysis-Burke-Schumann‟s analysis, mechanism of soot formation, Difference between premixed and diffusion flames, Liquid fuel combustion, Difference between premixed and diffusion flames, Liquid fuel combustion, Difference between premixed and diffusion flames, Liquid fuel combustion- Conservation equations, calculation of mass burning rate, Droplet burning time, Droplet combustion in convective environment.

Module -4 Combustion in Reciprocating and Gas- Turbine Engines: Description of the combustion process in piston engines, Combustion efficiency and factors affecting it, Rankine-Hugoniot curves, Deflagration and Detonation in reciprocating engines and preventive methods. Description of different types of combustion chambers in gas-turbine engines, primary requirements of the combustor, Flow structure, recirculation and flame stabilization in main combustion chamber, afterburners.

Module -5 Combustion in Rocket Engines and Emission: Types of Rockets based on combustion, Solid fuel combustion, combustion of carbon particle-simplified analysis, boundary layer combustion, combustion of carbon sphere with CO burning gas phase. Chemical Emission from combustion and its effects, Exhaust gas analysis, Emission control methods.

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. An Introduction to combustion Concepts and Application, Stephen R Turns, TMH Publication
2. Fundamentals and Technology of combustion, Fawzy El-Mahallawy, Saad El-Din Habik,Elsevier

Reference Books:

1. Industrial Combustion by Charles E. Baukal.
2. Fundamentals of combustion, D P Mishra, PHI Publication
3. Combustion, Fossil Power Systems by G. Singer. 4th Ed. 1966 Ed Pub.
4. Sharma, S.P., and Chandra Mohan "Fuels and Combustion", Tata Me. Graw Hill Publishing Co.,Ltd., New Delhi, 1987

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PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

05	16MAE424	Group-2	ROCKET AND SPACE PROULSION
Exam Hours:03			**Exam Marks:100**

Modules

Module -1 Introduction: Types of rocket engines, Liquid and Solid Propellant rocket engines, Rocket Propulsion theory, Rocket dynamics- Vertical flight of rocket, the rocket equation, Altitude gain during vertical flight, Escape velocity.

Module -2 Thermodynamics and Heat Transfer in Rocket Engines: Thermodynamics of Rocket Propulsion, Nozzle Theory, Over and Underexpanded Nozzles, two-phase flow, variable thrust, High velocity flow with heating in the chamber. General steady state Heat transfer relation, Rocket thrust chamber heat transfer, uncooled combustion devices, Heat transfer to flying vehicles, Exhaust jet and atmospheric interaction.

Module -3 Solid propellant and Liquid propellant rocket Engines : Properties and design of solid motors, Integrity of the combustion chamber, Ignition, Hybrid rocket motors, modern solid booster motors Basic configuration and types of liquid propellant rocket engines, Combustion chamber and nozzle, Cooling of liquid-fuelled rocket engines, Choice of propellant and performance of Liquid fuelled rocket engines .

Module -4 Combustion in Rocket Engines and launch vehicle dynamics: Combustion of carbon particle-simplified analysis, boundary layer combustion, combustion of carbon sphere with CO burning gas phase. Problems. Vertical motion in earth‟s gravity field, inclined motion in earth‟s gravity field, motion in atmosphere, Gravity turn, typical earth-launch trajectories.

Module -5 Electric and Nuclear Propulsion: Principles of electric propulsion, electric, electromagnetic, and plasma thrusters, Electrical power generation, Nuclear reactor fundamentals, nuclear fission and chain reaction, Typical nuclear rocket system and Operational issues with the nuclear rocket engine.

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. Rocket Propulsion Elements by G. P. Sutton and O. Biblarz, 8th Edition, John Wiley and Sons, 2001
2. Rocket and Spacecraft Propulsion: Principles, Practice and New Developments by M. J. L. Turner, Third Edition, Springer, 2009

Reference Books:

1. Spacecraft Propulsion by C. D. Brown, AIAA Education Series, Mechanics and Thermodynamics of Propulsion by P. Hill and C. Peterson, Second Edition, 1992, Addison-Wesley
2. Space Propulsion Analysis and Design, Revised Edition, by R. W. Humble, G. N. Henry and W. J. Larson, McGraw Hill, 1995

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PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

06	16MAP22	Group-2	FUELS AND COMBUSTION
Exam Hours:03		**Exam Marks (Maximum):100**	

Modules

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.

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 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.

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.

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.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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. Error! Hyperlink reference not valid.. Error! Hyperlink reference not valid., Macmillan India Limited, 1989
2. Wilson, P.J. and J.H. Wells, Coal, Coke and Coal Chemicals, New York, McGraw-Hill, 1960.
3. Williams, D.A. and G. James, Liquid Fuels, London Pergamon, 1963.
4. Gas Engineers Handbook, New York, Industrial Press, 1966.

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PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

07	16MAP23	Group-2	HEAT TRANSFER IN PROPULSION
Exam Hours:03			Exam Marks (Maximum):100

Modules

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.

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 endwalls. Turbine blade tip film cooling. Leading edge region film cooling. Flat surface film cooling. Film cooling effectiveness. Discharge coefficient of turbine cooling holes. Film cooling effect on aerodynamic losses. **Jet Impingement Cooling:** Heat transfer enhancement by a single jet, Impingement heat transfer in the mid-chord region by jet array, Impingement cooling of leading edge.

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 180o sharp turn, detailed heat transfer coefficient measurements in ribbed channel, effect of film cooling hole on ribbed channel heat transfer.

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.

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.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 16 marks.
- There will be 2full 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, SandipDutta&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‖,

2. NAL, Bangalore, ―Engine health monitoring as applied to gas turbine engines‖, 1983

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

Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

08	16MAP24	Group-2	GAS TURBINES AND ROCKET PROPULSION
Exam Hours:03		**Exam Marks (Maximum):100**	

Modules

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.

Module -2

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

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 .

Module -4

Velocity increment and mass ratio, burnout velocityand 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.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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.

Visvesvaraya Technological University, Belagavi.
PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)
As per 2017 Regulation

09	16MAP253	Group-2	RAMJET AND SCRAMJET
Exam Hours:03			Exam Marks:100

Modules

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.

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.

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 – Integral ram- rocket- Numerical problems.
Types of Scramjet Engines, Analysis of Scramjet Engines, performance, Thrust Equation, Problem, TS Diagram, Loss .

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.

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.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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 airbreathing propulsion by William H. Heiser, David T. Pratt
2. Scramjet Propulsion –edited by ET Curran and S N B Murthy , Progress in Astronautics and Aeronautics, AIAA
3. Ramjet Technology, EA Bunt and others
4. RAMJETS, AIAA

Reference Books:

1. AGARD, Advisory Group For Aerospace Research and Development.

Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

10	**16MAP424**	**Group-2**	**ADVANCED PROPULSION**
Exam Hours:03			**Exam Marks:100**

Modules

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.

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.

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 – power Hall Effect thruster (HET), high- power applied-field magneto plasma dynamic thruster (MPDT), and double stage HET. Micro Ion thruster, Microchip laser thruster. Colloid thruster. Fundamentals of ion propulsion.

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.

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.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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.

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.

Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

01	16MAE23	Group-3	AIRFRAME STRUCTURES AND STRUCTURAL DESIGN
Exam Hours:03			**Exam Marks:100**

Modules

Module -1

Fundamentals of structural analysis and structural components of aircraft: Basic elasticity, Two dimensional problems in elasticity, Loads on structural components, function of structural components, fabrication of structural components, connections, numerical **Statically determinate and indeterminate structures as applied to aircraft structures:** Statically determinate: Equilibrium of force systems, truss structures, externally braced wings, landing gear, beams – shear and moments, torsion-stresses and deflection. Statically indeterminate structures: Bending moment in frames and rings by elastic centre method, Continuous structure – moment distribution method. Numerical problems.

Module -2

Introduction to practical aircraft stress analysis: Introduction to wing stress analysis by modifies beam theory, Introduction to fuselage stress analysis by modified beam theory, Loads and stresses on ribs and frames. numerical problems.

Module -3

Buckling and stability as applied to aircraft structures: Introduction, columns and beam columns, crippling stress, buckling of this sheets, Thin skin-stringer panels, skin-stringer panels, Integrally stiffened panels, numerical problems, **Overview of structural design process:** Structural integrity, Material and mechanical properties, failure theories, Design criteria- safe life and fail safe, Designing against fatigue, prediction of aircraft fatigue life.

Module -4

Wing box structure and Fuselage: Introduction, wing box design, wing covers, spars, Ribs and bulkheads, wing root joints, variable swept wings, wing fuel tank design. Fuselage: Introduction, fuselage configuration, fuselage detail design, forward fuselage, wing and fuselage intersection, stabilizer and aft fuselage intersection, fuselage opening.

Module -5

Empennage structure, Landing gear and engine mounts: Landing gear: Empennage structure: introduction, Horizontal stabilizer, vertical stabilizer, elevator and rudder. Introduction, developments and arrangements, stowage and retraction, detail design. Engine mounts: Introduction, propeller driven engine mounts, inlet of jet engines, wing-pod (pylon) mounts, rear fuselage mounts and tail mounts, fuselage mounts (fighters).

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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. T.H.G.Megson, „Aircraft structures for engineering students‟, fourth edition, Butterworth-Heinemann, USA, 2007.
2. E.F.Bruhn, „Analysis and design of flight vehicle structures‟, Jacobs Publishing, Inc, USA, 1973.
3. Michael Chun-Yung Niu, „Airframe structural design‟, Lockheed Aeronautical systems company, Burbank, California, Hong Kong Conmilt Press Ltd, USA, February 2002,

Reference Books:

1. Aircraft structures by David Perry, McGraw Hill, 1982
2. Structural Analysis with Application to Aerospace Structures by O.A. Bauchau and J. I. Craig, Springer ,2009

Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

02	16MAE252	Group-3	THEORY OF AEROELASTICITY
Exam Hours:03			**Exam Marks:100**

Modules

Module -1

INTRODUCTION Aeroelasticity - Aeroelastic phenomenon: flutter, buffeting, dynamic loads problems, load distribution, divergence, control effectiveness & reversal. **Deformation of airplane structures under static loads:** Forces acting on aeroplane, Influence coefficients. Properties of influence coefficients. Deformation under distributed forces. Simplified elastic airplane. Bending, torsional and shear stiffness curves.

Module -2

Static aeroelastic phenomena: Load distribution and divergence-wing torsional divergence (two-dimensional case, & finite wing case). Prevention of aeroelastic instabilities. **Control effectiveness and reversal :** Aileron effectiveness and reversal -2 dimensional case, and finite wing case. Strip theory. Aileron effectiveness in terms of wing -tip helix angle. Critical aileron reversal speed. Rate of change of local pitching moment coefficient with aileron angle.

Module -3

Deformation of airplane structures under dynamic loads: Differential and Integral forms of equations of motions of vibrations. Natural modes and frequencies of complex airplane structures - introduction. Dynamic response phenomenon. **Dynamic problems of Aeroelasticity:** Determination of critical flutter speed. Aeroelastic modes. Wing bending and torsion flutter. Coupling of bending and torsion oscillations and destabilizing effects of geometric incidences, Flutter prevention and control.

Module -4

Test model similarities: Dimensional concepts. Vibration model similarity laws. Dimensionless form of equation of motion. Mode shapes and natural frequencies in dimensionless forms. Model scale factors. Flutter model similarity law. Scale factors. Structural simulation:-shape, mass and stiffness.

Module -5

Testing techniques: Measurement of structural flexibility, natural frequencies and mode shapes. Polar plot of the damped response. Identification and measurement of normal modes. Steady state and dynamic Aeroelastic model testing.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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. Dowell, E. H., Crawley, E. F., Curtiss Jr., H. C., Peters, D. A., Scanlan, R. H., and Sisto, F., A Modern Course in Aeroelasticity, Kluwer Academic Publishers, 3rd Edition, 1995. (TL574.A37.M62)
2. Bisplinghoff, R., Ashley, H., and Halfman, R. L., Aeroelasticity, Dover, 1955. (TL570.B622)

Reference Books:

1. Fung, Y. C., An Introduction to the Theory of Aeroelasticity, 1955 (Dover, 1969).
2. Megson THG,` Aircraft structures for Engineering students`, Edward Arnold.
3. Bisplinghoff, R. and Ashley, H., Principles of Aeroelasticity, Dover, 1962. (TL570.B623)

Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

03	16MAE421	Group-3	FATIGUE AND FRACTURE MECHANICS
Exam Hours:03			**Exam Marks:100**

Modules

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.

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.

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.

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. Fracture Resistance of Materials: Fracture criteria, atigue 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 **o**f temperature, loading rate and plate thickness on fracture toughness. Fracture testing in shear modes, fatigue testing, NDT methods.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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, ArtinusNijhoff, London 1999.

Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

04	**16MAE24**	**Group-3**	**FLIGHT VEHICLE DESIGN**
Exam Hours:03			**Exam Marks:100**

Modules

Module -1

Overview of Design Process: Introduction, Requirements, Phases of design, Conceptual Design Process, Initial Sizing, Take-off weight build up, Empty weight estimation, Fuel fraction estimation, Take- off weight calculation, **Thrust to Weight Ratio & Wing Loading:** Thrust to Weight Definitions, Statistical Estimate of T/W. Thrust matching, Spread sheet in design, Wing Loading and its effect on Stall speed, Take-off Distance, Catapult take-off, and Landing Distance. Wing Loading for Cruise, Loiter, Endurance, Instantaneous Turn rate, Sustained Turn rate, Climb, & Glide, Maximum ceiling.

Module -2

Configuration Layout & loft: Conic Lofting, Conic Fuselage Development, Conic Shape Parameter, Wing-Tail Layout & Loft. Aerofoil Linear Interpolation. Aerofoil Flat-wrap Interpolation. Wing aerofoil layout-flap wrap. Wetted area determination. Special considerations in Configuration Layout: Aerodynamic, Structural, Delectability. Crew station, Passenger, and Payload arrangements. **Design of Structural Components:** Fuselage, Wing, Horizontal & Vertical Tail. Spreadsheet for fuselage design. Tail arrangements, Horizontal & Vertical Tail Sizing. Tail

Module -3

Engine Selection & Flight Vehicle Performance: Turbojet Engine Sizing, Installed Thrust Correction, Spread Sheet for Turbojet Engine Sizing. Propeller Propulsive System. Propeller design for cruise. Take-
off, Landing & Enhanced Lift Devices:- Ground Roll, Rotation, Transition, Climb, Balanced Field Length, Landing Approach, Braking. Enhanced lift design -Passive & Active.

Module -4 Static Stability & Control: Longitudinal Static Stability, Pitch Trim Equation. Effect of Airframe components on Static Stability. Lateral stability. Contribution of Airframe components. Directional Static stability. Contribution of Airframe components. Aileron Sizing, Rudder Sizing. Flying qualities. Cooper Harper Scale. Environmental constraints, Aerodynamic requirements.

Module -5 Design Aspects of Subsystems: Flight Control system, Landing Gear and subsystem, Propulsion and Fuel System Integration, Air Pressurisation and Air Conditioning System, Electrical & Avionic Systems, Structural loads, Safety constraints, Material selection criteria.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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. Aircraft Design - A Conceptual Approach- Daniel P. Raymer, AIAA Education Series, IVth Edition © 2006
2. Design of Aircraft-Thomas C Corke, Pearson Edition. Inc. © 2003.

Reference Books:

1. Aeroplane Design -VOL 1 to 9 - J Roskam
2. Introduction to Aircraft Design - John Fielding, Cambridge University Press, 2009

Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

05	16MAP154	Group-3	AEROSPACE STRUCTURES
Exam Hours:03		**Exam Marks100**	

Modules

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.

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, Semimonocoque and monococque structures, Shear flow in single and multi-cell monocoque and semimonocoque box beams subject to torsion. **1**

Module -3

Thin Plate Theory Bending of thin plates: Pure bending of 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.

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.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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.

Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

06	16MAP423	Group-3	ADVANCED BEARINGS AND ROTOR DYNAMICS
Exam Hours:03		**Exam Marks:100**	

Modules

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 capability and methods of obtaining them, Influence of preload on the dynamic coefficients of journal bearings.

Module -2

Objective of Rotor dynamic Analysis, Concept of rigid and flexural critical speeds and mode shapes, External Dampers, Single degree spring-mass-damper system analysis as applied to Jeffcott rotors. Bending Critical Speeds of Simple Shafts, whirling of an unbalanced simple elastic rotor, Transfer Matrix Analysis for bending Critical Speeds, Effect of axial stiffness.

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.

Module -4

Introduction to Smart Materials, Structures and Products Technologies. Overview of application of smart materials to rotor 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.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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

Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

01	16MAE13	Group-4	INTRODUCTION TO AEROSPACE VEHICLES AND SYSTEMS
Exam Hours:03			**Exam Marks:100**

Modules

Module -1 General introduction to aeronautics: Fixed wing & Rotary wing aircraft: Light aircraft, Fighter aircraft, Passenger aircraft, and Cargo aircraft; Light helicopter, Large passenger and cargo helicopters Exploded views of various types of aircraft, identification of various structural parts and their functions and materials used. **Aircraft Systems:** System design and development processes;
Mechanical systems: Components and functions of Hydraulics & Landing Gear systems.

Module -2 Aircraft Electrical Systems: Generation, distribution and typical aircraft electrical systems and recent trends; **Avionic systems:** Flight control systems; Navigation system, Communication and radar systems their components and functions; Emergency systems and advanced systems. **Satellites & orbital dynamics:** Satellite missions, Different types of satellites and their applications, Spacecraft configurations.

Module -3 Spacecraft Launch Vehicles: Rocket propulsion principles and types and propellants; Sounding Rockets, Staging of rockets; major subsystems of launch vehicles and their functions; Different types of satellite launch vehicles, General description about Launch Vehicles of Indian origin.

Module -4

Standards & Specifications and Testing & Certification Aspects: Introduction to aircraft international and standards specifications for Military and Civil aircraft, Company standards; Airworthiness certification aspects aircraft; Ground testing and qualification testing. **Flight testing:** Purpose and scope, Test plans and procedures; flight test instrumentation; general flying and handling characteristics of aircraft; Preparation, and conduct of tests, fault reporting.

Module -5

Introduction to aerospace industries and institutions and their roles: Aircraft design and production industries; Components and systems manufactures, Service industries, Research and Development organizations and Academic institutions. **Introduction to Airport Engineering:** Development of air transportation, ICAO, IAAI,AAI, Aircraft characteristics which affect airport planning; Airport planning: Airport Master Plan, Regional Plan, Site selection; Terminal area and airport layout, Visual aids and ATC.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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. ChennaKeshu S and Ganapathy K K: Aircraft Production Technology and Management, Interline Publishing, Bangalore 1993
2. Ian Moir and Allan Seabridge: Aircraft Systems, mechanical, electrical and avionics subsystems integration, Professional Engineering Publishing Limited, UK, 2001

Reference Books:

1. Ralph D Kimberlin: Flight Testing of Fixed wing Aircraft, AIAA Education Series, 2003
2. J. Gordon Leishman: Principles of Helicopter Aerodynamics, Cambridge Aerospace series, 2000
3. Jane‟s All The World Aircraft
4. S K Khanna, M G Arora and S S Jain, Airport Planning and Design NEM Chand and Brothers, Roorki, 6th Edition, 2001

Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

02	16MAE21	Group-4	AIRCRAFT PERFORMANCE AND FLIGHT MECHANICS
Exam Hours:03			**Exam Marks:100**

Modules

Module -1 Aircraft Performance: Aviation history. Principles of Flight. Aircraft aerodynamics; Drag and Thrust. Steady and level Flight. Variation of Thrust, Drag, Power available, and Power required with speed and altitude. Minimum drag, minimum power, Maximum and minimum level flight speeds. Simple problems.

Module -2 Steady Performance: Airplane Steady Performance: General equation of motion, Steady level flight performance, Steady Climbing, Gliding Flights ; Minimum rate of sink and range in a glide. Range and Endurance of jet and piston prop airplanes. **Accelerated Performance:** Estimation of take-off and landing distances. Ground effect, Balanced Field Length. Turn performance; Bank angle, load factor, pull-up & pull-down maneuver; accelerated climbing, V-n diagram.

Module -3 Static Longitudinal Stability and Control: Equilibrium conditions, Definition of static stability, Definition of longitudinal static stability, stability criteria, Contribution of airframe components: Wing contribution, Tail contribution, Fuselage contribution, Power effects- Propeller airplane and Jet airplane. Trim condition. Static margin.stick fixed neutral points. Longitudinal control, Elevator power, Elevator angle versus equilibrium lift coefficient, Elevator required for landing, Restriction on forward C.G. range, Hinge moment parameters, Stick-free Neutral point, Stick force gradient in unaccelerated flight, Restriction on aft C.G .

Module -4 Static Directional Stability and Control: Introduction, Definition of directional stability, Static directional stability rudder fixed, Contribution of airframe components, Directional control. Rudder power, Stick-free directional stability, Requirements for directional control, Rudder lock, Dorsal fin. One engine inoperative condition, Weather cocking effect. **Static Lateral Stability And Control:** Introduction, definition of Roll stability. Estimation of dihedral effect., Effect of wing sweep, flaps, and power, Lateral control, Estimation of lateral control power, Aileron control forces, Balancing the aileron.

Module -5 Dynamic Longitudinal Stability: Definition of Dynamic longitudinal stability: types of modes of motion: long or phugoid motion, short period motion. Airplane Equations of longitudinal motion, Derivation of rigid body equations of motion, Orientation and position of the airplane, gravitational and thrust forces, Small disturbance theory. **Dynamic Lateral and Directional Stability:** Routh‟s criteria. Factors affecting period and damping of oscillations. Effect of wind shear.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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. Anderson J.D.: Introduction to Flight, McGraw Hill, 1987
2. Perkins, C.D., and Hage, R.E.: Airplane Performance, stability and Control, John Wiley & Sons Inc, New York, 1988.

Reference Books:

1. McCormick B.W., Aerodynamics, Aeronautics and Flight Mechanics, John Wiley & Sons New York, 1979.
2. Anderson J.D., Foundation of Aerodynamics, McGraw Hill Book Co, New York,1985
3. Ojha S.K., Flight Performance of Aircraft, AIAA Education Series. Editor in Chief, J.S. Przemieniecki 1995.
4. Bandu N. Pamadi, ` Performance, Stability, Dynamics and Control of Airplanes`, AIAA 2nd Edition Series, 2004.

Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

03	16MAE251	Group-4	AIRCRAFT NAVIGATION SYSTEMS
Exam Hours;30		**Exam Marks'100**	

Modules

Module -1 Introduction: Guidance versus Navigation, categories of navigation, the vehicle, phases of flight, design trade-offs; Evolution of Air navigation, integrated avionics. The Navigation equations: Geometry of earth, coordinate frames, dead-reckoning computations, positioning, positioning, terrain-matching, course computation, errors, digital charts, software aspects and future trends.

Module -2 Terrestrial Radio-Navigation Systems: General principles, system design considerations, point source systems, hyperbolic systems, future trends. Terrestrial Integrated Radio communication - Navigation Systems: Inertial navigation: Introduction, JTIDS relative navigation, position location reporting system, future trends.

Module -3 Inertial Navigation: The system, Instruments, Platforms, Mechanization equations, error analysis, alignment. Satellite Radio Navigation: Basics, orbital mechanics and clock characteristics, atmospheric effects on satellite signals, NAVSTAR GPS, GLONASS, GNSS, future trends.

Module -4

Air data Systems: Air-data measurements, equations, systems, specialty designs, calibration and system test, future trends. Attitude and Heading References: basic instruments, vertical references, heading references, initial alignment of heading references, future trends. **Doppler and Altimeter Radars:** Doppler radars, radar altimeters, future trends. **Mapping and Multimode Radars:** radar pilot age, semiautomatic position fixing, semiautomatic position fixing with synthetic, precision velocity update, terrain following and avoidance, multimode radars, signal processing, airborne weather radar, future trends.

Module -5 Celestial Navigation: star observation geometry, theory of stellar-inertial navigation, stellar sensor design characteristics, Celestial Navigation system design, star catalog characteristics, system calibration and alignment, future trends. **Landing Systems:** the mechanics of landing; low-visibility operations, automatic landing systems: ILS, microwave-landing system, satellite landing system, carrier- landing system, future trends

Air Traffic Management: flight rules and procedures, phases of flight, subsystems, facilities and operations, system capacity, airborne collision avoidance systems.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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. Myron Kayton and Walter R. Fried: Avionics Navigation Systems, John Wiley & Sons Inc., 2nd Edition, 1996
2. Collinson RPG, Introduction to Avionics, Second Edition, Kluwer Academic Publishers, Chapman & Hall, 2003.

Reference Books:

1. Siouris G M: Aerospace avionic systems – A Modern Synthesis, Academic Press 1993

Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

04	16MAE253	Group-4	FLIGHT TESTING
Exam Hours:03		**Exam Marks:100**	

Modules

Module -1 Introduction: Sequence, Planning and governing regulations of flight testing. Aircraft weight and center of gravity, flight testing tolerances. Method of reducing data uncertainty in flight test data -sources and magnitudes of error, avoiding and minimizing errors. **Flight test instrumentation:** Planning flight test instrumentation, Measurement of flight parameters. Onboard and ground based data acquisition system. Radio telemetry.

Module -2 Performance flight testing - range, endurance and climb: Airspeed – in flight calibration. Level flight performance for propeller driven aircraft and for Jet aircraft - Techniques and data reduction. Estimation of range, endurance and climb performance. **Performance flight testing - take-off, landing, turning flight:** Maneuvering performance estimation. Take-off and landing - methods, procedures and data reduction.

Module -3 Stability and control - longitudinal and maneuvering: Static & dynamic longitudinal stability: - methods of flight testing and data reduction techniques. Maneuvering stability methods & data reduction. **Stability and control - lateral & directional:** Lateral and directional static & dynamic stability:-Coupling between rolling and yawing moments. definition of Roll stability. Adverse yaw effects. Aileron reversal. Regulations, test techniques and method of data reduction.

Module -4 Flying qualities: MIL and FAR regulations. Cooper-Harper scale. Pilot Rating. Flight test procedures. **Hazardous flight testing:** Stall and spin- regulations, test and recovery techniques. Test techniques for flutter, vibration and buffeting.

Module -5 Static Directional Stability and Control: Introduction, Definition of directional stability, Static directional stability rudder fixed, Contribution of airframe components, Directional control. Rudder power, Stick-free directional stability, Requirements for directional control, Rudder lock, Dorsal fin. One engine inoperative condition. Weather cocking effect.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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. Ralph D Kimberlin, Flight Testing of Fixed Wing Aircraft, AIAA educational Series,2003.
2. Perkins, C.D., Hege R.E, Airplane performance, stability and control, John wiley&sons inc, Newyork, 1988.

Reference Books:

1. AGARD, Flight Test Manual Vol. I to IV.

Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

05	16MAE41	Group-4	AIRCRAFT FLIGHT DYNAMICS AND AUTOMATIC FLIGHT CONTROL
Exam Hours: 03			**Exam Marks: 100**

Modules

Module -1

Review of feedback system analysis and aerodynamic fundamentals: Mathematical models of linear open loop and closed loop systems, Transfer functions and Bode plot and root locus methods of analysis, analysis of multi-loop vehicular control systems; Definition of airframe parameters, coefficients and reference geometries, aerodynamic characteristics of plan forms and fuselage and effectiveness of control surfaces.

Module -2

Vehicle equations of motion and axis systems: Newton‟s Second Law and reference frames Expansion of inertial forces and moments, gravity forces and their linearization, Expansion of aerodynamic forces and moments and direct thrust forces, Complete linearized equations of motion, description of dimensional and non-dimensional stability axis derivatives.

Module -3

Longitudinal dynamics: Review of simplifying assumptions and derivation of simplified longitudinal equations of motion, longitudinal controls and control input transfer functions, two degrees of freedom short period approximations and typical example transfer functions of conventional aircraft and their responses Lateral dynamics: Simplified lateral equations of motion, lateral controls and control input transfer functions, two degrees of freedom Dutch roll approximations, typical example transfer functions of conventional aircraft and their responses.

Module -4 Longitudinal and lateral feedback control: Longitudinal Feedback Control: Feedback of pitch angle and pitch rate to the elevator, feedback of speed error to elevator, feedback of angle of attack and normal acceleration to elevator, feedback of altitude to the elevator Lateral Feedback Control: Feedback of bank angle and rolling velocity to ailerons, feedback of other quantities to ailerons, feedback of heading angle to rudder, feedback of yawing velocity to rudder, feedback of sideslip to rudder, feedback of lateral acceleration to rudder.

Module -5 Longitudinal and lateral autopilots: Longitudinal Autopilots: Displacement autopilot, pitch orientational control system, acceleration control system, glide slope coupler and automatic flare control, flight path stabilization, attitude reference systems, effect of nonlinearities. **Lateral Autopilots:** Damping of Dutch roll, discussion on coordination techniques and methods of obtaining coordination, yaw orientational control system and other lateral autopilot configurations, automatic lateral beam guidance.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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. Jan Roskam: Airplane flight dynamics and automatic flight controls, Part I & II, Published by Design Analysis and Research Corporation (DAR Corporation), 2003, USA.
2. D McRuer, I Ashkenas and D Graham: Aircraft Dynamics and Automatic Control, Princeton University Press, Princeton, New Jersey, 1973

Reference Books:

1. Blake lock J H: Automatic Control of Aircraft and Missiles, John Wiley & Sons, Inc, 1991
2. Babister, A. W: Aircraft dynamic Stability and Response, Pergamon Press, Oxford, 1980.

Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

06	16MAP13	Group-4	INTRODUCTION TO SPACE TECHNOLOGY
Exam Hours:03			**Exam Marks:100**

Modules

Module -1 Fundamentals of Rocket Propulsion: 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.

Module -2 Atmospheric Reentry: Introduction-Steep Ballistic Reentry-Ballistic Orbital Reentry-Skip Reentry-"Double-Dip" Reentry - Aero-braking - Lifting Body Reentry.

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.

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**

Module -5 Space Mission Operations: Supporting Ground Systems Architecture and Team interfaces - Mission phases and Core operations - Team Responsibilities - Mission Diversity - Standard Operations Practices.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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.

Reference Books:

1. "Rocket Propulsion and Space flight dynamics", Cornelisse, Schoyer HFR and Wakker KF, Pitman, 1984.
2. Vincet L. Pisacane, "Fundamentals of Space Systems", Oxford University Press, 2005.
3. "Understanding Space: An Introduction to Astronautics", J.Sellers, McGraw Hill, 2000.
4. "Introduction to Space Flight", Francis J Hale, Prentice-Hall, 1994.
5. "Spacecraft Mission Design", CharlesD.Brown, AIAA education Series, 1998.
6. "Elements of Space Technology for aerospace Engineers", Meyer Rudolph X, Academic Press, 1999.

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PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

07	16MAP252	Group-4	ENGINE PERFORMANCE, CONTROL AND SIMULATION
Exam Hours:30		**Exam Marks:100**	

Modules

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 after burning, 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.

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

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.

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.

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.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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. SaeedFarokhi, ― 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.

Visvesvaraya Technological University, Belagavi.
PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)
As per 2017 Regulation

08	16MAP254	Group-4	SPACE TRANSPORTATION SYSTEMS
Exam Hours:03		**Exam Marks:100**	

Modules

Module -1

Systems Engineering and Systems Design Considerations: Introduction, Systems engineering definition, System engineer, Systems engineering cycle, Systems engineering process, Doctrine of successive refinement, Systems engineering in a DOD Context, Systems Engineering in a NASA Context, Systems Design Considerations: Overview of design process, System integration, System interfaces and control, Tools and methodologies, Systems analysis, Modeling, and the trade study process, Basic launch vehicle system trade analysis methodology, System effective studies.

Module -2

Transportation System Architecture, Infrastructures and U.S. Space Shuttle: Introduction, Historical drivers for space infrastructure, Political considerations, National mission model, Private sector and commercialization, Development of commercial space transportation architecture and system concepts, Cost drivers for space transportation architecture options, Recommended improvements to space transportation architectures, Planning for future space infrastructure, Transportation Infrastructure for moon and mars missions U.S. Space Shuttle: Introduction, Historical background, Development of shuttle system, Orbiter development, Current shuttle vehicle and operations, Shuttle evolution and future growth.

Module -3

Expendable Space Transportation Systems and Reusable Space Launch Vehicles: Introduction, Expendable launch vehicle design, History behind existing Expendable Launch Vehicles, Evolving the expendable launch vehicle, Reusable space launch vehicles: Background—Previous efforts at hypersonic flight, Early aerospace plane conceptual studies, The X-series of research aircraft, Challenges facing manned aerospace planes, Manned reusable systems development programs-Past and Ongoing., NASA reusable launch vehicle studies in 1990s., Hypersonic wave riders, Importance of vehicle health management, Future reusable space launch vehicles Operations and Support Systems: Introduction, Launch operations definition, Shuttle mission operations, Facility requirements for launch operations, Obstacles to streamlining launch operations, Evolutionary launch operations strategies, Designing for future expendable launch vehicle launch operations, Improving Existing Launch Operations, Future launch operations.

Module -4

Systems and Multidisciplinary Design Optimization : Introduction, Launch vehicle conceptual design problem, Modeling needs, Optimization strategies and applications, Collaborative work environment of the future Systems Technology Development: Introduction, Vehicle technologies, Propulsion technologies, Ground and mission operations technologies, Assessing technological options, Technology transfer and commercialization, Applying a commercial development process for access to space.

Module -5

Program Planning, Management, and Evaluation: Introduction, Management Trends, Good Project Management as Team Building and a Balancing Act, Types of Project Management, Configuration Management, Risk Management, Earned value management, Total Quality Management, Managing ultra-large projects Future Systems: Introduction, Next generation space transportation systems, Accelerator concepts, Nuclear fission and fusion based concepts, Antimatter-based propulsion concepts, Solar propulsion concepts, Laser and beamed energy propulsion Concepts, Magnetic Monopoles Concept, Field and Quantum Effect Propulsion Concepts.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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. Space Transportation: A Systems Approach to Analysis and Design, Walter Hammond, AIAA Education Series, American Institute of Aeronautics and Astronautics, Inc, 1999.
2. Integrated Design for Space Transportation System, , BN Suresh and K Sivan, Springer

Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

Reference Books:

1. Design Methodologies for space transportation systems, Walter Hammond, AIAA Education Series, American Institute of Aeronautics and Astronautics, Inc

09	16MAP41	Group-4	AEROSPACE INSTRUMENTATION AND CONTROLS
Exam Hours:03		**Exam Marks:100**	

Modules

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.

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.

Module -3

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 observe ability of control systems:** General concept of control ability, definition of state controllability, alternate tests on control ability, Definition of observability, alternate tests on observability, relationship among controllability, observability and transfer functions.

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.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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.

Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

2. Harrison & Bollinger, ―Automatic Control Systems‖ International Text Book Company.
3. Francis H. Raven, ―Automatic Control Engineering‖, McGraw- Hill International

Visvesvaraya Technological University, Belagavi.
PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)
As per 2017 Regulation

01	16MAP21	Group-5	COMPUTATIONAL FLUID DYNAMICS
Exam Hours		**Exam Marks**	

Modules

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 andits 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.

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 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).

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.

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.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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.

Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

02	16MAP14	Group-5	FINITE ELEMENT METHODS
Exam Hours:03			**Exam Marks:100**

Modules

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.

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.

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.

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.

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.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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

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PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

03	16MAE254	Group -5	STATE SPACE METHODS
Exam Hours:03		**Exam Marks:100**	

Modules

Module -1

Introduction. Basic idea of state space and its analysis. Linear state space model, local level model, non-Gaussian & nonlinear models. Prior knowledge, notations. Concept of filtering, forecast errors, error recursion, state smoothing. Disturbance smoothing parametric estimation –log likelihood method.

Module -2

Linear State Space Model. Univariate structural time series model. Introduction to multivariate structural time series models. Regression model. Space state models in continuous time. Spline smoothing. Filters, Smoothing & Forecasting. State smoothing, smoothened state error, state smoothing recursion, disturbance smoothing, weight functions, simulation smoothing state model in matrix form.

Module -3

Maximum Likelihood Estimation of Parameters. Likelihood qualification. Log likelihood when initial conditions are known. Diffuse log likelihood. Likely hood when model contains regression effects. Likelihood when large observation vector is collapsed. Numerical maximisation algorithm. Goodness of fit. Diagnostic checking. Illustrations of Use of Linear Model. Structural time series model. Bivariate structural time series analysis.

Module -4

Non-Gaussian & Nonlinear State Space Models. Special cases of nonlinear linear and non-Gaussian models. Models with linear Gaussian signals. Exponential family models. Heavy tailed distribution. Stochastic Volatility model. Filtering, and smoothing of non-Gaussian and nonlinear model.

Module -5 Approximate Model Filtering & Smoothing. Multicaptive- Introduction. Trend cycle decomposition. Nonlinear Smoothing- Extended Smoothing. Unscetented smoothing. Approximate mode estimation. Improvement of sampling from smoothing. Filtering and smoothing in Dynamic systems.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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. J Durbin & SJ Koopman, Time series analysis-State Space Methods, 2nd Edition, Oxford 2012.

Reference Books:

1. Daniel Alpay & Israel Gohberg, State Space Method:- Generalisation & Applications, Springer

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PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

04	16MAP152	Group-5	CONTINUUM MECHANICS
Exam Hours:03		**Exam Marks:100**	

Modules

Module -1 Analysis of Stress: Continuum concept, homogeneity, isotropy, mass density, body force, surface force Cauchy's stress principle-stress vector, State of stress at a point- stress tensor, stress tensor –stress vector relationship, Force and moment, equilibrium, stress tensor symmetry. Stress transformation laws, stress quadric of Cauchy. Principal stresses, Stress invariants, stress ellipsoid, maximum and minimum shear stress, Mohr's circle for stress, plane stress, deviator and spherical stress tensors.

Module -2 Deformation and Strain: Particles and points, continuum configuration-deformation and flow concepts. Position vector, displacement vector-Lagrangian and Eulerian description, deformation gradient, displacement gradient. Deformation tensors, finite strain tensors,small deformation theory, infinitesimal strain tensors. Relative displacement-linear, rotation tensors. Transformation properties of strain tensors. Principal strains, strain invariants, cubical dilatation, spherical and deviator strain tensors, plane strain, Mohr's circle, and compatibility equations. **Motion and Flow:** Motion, flow, material derivative. Velocity, acceleration, instantaneous velocity field. Path line, stream line, steady motion. Rate of deformation, Vorticity, natural strain –physical interpretation. Material derivatives of volume, area and line element, material derivatives of volume, surface and line integrals.

Module -3

Fundamental Laws of Continuum Mechanics: Conservation of mass, continuity equation. Linear momentum principle, equation of motion, equilibrium equations. Moment of momentum principle. Conservation of energy- first law of thermodynamics energy equation. Equation of state, entropy, second law of thermodynamics. Clausius-Duhem inequality, dissipation function. Constitutive equations-thermomechanical and mechanical continua. **Linear Elasticity:** Generalized Hooke's law, Strain energy function, isotropy, anisotropy, elastic symmetry. Isotropic media-elastic constants. Elastostatic and Elastodynamic problems. Theorem of superposition, uniqueness of solutions, St. Venant's principle. Two dimensional elasticity- plane stress, plane strain, Airy's stress function. Two dimensional elastostatic problems in polar coordinates. Hyperelasticity, Hypoelasticity, linear thermoelasticity.

Module -4 Fluids: Fluid pressure, viscous stress tensor, barotropic flow. Constitutive equations-Stokesian, Newtonian fluids. Basic equation for Newtonian fluid, Nevier-Strokes-Duhum equations. Steady flow, hydrostatic, irrotational flow. Perfect fluids- Bernoulli's equation, circulation, potential flow, plane potential flow.

Module -5 Plasticity: Basic concept and definitions, idealized plastic behavior. Yield condition- Tresca and Von-Mises criteria. Stress space-□-plane, yield surface. Post yield behavior-isotropic and kinematic hardening. Plastic stress-strain equations, plastic potential theory. Equivalent stress, equivalent plastic strain increment. Plastic work, strain hardening hypothesis. Total deformation theory-elastoplastic problems. Elementary slip line theory for plane plastic strain**. Viscoelasticity:** Linear viscoelastic behavior. Simple viscoelastic models-generalized models, linear differential operator equation. Creep and Relaxation- creep function, relaxation function, hereditary integrals. Complex moduli and compliances. Three dimensional theory- viscoelastic stress analysis, correspondence principles.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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. J. N. Reddy, ―Introduction to Continuum Mechanics with Applications‖, Cambridge University Press, New York-2008
2. W. Michael Lai, David Rubin, Erhard Krempl―Introduction to Continuum Mechanics‖, Fourth edition, 2010, Butterworth-Heinemann -Elsevier Inc. USA
3. George. E. Mase, ―Continuum Mechanics‖,Schaum's outline series, 'McGraw Hill Book Company inc, USA.

Reference Books:

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

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PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

01	16MAE151	Group-6	INTRODUCTION TO ADVANCED COMPOSITES
Exam Hours:03		**Exam Marks:100**	
Modules			
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.			
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.			
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.			
Module -4 **Materials for thermoelectric, dielectric application, optical & 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.			
Question paper pattern: • The question paper will have ten questions. • Each full question consists of 20 marks. • There will be 2full 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.			

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PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

02	16MAP151	Group-6	AEROSPACE MATERIALS & PROCESSES
Exam Hours:03		**Exam Marks:100**	

Modules

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.

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 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.

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.

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.

Question paper pattern:

- The question paper will have ten questions.
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- 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 EngineeringApplications, 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. SeropeKalpakjian, Steven R Schmid, Manufacturing Engineering and Technology, PearsonEducation, 2003

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PhD Coursework Courses – 2018 (Aerospace and Aeronautical Engineering)

As per 2017 Regulation

03	16MAP153	Group-6	ADVANCED COMPOSITES MATERIALS
Exam Hours:03		**Exam Marks:100**	

Modules

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.

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.

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.

Module -4 Materials for thermoelectric, dielectric application, optical & 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.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2full 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.
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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.