Group No.	Course Code	Course Title	UNIQUE CODE
1	**20MAP21**	**Computational Fluid Dynamics in Aeronautical**	201AE001
1	20MAP322	Hypersonic Aerodynamics	201AE002
1	20MAE322	Theory of Aeroelasticity	201AE003
1	20MAP254	Introduction to reacting flows.	201AE004
2	20MAP12	Aerospace Propulsion	202AE001
2	20MAP22	Fuels and Combustion	202AE002
2	20MAP23	Heat Transfer in Propulsion Systems	202AE003
2	20MAP242	Engine Performance Control & Simulation	202AE004
2	20MAP251	Ramjet and Scramjet	202AE005
2	20MAP323	Advanced Gas Turbines	202AE006
2	20MAP331	Missile and Launch Vehicles	202AE007
2	20MAP332	Advanced Propulsion Systems	202AE008
2	20MAP333	Gas Turbine and Rocket Propulsion	202AE009
3	**20MAP31**	**Aerospace Instrumentation and Control**	203AE001
3	20MAE13	Introduction to Aerospace Vehicles and Systems	203AE002
3	20MAE21	Aircraft Performance and Flight Mechanics	203AE003
3	20MAE31	Aircraft Flight Dynamics and Automatic Flight Control	203AE004
4	20MAP241	Fatigue and Fracture Mechanics	204AE001
4	20MAP243	Aerospace Structures	204AE002
4	20MAP252	Mechanical Aspects of Rotating Machinery	204AE003
4	20MAP321	Advanced Bearings and Rotor Dynamics	204AE004
4	20MAE23	Airframe Structures and Structural Design	204AE005
4	20MAP13	Finite Element Methods	204AE006
5	**20MAP14**	**Aerospace Materials and processes**	205AE001
5	20MAP253	Advanced Composite Materials	205AE002
5	20MAE324	New Product Development	205AE003
5	20MAP324	Advanced materials for aerospace applications.	205AE004
6	20MAP334	**Introduction to AI&ML**	206AE001
6	20MAE243	Artificial Intelligence and Robotics	206AE002
6	20MAE252	Unmanned Aerial Vehicles	206AE003

Ph.D Coursework Courses under Aerodynamics

Group 01

01

Group no. 01	
Group 1 : 20MAP21 - COMPUTATIONAL FLUID DYNAMICS IN AERONAUTICAL	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100

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 vs Differential Forms of Equations. Form of Equations particularly suitable for CFD work. Shock capturing, Shock fitting, Physical Boundary conditions.

Mathematical Behaviour 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, Familiarization with CFD softwares and solvers.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■.

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Computational Fluid Dynamics, The Basics with Applications	John D Anderson Jr.	McGraw Hill International Edn	2nd edition &1995
2	Computational Fluid Dynamics	T J Chung	Cambridge University Press	2nd edition &2008
Reference Books				
1	Computational Fluid Dynamics - An Introduction	F. Wendt (Editor)	Springer – Verlag, Berlin	3rd edition &2009.
2	Numerical Computation of Internal and External Flows, Vols. I and II	Charles Hirsch	John Wiley & Sons, New York	1st edition &1988.
3	Computational Fluid Dynamics- A Practical Approach	JiyuanTu, Guan HengYeoh, and Chaoqun Liu	Elsevier Inc	2008

Aerodynamics Group 01 : 20MAP322 – Hypersonic Aerodynamics	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100

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 is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Hypersonic Inviscid Flows	Wallace D Hayes &	Dover Publication	2004
2	Hypersonic Flow Theory	Wallace Hayes	Academic Press Inc	1959
Reference Books				
1	Hypersonic and High Temperature Gas Dynamics	John D Anderson Jr	AIAA	2000
2	Advanced Hypersonic Test Facilities	Frank K.Lu and Dart E. Marran	AIAA	2002
3	Introduction to Hypersonic Flow	Cherynl C.G.	Academic Press	1961

Aerodynamics Group 01: 20MAE322 – Theory of Aeroelasticity	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100

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 is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Aeroelasticity	Dowell, E. H., Crawley, E. F., Curtiss Jr., H. C., Peters, D. A., Scanlan, R. H., and Sisto	Kluwer Academic Publishers	3rd Edition, 1995

2	Aeroelasticity	Bisplinghoff, R., Ashley, H., and Halfman, R. L.	Dover	1955
Reference Books				
1	Introduction to the Theory of Aeroelasticity	Fung, Y. C	Dover	1955
2	Aircraft structures for Engineering students	Megson THG	Edward Arnold.	5th edition &2012
3	Principles of Aeroelasticity	Bisplinghoff, R. and Ashley, H.,	Dover	1962

Aerodynamics Group 01 : 20MAP254 – Introduction to Reacting Flows	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100
Module-1	
Introduction to Transport Processes: Physical Factors Governing Reaction Rates and Pollutant Emission, Gaseous Fuel Jet, Single Fuel Droplet and Fuel Droplet Spray Combustion, Conservation of Mass, Conservation of Momentum, Conservation of Energy, Approach (Reynolds') to Treatment of Turbulence via Time- Averaging the Conservation Equations, Approach to the Treatment of Multiphase Continua via Volume-Averaging the Conservation Equations, Continuum/Molecular, Compressible/Incompressible, Viscous/Inviscid, Newtonian/Non-Newtonian, Steady/Unsteady, Laminar/Turbulent.	
Module-2	
Constitutive laws: Constitutive Laws/Coefficient, Equations of State, Chemical Kinetics, Diffusion Flux-Driving Force Laws/Coefficients, Linear-Momentum Diffusion (Contact Stress), Stokes' Extra Stress ***vs.*** Rate of Deformation Relation, Energy Equation in Terms of the Work Done, Viscous Dissipation, The Dynamic Viscosity Coefficient of Gases and Liquids, Energy Diffusion Flux and Gradients of Temperature and Species Concentration, Fourier's Heat-Flux Law, Thermal Conductivity Coefficient of Gases, Liquids, and Solids,Mass Diffusion Flux, Fick's Diffusion-Flux Law for Chemical Species, Nonlinear Fluids, Nonlocal Temporal Behavior-Fluids with Memory, Multiphase Effects: Nonlinear Species "Drag" Laws	
Module-3	
Momentum Transport Mechanisms, Rates, and Coefficients: Classification of Fluid Flow System, Mechanisms of Momentum Transport, Transport Properties, Energy and Mass Transport, Steady One-Dimensional Compressible Fluid Flow, "Shock" Waves, Sound Waves, Detonation Waves, and "Deflagration" Waves, Local Velocity Fields, Wall Momentum Transfer Rates, and Wall CoefficientsConservation Equations Governing Velocity and Pressure, Velocity Fields and Surface Momentum-Transport Coefficients: Steady Laminar Flow of an Incompressible Newtonian Fluid, Example duct and plate, Laminar Round Jet of an Incompressible Newtonian Fluid: Far-Field Momentum Transfer for Fluid Flow in Porous Media or Packed Beds	
Module-4	
Energy Transport Mechanisms, Rates, and Coefficients: Mechanisms of Energy Transport, Transfer Rates and Coefficients, Conservation Equation, Boundary Conditions, and Solution Methods, Temperature and Surface Heat Transfer (Quiescent Media of Uniform Composition), Temperature and Surface Heat-Transfer (Steady Laminar Flows), Time-Averaged Temperature Distributions and Surface Heat-Transfer ("Steady" Turbulent Flows), Energy and Momentum Transport,Fully Turbulent Jet Flow into a Co-Flowing Surrounding Stream, Convective Energy Transport in Chemically Reacting Systems, Radiation-Energy Transfer.	
Module-5	

Mass Transport Mechanisms, Rates, and Coefficients: Transport-Controlled Situations, Kinetically Limited Situations, Mechanisms of Mass Transport and Associated Transport, Properties, Concentration Fields and Surface-Transfer, Rates/Coefficients, Concentration Distributions and Surface Mass-Transfer Coefficients (Quiescent Media), Convective Mass Transfer in Laminar- and Turbulent-Flow, Two-Phase Flow: Mass-Transfer Effects, Inertial "Slip" and "Isokinetic", Eddy, Residence-Time Distributions: Tracer "Diagnostics" with Application to the Mathematical Modeling of Nonideal-Flow Reactors.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Transport Processes in Chemically Reacting Flow Systems	Daniel E. Rosner	Dover Publ, Inc. USA.	2000
2				
Reference Books				
1	Multiphase Flow and Transport Process in Subsurface	Rainer Helmig	Springer Publ Inc., Germany.	1997.

Ph.D Coursework Courses under Propulsion

Group 02

Propulsion System Group : 20MAP12 – Aerospace Propulsion	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100

Module-1

Introduction to 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

Fuel and Fuel Systemsfor Gas Turbine Engines: 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 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-4

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, introduction to Electric propulsion.

Module-5

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.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Aerospace Propulsion	Dennis G Shepherd	American Elsevier Publishing Co Inc NY.	1972
2	Aircraft power plants	Michael J Kroes and Thomas W Wild	Macmillan/McGraw Hill NY.	8th edition &2013

3	Rocket Propulsion Elements	George P Sutton and Donald M Ross	John Wiley & Sons NY.	1957
Reference Books				
1	Aircraft Gas Turbine Engine Technology	E. Irwin	Treager	3rd Edition, 1995
2	Mechanics & Thermodynamics of Propulsion	Hill, P.G. , Peterson, C.R. Addison	Wesley Longman INC	1999
3	Design of Liquid Propellant Rocket Engines	Huzel and Houng	NASA SP 125	1971.
4	Rocket Propulsion	Barrere et al	Elsevier Co.,	1960
5	Fundamental Aspects of Solid Propellant Rockets	Williams F A. et al	Agardograph, 116 Technivision	1970
6	Gas turbine engineering handbook	Meherwan P. Boyce	Gulf professional publisher, Elsevier	2006

Propulsion System Group : 20MAP22 – Fuels and Combustion	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100
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 Vapour 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 is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Gas Turbine Combustion, Alternative fuels and Emissions	Arthur H.Lefebvre&Dilip R. Ballal	CRC Press	3rd Edition, 2010
2	Chemistry of Combustion Reaction	Minkoff, G.J., and C.F.H. Tipper	Butterworths,London	1962
3	Fuels & Combustion	Samir Sarkar	Orient Long man	1996
Reference Books				
1	Coal, Coke and Coal Chemicals	Wilson, P.J. and J.H. Wells	McGraw-Hill, New York,	1960.

2	Liquid Fuels	Williams, D.A. and G. James	London Pergamon, London	1963
3	Gas Engineers Handbook	C George Segeler	Industrial Press, New York,	1966

Propulsion System Group : 20MAP23 – Heat Transfer in Propulsion Systems	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100
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 end walls. Turbine blade tip film cooling. Leading edge region film cooling. Flat surface film cooling. Film cooling effectiveness. Discharge coefficient of turbine cooling holes. Film cooling effect on aerodynamic losses. **Jet Impingement Cooling:** Heat transfer enhancement by a single jet, Impingement heat transfer in the mid-chord region by jet array, Impingement cooling of leading edge.	
Module-3	
Rib Turbulated Cooling: Effect of rib layouts and flow parameters on ribbed channel heat transfer, heat transfer coefficient and friction factor correlation, high performance ribs, effect of surface heating conditions, nonrectangular cross section channels, effect of high blockage ratio ribs, effect of rib profile effect of number of ribbed walls, effect of a 180^{o} sharp turn, detailed heat transfer coefficient measurements in ribbed channel, effect of film cooling hole on ribbed channel heat transfer.	
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 SEE question paper will be set for 100 marks and the marks scored will be proportionately reduced to 60.

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

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Gas Turbine Heat Transfer and Cooling	Technology Je Chin Han, SandipDutta&Srinath V Ekkad.	Taylor and Francis New York	2000
2	Heat Transfer	JP Holman	McGraw – Hill Book Company	1996
Reference Books				
1	Gas Turbine Handbook	Anthony Giampaolo	Fairmont Pr	1997
2	Engine health monitoring as applied to gas turbine engines	NAL, Bangalore		1983
3	Measurement techniques in heat transfer	Eckert, E R G and Goldstein R J Ed	Washington: Hemisphere Pub. Corp.	

Propulsion System Group : 20MAP242 – ENGINE PERFORMANCE, CONTROL AND SIMULATION	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100

Module-1

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

Component performance, atmospheric model, correlations for variation of gas properties, inlet anddiffuser pressure recovery, compressor and turbine isentropic and polytrophic efficiencies, Burnerefficiency, pressure loss and pattern factor. Exit nozzle loss, propeller performance parameters, variableand 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 after burning mixed exhaust streams, turbo prop engine.

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

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 shaftand turbo prop, active and passive methods for noise reduction, International standards for aero enginenoise

Module-4

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

Module-5

Aero engine control, FADEC architecture, Digital electronic control unit for aero engine, Gasgenerator control, engine limit protection, engine automatic and manual starting, power management,engine data for cockpit indication, engine condition parameters display in the cockpit, thrust reversercontrol 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 is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Elements of Gas Turbine Propulsion	Jack D. Mattingly	Tata McGraw-Hill Publishing CompanyLimited, New Delhi,	1996
2	Aerothermodynamics of Gas Turbine and Rocket Propulsion	Gordon C. Oates	AIAA EducationSeries	1st edition &1984

Reference Books

1	Aircraft Engine Design	Jack. D. Mattingly, William H. Heiser, David.T.Pratt	AIAA EducationSeries	3rd edition & 2017
2	Jet Propulsion	Nicholas Cumpsty	Cambridge University Press	1997
3	Aircraft Propulsion	Saeed Farokhi	John Wiley & Sons, Inc	2nd edition 2014
4	Aircraft Propulsion and Gas Turbine Engines	Ahmed F. E1-Sayed	CRC Press, Taylor and Francis Group	2nd edition &2017
5	Gas Turbine Performance	Philip P. Walsh and Paul Fletcher	Blackwell Science Ltd, Blackwell Publishing company	1998
6	Systems of Commercial Turbo Fan Engines-An Introduction to SystemFunctions,	Andreas Linke-Diesinger	Springer Publications	2008

Propulsion System Group : 20MAP251 – Ramjet and Scramjet	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100
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 coefficient, Combustion Chamber, Types of Injection	
Module-4	
Scramjet Propulsion: Practical Progress, Heat addition in duct with Area variations, Isolators, Aerothermodynamics of dual mode combustion system, Real H-K diagram, Interoperation of Experimental Data, Fuel-air mixing processes, Measures of local goodness of mixing, Mixing in a Turbulent shear layer	
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 is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■.

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Hypersonic airbreathing propulsion	William H. Heiser, David T. Pratt	AIAA	1994
2	Scramjet Propulsion, Progress in Astronautics and Aeronautics	ET Curran and S N B Murthy	AIAA	2001
Reference Books				
1	Ramjet Technology	EA Bunt and others	US Defence	

Propulsion System Group : 20MAP323 – Advanced Gas Turbines	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100

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 is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.

Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Gas turbines	V Ganesan	Tata McGraw-Hill Publishing company limited	3rd edition &2017
2	Gas turbine theory	H.I.H Saravanamuttoo, G.F.C. Rogers and H. Cohen PV Straznicky	Pearson Education Canada	7th edition &2017
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	1972
3	Aircraft Gas Turbine Engine	E. Irwin Treager		3rd Edition

Propulsion System Group : 20MAP331 – Missiles and Launch Vehicles	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100

Module-1

Introduction: Space launch Vehicles and military missiles, function, types, role, mission, mission profile, thrust profile, propulsion system, payload, staging, control and guidance requirements, performance measures, design, construction, operation, similarities and differences. Some famous space launch vehicles and strategic missiles.

Module-2

Solid Propellant Rocket Motor Systems: Solid Propellant rocket motors, principal features, applications. Solid propellants, types, composition, properties, performance. Propellant grain, desirable properties, grain configuration, preparation, loading, structural design of grain. Liners, insulators and inhibitors, function, requirements, materials. Rocket motor casing – materials. Nozzles, types, design, construction, thermal protection. Igniters, types, construction. Description of modern solid boosters I) Space Shuttle SRB, II)theArienne SRB

Liquid Propellant Rocket Motor Systems: Liquid propellants, types, composition, properties, performance. Propellant tanks, feed systems, pressurization, turbo-pumps, valves and feed lines, injectors, starting and ignition. Engine cooling, support structure. Control of engine starting and thrust build up, system calibration, integration and optimisation – safety and environmental concerns. Description of the spaceshuttle main engine. Propellant slosh, propellant hammer, geysering effect in cryogenic rocket engines.

Module-3

Aerodynamics of Rockets and Missiles: Classification of missiles. Airframe components of rockets and missiles, Forces acting on a missile while passing through atmosphere, method of describing aerodynamic forces and moments, lateral aerodynamic moment, lateral damping moment, longitudinal moment of a rocket, lift and drag forces, drag estimation, body upwash and downwash in missiles. Rocket dispersion, re-entry body design considerations.

Module-4

Launch Vehicle Dynamics: Tsiolskovsky's rocket equation, range in the absence of gravity, vertical motion in the earth's gravitational field, inclined motion, flight path at constant pitch angle, motion in the atmosphere, the gravity turn – the culmination altitude, multi staging. Earth launch trajectories – vertical segment, the gravity turn, constant pitch trajectory, orbital injection. Actual launch vehicle trajectories, types. Examples, the Mu 3-S-II, Ariane, Pegasus launchers. Reusable launch vehicles, future launchers, launch assist technologies.

Attitude Control Of Rockets And Missiles: Rocket Thrust Vector Control – Methods of Thrusts Vector Control for solid and liquid propulsion systems, thrust magnitude control, thrust termination; stage separation dynamics, separation techniques

Module-5

Rocket Testing: Ground Testing and Flight Testing, Types of Tests facilities and safeguards, monitoring and control of toxic materials, instrumentation and data management. Ground Testing, Flight Testing, Trajectory monitoring, post -accident procedures. Description of a typical space launch vehicle launch procedure.
Materials: Criteria for selection of materials for rockets and missiles, requirements for choice of materials for propellant tanks, liners, insulators, inhibitors, at cryogenic temperatures, requirements of materials at extremely high temperatures, requirements of materials for thermal protection and for pressure vessels.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■.

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	RocketPropulsionElement	GeorgePSuttonandOscar Biblarz	John WileyandSonsInc	7th edition,2010
2	MissileAerodynamics	JackNNeilson	AIAA	1st edition, 1988
Reference Books				
1	MissileConfigurationDesign'	SSChin		1st edition &1961
2	Rocket Propulsion and Space-Flight Dynamics	Cornelisse, J.W., Schoyer H.F.R. and Wakker,. K.F	Pitman	1979
3	Rocket and Spacecraft propulsion	Turner, M.J.L	Springer	3rd edition,2010
4	Space Vehicle Dynamics	Ball, K.J., Osborne, G.F.,	Oxford University Press	1967
5	Materials for Missiles and Spacecraft	Parker, E.R	McGraw Hill	1982

Propulsion System Group : 20MAP332 – Advanced Propulsion Systems	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100
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 magnetoplasmadynamic thruster (MPDT), and double stage HET. Micro Ion thruster, Microchip laser thruster. Colloid thruster. Fundamentals of ion propulsion body design considerations.	
Module-4	

Nuclear Propulsion. Nuclear rocket engine design and performance, nuclear rocket reactors, nuclear rocket nozzles, nuclear rocket engine control, radioisotope propulsion, basic thrusters configuration, thrusters technology, heat source development, nozzle development, nozzle performance of radio isotope propulsion systems. Testing of Nuclear rocket engines

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 is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Advance Propulsion Systems & Technologies: Today to 2020	Claudio Bruno, and Antonio Accettura	AIAA	2008
2	Rocket Propulsion Elements	G P Sutton	John Wiley & Sons Inc., New York	1998
Reference Books				
1	Advanced Space Propellant Systems	Martin Tajmar	Springer	2003
2	Hypersonic Airbreathing Propulsion	William H. Heiser and David T. Pratt	AIAA Education Series,	2001
3	Spacecraft Systems Engineering	Fortescue and Stark	Wiley	4th 2011

Propulsion System Group : 20MAP333 – Gas Turbine and Rocket Propulsion	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100

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 is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Rocket Propulsion Elements	Sutton, G.P.,	John Wiley & sons	5th Edition,

2	Aerospace Propulsion	D.G.Shepherd	American Elsevier Publishing Company, Inc.	1972
3	Elements of Gas Turbine Propulsion	Jack D. Mattingly	Tata McGraw-Hill Publishing Company	1996.
Reference Books				
1	Aircraft Engine Design	Jack. D. Mattingly, William H. Heiser and	AIAA Education Series	3rd edition &2018
2	Aerothermodynamics of Gas Turbine and Rocket Propulsion	Gordon C. Oates	AIAA Education Series	1st edition &1984
3	Fundamentals of Gas Turbines	William W. Bathe,	John Wiley and Sons	
4	Gas Turbine Theory	HIH Sarvanamuttoo, GFC Rogers, H.Cohen	Pearson Education, Asia	5th Edition,
5	Mechanics & Thermodynamics of Propulsion	Hill, P.G and Peterson, CR	Addition-Wesley Longman INC	1999.

Ph.D Coursework Courses under Control System

Group 03

Control System Group : 20MAP31 –AEROSPACE INSTRUMENTATION AND CONTROL	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100

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 observeability of control systems: General concept of controllability, definition of state controllability, alternate tests on controllability, 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 is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Instrumentation, Measurement and Analysis	Nakra and Chaudhry, B C Nakra K KChaudhry	Tata McGraw-Hill Companies, Inc, New York	Seventh Edition 2006
2	Mechanical measurements	R. S. Sirohi, H. C. Radha Krishna	NewAge International Pvt. Ltd., New Delhi	2004
3	Automatic Control Systems	B.C. Kuo	Prentice Hall Inc	9th edition &2014
4	Modern Control Engineering	K. Ogata	Prentice Hall Inc.	5th edition &2010
Reference Books				
1	Introduction to Measurements and Instrumentation‖	Arun K. Ghosh	Prentice-Hall of India	2nd Edition 2007
2	Automatic Control Systems	Harrison & Bollinger	International Text Book Company	1969
3	Automatic Control Engineering	Francis H. Raven	McGraw- Hill International	2nd edition &1955

Control System Group : 20MAE13 –INTRODUCTION TO AEROSPACE VEHICLES AND SYSTEMS	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100
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 MasterPlan, 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 is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■.

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Aircraft Production Technology and Management	ChennaKeshu S and Ganapathy K K	Interline Publishing	2nd edition & 1993
2	Aircraft Systems, mechanical, electrical and avionics subsystems integration	Ian Moir and Allan Seabridge	Professional Engineering Publishing Limited	3rd edition & 2011

Reference Books

1	Flight Testing of Fixed wing Aircraft	Ralph D Kimberlin	AIAA Education Series	1st Edition & 2003
2	Principles of Helicopter Aerodynamics	J. G. Leishman	Cambridge Aerospace series	2nd Edition & 2005
3	Airport Planning and Design	K Khanna, M G Arora and S S Jain	NEM Chand and Brothers, Roorki	6th Edition &1999

Control System Group : 20MAE21 –AIRCRAFT PERFORMANCE AND FLIGHT MECHANICS	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100

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 is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks				
Sl No	**Title of the book**	**Name of the Author/s**	**Publisher Name**	**Edition and year**
1	Introduction to Flight	Anderson J.D	McGraw Hill	7th edition &2011
2	Airplane Performance, stability and Control	Perkins, C.D., and Hage, R.E	John Wiley & Sons Inc, New York,	1988
Reference Books				
1	Aerodynamics, Aeronautics and Flight Mechanics	McCormick B.W.,	John Wiley & Sons New York	1979
2	Flight Performance of Aircraft,	Ojha S.K.	AIAA Education Series	1995.
3	Performance, Stability, Dynamics and Control of Airplanes	Bandu N. Pamadi	AIAA	2nd Edition Series,2004

Control System Group : 20MAE31 –AIRCRAFT FLIGHT DYNAMICS AND AUTOMATIC FLIGHT CONTROL	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100
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 is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■.

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Airplane flight dynamics and automatic flight controls, Part I & II	Jan Roskam	Design Analysis and Research Corporation (DAR Corporation)	2003
2	Aircraft Dynamics and Automatic Control	D McRuer, I Ashkenas and D Graham	Princeton University Press, Princeton, New Jersey	1973
Reference Books				
1	Automatic Control of Aircraft and Missiles	Blake lock J H	John Wiley & Sons	1991
2	Aircraft dynamic Stability and Response	Babister, A. W	Pergamon Press	1980.
3				

Ph.D Coursework Courses under Structures

Group 04

Structures Group : 20MAP241 –FATIGUE AND FRACTURE MECHANICS	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100

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, fatigue cracking criteria, effect of alloying and second phase particles, effect of processing and anisotropy, effect of temperature.

Module-5

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

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

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Introduction to Fracture Mechanics	Karen Helen	McGraw Hill	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	Springer	1999

Structures Group : 20MAP243 –AEROSPACE STRUCTURES	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100
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, Semi monocoque and mono cocque structures, Shear flow in single and multi-cell monocoque and semimonocoque box beams subject to torsion.	
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 is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Analysis & Design of Flight Vehicle Structures	E.F. Bruhn	Tristate Offset Co.,	1980
2	Aircraft Structures for Engineering Students	Megson, T.M.G	Edward Arnold	1995
3	Mechanics of Composite Materials	Autar K. Kaw	CRC Press LLC	1997
Reference Books				
1	Aircraft Structures	Peery, D.J. and Azar, J.J	McGraw-Hill, New York	2nd Edition 1993
2	Theory and Analysis of Flight structures	Rivello, R.M	McGraw-Hill, N.Y	1993
3	Analysis and Performance of fiber composites	B.D. Agarwal and L.J. Broutman	John-Wiley and Sons	1990

Structures Group : 20MAP252 –MECHANICAL ASPECTS OF ROTATING MACHINERY	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100

Module-1

Introduction: Definition of a rotating machinery, parts of a rotating machinery w.r.t different aero engine configurations namely like turboprop, turbo shaft, turbojet and turbo fan. Basic issues in rotating machinery like vibrations, unbalance, casing rub and oil debris. Vibration: An overview of basics of vibrations and their significance in rotating machinery, Sources of vibrations in rotating machinery and its characterization. Vibration isolators, vibration measurement, sensors and analysis, industrial standards for vibration.

Module-2

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

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

diagrams.

Module-3

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

Module-4

Imbalance characterization in engines: Rigid and flexible rotors, impact of unbalance on aero engine performance, sources of unbalance, single and multi-plane balancing, Shaft Alignment , Balancing standards for rotating machinery in industries. Bearings, Lubrication and Seals: Types of bearings in aero engines, Load and life evaluation of aircraft engine bearings, lubrication and its characterization. Application of magnetic and foil bearings in aero engines, Different types of seals used in aero engines.

Module-5

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

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Mechanical Vibration	W.T. Thomson	Prentice- Hall	5th Edition 1997
2	Rotordynamics Prediction in Engineering	MichellLalanne and Ferraris	John Wiley	1998.

Reference Books

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

Structures Group : 20MAP321 –ADVANCED BEARINGS AND ROTOR DYNAMICS	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100

Module-1

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

Module-2

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

Module-3

Concepts of rotating machinery: 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

Application of smart materials in rotor dynamics: 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 Studies: 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 is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Rotor dynamics	JS Rao	New Age International Publishers	3rd edition &2018
2	Machinery Vibration and rotor Dynamics	John Vance, FouadZeidan and Brian Murphy	John Wiley & Sons	1st edition &2010
Reference Books				
1	Rotor Dynamics	AgnieszkaMuszyńska	CRC Press	1st edition &2005

2	Rotor Dynamics of Turbo machinery	John M. Vance	John Wiley & Sons	1st edition &1988

Structures Group : 20MAE23 –AIRFRAME STRUCTURES AND STRUCTURAL DESIGN	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100
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, Designingagainst 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 is for 20 marks. • There will be 2 full questions (with a maximum of four sub questions in one full question) from each module. • Each full question with sub questions will cover the contents under a module. • Students will have to answer 5 full questions, selecting one full question from each module. ■	
Textbook/ Textbooks	

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Aircraft structures for engineering	T.H.G.Megson,	Butterworth-	4th edition
2	Analysis and design of flight vehicle structures	E.F.Bruhn	Jacobs Publishing, Inc, USA	1973.
Reference Books				
1	Airframe structural design	Michael Chun-Yung Niu	Lockheed	February 2002
2	Aircraft Structures	D.J. Peery	Dover Publications	2011

Structures Group : 20MAP13 –FINITE ELEMENT METHODS	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100
Module-1	
Introduction to Finite Element Method, One-Dimensional Elements-Analysis of Bars: Introduction to FEM and fundamental principles,Engineering Analysis, Variational formulations, weighted residual methods. Basic Equations and Potential Energy Functional, 1-0 Bar Element, Strain matrix, Element equations, Stiffness matrix.	
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 Dynamics: Formulation for point mass and distributed masses, Consistent element mass matrix of one dimensional bar element, truss element, axi-symmetric triangular element, quadrilateral element, beam element. Lumped mass matrix, Evaluation of eigen values and eigen vectors, Applications to bars, stepped bars and beams, familiarization with commercial FEM softwares.	

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Finite Elements in engineering	Chandrupatla T. R.	PHI	2nd Edition 2007
2	Finite Elements Method in Engineering	Rao S. S	Elsevier	4th Edition 2006
Reference Books				
1	Finite Elements Analysis	Lakshminarayana H. V.	Universities Press,	2004
2	Textbook of Finite Element Analysis	P.Seshu	PHI	2004
3	Finite Element Method	J.N.Reddy	McGraw -Hill International Edition	3rd edition &2005
4	Finite Elements Procedures	Bathe K. J.	PHI	**2007**

Ph.D Coursework Courses under Manufacturing Processes **Group 05**			
S.No	Course Code	Course Name	Page No.
1.	20MAP14	Aerospace Materials and processes	**2**
2.	20MAP253	Advanced Composite Materials	**3**
3.	20MAE324	New Product Development	**5**
4.	20MAP324	Advanced materials for aerospace applications.	**7**

Manufacturing Processes Group : 20MAP14 –AEROSPACE MATERIALS AND PROCESSES	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100

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.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Development of Gas Turbine Materials	G. W. Meetham	Applied Science Publications, London	1981
2	Metal Matrix Composites	K. U. Krainer	Wiley-VCH, Verlag GmbH & Co	2006
3	Fundamentals of Modern Manufacturing: Materials, Processes, and Systems	Mikell P. Groover	Wiley	2nd Edition 2005
Reference Books				
1	Materials for High Temperature EngineeringApplications	G. W. Meetham and M. H. Van de Voorde	Springer	2006
2	Mechanical Metallurgy	George E. Dieter,	McGraw-Hill	1988
3	Materials Science and Engineering: an Introduction	William D. Callister	John Wiley and sons	6th edition 2005
4	Manufacturing Engineering and Technology	SeropeKalpakjian, Steven R Schmid	PearsonEducation	2003

Manufacturing Processes Group : 20MAP253 –ADVANCED COMPOSITES MATERIALS

Exam Hours: **3 Hours**	Exam Marks (Maximum): 100

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, nano composites.

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 is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
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	ASTM STP Publication,	1996
2	Composite materials-Properties as Influenced by Phase geometry	Nielson	Springer-Verlag Berlin Heidelberg	2005

Manufacturing Processes Group : 20MAE324 –NEW PRODUCT DEVELOPMENT	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100

Module-1

The Business Objective

The fit, the strategy, consistency, differentiating research and development, leverage, continuity, flow, symbiosis, pursuit, singularity versus plurality, market investigation, understanding the marketplace, global product and business development.

The market opportunity:

The business concept embodied in the new product idea, solving the customer's problem in the product, the product as a business, the competitive game, idea evaluation within the framework of the business, playing the game well, it's faster changing world, winning the game, new product development as a competitive weapon, the strategic difference between large and small companies, the product evolution flow chart.

Module-2

Refinement of the product concept into a new product and business:

The idea, competitive analysis, the route to market, strategy and tactics in operational planning, background/format, reducing the risk of new product failure, the assignment, the configuration, mass customization and generic platforms, creeping functionalism, designing to cost, development engineer's influence on factory cost, manufacturing, global marketing, requirements specification

The product and Business Plan:

The plan, program timing, structuring the business plan, product mix/offering, pricing policy, facilitating change in the business to execute the plan, management focus, the importance of the accounting function, trading time saved for technology, selling the plan.

Module-3

Justifying a program: The accounting viewpoint

Accounting and finance as partners, financial and economic analysis, timing and lost opportunity cost, critical unit volume during amortization, generating cash and profit, profit in backlog, cost, volume, and profit-breakeven, financial models for the sales transactions, financial impact of lack of continuity,

Stating Out:

A statement about teamwork, identifying the requirements, assembling the team members, organizational form, apprenticeship and mentoring, management of the team, culture of the group, incentives for the development group, management reporting, communicatios systems, the program initiation.

Module-4

Executing the plan:

Mechanics of product development, managing people, executing the product development plan, product development phases, tracking performance, obstacle removal, key players and backup, dealing with shiting linking objectives, problem solving, issues review, cause assesment, decision management, planning architecture, quality management systems, intellectual property protection.

Manufacturing Development:

Concurrency of development phases, design for manufacturing, manufacturing, process, layout, product configuration, manufacturing process control, certification of manufacturing personnel, procurement and parts configuration, certification of vendors, information retention and recordkeeping, field problems and event status monitoring, forecasting, cycle time managament, sychronization.

Module-5

The prelaunch checklist: Setting up the organization

Preflight checklist, confirming agency certification, pilot run manufacturing, beta testing program, literature, setting up the infrastructure, training for personnel, applications support, field organization set-up, final pricing.

The Launch:

The product rollout, initial monitoring of results, early modifications for success, the myth of the hockey stick forecast, forecasting and building inventory, product promotion and customer visits, tools, measurements, sales channel and launch objectives, communication, agreement and commitment to objectives.

New product development records format: organizational format.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	New Product Development: From Initial Idea to Product Management	Marc Annacchino	Elsevier	2003.
2	Product Design and Development	Karl Ulrich and Steven Eppinger	McGraw-Hill	2011.
Reference Books				
1	Handbook of New Product Development Management	Christoph Loch, Stylianos Kavadias	Elsevier	2007
2	New Product Development: Successful Innovation in the Marketplace	Erdener Kaynak, Nicholas Mills, Michael Z	Routledge, T&F	2012

Manufacturing Processes Group : 20MAP324 –ADVANCED MATERIALS FOR AEROSPACE APPLICATIONS	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100

Module-1

Introduction:

Mechanical Behaviors and their Origins-Atomic packing and bonding of condensed matters-Elasticity-Anelasticity-Plasticity and Creep. Aerospace Materials: Design, Fabrication, and Characterization-Grains and interfaces/interphases-Metal alloys-Polymers and composites.

Module-2

Materials Classification:

Classification of materials, mechanical properties, testing of aerospace materials, classification of Alloys – aluminum, steel, titanium and other alloys used in aerospace. Characteristics of composites and ceramics, ceramic reinforced, refractory materials.

Module-3

Superalloys and other Materials:

Iron base, Nickel base, Cobalt base super alloys, composition control, solid solution strengthening, precipitation hardening by gamma prime, grain boundary strengthening, TCP phase, embrittlement, solidification of single crystals, intermetallics, high temperature ceramics.

Module-4

Smart and Intelligent Materials:

Introduction, piezo, pyro and Ferro electric effects, hysteretic effects, fundamentals of continuum mechanics, Application to aerospace vehicles. Dynamics and controls, concepts, Electro-magnetic materials and shape memory alloys processing and characteristics. Sensing and Actuation: Principals of electromagnetic, acoustics, chemical and mechanical sensing and actuation, Types of sensors and their applications, their compatibility wrt conventional and advanced materials, signal processing, principals and characterization..

Module-5

Advanced Materials: Engineering in Multiple Scales-Case studies: nano-engineered materials, bio-inspired materials, metamaterials -Existing challenges: scalable manufacturing, certification, unknowns.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1.	Engineering Materials 1, An Introduction to their Properties and Applications.	Ashby and Jones	Butterworth Heinemann	1996

2.	Smart Materials and Structures	M V Gandhi and B S Thompson	Chapmen & Hall, London	1992
3.	Materials for Missiles and Spacecraft	E.R. Parker	McGraw Hill	1978
Reference Books				
1	Ceramics: Mechanical Properties, Failure Behaviors, Materials Selection.	Munz and Fett	Springer	1999
2	Principle of Polymer Systems	Rodriguez, Cohen, Ober, and Archer	CRC Press	2003
3	Fracture Mechanics: Fundamentals	Anderson	CRC Press	1994

Ph.D Coursework Courses under Intelligent Systems **Group 06**			
S.No	Course Code	Course Name	Page No.
1.	20MAP334	Introduction to AI & ML	
2.	20MAE243	Artificial Intelligence and Robotics	
3.	20MAE252	Unmanned Aerial Vehicles	

Intelligent Systems Group : 20MAP334 –Introduction to AI&ML(Artificial intelligence and machine learning)	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100

Module-1

Introduction to Data Science and AI & ML, Data Science, AI & ML, Essential Concepts in AI and ML Data Understanding, Representation and Visualisation

Module-2

Machine Learning: Linear Methods, Linear Regression, Multiple Linear Regression, Non-Linear Regression, Clustering, Forecasting models, Perceptron and Neural Network, Decision Trees, Support Vector Machines.

Module-3

Probabilistic Models, Dynamic programming and Reinforcement Programming, Evolutionary Algorithms, Time Series Models, Deep Learning, Emerging Trends in ML, Unsupervised Learning

Module-4

Foundations for AI, AI Basics , AI Classification, Supervised Learning, Feature Engineering Regression, Model Selection, Model Performance , Ranking

Module-5

Introduction to ML with R and using Python, Python and R for Artificial Intelligence, Machine Learning, and Data Science, AI/ML in aerospace industry

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■.

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Machine Learning and Artificial Intelligence	Ameet V Joshi	Springer	2019
2	Artificial Intelligence and Machine Learning fundamentals	Zsolt Nagy	Packt Publishing	2018
Reference Books				
1	Artificial Intelligence and Machine Learning	Vinod Chandra SS	PHI Learning	2014
2	Basics of Artificial Intelligence and Machine Learning	DheerajMehrotra	Notion Press	2019

Intelligent Systems Group : 20MAE243 – Artificial Intelligence and Robotics	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100

Module-1

Introduction & Propositional Logic: History of AI, Propositional logic-Computability & Complexity, Applications, Ist Order Predicate logic, limitations of logic.

Module-2

Logic Programming: Prolog system & Implementation, Execution control, Constraint Logic programming, Planning and examples.

Module-3

Machine Learning and Data Mining: Data analysis, learning rule, nearest neighbor method, Decision tree learning, Clustering-Distance matrices, Hierarchical learning.

Module-4

Neural Networks: Mathematical Model, Neural anociative memory, spelling correction program, support vector machine, application of deep learning, application of neural network.

Module-5

Robotics: Introduction, Mathematical representation of robots, kinematics of serial manipulators, kinematics of parallel manipulators, Dynamics of manipulators.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Introduction to Artificial Intelligence	Wolfgang Ertel	Springer	2017
2	Robotics-Fundamental Concepts and Analysis	AshitaraGhosal	Oxford Press	2006

Reference Books

1	Artificial Intelligence and Machine Learning	Vinod Chandra S.S., and Anand Hareendran S	PHI Learning Pvt. Ltd	2014
2	Introduction to Robotics-Analysis,Control, Application	Saeed B Niku	Wiley	2011

Intelligent Systems Group : 20MAE252 –UNMANNED AERIAL VEHICLES	
Exam Hours: **3 Hours**	Exam Marks (Maximum): 100

Module-1

Introduction

Aviation History and Overview of UAV systems, Classes and Missions of UAVs, Definitions and Terminology, UAV fundamentals, Examples of UAV systems-very small, small, Medium and Large UAV

Module-2

The Air Vehicle

Basic Aerodynamics:

Basic Aerodynamics equations, Aircraft polar, the real wing and Airplane, Induced drag, the boundary layer, Flapping wings, Total Air-Vehicle Drag

Performance:

Overview, climbing flight, Range and Endurance – for propeller-driven aircraft, range- a jet-driven aircraft, Guiding Flight

Module-3

Stability and Control

Overview, Stability, longitudinal, lateral, dynamic stability, Aerodynamics control, pitch control, lateral control, Autopilots, sensor, controller, actuator, airframe control, inner and outer loops, Flight-Control Classification, Overall Modes of Operation, Sensors Supporting the Autopilot

Module-4

Propulsion

Overview, Thrust Generation, Powered Lift, Sources of Power, The Two-Cycle Engine, The Rotary Engine, The Gas Turbine, Electric Motors, Sources of Electrical Power

Loads and Structures

Loads, Dynamic Loads, Materials, Sandwich Construction, Skin or Reinforcing Materials, Resin Materials, Core Materials, Construction Techniques

Module-5

Mission Planning and Control: Air Vehicle and Payload Control, Reconnaissance/Surveillance Payloads, Weapon Payloads, Other Payloads, Data-Link Functions and Attributes, Data-Link Margin, Data-Rate Reduction, Launch Systems, Recovery Systems, Launch and Recovery Tradeoffs

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbook/ Textbooks

Sl No	Title of the book	Name of the Author/s	Publisher Name	Edition and year
1	Introduction to UAV Systems	Paul Gerin Fahlstrom, Thomas James Gleason	John Wiley & Sons, Ltd	2012

2	Unmanned Aerial Vehicle	Landen Rosen	Alpha Editions	2015
Reference Books				
1	Unmanned Aerial Vehicles	DOD's Acquisition Efforts	Alpha Editions	
2	Unmanned Aerial Vehicles	Valavanis, Kimon P	Springer	2011.
3	Handbook of Unmanned Aerial	Valavanis,	Springer	2015.