PG-Curriculum
(Structure and Course Contents)
Aerospace Engineering
With effect from July 2022

Aerospace Engineering
Punjab Engineering College
(Deemed to be University)
Chandigarh

Index

PG Curriculum Structure
(Semester I)

S. No.	CourseStream	Code	Course Name	Credits
1.	Program Core (DCC-I)	AER1101	Computational and Experimental Aerodynamics	3.0
2.	Program Core (DCC-II)	AER1102	Computational Methods for Structural Analysis	3.0
3.	Program Core (DCC-III)	AER1103	Advance Propulsion Systems	3.0
4.	Deptt. Elective Course (DEC-I)	AER120x	Any One from Deptt. Elective Basket	3.0
5.	Engineering Mathematics (NCB)	EMR100x	Engineering Mathematics (NCB)	3.0
6.	Soft Computing/ Soft Skills & Management	SCR1001/ SMR1001		3.0
			Total	18

(Semester II)

S. No.	CourseStream	Code	Course Name	Credits
1.	Program Core-IV (DCC-IV)	AER1104	Aerospace System Engineering and Analysis	3.0
2.	Program Core-V (DCC-V)	AER1105	Flight Stability Analysis	3.0
3.	Program Core-VI (DCC-VI)	AER1106	Guidance, Control and Navigation (GCN) Technology	3.0
4.	Department Elective Course (DEC-II)	AER125x	Any One from Deptt. Elective Basket	3.0
5.	Open Elective	AER300x	Any One from the Open Elective Basket	3.0
6.	Design of Experiment s & Research Methodology (NCB)	AER1001	Design of Experiment s & Research Methodology	3.0
7.	Industrial tour	AER4001		0.0
			Total	**18**

Summer Term

Industrial tour will be held in winter vacation after 1st semester and it will be recorded in 2nd semester.

S. No.	Course Code	Course Name	Credits
1.		Industrial visit (3 days to one week of visit, submission and presentation of visit report)	Satisfactory/ Not-satisfactory

3rd Semester

S. No.	Course Code	Course Name	LTP	Credits
1.	AER5001	Seminar and Report Writing		2
2.	RPR6001	Research and Publication Ethics		2
3.	AER7001	Dissertation-I	0-0-28	14
Total				18

4th Semester

S. No.	Course Code	Course Name	LTP	Credits
1.	AER8001	Dissertation-II	0-0-36	18
Total				18

Total Credits= 18 + 18 + 18 + 18 = 72

- ***20% courses/ semester can be offered in blended mode MOOC's/Industry.***
- ***MOOC's/Industry offered course is having fractional credits. Industry offering course content will be designed by industry will be as per expert availability. Industry person will deliver and evaluate this subject. As per the duration of MOOC's/industry offered course, credits of this course can be decided (fractional credits).***

List of Program Electives (Any two from a specific stream) (DEC-I & II)

S. No	Course Code	Course Name	L-T-P	Credits
1		Computational Fluid Dynamics	2-0-2	3
2		Experimental Aerodynamics	2-0-2	3
3		Unmanned Aerial Vehicle Design	3-0-0	3
4		Unmanned Air Systems	3-0-0	3
5		Aircraft System Identification	3-0-0	3
6		Advanced Control Systems for Aerospace Vehicles	3-0-0	3
7		Guidance of Missiles	3-0-0	3
8		Optimal Control, Guidance and Estimation	3-0-0	3
9		Acoustic Instabilities in Aerospace Propulsion	3-0-0	3
10		Aeroelasticity	3-0-0	3
11		Composite Materials and Structures	3-0-0	3
12		Hypersonic Aerodynamics	3-0-0	3
13		Design of Fixed Wing UAVs	3-0-0	3
14		Aerospace Industry	3-0-0	3
15		Avionics	3-0-0	3
16		System Engineering	3-0-0	3
17		Machine Learning	3-0-0	3
18		Control Theory and Guidance	3-0-0	3
19		Artificial Intelligence	3-0-0	3
20		Shock Wave Theory	3-0-0	3

List of Open Elective (Select any one from Sr. No. the following- For other branches)

S. No	Course Code	Course Name	L-T-P	Credits
1		Computational Fluid Dynamics	3-0-0	3
2		Experimental Aerodynamics	3-0-0	3
3		Unmanned Aerial Vehicle Design	3-0-0	3
4		Composite Materials and Structures	3-0-0	3

SOFT COMPUTING

Course Name	:	**Internet of Things**
Course Code	:	
Credits	:	**1.5**
L T P	:	**2 0 2**
Segment	:	**1-3**

Total no. of lectures: 14
Total no. of Lab hrs:14

Course Objectives:

The main objectives of this course are:	
1.	Understand core technology, applications, sensors used and IOT architecture along with the industry perspective.
2.	Principles and operations of different types of sensors commonly used on mobile platform will be taught in a manner that by the end of the course the students will be able to design and implement real time solutions using IOT.

Course Contents:

S.No.	**Course Contents**	**No. of Lectures**
1	**Introduction to IoT** What is IoT, how does it work? Difference between Embedded device and IoT device, Properties of IoT device, IoT Ecosystem, IoT Decision Framework, IoT Solution Architecture Models, Major IoT Boards in Market	2
2	**Setting Up Raspberry/Arduino to Create Solutions** Explore Raspberry Pi, Setting up Raspberry Pi, Showing working of Raspberry Pi using SSH Client and Team Viewer, Understand Sensing actions, Understand Actuators and MEMS	3
3	**Communication Protocols used in IoT** Types of wireless communication, Major wireless Short-range communication devices, properties, comparison of these devices Bluetooth, WIFI, ZigBee, 6LoWPAN), Major wireless Long-rangecommunication devices, properties, comparison of these devices (CellularIoT, LPWAN)	3
4	**IoT Applications** Industrial Internet 4.0, Applications such as: Smart home, wearables, smart city, smart grid, , connected car, connected health(digital health, telehealth, telemedicine), smart retail	3
5	**Sensors:** Applications of various sensors: Google Maps, Waze, Whats App, Ola Positioning sensors: encoders and accelerometers, Image sensors: cameras, Global positioning sensors: GPS, GLONASS, IRNSS, Galileo and indoor localization systems, Motion & Orientation Sensors: Accelerometer, Magnetometer, Proximity Sensor, Gyroscope Calibration, noise modeling and characterization and-noise filtering and sensor data processing. Privacy &Security	3

Lab Work:

Sr. No.	Lab contents	No. of Hours
1.	Design and build systems that will use sensors, communication protocol and actuators.	14

Course Outcomes:

At the completion of this course, students will be able to:	
1.	Understand concept of IOT and ability to implement in real time scenarios
2.	Design solutions based on IOT architecture and applications in various fields
3.	Critically analyze security and privacy issues in IOT
4.	Apply knowledge to Design and develop variousapplicationsofsensorsinIndustrial,healthcare,commercial,andbuildingautomation

Bibliography:

S.No.	Book Detail	Year of Publishing
1	Vijay Madisetti and ArshdeepBahga, Internet of Things (AHands-on Approach), 1st Edition, VPT	2014
2	Francis daCosta, Rethinking the Internet of Things: A ScalableApproach to Connecting Everything, 1stEdition, Apress Publications	2013
3	CunoPfister, Getting Started with the Internet of Things, OReillyMedia	2011
4	Kyung, C.-M., Yasuura, H., Liu, Y., Lin, Y.-L., Smart Sensorsand Systems, Springer International Publishing	2015

MOOCs on this course are available at:

1) Introduction to Internet of Things - https://www.edx.org/course/introduction-to-the-internet-of-things-iot
2) IoT Programming and Big Data -https://www.edx.org/course/iot-programming-big-data-curtinx-iot4x

Course Name	**:**	**Machine Learning & Python**
Course Code	**:**	
Credits	**:**	**1.5**
L T P	**:**	**2 0 2**
Segment	**:**	**4-6**

Total no. of lectures: 14

Total no. of lab hrs: 14

Course Objectives:

	The main objectives of this course are:
1.	To formulate machine learning problems corresponding to different applications.
2.	To understand a range of machine learning algorithms along with their strengths and weaknesses.
3.	To develop reasoning behind Model selection, model complexity, etc.

Course Contents:

S.No.	**Course Contents**	**No. of Lectures**
1	**BASICS OF MACHINE LEARNING:** Applications of Machine Learning, processes involved in Machine Learning, Introduction to Machine Learning Techniques: Supervised Learning, Unsupervised Learning and Reinforcement Learning, Real life examples of Machine Learning.	3
2	**SUPERVISED LEARNING:** Classification and Regression: K-Nearest Neighbour, Linear Regression, Logistic Regression, Support Vector Machine (SVM), Evaluation Measures: SSE, MME, R2,confusionmatrix,precision,recall,F-Score,ROC-Curve.	6
3	**UNSUPERVISED LEARNING:** Introduction to clustering, Types of Clustering: Hierarchical-Agglomerative Clustering and Divisive clustering; Partitioned Clustering - K-means clustering, Principal Component Analysis, ICA.	5

Lab Work:

S.No.	**Lab Contents**	**No. of hours**
1	Python Introduction: Loops and Conditions and other preliminary stuff, Functions, Classes and Modules, Exceptions, Database access, Mathematical computing with Python packages like: numpy, Mat- plot Lib, pandas Tensor Flow, Keras	8
2	Application Oriented Project Work	6

Course Outcomes:

At the completion of this course, students will be able to:	
1.	Design and implement machine learning solutions to classification, regression and clustering problems
2.	Evaluate and interpret the results of the different ML techniques
3.	Design and implement various machine learning algorithms in a range of Real-world applications.
4.	Use Python for various applications.

Bibliography:

S.No.	Book Detail	Year of Publishing
1.	Tom Mitchell, Machine Learning, McGraw Hill,	2017
2.	Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer,	2011
3.	T. Hastie, R. Tibshirani, J. Friedman. The Elements of Statistical Learning, 2e,	2008
4.	Yuxi (Hayden) Liu, "Python Machine Learning By Example", Packet Publishing Limited	2017

MOOCs on this course are available at:

1) Data Science: Machine Learning -https://www.edx.org/course/data-science-machine-learning
2) Machine Learning - https://www.coursera.org/learn/machine-learning

DESIGN OF EXPERIMENTS
&
RESEARCH METHODOLOGY

Course Name	:	**Design of Experiments and Research Methodology**
Course Code	:	
Credits	:	**3**
L T P	:	**2-0-2**
Segment	:	**1-6**

Total No. of Lectures: 28
Total No. of Lab Hrs : 28

Course Objectives:

	The main objectives of this course are:
1.	To introduce objective of research for various types of research
2.	To enhance competence analysing experimental results
3.	To enhance competence in understanding mathematical relation between process variables and results
4.	To introduce contribution of Taguchi in designing, analysing and interpreting experiments.

Course Contents:

Sr. No.	Course contents	No. of Lectures
1.	Overview of Scientific research& Engineering Research: Nature and objective of research, Research topic, Literature review, steps in conducting literature review Formulation of problem, research questions and hypothesis, types of hypothesis, evaluation of hypothesis Research design, Sampling design, Measurement and scaling technique, Methods of Data collection, Statistical and sensitive analysis of data, Interpretation of Result	4
2.	Analyzing results of from experiment: Various Tests of significance based on type of input and output data, Steps involved in testing for significance, concept of p value, testing for means, Testing for variance, chi-square test-Goodness of fit, test of independence	3
3.	Regression & Correlation, linear and non-linear regression, multi variable liner regression	3
4.	Classification of experimental designs, Analysis of variance (ANOVA), ANOVA for detecting sources of variation – Statistical procedure for one-way ANOVA, Procedure for two-way ANOVA	3
5.	Engineering Research: Planning & management of experiments; Conventional method for experiment: One factor at a time (OFAT) experiment, Concept of design of experiments: Common terms, Designed experiment, Full factorial experiments: Orthogonality of experiments, Y = F (x) for DoE, main effect analysis, interaction analysis and results	4
6.	Fractional factorial experiments, Resolution of design, screening DoE, practicing with excel and statistical software, Optimizing using Response Surface Methodology (RSM)	4

7.	Taguchi Methods: Difference between conventional DoE and Taguchi methods, Orthogonal arrays, Taguchi's Robust parameter design, Noise factors, S/N ratio, Selection of right orthogonal array	5
8.	Procedure for writing a research report and manuscript: steps of writing a report, layout of report, layout of research paper, ethical issues related to publishing, Plagiarism and Self-Plagiarism.	2

Lab Work

Performing following analysis using statistical software	
1. Hypothesis tests (Z-test, t-test, 2t test, paired t-test, Chi s square and test of equal variance etc)	5
2. Correlation analysis between independent events, Regression analysis for dependent variables (having cause & effect) and developing Y = F (x)	5
3. One-way ANOVA, Two-way ANOVA, General Linear Model	5
4. Creating and analysing 2^k Experiments (Full & Fractional Factorial) and General Full Factorial Design	5
5. Development of model using Response Surface Methodology	4
6. Creating and analysing Taguchi design	4

Course Outcomes:

After successful completion of the course, students will be able to	
1.	Plan a research activity including sample design, scaling, data collection and analysis
2.	Perform a required statistical analysis for the a research/ experiment
3.	Understand the relationship between process variables and output as Y = f(x)
4.	Select the appropriate orthogonal array for a Taguchi design

Bibliography:

Sr. No.	Book Detail	Year of Publication
1.	Design and Analysis of Experiment, Douglas C Montgomery, John Wiley & Sons	2016
2.	Taguchi Techniques for Quality Engineering Phillip, J. Ross; The Tata McGraw-Hill	2017
3.	Research Methodology - Methods and Techniques, C. K. Kothari, New Age International, 2nd Edition	2004

PROGRAM CORE

Course Name	**:**	**Computational and Experimental Aerodynamics**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**2-0-2**

Course Objectives:

To help the students understand the concepts in computational and experimental aerodynamics, and apply various types of equations for the analysis of the flow, generate various types of grid a6nd solve various 2D and 3D flow problems, have knowledge of various experimental techniques and equipments.

Total No. of Lectures – 42

Lecture wise breakup		**No. of Lectures**
1	**INTRODUCTION:** Insight into power and philosophy of CFD. CFD ideas to understand. CFD application. Need for parallel computers for CFD algorithms. Models of flows. Substantial derivative, Divergence of velocity.	3
2	**Governing Equations** Continuity, Momentum and Energy equations; derivation in various forms: Primitive variable, Derived variable. Integral versus Differential form of equations. Comments on governing equations. Forms of the governing equations particularly suited for CFD work: Shock fitting and Shock capturing methods. Generic form of equations. Equations in inertial and non-inertial frame of reference, Physical boundary conditions.	6
3	**Discretization:** Essence of discretization. Taylor series approach for the construction of finite-difference quotients. Higher order difference quotients. Up-wind differencing. Mid-point leap frog method. Reflection boundary condition. Difference equations. Explicit and Implicit approach: definition and contrasts. Errors and analysis of stability. Error propagation. Stability properties of Explicit and Implicit methods.	6
4	**Grid Generation:** Body –fitted coordinate system. Need for grid generation. Essential properties of grids. Types of grids (O-type, C-type and H-type). Various grid generation techniques - Algebraic and Numerical grid generation. Elliptic grid generation. Structured, Un-structured grids, Adaptive grids, Grid collapse. Multi-Grid methods. Grid accuracies	6
5	**Spectral Analysis of Numerical Schemes and Aliasing Error** Spatial Discretization of First Derivatives, Discrete Computing and Nyquist Criterion, Spectral Accuracy of Differentiation, Role of Upwinding, Numerical Stability and Concept of feedback, Temporal Discretization Scheme, High Accuracy Methods: Optimized Compact Schemes: OUCS3, OUCS4.	7

6	**Solution of Navier-Stokes Equations** Stream Function-Vorticity Formulation for 2D Flows, Start-up and Initial Condition, Solution of Stream Function Equation (SFE), Wall-Vorticity Estimation, Solution of Vorticity-Transport Equation (VTE), Solution of Flow in Lid Driven Cavity, Taylor-Green Vortex.	7
7	**Introduction to Experimental Methods** Types of experimental facilities, Types of wind tunnels: Subsonic, Transonic, supersonic wind tunnels, shock tube. Flow measurement instruments: Wind tunnel balances, measurement of forces and moments, measurement of profile drag by Pitot traverse of wake, shadowgraph system, Schlieren system, interferometer, Hot wire Anemometer	7

List of Experiments:

S. No.	**Experiment**	**No. of Turns**
1	Numerical solution of two-dimensional convection-diffusion equation.	2
2	Numerical solution of two dimensional incompressible Navier Stokes equations: Taylor-Green Vortex Flow	2
3	Structured grid generation over NACA0012 airfoil	2
4	Numerical solution of two dimensional incompressible Navier Stokes equations: Lid Driven Cavity	2

Course Outcomes: At the end of this course, students will be able to

1	Describe difference between serial and parallel computing and familiarize with the need for parallel computing.
2	Derive finite difference approximations, discretization methods, estimate errors.
3	Generate various type of grids based on the problem.
4	Analyze various spatial and temporal discretization schemes based on high accuracy.
5	Solve various benchmark two dimensional and three dimensional flow problems.
6	Use various experimental instruments for research work.

Suggested Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	High Accuracy Computing Methods, Fluid Flows and Wave Phenomena" Tapan K. Sengupta, 1st Ed., Cambridge University Press	2013
2	"Fundamentals of Computational Fluid Dynamics", Tapan K. Sengupta, 1st Ed., Universities Press	2004
3	"Computational Aerodynamics and Aeroacoustics", T. K. Sengupta and Y. G. Bhumkar, 1st Ed., Springer	2020
4	"Computational Fluid Dynamics The Basics with Applications", John D. Anderson Jr., 1st Ed., McGraw Hill Education India	2017
5	"Numerical Computation of Internal and External Flows: The Fundamentals of Computational Fluid Dynamics", C. Hirch, Volume-2, 2nd Ed., Butterworth-Heinemann	2007

Course Name	:	Computational Methods for Structural Analysis
Course Code	:	
Credits	:	3
L T P	:	2-0-2

Course Objectives:

At the end of this course, the student should be able to understand various computational approaches for structural analysis of structures made of isotropic, composite, and other advanced materials. The student should be able to formulate the finite element model for different structural elements, i.e., bars, truss, beams and composite plates. Also, get the understanding of NURBS-based isogeometric finite element method for structural analysis of various structural elements.

Total No. of Lectures – 42

Lecture wise breakup		No. of Lectures
1	**Introduction to Computational Method** Basic Equations in elasticity. Types of Solution – Analytical, 3-D Elasticity Solution, Navier Solution/closed-form Solution, Numerical Solution using Weighted residual approach and Variational approach. Numerical Integration techniques used in FEA. FEM Vs Classical method, FEM Vs FDM, Matrix displacement formulation, FEA for stress analysis.	7
2	**Introduction to Finite Element Method** Finite element modeling, Element Shapes, Nodes, Nodal Unknown and Coordinate systems, Shape Functions, Discretization of a structure, Isoparametric formulation, Strain displacement matrix, assembly of Global Stiffness matrix and load vector, properties of K, quadratic shape function. Stress calculation, Boundary Condition	7
3	**Finite Element Analysis of 1-D Structures** Truss, Bar, Beam Theories. Structural analysis of Truss, Bar, Beams.	7
4	**Finite Element Analysis of 2-D Structures** Plate Theories. Structural analysis of Plates. Thermal bending problem.	7
5	**Structural Analysis of Composite Plates** Static and dynamic analysis of sandwich and laminated composite plates, FGM plates, smart structures.	7

6	**Isogeometric Analysis** Limitations of FEM, CAD Model Vs FEA Model, Integration of CAD and FEA: Isogeometric Analysis. Curve and surface representation, Knot vectors, Bezier Curve, B-spline Curves, Rational B-spline curves (NURBS), Refinement, Boundary Conditions, Isogeometric mathematical formulation.	7

List of Experiments

Sr. No.	**Experiment**	**No. of Turns**
1	Static analysis of isotropic plate using FSDT via FEM	1
2	Free Vibration analysis of isotropic plate using FSDT via FEM	2
3	Static analysis of composite plates using FSDT via FEM	2
4	Free Vibration analysis of composite plates using FSDT via FEM	1
5	Static and free Vibration analysis of composite plates using FSDT via IGA	2

Course Outcomes: At the end of this course, students will be able to:

1	Apply various computational approaches for different problems.
2	Derive the mathematical formulation for truss, bars and beams element using FEA.
3	Form various plate elements for different structural problem with/without thermal environment
4	Apply finite element method to composite structures.
5	Evaluate computational approach for the integration of CAD and FEA.

Text Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	"An Introduction to finite elements method", J.N. Reddy,Mc- Graw Hill. 3rd Ed.	2006
2	Mechanics of Laminated Composite Plates and Shells, Theory and Analysis, J.N. Reddy, CRC Press. 2nd Ed.	2004

3	Vibration of Continuous System, S S Rao Willey, 2nd Ed.	2019
4	Cottrell, J. Austin, Thomas JR Hughes, and Yuri Bazilevs. Isogeometric analysis: toward integration of CAD and FEA. John Wiley & Sons.	2009

Reference Books:

Sr. No.	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint
1	Bhavikatti, S. S. “Finite element analysis”. New Age International	1950
2	I.H. Shames and C. L. Dym “Energy and Finite Element Methods in Structural Mechanics, 1st Ed. Taylor Francis.	2017
3	“Introduction to finite elements in engineering”, T.R.Chandrupatla and A.D.Belegundu, 4th Ed. , Prentice- Hall of India	2012

Course Name	**:**	**Advance Propulsion and Power-Plants**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

This course will lead the student to enhance knowledge of the aerothermodynamics of pulse detonation engines. This course also includes generalized internal compressible and incompressible flows, thermo-chemistry and heat transfer in ramjet and scramjet engine applications. Advanced techniques for space propulsion are also covered under this course.

Total No. of Lectures: 42

Lecture wise Breakup		**No. of Lectures**
1.	**Pulse Detonation Engine (PDE):** Introduction, Difference between pulse jet and PDE, Detonation theory, PDE cycle, Specific Impulse of PDE, Operational constraints, Advantages and disadvantages of PDE	7
2.	**Rotating Detonation Engine (RDE):** Introduction, Thermodynamic cycle, existing RDE design, Factors influencing the performance of RDE.	7
3.	**Ramjet Engine** Ramjet and Air augmented rockets – Thermodynamic cycles with and without losses	4
4.	**Scramjet Engine** Fundamental considerations of hypersonic air breathing vehicles – Preliminary concepts in engine airframe integration – calculation of propulsion flow path – flow path integration.	5
5.	**Supersonic Combustors** Various types of supersonic combustors – fundamental requirements of supersonic combustors – Injectors, Mixing of fuel jets in supersonic cross flow – performance estimation of supersonic combustors.	5
6	**Space Propulsion: Cryogenic, Cold and Gelled propulsion** Introduction to cryogenic propellants, advantages and disadvantages of cryogenics, cryogenic loading problems, properties of cold and gelled propulsion systems, advantages and disadvantages of cold gas systems	7
7	**Space Propulsion: Nuclear and Micro Propulsion** Nuclear rocket engine design and performance – nuclear rocket reactors – nuclear rocket nozzles – nuclear rocket engine control – radioisotope propulsion – basic thruster configurations – thruster technology , Basic concepts in electric propulsion – power requirements and rocket efficiency – classification of thrusters – electrostatic thrusters – plasma thruster of the art and future trends – Fundamentals of ion propulsion – performance analysis – ion rocket engine.	7

Course Outcomes: At the end of the course, students will be able:

1	Describe basic principles of PDE and difference between the pulse jet and PDE.
2	Evaluate existing RDE design and factors influencing the performance of RDE.
3	Describe basic concepts of air augmented rockets.
4	Describe basic concepts of hypersonic air breathing engines.
5	Analyze various types of supersonic combustors and their fundamental requirements.
6	Analyze cryogenic, cold and gelled propellants and propulsion system.
7	Evaluate various types of propulsion systems use for space exploration.

Suggested Books:

Sr. No.	**Book**	**Year of Publication**
1	Sutton G.P. and Biblarz O., "Rocket Propulsion Elements", John Wiley & Sons Inc., 7th edition New York, 2001.	2001
2	Hesse W.J., "Jet Propulsion for Aerospace Applications", 2nd edition, Pitman publication, 1964.	1964
3	Krishnan S., Chakravarthy S. R., and Athithan S. K., "Propellants and Explosives Technology", Allied Publishers Limited, Chennai, 1998.	1998

Reference Books:

Sr. No.	**Book Detail**	**Year of Publication**
1	Hill P.G. and Peterson C.R., Mechanics and Thermodynamics of Propulsion, Pearson Education, 1999	1999
2	Mattingly Jack D., Elements of Propulsion: Gas Turbines and Rockets, AIAA Education Series, 2006.	2006

Course Name	**:**	**Aerospace System Engineering and Analysis**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

The course is intended to provide knowledge to the students about the aerospace systems engineering, system requirements, and basics of system design, architecture, operational requirements, system reliability and management.

Total No. of Lectures: 42

Lecture wise Breakup		**No. of Lectures**
1.	**Introduction** Background of System engineering & its application to aerospace systems. Fundamentals of systems engineering and system architecting of weapon system, system engineering. Standards 15288, requirements analysis, functional analysis and allocation, preliminary system architecture.	9
2.	Systems analysis, system design, and the basics of test and evaluation, Introduction to combat systems. System development phases (Conceiving, Designing, Implementing, and Operating). Techniques of system design and assessment for operational feasibility, including reliability, maintainability, usability (including human factors and human performance). Supportability, and product ability, System cost assessment and effectiveness estimation.	12
3.	Reliability analysis and management (basic tools and methods of reliability for developing complex systems including electronic components, mechanical components, and software), redundancy, graceful degradation, fault tolerance, MTBF	12
4.	Implementation of System engineering approaches to aerospace vehicle and its impact. Key Drivers in the Missile Design and System Engineering Process leading to design optimization.	9

Course Outcomes: At the end of the course, students will be able:

1	Evaluate the system design requirements, architecture and functional requirements.
2	Create the system requirements documents as per the requirement analysis.
3	Analyze the system reliability, maintainability, usability issues.
4	Carry out the system reliability analysis.

Suggested Books:

Sr. No.	Book	Year of Publication
1	INCOSE Systems Engineering Handbook", by Cecilia Haskins, version 3, INCOSE, 2006.	2006
2	"The Engineering Design of Systems: Models and Methods", by Buede D.M. John Wiley & Sons Inc.	1964
3	"Systems Engineering Fundamentals", by Defense Acquisition University Pressfort Belvoir, Virginia	1998
4	"NASA System Engineering Handbook", by Steven R. Hirshorn, NASA SP-2016-6105 Rev2, NASA, 2016.	2016

Reference Books:

Sr. No.	Book Detail	Year of Publication
1	"System Analysis Design and Development", by Charles S. Wasson. Wiley Series in System Engineering and Management.	1999
2	"Missile Design and System Engineering", Eugene Fleeman, Reston, VA : American Institute of Aeronautics and Astronautics, 2012.	2012
3	**"Reliability Engineering",** by Srinath L S. Publisher: Affiliated East-West Press Limited, New Delhi, 2002.	2002
4	**"Guided Weapons System Design",** R Balakrishnan, DESIDOC, Defence Research Development Organisation, 1998.	1998

Course Name	**:**	**Flight Stability Analysis**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

At the end of this course, the student should be able to describe the concepts related to flight vehicle stability, system identification, parameter estimation and various estimation methods. The student should be able to estimate and analyze stability & control characteristics of various

Total No. of Lectures: 42

Lecture wise Breakup		**No. of Lectures**
1.	**Flight Stability** Static Stability, Longitudinal dynamic stability, Spring-mass system. Stability & control derivatives, Lateral dynamic stability, Cross coupling of lateral & directional effects, Longitudinal & Lateral stability modes. Aircraft system identification, Parameter estimation.	8
2.	**Mathematical Model of An Aircraft** Reference frames & sign convention, Six-DOF equations of motion, Rigid-body equations of motion, Rotational kinematic equations, Navigation equations, Force equations, Aerodynamic model equations, Simplified equations of motion.	8
3.	**Experiment Design & Data Compatibility** Data acquisition, Data acquisition system, Instrumentation, Input design, Data compatibility, Kinematic equations, Data reconstruction, Aircraft instrumentation error, Model equations for data compatibility check, Instrumentation error estimation methods.	8
4.	**Parameter Estimation Methods** Analytical & Experimental methods, Output-error methods, Filter error methods, Equation error methods, Artificial Neural network based methods.	8
5	**Parameter Estimation & Data Analysis** Parameter estimation using various estimation methods, Model validation, Data analysis, filtering, smoothing, interpolation, Parameter estimation from simulated & real flight data using Matlab. Case studies of various types of aircrafts.	10

Course Outcomes: At the end of the course, students will be able:

1	Describe concepts related to flight stability and system identification.
2	Develop six-DOF mathematical model of different types of aircraft.
3	Design experiments for flight data acquisition and check data compatibility.
4	Apply various parameter estimation methods for aircraft system identification.
5	Estimate parameters of various flight vehicles from real flight data in aviation industry.

Suggested Books:

Sr. No.	Book	Year of Publication
1	"Flight Stability and Automatic Control", R. C. Nelson, 2nd edition, McGraw – Hill	2017
2	"Flight Vehicle System Identification: A Time Domain Methodology", R.V. Jategaonkar, AIAA	2006
3	"Aircraft System Identification – Theory and Practics", Vladislav Klein & Eugene A. Morelli, AIAA Education Series	2006

Course Name	**:**	**Guidance, Control and Navigation (GCN) Technology**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

The course will help students to understand fundamental of missile/spacecraft/satellite Control, Guidance and Navigation, which includes basic to advanced level knowledge control systems (command processing and actuation), Guidance (command generation based upon relative positional analysis) and navigation mathematics, principles of radio navigation, INS/ GNSS integration and its derivatives, technology of modern control/guidance/navigation systems, particularly satellite-based systems, UAV guidance systems, GPS, SLAM.

Total No. of Lectures: 42

Lecture wise Breakup		**No. of Lectures**
1.	**Introduction and Mathematical Modeling:** Basics of control systems, control elements, block diagrams, close loop / open loop control. Missile Control Methods: Aerodynamic and Thrust Vector Control, Polar and Cartesian Control. Mathematical Modeling of Missile Dynamics; Missile Actuators and Sensors. Roll and Roll Rate Stabilization. Design and Analysis of Lateral Autopilots, 6 DOF simulations for aircraft/missile. Introduction to missile and spacecraft/satellite guidance, guidance laws and its implementation. Introduction to Navigation, Navigation Mathematics.	9
2.	**GNSS: fundamentals, Signals, and Satellites:** Fundamentals of Satellite Navigation, Inertial Navigation, Advanced satellite Navigation, Principles of radio Positioning, Terrestrial radio Navigation, Short-Range Positioning, Satellite Navigation Processing. Errors and Geometry, Dead Reckoning, Attitude, and Height Measurement, Feature matching, INS/GNSS Integration. Principles of satellite navigation, inertial navigation, radio positioning. Designing a navigation system.	9
3.	**Modeling and Simulation:** Mathematical model of missile dynamics, simulations for aircraft/missile, basic principle of operation of a global navigation satellite system, governing equations for the navigation equations. Path planning (UGV / UAV). Position estimation from a given satellite constellation.	9
4.	**Introduction on Navigation and Guidance systems:** Guidance approaches: conventional guidance such as PN (Proportional Navigation), Geodetic fundamentals of navigation, positioning, reference- and coordinate systems and computational methods for navigation and positioning on the surface of the earth, Geometric guidance, path planning and following, and optimal guidance; path planning for UGV/UAV guidance systems,	9

5	**Navigation Approaches:** Navigation systems, Global Positioning System (GPS), GNSS (Global Navigation Satellite System), terrain based navigation, SLAM (Simultaneous Localization and Mapping); Cooperative guidance and collision avoidance.	6

Course Outcomes: At the end of the course, students will be able:

1	Describe the principles of satellite navigation, inertial navigation, radio positioning and various aspects of designing a navigation system.
2	Develop mathematical model of missile dynamics.
3	Carry out simulation for aircraft/missile using mathematical tools like MATLAB.
4	Describe the basic principle of operation of a global navigation satellite system and solve the equations for calculating a position estimate from a given satellite constellation.
5	Design the navigation systems and derive the navigation equations and carry out path planning the UGV / UAV.

Suggested Books:

Sr. No.	Book	Year of Publication
1	"Automatic Control Systems", Farid Golnaraghi & BC Kuo, John Wiley & Sons, 2010	2010
2	"Modern Control Engineering", Katsuhiko Ogata, Prentice-Hall of India, New Delhi, 2017.	2017
3	**"Modern Control Systems Theory"**, M. Gopal, 2nd Edition, John Wiley, 1993.	1993
4	"The Global Positioning System & Inertial Navigation", by Jay Farrell. Publisher : McGraw-Hill Education, 1998.	**1998**

Reference Books:

Sr. No.	Book Detail	Year of Publication
1	"MATLAB for Engineering Applications", by William Palm., McGraw-Hill Education, 2018.	2018
2	"Global Navigation Satellite Systems, Inertial Navigation, and Integration", by Grewal, M. S., Andrews, A. P., Bartone, C. G. John Wiley and Sons Inc., 2013.	2013
3	"Global Positioning Systems, Inertial Navigation, and Integration", by Grewal, M. S., Weill, L. R., Andrews, A. P., John Wiley & Sons, New York, 2006	2006
4	"GNSS – Global Navigation Satellite Systems", by Verlag Wien. Hofmann-Wellenhof, B., Lichtenegger, H., Wasle, E.. Springer 2008.	2008

ENGINEERING MATHEMATICS

Course Name	**:**	**Differential Equations**
Course Code	**:**	
Credits	**:**	**01**
L T P	**:**	**2-1-0**
Segments	**:**	**1-2**

Total No. of Lectures – 10
Total No. of Lab Hrs - 05

Course Objectives:

1. To learn the methods to formulate and solve linear differential equations.
2. To apply differential equations in the applications of engineering problems.

Course contents:

Sr.No	Course Contents	No. of Lectures
1	Order and degree of differential equations, Solutions of differential equations, First order equations, second order linear homogeneous differential equations with constant coefficients. Applications to Engineering problems.	**04**
2	Wronskian, Non-homogeneous equations of order two, Homogeneous equations of n^{th} order, Initial value problem, Applications to Engineering problems.	**04**
3	Use of Mathematica / MATLAB to solve differential equations numerically	**02**

Course Outcomes:

By the end of this course the students will be able to	
1	learn the methods to formulate and solve linear differential equations.
2	apply differential equations in the applications of engineering problems.
3	use Mathematica / MATLAB to solve differential equations numerically

Bibliography:

Sr.No.	Name of Book / Authors / Publishers	Year of Publication/ Edition
1	"An introduction to ordinary differential equations", E A Coddington.	1972
2	"Advanced Engineering Mathematics", E. Kreyszig. 9th Edition, Wiley.	2006
3	"Elementary Differential Equations and Boundary Value Problems", Boyce, W.E. and Diprima, , John Wiley and Sons, USA	2001

Course Name	**:**	**Numerical Methods**
Course Code	**:**	
Credits	**:**	**1**
L T P	**:**	**2-0-2**
Segments	**:**	**3-4**

Total No. Lectures:-10
Total No. of Lab Hours – 10

Course Objectives:

1. To understand the basics of numerical methods.
2. To solve problems on system of linear equations and Interpolation by numerical methods.

Course Contents:

Sr.No	Course Contents	No. of Lectures
1	**Error Analysis:** Definition and sources of errors, Propagation of errors, Floating-point arithmetic and rounding errors.	**02**
2	**Interpolation:** Interpolation using Finite differences, Numerical Differentiation and Numerical integration, Trapezoidal and Simpson's rules.	**04**
3	**Numerical Solution of Differential Equations:** Picard's method, Taylor series method, Euler and modified Euler methods, Runge-Kutta methods, Predictor-Corrector method.	**04**

Lab Work:

Sr.No	Lab contents	No. of Hours
1.	Solving Interpolation, Numerical Differentiation and Numerical integration problems using Mathematica.	**04**
2.	Solving Differential equations numerically using Mathematica.	**06**

Course Outcomes:

At the end of the course, students will have:	
1.	Problems on Interpolation.
2.	Problems on Differentiation, Integration.
3.	Solve differential equations

Bibliograhy:

Sr.No	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint
1	"Introduction to Numerical Analysis",Atkinson K. E., John Wiley.	**1989**
2	"Applied Numerical Analysis", Gerald C. F. and Wheatley P. O., Pearson	**2004**
3	"Numerical Methods for Scientific and Engineering Computation", Jain M. K., Iyengar S.R.K. and Jain R. K., New Age International Publisher.	**2004**
4	"Elements of Numerical Analysis", Gupta R.S., Macmillan India Ltd .	**2008**

Course Name	**:**	**Optimization Techniques-II**
Course Code	**:**	
Credits	**:**	**1**
L T P	**:**	**2-0-2**
Segment	**:**	**5-6**

Total No. Lectures:-10
Total No. of Lab hours – 10

Course Objectives:

1. To understand the need of Optimization Techniques and develop the ability to form mathematical model of optimization problems.
2. To identify and solve various optimization problems using Genetic Algorithms.

Course Contents:

Sr.No	Course Contents	No. of Lectures
1	Introduction to optimization problem, local and global optimum, conversion of a constrained problem to unconstrained problem.	**04**
2	Genetic Algorithms, Binary and Real coded Genetic Algorithms, Coding and decoding of variables, Key steps in a GA, starting population, fitness evaluation, reproduction, crossover, mutation, evaluation.	**06**

Lab Work:

Sr.No	Lab contents	No. of Hours
1.	Using Genetic Algorithms in various optimization Problems	**10**

Course Outcomes:

At the end of the course, students will have:	
1	The students are able to form mathematical model of optimization problems .
2	The students are able to distinguish between linear and nonlinear models .
3	The students are able to solve simple problems using Mathematica/MATLAB

Bibliography:

Sr.No	Name of Book/ Authors/ Publisher	Year of Publication/Reprint
1	"Practical Genetic Algorithms", Haupt, R. L. and Haupt, S.E., John Wiley &Sons	**1998**
2	"Genetic Algorithm in Search, Optimization and Machine Learning" , Goldberg, D.E., Addison Wesley.	**1989**
3	"Engineering Optimization", Ranjan, Ganguli,University Press.	**2011**

SOFT SKILLS
&
MANAGEMENT

Course Name	**:**	**Communication Skills**
Course Code	**:**	
Credits	**:**	**1.5**
L T P	**:**	**1-0-4**
Segment	**:**	**1-3**

Total No. Tutorials-7
Total No. of Lab hours – 28

Course Objectives:

	The main objectives of this course are:
3.	To enhance competence in communication skills: verbal and nonverbal.
4.	To provide orientation in technical communication skills: spoken and written.
5.	To sensitize students to attitude formation and behavioural skills.

Course Contents:

Sr. No	**Course contents**	**No. of Tutorials**
1.	**Introduction to Communication Skills, Soft Skills and Interpersonal Communication**	**1**
2.	**Speech:** Structure, Elements, Content, Organization and Delivery, J-a-M	**1**
3.	**Writing Skills:** Letters, Minutes of Meeting	**1**
4.	**Technical Report Writing:** Concept and Structure	**1**
5.	**Research Writing:** Concept and Structural Framework	**1**
6.	**Power Point Presentation:** Project Presentation	**1**
7.	**Interviews**	**1**

Lab Work:

Sr.No	**Lab contents**	**No. of Hours**
1.	Self- Introduction	**2**
2.	Negotiation Skills & Role Play	**2**
3.	J-a-M Session	**2**
4.	Building Word Power through Reading	**2**
5.	Group Discussion and Case Study	**4**
6.	Writing Skills: Letters, Minutes of Meeting	**2**
7.	Technical Report Writing: Concept & Structure	**4**
8.	Research Writing: Concept and Structural Framework	**4**
9.	Power Point Presentation: Project Presentation	**4**
10.	Interviews	**2**

Course Outcomes:

At the completion of this course, students will be able to:	
1.	Show enhanced competence in communication skills and technical communication.
2.	Develop awareness of attitude formation and behavioural appropriateness
3.	Gain self-confidence and perform better in their academic and professional life.

Bibliography:

Sr.No	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint
1.	"Technical Communication", Raman Meenakshi and Sharma Sangeeta, Oxford University Press.	**2015**
2.	"English for Research Paper Writing", Wallwork Adrian, Springer, London.	**2011**
3.	"English Vocabulary In Use: Advanced+ CD", Michael McCarthy, CUP, Cambridge.	**2004**
4.	"Advanced English Grammar", Hewings Martin, CUP, Cambridge.	**2003**
5.	"Study Listening", Tony Lynch, CUP, Cambridge.	**2004**
6.	"Study Speaking", Kenneth Anderson, CUP, Cambridge.	**2010**
7.	"Study Reading", Glendenning H. Eric, CUP, Cambridge.	**2004**
8.	"Study Writing", Hamp Lyons Liz & Heasley Ben, CUP, Cambridge.	**2004**
9.	"Study Skills in English", Wallace Michael J., CUP, Cambridge.	**2004**

MOOCs on this course are available at:

Sr. No.	Link
1.	"Take Your English Communication Skills to the Next Level". Available at Coursera (Offered by Georgia Institute of Technology), 4 weeks, Starts on September 10, 2018. https://www.coursera.org/learn/english-communication-capstone
2.	"Effective Communication in Globalised Workplace- The Capstone". Available at Coursera (Offered by National University of Singapore), 3 weeks, Starts on August 06, 2018. https://www.coursera.org/specializations/effective-communication

Course Name	**:**	**Management Entrepreneurship and IPR**
Course Code	**:**	
Credits	**:**	**1**
L T P	**:**	**0-2-0**
Segment	**:**	**4-5**

Total No. Tutorials – 14

Course Objectives:

The main objectives of this course are:	
1.	To make students familiar with the concepts of Management, Entrepreneurship and Intellectual Property Rights (IPRs).
2.	To make students understand how to initiate a new Start-up and manage it effectively.
3.	To enable students to convert their innovative ideas into different forms of IPRs.

Course Contents:

Sr.No	Course contents	No. of Tutorials
1.	**Introduction to Management:** Concepts and Principles of Management	**1**
2.	**Functions of Management:** Planning Process - Hypothetical Planning of an Event/Activity, Form of Organization Structure - Case Study, Human Resource Planning and Process, Elements of Directing and Effective Control Mechanism, Activity: Role Playing/Management Game	**4**
3.	**Introduction to Entrepreneurship:** Concepts of Entrepreneurship and Characteristics of Entrepreneurs	**1**
4.	**Development Phases of Entrepreneurship:** Innovation and Idea Generation, Project Formulation and Validation (Feasibility Analysis), Business plan	**2**
5.	**Ecosystem for Entrepreneurship Development:** Government Schemes and Initiatives, Financial and Non-Financial Institutional Support, Legal Framework, Role of Incubator, Venture Capitalist, Angel Investor, Crowd Funding Accelerator etc.	**2**
6.	**Intellectual Property Rights (IPRs):** Concept and Relevance of IPRs, Process for filing IPR	**2**
7.	**Different Forms of IPRs:** Patents, Copyright, Trademarks, Industrial Designs and Geographic Indicator	**2**

Course Outcomes:

At the completion of this course, students will be able to:	
1.	Develop and manage new project/Start-up.
2.	Apply managerial skills for success of entrepreneurial/business venture.
3.	Make effective use of IPR practices in their ventures.

Bibliography:

Sr.No	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint
1.	"Management Principles and Practice", Srinivasan R. and Chunawalla S.A., Himalaya Publishing House.	**2017**
2.	"Introduction to Management", Schermerhorn John R. Jr. And Bachrach Daniel G., 13th Edition, Wiley Publications	**2016**
3.	"Principles & Practice of Management", Prasad L.M., 8th Edition, Sultan Chand & Sons.	**2015**
4.	"The New Era of Management", Daft R.L., 11th Edition, Pubs: Cengage Learning.	**2014**
5.	"Case Studies in Management", Pandey Chandra Akhilesh, 2nd Edition, I.K. International Publishing House Pvt. Ltd.	**2015**
6.	"Harvard Business Review: Manager's Handbook", Harvard Business School Press.	**2018**
7.	"Entrepreneurship", Trehan Alpana, Dreamtech Press.	**2016**
8.	"Entrepreneurship and Small Business" Schaper Michael, Volery Thierry, Weber Paull and Lewis Kate, 3rd Asia-Pacific Edition, Wiley Publications	**2018**
9.	"Harvard Business Review: Entrepreneur's Handbook", 1st Edition, Harvard Business Review Press	**2018**
10.	"Take Me Home", Bansal Rashmi, 1st Edition, Westland.	**2014**
11.	"Intellectual Property Law", Narayanan P., 3rd Edition, Eastern Law House	**2017**
12.	"Intellectual Property Rights", Pandey Neeraj and Dharni Khushdeep, PHI Learning	**2014**
13.	"Intellectual Property Rights", Rosedar S.R.A., LexisNexis (Quick Reference Guide – Q&A Series)	**2016**
14.	MSME Annual Publications (www.msme.gov.in)	**Annual**
15.	WIPO Annual Publications (www.wipo.int)	**Annual**

MOOCs on this course are available at:

Sr. No.	Link
1.	"Entrepreneurship: Do Your Venture", Available at edx (Offered by IIM Bangalore),Self-Paced (6 weeks). https://www.edx.org/course/entrepreneurship-do-your-venture
2.	"Becoming an Entrepreneur", Available at edx (Offered by MIT), Self-Paced (6 weeks). https://www.edx.org/course/becoming-entrepreneur-mitx-launch-x-4
3.	"How to Build a Start-up", Available at Udacity, Self-Paced (One Month). https://in.udacity.com/course/how-to-build-a-startup--ep245
4.	"Intellectual Property Rights: A Management Perspective, Available at edx (Offered byIIM Bangalore), Starts on 1 August 2018 (6 weeks). https://www.edx.org/intellectual-property-rights-a-management-perspective

Course Name	**:**	**Professional Ethics**
Course Code	**:**	
Credits	**:**	**0.5**
L T P	**:**	**0-1-0**
Segment	**:**	**6**

Total No. Tutorials -7

Course Objectives:

	The main objectives of this course are:
6.	To imbibe ethical values and understanding.
7.	To develop moral thinking that will help students to recognize their potential.
8.	To engage and motivate the students to perform ethically in their professional life.

Course Contents:

Sr.No	**Course contents**	**No. of Tutorials**
1.	**Introduction to Ethics:** Concept of Ethics – Nature, Scope, Sources, Types, Functions and Factors influencing Ethics, Ethics in Engineering	**2**
2.	**Ethics in Profession:** Concepts of Honesty, Integrity, Reliability, Risk, Safety and Liability, Responsibilities and Rights of Professionals, Professional accountability.	**2**
3.	**Ethics and Business:** Concept of Business Ethics – Nature and Objectives, Ethical dilemmas in business ethics.	**1**
4.	**Self-Development:** Concept of Self-Assessment – SWOT Analysis, Self-Concepts, Self-Confidence, Self-Esteem, Managing Time and Stress, Human values.	**2**

Course Outcomes:

At the completion of this course, students will be able to:	
1.	Demonstrate knowledge and better understanding of self and to manage time and stress effectively.
2.	Have subjective well-being.
3.	Have ethical decision making ability in their personal and professional life.

Bibliography:

Sr.No	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1.	"Professional Ethics", Subramaniam R., 2nd Edition, Oxford University Press.	**2017**
2.	"Introduction to Psychology", Kalat James W., 11th Edition, Cengage Learning.	**2017**
3.	"Business Ethics – Text and Cases", Murthy C.S.V., 1st Edition, Himalaya Publishing House.	**2014**
4.	"A Foundation Course in Human Values and Professional Ethics", Gaur R.R., Sangal R. and Bagaria G.P., Excel Books.	**2010**
5.	"Issues and Ethics in the Helping Professions", Corey G., Corey M.S. and Callanan P., 8th Edition, Brooks/Cole, Cengage	**2010**

	Learning.	
6.	"The Curse of Self: Self-awareness, Egotism and the Quality of Human Life", Leary M.R., 1st Edition, Oxford University Press.	**2007**
7.	"Business Ethics", Hartman L.P. and Chatterjee A., 3rd Edition, Tata McGraw Hill.	**2006**
8.	"Business Ethics and Professional Values", Rao A.B., Excel Books.	**2006**
9.	"Business Ethics – Concepts and Cases", Velasquez M.G., 5th Edition, Prentice Hall.	**2001**
10.	"Theories of Personality", Hall C.S., Lindzey D. and Cambell J.B., 4th Edition, Hamilton Printing Company.	**1997**

MOOCs on this course are available at:

Sr. No.	Link
1.	"Ethics in Engineering Practice". Available at SWAYAM (Offered by IIT Kharagpur),8 weeks, Starts on August 27, 2018. https://swayam.gov.in/courses/4799-july-2018-ethics-in-engineering-practice
2.	"Ethics, Technology and Engineering". Available at Coursera (Offered by Eindhoven University of Technology), 8 weeks, Starts on July 16, 2018. https://www.coursera.org/learn/ethics-technology-engineering

PROGRAM ELECTIVE

Course Name	**:**	**Computational Fluid Dynamics**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**2-0-2**

Course Objectives:

To help the students understand the concepts, to be able to solve and apply various types of equations for the analysis of the flow, generate various types of grid and use panel method for solving flow problems.

Total No. of Lectures – 42

Lecture wise breakup		**No. of Lectures**
1	**Classifications of partial differential Equations (PDEs):** Classification of partial differential equations, Linear/Nonlinear partial differential equations, Elliptic, parabolic, hyperbolic partial differential equations, System of first order partial differential equations, Initial and Boundary Conditions.	7
2	**Methods For Approximate Solution of PDEs:** Brief overview of finite difference, finite volume and finite elements approaches	2
3	**Finite Difference Methods:** Taylor table approach for constructing finite difference schemes of arbitrary orders of accuracy, implementation of schemes near boundaries, Explicit and Implicit methods, Discretization using Orthogonal Polynomials, Truncation error estimates.	2
4	**Methods For Parabolic Equations:** Parabolic partial differential equation, Numerical solution of unsteady heat conduction (Parabolic PDE) using various schemes, implementing initial and boundary conditions, Von Neumann stability analysis, Consistence analysis, Solution of tridiagonal systems.	8
5	**Hyperbolic Equations And Panel Method:** Solution of hyperbolic equations- Burgers equation, Numerical solution of linear wave equation (Hyperbolic PDE) using various schemes, artificial viscosity, diffusion and dispersion error, stability analysis.	7
6	**Methods For Elliptic Equations** Numerical solution of steady state heat conduction (Elliptic PDE) using various explicit and implicit schemes, implementation of boundary conditions, mesh dependence and convergence of solution.	8
7	**Grid Generation Techniques** Structured and Unstructured grids, Boundary fitted grids, Elliptic grid, generation, Algebraic grid generation.	8

List of Experiments:

Sr. No.	Experiments	No. of turns
1	Analysis of numerical properties of schemes for high accuracy	2
2	Numerical solution of one dimensional convection equation	2
3	Comparison of solution of 1D convection equation using various numerical methods to understand diffusion, dispersion and dissipation	2
4	Numerical solution of one dimensional convection-diffusion equation	2
5	Numerical solution of two dimensional incompressible Navier Stokes equations	2
6	Structured grid generation over NACA0012 airfoil	2

Course Outcomes: By the end of this course, the student will be able to:

1	Classify different types of partial differential equations (PDEs), boundary conditions.
2	Basic understanding of difference between finite difference, finite element and finite volume methods.
3	Derive finite difference approximations, discretization methods, estimate errors.
4	Solve parabolic differential equations by implicit and explicit methods and carry out stability analysis of PDEs.
5	Solve hyperbolic equations and various two dimensional and three dimensional flow problems using panel methods.
6	Solve elliptic equations by various iterative methods using finite difference approximations.
7	Generate various type of grids based on the problem.

Suggested Books:

Sr. No.	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint
1	"High Accuracy Computing Methods, Fluid Flows and Wave Phenomena" Tapan K. Sengupta, 1st Ed., Cambridge University Press	2013
2	"Fundamentals of Computational Fluid Dynamics", Tapan K. Sengupta, 1st Ed., Universities Press	2004
3	"Computational Aerodynamics and Aeroacoustics", T. K. Sengupta and Y. G. Bhumkar, 1st Ed., Springer	2020
4	"Computational Fluid Dynamics The Basics with Applications", John D. Anderson Jr., 1st Ed., McGraw Hill Education India	2017
5	"Numerical Computation of Internal and External Flows: The Fundamentals of Computational Fluid Dynamics", C. Hirch, Volume-2,	2007

	2^{nd} Ed., Butterworth-Heinemann	

Course Name	**:**	**Experimental Aerodynamics**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**2-0-2**

Course Objectives:

This course will help students to understand the state of the art experimental techniques and facilities in the various speed ranges corresponding to subsonic, supersonic and hypersonic Mach numbers. Also, get familiar with the important considerations for the design of such facilities, significance of their components and some hard ware details.

Total No. of Lectures – 42

Lecture wise breakup		**No. of Lectures**
1	**Introduction to Experimental Methods** Types of experimental facilities, Types of wind tunnels: Subsonic, Transonic, supersonic wind tunnels, shock tube. Flow measurement instruments: Wind tunnel balances, measurement of forces and moments, measurement of profile drag by pitot traverse of wake, shadowgraph system, Schlieren system, interferometer, Hot wire Anemometer	10
2	**Flow Visualization Techniques** Low speed flow visualization techniques, Schlieren, shadowgraph, interferometry, introduction to laser diagnostic techniques	5
3	**Measurements** Measurement of temperature using thermocouples, resistance thermometers, temperature sensitive paints and liquid crystals, Steady and unsteady pressure measurements and various types of pressure probes and transducers, errors in pressure measurements, thermocouples, thermography, velocity measurement using hot wire anemometry , Laser Doppler Velocimetry and Particle Image Velocimetry	6
4	**Data acquisition** Data acquisition and digital signal processing techniques, wind tunnel data acquisition, measurement of steady and unsteady pressure, velocity, temperature, turbulence intensity, calibration of force, pressure and acoustic sensors. Virtual instrumentation, Calibration of single and two wire probes.	9
5	**Wind Tunnel Modeling** Skin friction, forces and moments – Model design and fabrication force measurement techniques. Introduction to dynamic testing	12

Course Outcomes: By the end of this course, the student will be able to:

1	Understand the types of wind tunnel test facilities corresponding to various flow fields ranging from subsonic to supersonic Mach numbers and significance of wind tunnel components for designing an efficient tunnel.

2	Demonstrate and analyze the various visualization techniques from subsonic to supersonic flow-field.
3	Perform experiments using various probes and transducers, their uses and measurement for industry or research purposes.
4	Analyze and interpret the experimental data using various softwares and manage and store huge amount of data for post-processing.
5	Able to design experiments required for any particular problem in aerodynamics for research or industry purposes.

List of Experiments:

Sr. No.	Experiments	No. of turns
1	Calibration and uncertainty analysis of major type of experimental facilities.	1
2	Flow visualization over different bodies in low subsonic wind tunnel facility: Tufts, Oil flow and smoke.	1
3	Force and moment measurements – steady and unsteady flow over airfoils using force balance.	1
4	Pressure measurements – static, stagnation, and dynamic pressure over airfoils.	1
5	Turbulence measurement of low speed wind tunnel using hot-wire anemometer.	1
6	Boundary layer thickness measurement, velocity profile and shear stress variation over flat plate.	1
7	Critical location and critical Reynolds number determination for flow over flat plate.	1
8	Shock wave visualization for flow over different bodies using Schlieren system.	1
9	Hypersonic flow visualization and measurement of shock speed with different pressure ratios in Reddy shock tube.	1

Suggested Books:

Sr. No.	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint
1	“Wind Tunnel Techniques - Pankrust, R.C and Holder, D.W.	1968
2	“Wind Tunnels: Aerodynamics, Models & Experiments”, Justin D. Pereira., Nova science Pub. Inc.	2010
3	“Instrumentation, Measurements, and Experiments in Fluids”, E. Rathakrishnan, CRC Press.	2007

4	"Low Speed Wind Tunnel Testing", W. E. Rae and A. Pope., John Wiley	1999
5	"High Speed Wind Tunnel Testing", K. L. Goin, and A. Pope., KrieZKR.	1978

Course Name	**:**	**Unmanned Aerial Vehicle Design**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

This course will help students in the designing and sizing process by using simulations or experiments for fixed wing UAV technology, including the performance and stability analysis and the prototype testing.

Total No. of Lectures – 42

Lecture wise breakup		**No. of Lectures**
1	Understanding the static stability of various UAVs. Significance of location of Neutral point and Centre of gravity for a stable flight	7
2	Approach for wing design and airfoil selection with examples	5
3	Tail sizing, control surface sizing and significance of tail volume ratio with examples	5
4	Developing subroutine for design process	7
5	Design example for conventional takeoff fixed wing UAV for various mission requirements	6
6	Design example for hand launch fixed wing UAV for various mission requirement	6
7	Design example for VTOL fixed wing UAV for various mission requirement	6

Course Outcomes: By the end of this course, the student will be able to:

1	To locate neutral point and center of gravity for a stable flight and describe static stability of different UAVs.
2	Design wing, airfoils and control surfaces based on the desired performance parameter.
3	Write their own subroutines or modify the available routines required for designing.
4	Design various types of fixed wing UAVs based on mission requirements.

Suggested Books:

Sr. No.	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint
1	Small unmanned fixed wing aircraft design: A practical approach book by Andrew J. Keane	2017
2.	Unmanned aircraft systems : UAVs , design , development and deployment book by Reg Austin .	2010
3.	Design of unmanned aerial systems book by Mohammed H. Sadraey	2020

Course Name	**:**	**Unmanned Air Systems**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

To make students familiar with the concepts needed in modeling and analyzing an unmanned system.

Total No. of Lectures – 42

Lecture wise breakup		**No. of Lectures**
1	**Introduction** Introduction to UAV, History of UAV, classification, basic terminology, applications-Airframe configurations.	8
2	**Basics of Airframe And Aerodynamic Design** Scale effects, Packaging Density, Airframe Structures and Mechanisms, Aerodynamics, Power plant Selection -equipment maintenance and management-control surfaces-specifications – Modular construction.	8
3	**Avionics Hardware** Autopilot –AGL-pressure sensors servos, accelerometer, gyros-actuators, power supply, processor, integration, installation, configuration, and testing.	8
4	**Communication, Payload and Control** Dispensable and Non-Dispensable payloads – Control of HTOL, VTOL, Hybrid UAVs – Control of Payloads and Sensors - Communication media, Radio communication, Mid-Air Collision Avoidance.	10
5	**Control Stations** Mini UAV Laptop GCS, Close Range UAV System GCS, Medium and Long-Range UAV GCS, Launch and Recovery -Recent trends in UAV-Case Studies.	8

Course Outcomes: After the course completion, the students will be able to

1	Have an understanding of what UAVs are and its current usage.
2	Application of UAVs and its development
3	Apply the software and hardware strategy to develop realistic models
4	Learn the various developmental and testing systems of UAV
5	Understanding the various types of control systems used and its functioning

Suggested Books:

Sr. No.	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint
1	Randal W. Beard and Timothy W. McLain: Small Unmanned Aircraft: Theory and Practice, Princeton University Press	2012
2.	Kimon P. Valavanis: Advances in Unmanned Aerial Vehicles: State of the Art and the Road to Autonomy, Springer	2007
3.	Paul G Fahlstrom, Thomas J Gleason, “Introduction to UAV Systems”, UAV Systems, Inc	1998

Course Name	**:**	**Aircraft System Identification**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

This course will provide students with a fundamental insight into analytical methods and flight test techniques used for the derivation of mathematical models of an aircraft.

Total No. of Lectures – 42

Lecture wise breakup		**No. of Lectures**
1	**ELEMENTS OF SYSTEM IDENTIFICATION** System identification parameter estimation, Aircraft system identification, Outline of system theory.	06
2	**MATHEMATICAL MODEL OF AN AIRCRAFT** Reference frames & sign convention, Rigid-body equations of motion, Rotational kinematic equations, Navigation equations, Force equations, Aerodynamic model equations, Simplified equations of motion.	08
3	**EXPERIMENT DESIGN & DATA COMPATIBILITY** Data acquisition, Data acquisition system, Instrumentation, Input design, Data compatibility, Kinematic equations, Data reconstruction, Aircraft instrumentation error, Model equations for data compatibility check, Instrumentation error estimation methods.	08
4	**PARAMETER ESTIMATION METHODS** Output-error methods, Filter error methods, Equation error methods, Artificial Neural network based methods.	10
5	**PARAMETER ESTIMATION & DATA ANALYSIS** Parameter estimation using various estimation methods, Model validation, Data analysis, filtering, smoothing, interpolation, Parameter estimation from simulated & real flight data using Matlab.	10

Course Outcomes: After the course completion, the students will be able to

1	Identify different aircraft systems.
2	Develop mathematical model of different types of aircraft.
3	Design experiments for flight data acquisition and check data compatibility.
4	Apply various parameter estimation methods for aircraft system identification.
5	Estimate parameters of aircraft from real flight data in aviation industry.

Suggested Books:

Sr. No.	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint
1	“Flight Vehicle System Identification: A Time Domain Methodology”, 2 nd Ed., R.V. Jategaonkar, AIAA Series	2015
2	“Aircraft System Identification – Theory and Practice”, Eugene A. Morelli, Vladislav Klein, 1 st Ed., AIAA Education Series	2006
3	“Flight Stability and Automatic Control”, R. C. Nelson, 2 nd Ed., McGraw Hill Education.	2017

Course Name	**:**	**Advanced Control Systems for Aerospace Vehicles**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

This course will provide students with the concepts and techniques of linear and nonlinear control system analysis and synthesis in the modern control framework.

Total No. of Lectures – 42

Lecture wise breakup		**No. of Lectures**
1	Introduction and Motivation for Advanced Control Design; Review of Classis Control and Overview; Flight Dynamics: Basic Principles of Atmospheric Flight Mechanics and overview; Representation of linear systems; Review of Matrix Theory; Review of Numerical Methods	15
2	Linearization of non-linear Systems; Time Response, Stability, Controllability and Observability of Linear Systems: First and Second Order Linear Differential Equations, Time Response, Stability, Controllability and Observability; Pole Placement, Controller and Observer Design of Linear Systems;	07
3	Static Optimization; Optimal Control Design; Calculus of Variations, Optimal Control Formulation using Calculus of Variations, Classical Numerical Methods for Optimal Control, Linear Quadratic Regulator (LQR) Design	06
4	Linear Control Applications in Flight Control Design; Nonlinear System Analysis Using Lyapunov Theory: Lyapunov Theory, Constructions of Lyapunov Functions	07
5	Nonlinear Control Synthesis: Dynamic Inversion, Neuro-Adaptive Design and flight control; Integrator Back-Stepping; Linear Quadratic (LQ) Observer; Kalman Filter Theory	07

Course Outcomes: After the course completion, the students will be able to

1	Explain basic principles for atmospheric flight mechanics, matrix theory and various numerical methods.
2	Linearize non-linear systems and determine their time response, stability, controllability and observability.
3	Carry out optimum control design using various numerical methods for optimum control.
4	Construct Lyapunov functions for Lyapunov theory to analyze nonlinear systems.
5	Perform nonlinear control synthesis using Kalman filter theory.

Suggested Books:

Sr. No.	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint
1	N.S. Nise: Control Systems Engineering, 4th Ed., Wiley.	2004
2	K. Ogata: Modern Control Engineering, 3rd Ed.,Prentice Hall.	1999
3	B. Friedland: Control System Design, McGraw Hill.	1986
4	E.Bryson and Y-C Ho:Applied Optimal Control, Taylor and Francis.	1975

MOOCs on this course are available at:

1) Advanced Control System Design for Aerospace Vehicles by Dr. Radhakant Padhi, IISc Bangalore-**https://nptel.ac.in/courses/10110804**

ourse Name	**:**	Guidance of Missiles
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

This course will equip students with the basic of missile guidance theory and its applications to tactical missiles, familiarize them with the classical and modern developments in missile guidance using both an empirical approach and a control theoretic approach.

Total No. of Lectures – 42

Lecture wise breakup		**No. of Lectures**
1	History of guided missiles; Category of guided missiles for air defence; Major Components of Guided Missiles; Fundamental of Guidance	08
2	Basic results in interception and avoidance; Capturability in relative velocity space; Taxonomy of guidance laws.	08
3	Command and homing guidance. Classical guidance laws - Pursuit, Line-of-Sight, Command to Line-of-Sight, Beam Rider, Constant Bearing guidance laws.	08
4	Proportional Navigation (PN) and its variants like T (True) PN, P (Pure) PN, B (Biased) PN, G (Generalized) PN, and I (Ideal) PN. Modern Guidance laws - Optimal control based guidance laws, Linear formulations.	10
5	Non-linear formulations; Two point boundary value problems. Approximations and closed-form solutions; Equivalence with PN guidance laws Numerical solutions for guidance problems.	08

Course Outcomes: After the course completion, the students will be able to

1	Understand the history and development of guided missiles over the time.
2	Comprehend interception and avoidance using various guidance laws.
3	Explain classical, pursuit, line-of-sight, command to line-of-sight, beam rider constant bearing guidance laws.
4	Describe proportional navigation, modern guidance laws and associated linear formulations.
5	Solve non-linear guidance problems using proportional navigation laws.

Suggested Books:

Sr. No.	Name of Book/ Authors/ Publisher	Year of Publication/

		Reprint
1	P. Zarchan: Tactical and Strategic Missile Guidance, AIAA.	2007
2	G.M. Siouris: Missile Guidance and Control Systems, Springer Verlag,	2004

MOOCs on this course are available at:

1) Guidance of Missiles by Prof. Debasish Ghose, IISc Bangalore - **https://nptel.ac.in/courses/101108054**

Course Name	**:**	Optimal Control, Guidance and Estimation
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

This course will provide students with the concepts and techniques of optimal guidance, control and state estimation for the aerospace vehicles especially for aircrafts, launch vehicles and missiles, both in linear and nonlinear systems theory framework.

Total No. of Lectures – 42

Lecture wise breakup		**No. of Lectures**
1	**Introduction** Motivation and Overview; Overview of SS Approach and Matrix Theory; Review of Numerical Methods; Static Optimization; Optimal Control through Calculus of Variation: Review, Optimal Control Formulation	08
2	Classical Numerical Methods to Solve Optimal Control Problems; Linear Quadratic Regulator (LQR) Theory; Discrete Time Optimal Control; Overview of Flight Dynamics	09
3	Linear Optimal Missile Guidance using LQR; State Dependent Riccati Equation and θ–D Designs; Dynamic Programming; Approximate Dynamic Programming (ADP), Adaptive Critic (AC) and Single Network Adaptive Critic (SNAC) Design; Advanced Numerical Techniques for Optimal Control: Transcription Method to Solve Optimal Control Problems, Model Predictive Static Programming (MPSP) and Optimal Guidance of Aerospace Vehicles, MPSP for Optimal Missile Guidance, Model Predictive Spread Control (MPSC) and Generalized MPSP (G-MPSP) Designs	10
4	LQ Observer and Kalman Filter Design: Linear Quadratic Observer & An Overview of State Estimation, Review of Probability Theory and Random Variables, Kalman Filter Design; Integrated Estimation, Guidance and Control; LQG Design; Neighboring Optimal Control & Sufficiency Condition	08
5	Constrained Optimal Control; Optimal Control of Distributed Parameter Systems	07

Course Outcomes: After the course completion, the students will be able to

1	Understand optimal control formulation through calculus of variation.
2	Solve optimal control problems using classical numerical methods and linear quadratic regulator (LQR) theory.
3	Explain advanced numerical techniques for optimal guidance of aerospace vehicles.

4	Design Kalman filter with integrated estimation, guidance and explain sufficiency condition.
5	Describe constrained optimal control of distributed parameter systems.

Suggested Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	D.S. Naidu: Optimal Control Systems, CRC Press	2002
2	A.Sinha: Linear Systems: Optimal and Robust Control, CRC Press	2007
3	A.E.Bryson and Y-C Ho:Applied Optimal Control, Taylor and Francis	1975
4	A.P.Sage and C. C. White, III: Optimum Systems Control (2^{nd} Ed.),Prentice Hall	1977
5	D.E.Kirk: Optimal Control Theory:An Introduction,Prentice Hall	1970
6	J. L. Crassidis and J. L. Junkins: Optimal Estimation of Dynamic Systems, CRC Press	2004

MOOCs on this course are available at:

1) Optimal Control, Guidance and Estimation by Dr. Radhakant Padhi, IISc Bangalore - **https://nptel.ac.in/courses/101108057**

Course Name	**:**	Acoustic Instabilities in Aerospace Propulsion
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

This course will provide students with the fundamental concepts in acoustics and wave propagation, basic principles of combustion driven oscillations and familiarize students with modal and non-modal analysis required for understanding combustion instability.

Total No. of Lectures – 42

Lecture wise breakup		**No. of Lectures**
1	Introduction to acoustics and combustion driven oscillations; Derivation of the wave equation; Traveling wave solutions; Acoustic energy corollary	08
2	Impedance & admittance; Standing wave solutions; Reflection and transmission; Impedance tube technique	08
3	Effect of area and temperature variation on wave Propagation; Wave equation in cylindrical co-ordinates and its applications; Basic principles of combustion driven oscillations; Rayleigh criteria;	08
4	Mechanisms for instability in solid and liquid rockets, ramjets, gas turbines; Pulse combustors and their analysis using Galerkin technique	08
5	Modal analysis; Non-modal stability analysis; Passive and active control of combustion instability	10

Course Outcomes: After the course completion, the students will be able to

1	Comprehend acoustics and wave propagation.
2	Understand various types of wave solutions
3	Analyze effect of area and temperature on wave propagation and basic principles of combustion driven oscillations.
4	Describe various mechanism of instability in solid and liquid rockets.
5	Comprehend modal and non-modal analysis of combustion instability.

Suggested Books:

Sr. No.	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint
1	L. E. Kinsler, A. R. Frey, A. B. Coppens and J. V. Sanders, Fundamentals of Acoustics, 4th Edition, Wiley.	2000

MOOCs on this course are available at:

1) Acoustic Instabilities in Aerospace Propulsion by Prof. R.I. Sujith, IIT Madras - **https://nptel.ac.in/courses/101106031**

Course Name	:	Aeroelasticity
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

This course will provide students with the basic understanding of prediction of aero/structural interactions and the ability to model, analyze and control aircraft aero-elastic phenomena, including aerodynamic and control effectiveness, aero-structural stability, both static and dynamic.

Total No. of Lectures – 42

Lecture wise breakup		No. of Lectures
1	**Introduction** Aeroelastic Problems, Deformation of Structures and Influence Coefficients, Energy Methods; Classification and Solution of Aero elastic Problems	08
2	Static Aero elasticity: Divergence of 2-D airfoil and Straight Wing, Aileron Reversal, Control Effectiveness, Wing loading and deformations, Swept Wing	10
3	Dynamic Aeroelasticity, Dynamic/Flutter model of 2-D Airfoil;	04
4	Unsteady Aerodynamics: 2-D and 3-D Supersonic flow, Subsonic flow (Kernal Function Approach), Theodorsen Theory, Finite State Model	10
5	Flutter Calculation: U-g Method, P-k Method, Exact Treatment of Bending – Torsion, Flutter of Uniform Wing, Flutter Analysis by Assumed Mode Method; Panel Flutter	10

Course Outcomes: After the course completion, the students will be able to

1	Classify aero elastic problems and determine their solutions based on the classification.
2	Describe static aero elasticity for 2D airfoil and straight wing.
3	Explain dynamic aeroelasticity and flutter of 2D airfoil.
4	Analyze unsteady subsonic and supersonic flow using different theories.
5	Perform flutter calculation using U-g, p-k methods and flutter analysis using assumed mode method.

Suggested Books:

Sr. No.	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint

1	E.H. Dowell et.al., "A Modern Course in Aero elasticity", Sijthoff & Noordhoff	1980
2	R.L. Bisplinghoff, H. Ashley and R.L. Halfman, "Aero elasticity", Addison- Wesley	1955
3	D.H. Hodges and G.A. Pierce, "Introduction to Structural Dynamics and Aeroelasticity" Cambridge Aerospace Series	2002
4	V.V. Bolotin, "Nonconservative Problems of the Elastic Theory of Stability", Pergamon Press	1963
5	R.L. Bisplinghoff and H. Ashley, "Principles of Aeroelasticity", Dover	1962
6	R.H. Scanlan and R. Rosenbaum, "Introduction to the study of Aircraft Vibration and Flutter" Macmillan	1951
7	Y.C. Fung, "An Introduction to the Theory of Aeroelasticity", John Wiley & sons	1955
8	AGARD Manual on Aeroelasticity, Vol. I-Vi, Since 1959 with continual updating	1959
9	H. Ashley, "Aeroelasticity", Applied Mechanics Reviews	1970
10	E. Simiu & Scanlan, R.H., Wind effects on structures: An Introduction to wind Engineering, John Wiley	1978
11	Blevins, R.D., Flow induced Vibrations, Von Nostrand Rheinhold co.	1977

MOOCs on this course are available at:

1) Aeroelasticity by Prof. Prof. C. Venkatesan, IIT Kanpur- **https://nptel.ac.in/courses/101104005**

Course Name	**:**	Composite Materials and Structures
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

This course will equip students with the ability to design composite structures, select composite materials, conduct stress analyses of selected practical applications using laminated plate theories and appropriate strength criteria, and be familiar with the properties and response of composite structures.

Total No. of Lectures – 42

Lecture wise breakup		No. of Lectures
1	Introduction to fibrous composites: Fiber, matrix: materials, properties and fabrication processes, types/classification of composites, fabrication methods of composites, advantages and applications; 3D constitutive equations (principal material and global directions), thermal, hygroscopic effects and hygrothermoelastic constitutive equation.	08
2	Plane stress (or reduced) constitutive equations (principal material and global directions) and hygrothermoelastic constitutive equation, lamina engineering constants; Lamination theory, hygrothermoelastic lamination theory; Designing with laminates	08
3	Test methods: Quality assessment, physical and mechanical property characterization; Micromechanics: Strength of materials and continuum; approaches for effective properties; Failure mechanisms, lamina failure theories	09
4	Damage mechanics of composites; Fracture mechanics of composites; Interlaminar stresses; Composite joints	09
5	Nanocomposites; Stitched composites; 3D composites	08

Course Outcomes: After the course completion, the students will be able to

1	Understand composite materials and their properties
2	Comprehend and derive plane stress constitutive equations, laminar theory and design with laminates
3	Analyze various test methods for quality assessment based on physical and mechanical properties of the materials.
4	Comprehend damage mechanism in composites materials and joints.
5	Understand various different types of composites.

Suggested Books:

Sr. No.	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint
1	Mechanics of Fibrous Composites, C.T. Herakovich, John Wiley & Sons, Inc. New York.	1998
2	Analysis and Performance of Fibre Composites, B.D. Agarwal and L.J. Broutman, 4^{th} Ed., John Wiley & Sons, Inc. New York.	2017
3	Mechanics of Composite Materials, R.M. Jones, 2^{nd} Ed., Technomic Publication.	1999
4	Mechanics of Composite Materials, RM Christensen, Krieger Publishing Company, Florida, USA.	2012
5	Mechanical Testing of Advanced Fibre Composites, J.M. Hodgkinson, Woodhead Publishing Limited, Cambridge.	2000

MOOCs on this course are available at:

1) Composite Materials and Structures by Dr. P.M. Mohite, IIT Kanpur- **https://nptel.ac.in/courses/101104010**

Course Name	**:**	Hypersonic Aerodynamics
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

This course will equip students with the aerodynamic features of hypersonic flows with their basic governing equations and their applications in various flow fields and to familiarize the students with the various experimental facilities used for simulating near realistic hypersonic/ hypervelocity flow conditions in the laboratory.

Total No. of Lectures – 42

Lecture wise breakup		No. of Lectures
1	General characteristics of Hypersonic flow; Basic governing equations: Concept of equilibrium and non-equilibrium flows, transport properties, Basic conservation equations and species continuity equation, hypersonic shock and expansion relations, hypersonic similarity parameters; Surface pressure distribution in hypersonic flow field: Newtonian, modified Newtonian, tangent wedge and cone and shock expansion techniques, Pressure distribution in separated regions and in reacting flows	09
2	Approximate and exact methods in hypersonic inviscid flows: Mach number independence, small disturbance theory, thin shock layer theory; Blast wave theory, method of characteristics, correlation for hypersonic shock wave.	08
3	Boundary layer and Convective heat transfer: Self similar and Non-similar hypersonic boundary layers, Reference temperature method, hypersonic transition, hypersonic turbulent boundary layer, aerodynamic heating; Viscous Interaction: Interaction parameter, weak and strong interactions, vorticity interaction, examples of viscous interaction.	09
4	Stagnation Point Field: Stagnation point properties, convective and radiative heat flux, shock standoff distance; Aerodynamic forces and moments: Aerodynamics of typical hypersonic vehicles, dynamic stability, design considerations.	07
5	Introduction to viscous high temperature flows, reentry aerodynamics, radiative gas dynamics, rarified flows; Experimental methods for hypersonic flows: Impulse facilities, hypersonic wind tunnels, shock tunnels, gun tunnels, free-piston shock tunnels, expansion tubes etc.	09

Course Outcomes: After the course completion, the students will be able to

1	Comprehend general properties of hypersonic flow and derive basic governing equations.
2	Explain approximate and exact methods to solve and analyze hypersonic inviscid flows.

3	Describe boundary layer formation, transition to turbulent boundary layer and convective heat transfer in hypersonic flows.
4	Understand stagnation point properties and aerodynamic design parameters for hypersonic vehicles.
5	Describe high temperature flows for reentry vehicles and various experimental methods for hypersonic flows.

Suggested Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	John D. Anderson Jr , Hypersonic and High Temperature Gas Dynamics, McGrawHill	1989
2	John J Bertin , Hypersonic Aerothermodynamics, AIAA Education Series., Washington DC	1994
3	Wallace D. Hayes and Ronald F. Probstein Hypersonic Flow theory, Academic Press, New York	1959
4	Ernst Heinrich Hirschel Basics of Aerothermodynamics, SpringerVerlag Berlin	2005
5	Wilbur L. Hankey Reentry Aerodynamics, AIAA Education series, Washington DC	1998

MOOCs on this course are available at:

1) Hypersonic Aerodynamics by Dr. N. Sahoo, Dr. Vinayak Kulkarni, IIT Guwahati- **https://nptel.ac.in/courses/101103003**

Course Name	**:**	**Design of Fixed Wing UAVs**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

This course will equip students with the initial designing and sizing process for rapidly growing fixed – wing UAV technology, integrated with its performance and stability analysis and prototype testing.

Total No. of Lectures – 42

Lecture wise breakup		**No. of Lectures**
1	Introduction to fixed-wing UAVs, Introduction to Design, Basic Design Parameters; Design Algorithm: Case Study, Design Algorithm: Mission Requirements.	08
2	Design Algorithm: Feasible Design Parameters; Configuration Layout: Airfoil Selection Configuration; Layout: Planform Geometry selection	08
3	Weight and CG Estimation Analytical Parameter Estimation Analytical Parameter Estimation	08
4	Performance and Stability Analysis; Simulation; Detailed Sizing	08
5	Estimation of inertial properties using 3D modeling, Prototype Fabrication, Wind Tunnel Testing, Aerodynamic Characterization through Wind Tunnel Testing	10

Course Outcomes: After the course completion, the students will be able to

1	Comprehend basic design algorithm and parameters using a case study based on mission requirements.
2	Prepare a layout of the feasible design configuration including the airfoil and its planform selection.
3	Perform analytical parameter estimation and determine weight and center of gravity.
4	Carry out performance and stability analysis.
5	Determine inertial properties and wind tunnel testing of the fabricated prototype.

Suggested Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	"Small unmanned fixed wing aircraft design: A practical approach", Andrew J. Keane, 1st Ed., Wiley.	2017

2.	"Unmanned aircraft systems: UAVs, design, development and deployment", Reg Austin, 1st Ed., Wiley.	2011
3.	"Design of unmanned aerial systems", Mohammed H. Sadraey, 1st Ed., Wiley.	2020

MOOCs on this course are available at:

1) Design of Fixed Wing UAV by Prof. Saderla Subrahmanyam, IIT Kanpur- **https://nptel.ac.in/courses/101104073**

Course Name	**:**	**Aerospace Industry**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

This course will help students to understand the evolution and recent history of the aerospace industry and to appreciate value creation as a basis for successful aerospace programs and to articulate their career interests, with an emphasis on summer internships or post B.Tech plans.

Total No. of Lectures – 42

Lecture wise breakup		**No. of Lectures**
1	History and Introduction: The evolution of the aerospace industry and explore current events, a summary of relevant historic, economic and strategic developments characterizing the aerospace industry.	5
2	Case Studies: Good case studies for excellent recounts of successful projects and other islands of success, providing valuable insights and discuss current events shaping the aerospace industry and its programs - both aeronautics and astronautics.	13
3	Better, Faster, Cheaper: Lean practices and the adoption of digital technologies in production	12
4	Creating Enterprise Value; A Value-Creation Framework; Introducing framework, what is value; value identification, value proposition, value delivery and linking the value-creation framework across three levels	12

Course Outcomes: After the course completion, the students will be able to

1	Demonstrate comprehension of the evolution of the aerospace industry and current events shaping its future.
2	Demonstrate abilities for critical analysis of topical material and develop a sense of the linkages of current events with industrial evolution and enter the industry with “situational awareness”.
3	Appreciate value creation as a basis for successful aerospace programs and enterprises.
4	Exercise reflective thinking as a means to comprehend personal growth and their own relationship with the aerospace field.

Suggested Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/**

		Reprint
1	Lean Enterprise Value: Insights from MIT's Lean Aerospace Initiative. Murman, et al., Palgrave Macmillan, March 2002. ISBN: 0333976975.	2002
2.	Aviation Week & Space Technology. McGraw Hill.	

Course Name	**:**	**Avionics**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

The course enables the student to understand the role of avionic systems and their architecture. Introduction to the various avionic systems such as display systems, air-data sensors, communication, and navigation systems will be discussed thoroughly. It also focuses on the fundamental principles and their functioning in detail.

Total No. of Lectures – 42

Lecture wise breakup		**No. of Lectures**
1	**Introduction to Avionics** Role for Avionics in Civil and Military Aircraft systems, Avionics sub-systems and design, defining avionics System/subsystem requirements-importance of utilities‟, Avionics system architectures	8
2	**Avionics Systems Essentials** Trends in display technology, Alphanumeric displays, character displays etc., Civil and Military aircraft cockpits, MFDs, MFK, HUD, HDD, HMD, DVI, HOTAS, Synthetic and enhanced vision, situation awareness, Panoramic/big picture display, virtual cockpit-Civil and Military Electrical Power requirement standards, comparing the Military and Civil Requirements and Tips for Power System Design	9
3	**Avionics System Data Buses** MIL-STD-1553B, ARINC-429, ARINC-629, CSDB, AFDX and its Elements, Avionics system design, Development and integration-Use of simulation tools, stand alone and integrated Verification and Validation	8
4	**Avionics Packaging** Modular Avionics Packaging, Trade-off studies, ARINC and DOD types, system cooling, EMI/EMC requirements BIT and CFDS, Automatic Test Equipment, Speeds maintenance, ATLAS, Remote diagnostics and maintenance support-Life Cycle Costs for Military and Civil Avionics, Cash flow analysis, Software costs, Establishing spares level	8
5	**System Assessment** Fault tolerant systems and Hardware and Software, Evaluating system design and Future architecture Hardware assessment-FARs guide certification requirements-Fault Tree analysis – Failure mode and effects analysis, Criticality and damaging modes and effects analysis, Software development process models, Software Assessment and Validation -Civil and Military standards, Certification of Civil Avionics.	9

List of Experiments:

1	To learn the Testing and installation of MIL-STD-1553B
2	To learn the Testing and installation of ARINC 429 & ARINC 629 card
3	To learn the Testing and Calibration of Airspeed indicator using Pitot static tester
4	To learn the Testing and calibration of vertical speed indicator using Pitot static tester
5	To learn the Testing of VHF/UHF using IFR 4000 & IFR 6000

Course Outcomes: After the course completion, the students will be able to

1	Comprehend and explain the functioning of various avionic systems and sub systems.
2	Understand and describe the functioning of various air data sensors employed in an aircraft and comprehend their limitations for civil and military aircraft.
3	Explain working of various display systems and their functioning so as to visualize the required data during the operation of various avionics systems.
4	To understand the trends in display technology
5	To know modular avionics packaging and EMI/EMC requirements in avionics
	To study system assessment, validation, certification and maintenance of avionics system

Suggested Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	Spitzer, C.R. „Digital Avionics Systems", Prentice Hall, Englewood Cliffs, N.J., U.S.A	1987
2.	Cary R .Spitzer, The Avionics Handbook, Crc Press,	2000
3.	Collinson R.P.G. „Introduction to Avionics", Chapman and Hall	1996
4.	Middleton, D.H. „Avionics Systems", Longman Scientific and Technical, Longman Group UK Ltd., England	1989

Course Name	**:**	**Systems Engineering**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

To introduce system engineering concepts to design the manufacturing system for optimum utilization of source for effective functioning.

Total No. of Lectures – 42

Lecture wise breakup		**No. of Lectures**
1	**Systems** Definitions of Systems Engineering, Systems Engineering Knowledge, Life cycles, Life-cycle phases, logical steps of systems engineering, Frame works for systems engineering, Approach and activities	8
2	**Development and Testing** Formulation of issues with a case study, Value system design, Functional analysis, Business Process Reengineering, Quality function deployment, System synthesis, Approaches for generation of alternatives. Systems testing throughout development	8
3	**Models Used** Cross-impact analysis, Structural modeling tools, System Dynamics models with case studies, Economic models: present value analysis – NPV, Benefits and costs over time, ROI, IRR; Work and Cost breakdown structure	8
4	**Aircraft Systems** Intro to Aircraft Systems, Different types of Aircraft Systems, Development and Management of various systems. transfer function and errors, system block diagram, Different co-ordinate systems	10
5	**Decision Assessment** Decision assessment types, Five types of decision assessment efforts, Utility theory, Group decision making and Voting approaches, Social welfare function; Systems Engineering methods for Systems Engineering Management	8

Course Outcomes: After the course completion, the students will be able to

1	Have an understanding of what systems are is and its current usage.
2	Application of aircraft systems and its development
3	Apply the concept of selection of models for system creation.
4	Learn the various developmental and testing systems
5	Understanding the various decision assessment cycles and strategies used.

Suggested Books:

Sr. No.	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint
1	Systems engineering principles and practice by Alexander Kossiakoff	2003
2.	Textbook Of Control Systems Engineering (Vtu) by I.J. Nagrath and M. Gopal	2007
3.	Model-oriented Systems Engineering Science: A Unifying Framework for Traditional and Complex Systems by Duane W. Hybertson	2009

Course Name	**:**	**Machine Learning**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

This is an introductory course on machine learning and its possible usage and application in aerospace industry.

Total No. of Lectures – 42

Lecture wise breakup		**No. of Lectures**
1	**Introduction** Introduction to machine learning, Probability Theory, Linear Algebra, Convex Optimization, Introduction: Statistical Decision Theory - Regression, Classification, Bias Variance	8
2	**Regression** Linear Regression, Multivariate Regression, Subset Selection, Shrinkage Methods, Principal Component Regression, Partial Least squares	8
3	**Classification** Linear Classification, Logistic Regression, Linear Discriminant Analysis, Perceptron, Support Vector Machines	8
4	**Neural Networks** Neural Networks - Introduction, Early Models, Perceptron Learning, Back propagation, Initialization, Training & Validation, Parameter Estimation - MLE, MAP, Bayesian Estimation	10
5	**Aerospace Applications** Application of Machine learning in aerospace industry, role of avionics, future scope.	8

Course Outcomes: After the course completion, the students will be able to

1	Have an understanding of what machine learning is and its current usage.
2	Application of Machine learning in system creation
3	Apply the concept of machine regression and use it for development
4	Learn the various machine learning development techniques
5	Understanding the role of machine learning in an aircraft and creating dynamic systems based on it.

Suggested Books:

Sr. No.	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint
1	Understanding Machine Learning. Shai Shalev-Shwartz and Shai Ben-David. Cambridge University Press.	2017
2.	The Elements of Statistical Learning. Trevor Hastie, Robert Tibshirani and Jerome Friedman. Second Edition. 2009.	2009
3.	Foundations of Data Science. Avrim Blum, John Hopcroft and Ravindran Kannan. January 2017.	2017

Course Name	**:**	**Control Theory and Guidance**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

This is graduate level introductory course on guidance, navigation and control systems for the discipline of aerospace engineering. This is a core course for M. Tech students joining the aerospace engineering department.

Total No. of Lectures – 42

Lecture wise breakup		**No. of Lectures**
1	**Mathematical Modeling:** Linear Systems, Block Diagrams, Feedback, Input Test Signals, Laplace Transforms. Transfer Functions, State Space Representation.	6
2	**Stability** Definition of Stability – Response vs Pole Locations – Time Domain Specifications – System Type and Steady-State Errors – Routh's Stability Criterion – Root Locus – Guidelines for Sketching – Bode Plot Techniques – Nyquist Criterion – Stability Margins (Gain and Phase).	6
3	**Design Method** Root Locus Design Method: Dynamic Compensation (Lead/Lag), PID Controllers – Frequency Response Design Method – Robust Stability and Robust Performance – Introduction to State Space Design, Controllability and Observability – Introduction to State – Feedback and Estimator Design.	8
4	**Missiles** Guided missiles; Classifications; Description of tactical missiles. Guidance phases during flight; Categories of Homing and command guidance. The kinematic equations.	8
5	**Aircraft Navigation** Aircraft Navigation; Kinds of navigation - Position Fixing and Dead-reckoning systems. LORAN; DECCA; OMEGA. Very High Frequency Omni-Directional Range (VOR). Celestial navigation and GPS based navigation; Inertial Navigation Systems. Integrated navigation systems.	8
6	**Aerospace Applications** Frequency domain characteristics; Root Locus. Nyquist and Bode plots and their application to controller design for aerospace systems.	6

Course Outcomes: After the course completion, the students will be able to

1	Have an understanding of control system and basics of guidance

2	Application of the guidance and navigation system on aerospace applications
3	Apply the concept of missile guidance system and use it for development
4	Learn the various design methods used to develop and create guidance systems.
5	Understanding the role of stability in an aircraft and creating dynamic systems based on it.

Suggested Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	M .I. Skolnik: Introduction to Radar Systems, Tata McGraw-Hill, 2007.	2007
2.	M. Kayton and W. Fried: Avionics Navigation System, Wiley Interscience, 1997.	1997
3.	P. Zarchan: Tactical and Strategic Missile Guidance, AIAA,	2007

Course Name	**:**	**Artificial Intelligence**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

The main purpose of this course is to provide the most fundamental knowledge to the students so that they can understand what the Artificial Intelligence (AI) is. Due to limited time, we will try to eliminate theoretic proofs and formal notations as far as possible, so that the students can use the basic knowledge about AI to apply in aerospace applications

Total No. of Lectures – 42

Lecture wise breakup		**No. of Lectures**
1	**Meaning and definition of artificial intelligence** Physical Symbol System Hypothesis, production systems, Characteristics of production systems; Breadth first search and depth first search techniques. Heuristic search Techniques: Hill Climbing, Iterative deepening DFS, bidirectional search. Analysis of search methods. AI algorithm and their analysis. Introduction to Genetic algorithms.	8
2	**Knowledge Representation** Problems in representing knowledge, knowledge representation using propositional and predicate logic, logical consequences, syntax and semantics of an expression, semantic Tableau. Forward and backward reasoning.	8
3	**Representation and Reasoning** Network-based representation and reasoning, Semantic networks, Conceptual Graphs, frames. Description logic (DL), concept language, reasoning using DL. Conceptual dependencies (CD), scripts, reasoning using CD. Introduction to natural language processing.	8
4	**Fuzzy Logic** Reasoning in uncertain environments, Fuzzy logic, fuzzy composition relation, operations on fuzzy sets. Probabilistic reasoning, Bayes theorem, construction of Bayesian networks, belief propagation. Markov processes and Hidden Markov models.	10
5	**Aerospace Applications** Application of AI in Aerospace Industries, Development of Instrument and system that are artificially intelligent.	8

Course Outcomes: After the course completion, the students will be able to

1	Have an understanding of what Artificial Intelligence is and its current usage.
2	Application of Artificial Intelligence in making optimized and efficient systems
3	Apply the concept of fuzzy logic and use it for development

4	Learn the various representation and reasoning techniques to develop systems
5	Understanding the role of artificial intelligence in an aircraft and creating efficient control systems based on it.

Suggested Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	Artificial Intelligent e: Elaine Rich, Kevin Knight, Mc-Graw Hill.	1991
2.	Introduction to AI & Expert System: Dan W. Patterson, PHI.	1990
3.	Artificial Intelligent by Luger (Pearson Education)	1995

Course Name	**:**	**Shock Wave Theory**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

To make students familiar with the concepts shock waves, its propagation and its application in supersonic aircrafts. Understanding the compressible flow and impact of heat transfer.

Total No. of Lectures – 42

Lecture wise breakup		**No. of Lectures**
1	**Fundamentals** Ideal gas relationship, The adiabatic energy equation, Mach number and its significance, Mach waves, Mach cone and Mach angle, static and stagnation states, relationship between stagnation temperature, pressure, density and enthalpy in terms of Mach number, stagnation velocity of sound, reference speeds, various regions of flow, Effect of Mach number on compressibility, Area velocity relationship.	8
2	**Normal Shock Waves** Development of shock wave, Thickness of shock wave, governing equations, Strength of shock waves, Prandtl-Mayer relation, Rankine-Hugoniot relation, Mach number in the downstream of normal shock, variation of flow parameters across the normal shock, normal shock in Fanno and Rayleigh flows, impossibility of a rarefaction shock, supersonic diffusers, supersonic Pitot tube.	8
3	**Compressible Flow** Integral equations for quasi one dimensional flows, isentropic relations, One dimensional flows, normal shock relations, Area velocity relation, flow inside nozzles and diffusers, Oblique shock relations, shock polar diagram, Wave interactions , Thin supersonic airfoil theory, Small perturbation theory for lift and drag coefficients.	8
4	**Flow in Constant Area Duct with Friction** Fanno curve and Fanno flow equations, solution of Fanno flow equations, variation of flow properties, variation of Mach no. with duct length, isothermal flow in constant area duct with friction, tables and charts for Fanno flow, Experimental friction coefficients.	10
5	**Flow in Constant Area Duct with Heat Transfer (Rayleigh Flow):** Simple heating relation of a perfect gas, Rayleigh curve and Rayleigh flow equations, variations of flow properties, maximum heat transfer, tables and charts for Rayleigh flow.	8

Course Outcomes: After the course completion, the students will be able to

1	Have an understanding of how shock waves originate and propagate

2	Application of Shock wave into development of supersonic aircrafts.
3	Understand the difference between compressible and incompressible flow
4	Learn the flow movement in constant area duct with friction
5	Understanding the impact of heat transfer

Suggested Books:

Sr. No.	**Name of Book/ Authors/ Publisher**	**Year of Publication/ Reprint**
1	Fundamentals of Aerodynamics, John D Anderson	2010
2.	Fundamental of Compressible flow, S. M. Yahya, New age international Publication, Delhi	1965
3.	Modern Compressible Flow: With Historical Perspective, John D. Anderson, McGraw-Hill Higher Education	2004

OPEN ELECTIVE

Course Name	:	Computational Fluid Dynamics
Course Code	:	
Credits	:	3
L T P	:	3-0-0

Course Objectives:

To help the students understand the concepts, to be able to solve and apply various types of equations for the analysis of the flow, generate various types of grid and use panel method for solving flow problems.

Total No. of Lectures – 42

Lecture wise breakup		No. of Lectures
1	**Classifications of partial differential Equations (PDEs):** Classification of partial differential equations, Linear/Nonlinear partial differential equations, Elliptic, parabolic, hyperbolic partial differential equations, System of first order partial differential equations, Initial and Boundary Conditions.	7
2	**Methods For Approximate Solution of PDEs:** Brief overview of finite difference, finite volume and finite elements approaches	2
3	**Finite Difference Methods:** Taylor table approach for constructing finite difference schemes of arbitrary orders of accuracy, implementation of schemes near boundaries, Explicit and Implicit methods, Discretization using Orthogonal Polynomials, Truncation error estimates.	2
4	**Methods For Parabolic Equations:** Parabolic partial differential equation, Numerical solution of unsteady heat conduction (Parabolic PDE) using various schemes, implementing initial and boundary conditions, Von Neumann stability analysis, Consistence analysis, Solution of tridiagonal systems.	8
5	**Hyperbolic Equations And Panel Method:** Solution of hyperbolic equations- Burgers equation, Numerical solution of linear wave equation (Hyperbolic PDE) using various schemes, artificial viscosity, diffusion and dispersion error, stability analysis.	7
6	**Methods For Elliptic Equations** Numerical solution of steady state heat conduction (Elliptic PDE) using various explicit and implicit schemes, implementation of boundary conditions, mesh dependence and convergence of solution.	8
7	**Grid Generation Techniques** Structured and Unstructured grids, Boundary fitted grids, Elliptic grid, generation, Algebraic grid generation.	8

Course Outcomes: By the end of this course, the student will be able to:

1	Classify different types of partial differential equations (PDEs), boundary conditions.
2	Basic understanding of difference between finite difference, finite element and finite volume methods.
3	Comprehend and derive finite difference approximations, discretization methods, estimate errors.
4	Solve parabolic differential equations by implicit and explicit methods and carry out stability analysis of PDEs.
5	Solve hyperbolic equations and various two dimensional and three dimensional flow problems using panel methods.
6	Solve elliptic equations by various iterative methods using finite difference approximations.
7	Generate various type of grids based on the problem.

Suggested Books:

Sr. No.	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint
1	"High Accuracy Computing Methods, Fluid Flows and Wave Phenomena" Tapan K. Sengupta, 1st Ed., Cambridge University Press	2013
2	"Fundamentals of Computational Fluid Dynamics", Tapan K. Sengupta, 1st Ed., Universities Press	2004
3	"Computational Aerodynamics and Aeroacoustics", T. K. Sengupta and Y. G. Bhumkar, 1st Ed., Springer	2020
4	"Computational Fluid Dynamics The Basics with Applications", John D. Anderson Jr., 1st Ed., McGraw Hill Education India	2017
5	"Numerical Computation of Internal and External Flows: The Fundamentals of Computational Fluid Dynamics", C. Hirch, Volume-2, 2nd Ed., Butterworth-Heinemann	2007

Course Name	**:**	**Experimental Aerodynamics**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

This course will help students to understand the state of the art experimental techniques and facilities in the various speed ranges corresponding to subsonic, supersonic and hypersonic Mach numbers. Also, get familiar with the important considerations for the design of such facilities, significance of their components and some hard ware details.

Total No. of Lectures – 42

Lecture wise breakup		**No. of Lectures**
1	**Introduction to Experimental Methods** Types of experimental facilities, Types of wind tunnels: Subsonic, Transonic, supersonic wind tunnels, shock tube. Flow measurement instruments: Wind tunnel balances, measurement of forces and moments, measurement of profile drag by pitot traverse of wake, shadowgraph system, Schlieren system, interferometer, Hot wire Anemometer	10
2	**Flow Visualization Techniques** Low speed flow visualization techniques, Schlieren, shadowgraph, interferometry, introduction to laser diagnostic techniques	5
3	**Measurements** Measurement of temperature using thermocouples, resistance thermometers, temperature sensitive paints and liquid crystals, Steady and unsteady pressure measurements and various types of pressure probes and transducers, errors in pressure measurements, thermocouples, thermography, velocity measurement using hot wire anemometry , Laser Doppler Velocimetry and Particle Image Velocimetry	6
4	**Data acquisition** Data acquisition and digital signal processing techniques, wind tunnel data acquisition, measurement of steady and unsteady pressure, velocity, temperature, turbulence intensity, calibration of force, pressure and acoustic sensors. Virtual instrumentation, Calibration of single and two wire probes.	9
5	**Wind Tunnel Modeling** Skin friction, forces and moments – Model design and fabrication force measurement techniques. Introduction to dynamic testing	12

Course Outcomes: By the end of this course, the student will be able to:

1	Understand the types of wind tunnel test facilities corresponding to various flow fields ranging from subsonic to supersonic Mach numbers and significance of wind tunnel components for designing an efficient tunnel.

2	Demonstrate and analyze the various visualization techniques from subsonic to supersonic flow-field.
3	Perform experiments using various probes and transducers, their uses and measurement for industry or research purposes.
4	Analyze and interpret the experimental data using various softwares and manage and store huge amount of data for post-processing.
5	Able to design experiments required for any particular problem in aerodynamics for research or industry purposes.

Suggested Books:

Sr. No.	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint
1	"Wind Tunnel Techniques - Pankrust, R.C and Holder, D.W.	1968
2	"Wind Tunnels: Aerodynamics, Models & Experiments", Justin D. Pereira., Nova science Pub. Inc.	2010
3	"Instrumentation, Measurements, and Experiments in Fluids", E. Rathakrishnan, CRC Press.	2007
4	"Low Speed Wind Tunnel Testing", W. E. Rae and A. Pope., John Wiley	1999
5	"High Speed Wind Tunnel Testing", K. L. Goin, and A. Pope., KrieZKR.	1978

Course Name	:	**Unmanned Aerial Vehicle Design**
Course Code	:	
Credits	:	**3**
L T P	:	**3-0-0**

Course Objectives:

This course will help students in the designing and sizing process by using simulations or experiments for fixed wing UAV technology, including the performance and stability analysis and the prototype testing.

Total No. of Lectures – 42

Lecture wise breakup		No. of Lectures
1	Understanding the static stability of various UAVs. Significance of location of Neutral point and Centre of gravity for a stable flight	7
2	Approach for wing design and airfoil selection with examples	5
3	Tail sizing, control surface sizing and significance of tail volume ratio with examples	5
4	Developing subroutine for design process	7
5	Design example for conventional takeoff fixed wing UAV for various mission requirements	6
6	Design example for hand launch fixed wing UAV for various mission requirement	6
7	Design example for VTOL fixed wing UAV for various mission requirement	6

Course Outcomes: By the end of this course, the student will be able to:

1	To locate neutral point and center of gravity for a stable flight and describe static stability of different UAVs.
2	Design wing, airfoils and control surfaces based on the desired performance parameter.
3	Write their own subroutines or modify the available routines required for designing.
4	Design various types of fixed wing UAVs based on mission requirements.

Suggested Books:

Sr. No.	Name of Book/ Authors/ Publisher	Year of Publication/

		Reprint
1	Small unmanned fixed wing aircraft design: A practical approach book by Andrew J. Keane	2017
2.	Unmanned aircraft systems: UAVs, design, development and deployment book by Reg Austin .	2010
3.	Design of unmanned aerial systems book by Mohammed H. Sadraey	2020

Course Name	**:**	**Composite Materials and Structures**
Course Code	**:**	
Credits	**:**	**3**
L T P	**:**	**3-0-0**

Course Objectives:

This course will equip students with the ability to design composite structures, select composite materials, conduct stress analyses of selected practical applications using laminated plate theories and appropriate strength criteria, and be familiar with the properties and response of composite structures.

Total No. of Lectures – 42

Lecture wise breakup		**No. of Lectures**
1	Introduction to fibrous composites: Fiber, matrix: materials, properties and fabrication processes, types/classification of composites, fabrication methods of composites, advantages and applications; 3D constitutive equations (principal material and global directions), thermal, hygroscopic effects and hygrothermoelastic constitutive equation.	08
2	Plane stress (or reduced) constitutive equations (principal material and global directions) and hygrothermoelastic constitutive equation, lamina engineering constants; Lamination theory, hygrothermoelastic lamination theory; Designing with laminates	08
3	Test methods: Quality assessment, physical and mechanical property characterization; Micromechanics: Strength of materials and continuum; approaches for effective properties; Failure mechanisms, lamina failure theories	09
4	Damage mechanics of composites; Fracture mechanics of composites; Interlaminar stresses; Composite joints	09
5	Nanocomposites; Stitched composites; 3D composites	08

Course Outcomes: After the course completion, the students will be able to

1	Understand composite materials and their properties
2	Comprehend and derive plane stress constitutive equations, laminar theory and design with laminates
3	Analyze various test methods for quality assessment based on physical and mechanical properties of the materials.
4	Comprehend damage mechanism in composites materials and joints.
5	Understand various different types of composites.

Suggested Books:

Sr. No.	Name of Book/ Authors/ Publisher	Year of Publication/ Reprint
1	Mechanics of Fibrous Composites, C.T. Herakovich, John Wiley & Sons, Inc. New York.	1998
2	Analysis and Performance of Fibre Composites, B.D. Agarwal and L.J. Broutman, 4th Ed., John Wiley & Sons, Inc. New York.	2017
3	Mechanics of Composite Materials, R.M. Jones, 2nd Ed., Technomic Publication.	1999
4	Mechanics of Composite Materials, RM Christensen, Krieger Publishing Company, Florida, USA.	2012
5	Mechanical Testing of Advanced Fibre Composites, J.M. Hodgkinson, Woodhead Publishing Limited, Cambridge.	2000

MOOCs on this course are available at:

1) Composite Materials and Structures by Dr. P.M. Mohite, IIT Kanpur- **https://nptel.ac.in/courses/101104010**