

**ANNA UNIVERSITY, CHENNAI**  
**UNIVERSITY DEPARTMENTS**  
**REGULATIONS - 2019**  
**CHOICE BASED CREDIT SYSTEM**  
**M.E. AEROSPACE TECHNOLOGY (FT)**

**THE VISION OF THE DEPARTMENT OF AEROSPACE ENGINEERING**

The Department of Aerospace Engineering shall strive to be a globally known department, committed for its academic excellence, professionalism and societal expectations. The Department aims to impart state of the art technical knowledge, practical skills, leadership qualities, team spirit, ethical values and entrepreneurial skill to make all the students capable of taking up any task relevant to the area of Aerospace Engineering.

**THE MISSION OF THE DEPARTMENT OF AEROSPACE ENGINEERING**

The Mission of the Department of Aerospace Engineering is to

- Prepare the students to have a very good fundamental knowledge to meet the present and future needs of industries.
- Improve the technical knowledge of the students in tune with the current requirements through collaboration with industries and research organization.
- Make the students gain enough knowledge in various aspects of system integration.
- Motivate the students to take up jobs in national laboratories and aerospace industries of our country.
- Take up inter and multidisciplinary research, sponsored and consultancy projects with industries and research establishments.
- Encourage the faculty members and students to do research and to update with the latest developments in the area of Aerospace Engineering.

*Attested*

  
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Anna University, Chennai-600 025

## PROGRAMME EDUCATIONAL OBJECTIVES (PEOs):

- I. **PEO 1:** Successful Moulding of Graduate into Aerospace Technology Professional: Graduates of the programme will acquire adequate knowledge both in practical and theoretical domains in the field of Aerospace Technology through rigorous post graduate education.
- II. **PEO 2:** Successful Career Development: Graduates of the programme will have successful technical and managerial career in Aerospace industries and the allied management.
- III. **PEO 3:** Contribution to Aerospace Technology Field: Graduates of the programme will have innovative ideas and potential to contribute for the development and current needs of the Aerospace industries.
- IV. **PEO 4:** Sustainable interest for Lifelong learning: Graduates of the programme will have sustained interest to learn and adapt new technology developments to meet the changing industrial scenarios.
- V. **PEO 5:** Motivation to pursue research in Aerospace field: Graduates will have interest and strong desire to undertake research oriented jobs and responsibilities in Universities and Industries.

## PROGRAMME OUTCOMES (POs)

On successful completion of the programme,

PO #	Graduate Attribute	Programme outcome
1.	Engineering knowledge	Postgraduate will be able to use the Engineering knowledge acquired from the basic courses offered in the programme to pursue either doctoral studies or a career as an academician / scientist or engineer.
2.	Problem analysis	Postgraduate will acquire the ability to diagnose problems and conduct experiments as well as to analyse and interpret the data in the field of Aerospace Technology.
3.	Design / Development of solutions	Postgraduate will have the ability to design a system or a component to meet the design requirements with constraints exclusively meant for Aerospace Technology.
4.	Conduct investigations of complex problems	Postgraduate will have a firm scientific, technological and communication base that helps him/her to conduct investigations of complex problems in the aerospace industry and R&D organizations and other professional fields.
5.	Modern tool usage	Postgraduate will become familiar with modern engineering tools and analyse problems within the domains of Aerospace Technology.
6.	The Engineer and society	Postgraduate will be capable of doing research in inter and multidisciplinary areas which will result in more efficient and cheaper products that are beneficial to society.
7.	Environment and sustainability	Postgraduate will exhibit awareness of contemporary issues on environment focussing on the necessity to develop new materials design and testing methods for the solution of problems related to aerospace industry.
8.	Ethics	Postgraduate will acquire an understanding of professional and ethical responsibility with reference to their career in the field of Aerospace Engineering &

		Technology and other allied professional fields.
9.	Individual and team work	Postgraduate will be trained towards developing and understanding the importance of design and development of aerospace subsystems from system integration point of view which requires team work.
10.	Communications	Postgraduate will be able to communicate effectively both in verbal and nonverbal forms.
11.	Project management and finance	Postgraduate will show his ability for managerial skills in design or research teams and will be able to deliver cost effective solutions for products and services.
12.	Life-long learning	Postgraduate will be capable of understanding the value of life-long learning.

### PROGRAMME SPECIFIC OUTCOMES

- PSO1 :** The postgraduate will become familiar with approach to analysis for aerospace engineering problems and conversant with methods of solutions.
- PSO2 :** The post graduate will come well versed with usage of modern techniques, and software tools to design and develop aerospace subsystems and products.
- PSO3 :** The postgraduate will excel as an individual as well as team member in design and research teams in universities and aerospace industries.
- PSO4 :** The postgraduate will become an enthusiast to learn new technologies and methods life long in the area of aerospace engineering and technology.

### Mapping of PEOs with POs

Programme Educational Objectives	Programme Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO 6	PO7	PO 8	PO 9	PO10	PO11	PO12
I	✓	✓	✓		✓	✓	✓	✓		✓		✓
II	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓
III	✓		✓	✓	✓	✓	✓	✓	✓		✓	
IV	✓	✓	✓			✓	✓					✓
V	✓	✓	✓	✓	✓				✓		✓	✓

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			PO 1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO 12	
<b>YEAR 1</b>	<b>Sem. 1</b>	Advanced Mathematical Methods													
		Space Propulsion Systems	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	
		Aerospace Structural Analysis	✓	✓	✓	✓	✓	✓	✓					✓	
		Space Vehicle Aerodynamics	✓	✓	✓	✓	✓	✓	✓					✓	
		Program Elective – I													
		Research Methodology and IPR		✓	✓	✓						✓	✓		✓
		Audit course – i													
		Launch Vehicle Aerodynamics Laboratory	✓	✓	✓		✓		✓	✓	✓				✓
		Space Propulsion Laboratory	✓	✓	✓		✓		✓	✓	✓	✓			✓
	<b>Sem.2</b>	Hypersonic Aerodynamics	✓	✓	✓	✓	✓		✓						✓
		Orbital Mechanics	✓	✓	✓	✓	✓	✓	✓		✓				✓
		CFD for Aerospace Applications	✓	✓	✓	✓	✓	✓			✓				✓
		Program Elective – II													
		Program Elective – III													
		Audit course – II													
		Aerospace Structures Laboratory	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓
		Computation Laboratory	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓
		Mini Project with Seminar	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
<b>YEAR 2</b>	<b>Sem. 3</b>	Program Elective – IV													
		Program Elective – V													
		Open Elective													
	<b>Sem. 4</b>	Dissertation – I	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Dissertation – II	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

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		PO 1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	
<b>PROGRAM CORE COURSES (PCC)</b>	Space Propulsion Systems	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	
	Aerospace Structural Analysis	✓	✓	✓	✓	✓	✓	✓					✓	
	Space Vehicle Aerodynamics	✓	✓	✓	✓	✓	✓	✓					✓	
	Launch Vehicle Aerodynamics Laboratory	✓	✓	✓		✓		✓	✓	✓			✓	
	Space Propulsion Laboratory	✓	✓	✓		✓		✓	✓	✓	✓		✓	
	Hypersonic Aerodynamics	✓	✓	✓	✓	✓		✓						✓
	Orbital Mechanics	✓	✓	✓	✓	✓	✓	✓		✓				✓
	CFD for Aerospace Applications	✓	✓	✓	✓	✓	✓			✓				✓
	Aerospace Structures Laboratory	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
	Computation Laboratory	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓
<b>PROGRAM ELECTIVE COURSES (PEC)</b>	<b>Program Elective –I</b>													
	Elements of Satellite Technology	✓	✓	✓		✓	✓	✓					✓	
	Cryogenic Technology	✓	✓	✓	✓	✓	✓	✓		✓			✓	
	Experimental Techniques	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	
	Fundamentals of combustion	✓	✓	✓		✓		✓	✓	✓	✓		✓	
	Computational Heat Transfer	✓	✓	✓		✓	✓			✓			✓	
	<b>Program Elective – II</b>													
	Missile Aerodynamics	✓	✓	✓	✓	✓	✓							✓
	Spacecraft Attitude Dynamics and Control	✓	✓	✓	✓	✓	✓				✓		✓	✓
	Chemical Rocket Technology	✓	✓	✓	✓	✓							✓	✓

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Aerospace Materials	✓	✓	✓	✓	✓			✓		✓			✓
Space Vehicle Design	✓	✓	✓	✓	✓	✓				✓			✓
<b>Program Elective – III</b>													
Missile Guidance and Control	✓	✓	✓	✓	✓	✓				✓		✓	✓
Theory of Boundary Layers	✓	✓	✓	✓	✓	✓							✓
Finite Element Analysis	✓	✓	✓	✓	✓	✓	✓			✓			✓
Analysis of Composite Structures	✓	✓	✓	✓	✓			✓		✓			✓
Fatigue and Fracture Mechanics	✓	✓	✓	✓	✓			✓		✓			✓
<b>Program Elective - IV</b>													
Vibration Isolation and Control	✓	✓	✓			✓		✓		✓			✓
Non-Destructive Evaluation	✓	✓	✓	✓	✓			✓		✓			✓
Plasma Engineering	✓	✓	✓	✓	✓	✓		✓		✓			✓
Rocket and Missile Systems	✓	✓	✓	✓	✓					✓		✓	✓
Electric Propulsion Systems	✓	✓	✓	✓	✓	✓				✓		✓	✓
<b>Program Elective – V</b>													
Manned Space Missions	✓		✓		✓	✓				✓		✓	✓
High Temperature Gas Dynamics	✓	✓	✓	✓	✓	✓	✓						✓
High Speed Jet Flows	✓	✓	✓	✓	✓	✓	✓						✓
Smart Materials and Structural Health Monitoring	✓	✓	✓	✓	✓	✓				✓			✓
Unmanned Aerial Systems	✓	✓	✓	✓	✓	✓	✓			✓			✓

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**REGULATIONS - 2019**  
**CHOICE BASED CREDIT SYSTEMS**  
**M.E. AEROSPACE TECHNOLOGY (FULL – TIME)**  
**I SEMESTER**

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
<b>THEORY</b>								
1.	MA5152	Advanced Mathematical Methods	FC	3	1	0	4	4
2.	AS5101	Space Propulsion Systems	PCC	4	0	0	4	4
3.	AS5102	Aerospace Structural Analysis	PCC	3	1	0	4	4
4.	AS5103	Space Vehicle Aerodynamics	PCC	4	0	0	4	4
5.	RM5151	Research Methodology and IPR	RMC	2	0	0	2	2
6.		Program Elective-I	PEC	3	0	0	3	3
7.		Audit course-I*	AC	2	0	0	2	0
<b>PRACTICALS</b>								
8.	AS5111	Launch Vehicle Aerodynamics Laboratory	PCC	0	0	4	4	2
9.	AS5112	Space Propulsion Laboratory	PCC	0	0	4	4	2
<b>TOTAL</b>				<b>21</b>	<b>2</b>	<b>8</b>	<b>31</b>	<b>25</b>

\* Audit Course is optional.

**II SEMESTER**

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
<b>THEORY</b>								
1.	AS5251	Hypersonic Aerodynamics	PCC	3	0	0	3	3
2.	AS5201	Orbital Mechanics	PCC	4	0	0	4	4
3.	AL5251	CFD for Aerospace Applications	PCC	3	0	0	3	3
4.		Program Elective-II	PEC	3	0	0	3	3
5.		Program Elective-III	PEC	3	0	0	3	3
6.		Audit course-II*	AC	2	0	0	2	0
<b>PRACTICALS</b>								
7.	AS5211	Aerospace Structures Laboratory	PCC	0	0	4	4	2
8.	AL5261	Computation Laboratory	PCC	0	0	4	4	2
9.	AS5212	Mini Project with Seminar	EEC	0	0	4	4	2
<b>TOTAL</b>				<b>18</b>	<b>0</b>	<b>12</b>	<b>30</b>	<b>22</b>

\* Audit Course is optional.

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### III SEMESTER

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
<b>THEORY</b>								
1.		Program Elective-IV	PEC	3	0	0	3	3
2.		Program Elective-V	PEC	3	0	0	3	3
3.		Open Elective	OEC	3	0	0	3	3
<b>PRACTICALS</b>								
4.	AS5312	Dissertation - I	EEC	0	0	12	12	6
<b>TOTAL</b>				<b>9</b>	<b>0</b>	<b>12</b>	<b>21</b>	<b>15</b>

### IV SEMESTER

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
<b>PRACTICALS</b>								
1.	AS5411	Dissertation - II	EEC	0	0	24	24	12
<b>TOTAL</b>				<b>0</b>	<b>0</b>	<b>24</b>	<b>24</b>	<b>12</b>

**TOTAL NO. OF CREDITS: 74**

### FOUNDATION COURSES (FC)

Sl. No.	Course Code	Course Title	Periods per week			Credits	Semester
			L	T	P		
1.	MA5152	Advanced Mathematical Methods	3	1	0	4	1

### PROGRAM CORE COURSES (PCC)

Sl. No.	Course Code	Course Title	Periods per week			Credits	Semester
			L	T	P		
1.	AS5101	Space Propulsion Systems	4	0	0	4	1
2.	AS5102	Aerospace Structural Analysis	3	1	0	4	1
3.	AS5103	Space Vehicle Aerodynamics	4	0	0	4	1
4.	AS5111	Launch Vehicle Aerodynamics Laboratory	0	0	4	2	1
5.	AS5112	Space Propulsion Laboratory	0	0	4	2	1
6.	AS5251	Hypersonic Aerodynamics	3	0	0	3	2
7.	AS5201	Orbital Mechanics	4	0	0	4	2
8.	AL5251	CFD for Aerospace Applications	3	0	0	3	2
9.	AS5211	Aerospace Structures Laboratory	0	0	4	2	2
10.	AL5261	Computation Laboratory	0	0	4	2	2

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**PROGRAM ELECTIVE COURSES**

**SEMESTER I, ELECTIVE – I**

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	AS5072	Elements of Satellite Technology	PEC	3	0	0	3	3
2.	AS5001	Cryogenic Technology	PEC	3	0	0	3	3
3.	AS5002	Experimental Techniques	PEC	3	0	0	3	3
4.	AS5003	Fundamentals of Combustion	PEC	3	0	0	3	3
5.	AS5071	Computational Heat Transfer	PEC	3	0	0	3	3

**SEMESTER II, ELECTIVE – II**

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	AS5004	Missile Aerodynamics	PEC	3	0	0	3	3
2.	AS5005	Spacecraft Attitude Dynamics and Control	PEC	3	0	0	3	3
3.	AS5006	Chemical Rocket Technology	PEC	3	0	0	3	3
4.	AL5071	Aerospace Materials	PEC	3	0	0	3	3
5.	AS5007	Space Vehicle Design	PEC	3	0	0	3	3

**SEMESTER II, ELECTIVE – III**

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	AS5008	Missile Guidance and Control	PEC	3	0	0	3	3
2.	AL5078	Theory of Boundary Layers	PEC	3	0	0	3	3
3.	AL5252	Finite Element Analysis	PEC	3	0	0	3	3
4.	AL5072	Analysis of Composite Structures	PEC	3	0	0	3	3
5.	AL5073	Fatigue and Fracture Mechanics	PEC	3	0	0	3	3

**SEMESTER III, ELECTIVE – IV**

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	AL5079	Vibration Isolation and Control	PEC	3	0	0	3	3
2.	AL5075	Non-Destructive Evaluation	PEC	3	0	0	3	3
3.	AS5009	Plasma Engineering	PEC	3	0	0	3	3
4.	AS5010	Rocket and Missile Systems	PEC	3	0	0	3	3
5.	AS5011	Electric Propulsion Systems	PEC	3	0	0	3	3

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**SEMESTER III, ELECTIVE – V**

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	AS5012	Manned Space Missions	PEC	3	0	0	3	3
2.	AS5013	High Temperature Gas Dynamics	PEC	3	0	0	3	3
3.	AL5074	High Speed Jet Flows	PEC	3	0	0	3	3
4.	AL5077	Smart Materials and Structural Health Monitoring	PEC	3	0	0	3	3
5.	AS5014	Unmanned Aerial Systems	PEC	3	0	0	3	3

**RESEARCH METHODOLOGY AND IPR COURSES (RMC)**

SL. NO.	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
			L	T	P		
1.	RM5151	Research Methodology and IPR	2	0	0	2	2

**OPEN ELECTIVE COURSES [OEC]**

(Out of 6 Courses one Course must be selected)

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	OE5091	Business Data Analytics	OEC	3	0	0	3	3
2.	OE5092	Industrial Safety	OEC	3	0	0	3	3
3.	OE5093	Operations Research	OEC	3	0	0	3	3
4.	OE5094	Cost Management of Engineering Projects	OEC	3	0	0	3	3
5.	OE5095	Composite Materials	OEC	3	0	0	3	3
6.	OE5096	Waste to Energy	OEC	3	0	0	3	3

PROGRESS THROUGH KNOWLEDGE

**AUDIT COURSES (AC)**

Registration for any of these courses is optional to students

SL. NO	COURSE CODE	COURSE TITLE	PERIODS			CREDITS
			L	T	P	
1.	AX5091	English for Research Paper Writing	2	0	0	0
2.	AX5092	Disaster Management	2	0	0	0
3.	AX5093	Sanskrit for Technical Knowledge	2	0	0	0
4.	AX5094	Value Education	2	0	0	0
5.	AX5095	Constitution of India	2	0	0	0
6.	AX5096	Pedagogy Studies	2	0	0	0
7.	AX5097	Stress Management by Yoga	2	0	0	0
8.	AX5098	Personality Development Through Life Enlightenment Skills	2	0	0	0
9.	AX5099	Unnat Bharat Abhiyan	2	0	0	0

### EMPLOYABILITY ENHANCEMENT COURSES (EEC)

S. No.	Course Code	Course Title	Periods per week			Credits	Semester
			Lecture	Tutorial	Practical		
1.	AS5212	Mini Project with Seminar	0	0	4	2	2
2.	AS5312	Dissertation-I	0	0	12	6	3
3.	AS5411	Dissertation-II	0	0	24	12	4

### Summary

		Name of the Programme					
		Subject Area	Credits per Semester				Total credits
			I	II	III	IV	
1.	FC	04	00	00	00	04	
2.	PCC	16	14	00	00	30	
3.	PEC	03	06	06	00	15	
4.	RMC	02	00	00	00	02	
5.	OEC	00	00	03	00	03	
6.	EEC	00	02	06	12	20	
7.	Non Credit/Audit Courses	✓	✓	00	00		
		<b>25</b>	<b>22</b>	<b>15</b>	<b>12</b>	<b>74</b>	



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**COURSE OBJECTIVES:**

- To familiarize the students in the field of differential equations.
- To enable them to solve boundary value problems associated with engineering applications using transform methods.
- To expose the students to the concepts of calculus of variations.
- To introduce conformal mappings and their applications to fluid flows and heat flows.
- To give the students a complete picture of tensor analysis.

**UNIT I LAPLACE TRANSFORM TECHNIQUES FOR PARTIAL DIFFERENTIAL EQUATIONS****12**

Laplace transform: Definitions, properties - Transform of error function, Bessel's function, Dirac Delta function, Unit Step functions – Convolution theorem – Inverse Laplace Transform: Complex inversion formula – Solutions to partial differential equations: Heat equation, Wave equation

**UNIT II FOURIER TRANSFORM TECHNIQUES FOR PARTIAL DIFFERENTIAL EQUATIONS****12**

Fourier transform: Definitions, properties – Transform of elementary functions, Dirac Delta function– Convolution theorem – Parseval's identity – Solutions to partial differential equations: Heat equation, Wave equation, Laplace and Poisson's equations.

**UNIT III CALCULUS OF VARIATIONS****12**

Concept of variation and its properties – Euler's equation – Functionals dependant on first and higher order derivatives – Functionals dependant on functions of several independent variables – Variational problems with moving boundaries -Direct methods – Ritz and Kantorovich methods.

**UNIT IV CONFORMAL MAPPING AND APPLICATIONS****12**

Introduction to conformal mappings and bilinear transformations – Schwarz Christoffel transformation – Transformation of boundaries in parametric form – Physical applications : Fluid flow and heat flow problems.

**UNIT V TENSOR ANALYSIS****12**

Summation convention – Contravariant and covariant vectors – Contraction of tensors – Inner product – Quotient law – Metric tensor – Christoffel symbols – Covariant differentiation –Gradient, divergence and curl.

**TOTAL: 60 PERIODS****COURSE OUTCOMES:**

On successful completion of the course, the students will be able to

- develop the mathematical methods of applied mathematics and mathematical physics
- solve boundary value problems using integral transform methods
- apply the concepts of calculus of variations in solving various boundary value problems
- apply conformal mappings in fluid flows and heat flow problems
- familiarize with the concepts of tensor analysis.

**REFERENCES:**

1. Andrew L.C. and Shivamoggi B.K., "Integral Transforms for Engineers", Prentice Hall of India Pvt. Ltd., New Delhi, 2003.
2. Elsgolts L., "Differential Equations and the Calculus of Variations", MIR Publishers, Moscow, 2003.
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4. Gupta A.S., "Calculus of Variations with Applications", Prentice Hall of India Pvt. Ltd., New Delhi, 2004.

5. James G., "Advanced Modern Engineering Mathematics", Pearson Education, 4<sup>th</sup> Edition, Horlow, 2016.
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7. O'Neil P.V., "Advanced Engineering Mathematics", Thomson Asia Pvt. Ltd., 8<sup>th</sup> Edition, Singapore, 2017.
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**AS5101**

**SPACE PROPULSION SYSTEMS**

**L T P C**  
**4 0 0 4**

**COURSE OBJECTIVES:**

This course will enable students

1. To impart knowledge on the basic concepts of space propulsion.
2. To learn about the physics of ionized gases.
3. To get familiarize with the types of nuclear rockets and the basic concepts of nuclear propulsion systems.
4. To study about the radioisotope propulsion.
5. To realise the importance of advanced space propulsion concepts.

**UNIT I INTRODUCTION TO SPACE PROPULSION SYSTEMS 12**

Historical outline, Scramjet Propulsion-Scramjet Inlets; Scramjet Performance, Chemical rocket Propulsion-Tripropellants; Metalized Propellants; Free Radical Propulsion, Electric Propulsion, Micropropulsion- Micropropulsion Requirements, MEMS and MEMS- Hybrid Propulsion Systems.

**UNIT II BASIC CONCEPTS OF IONIZED GASES 12**

Electromagnetic theory: electric charges and fields, currents, and magnetic fields, and applications to ionized gases. Atomic structure of gases - Ionization processes - Particle collisions in an ionized gas - Electrical conductivity of an ionized gas - Kinetic Theory, Introduction to plasma physics- Electrode phenomena.

**UNIT III NUCLEAR ROCKET PROPULSION 12**

Nuclear Rocket Engine Design and Performance, Types of Nuclear Rockets, Overall Engine Design, Nuclear Rocket Performance, Component Design, Nuclear Rocket Reactors, General Design Considerations, Reactor Core Materials, Thermal Design, Mechanical Design, Nuclear Design, Shielding, Nuclear Rocket Nozzles, General Design Considerations, Heat-Transfer Analysis, Over-all Problem, Hot-Gas Boundary, Cold-Gas Boundary.

**UNIT IV RADIOISOTOPE PROPULSION 12**

Alternative Approaches, Direct Recoil Method, Thermal Heating Method, Basic Thruster Configurations, Propulsion System and Upper Stage, Relative Mission Capabilities, Primary Propulsion, Auxiliary Propulsion, Thruster Technology, Design Criteria, Performance, Safety, Heat Source Development, Radioisotope Fuel, Capsule Technology, General Considerations, Thermal Design, Fabrication and Non-Destructive Testing Techniques, Pressure Containment, Heat Source Simulation, Oxidation and Corrosion of Encapsulating Materials, Nozzle Performance.

*Attested*

**UNIT V          ADVANCED SPACE PROPULSION CONCEPTS****12**

Introduction, General Consideration for Propulsion in Space, Power Supply, Propellant Storage and Handling Facilities, Electrostatic and Electromagnetic Thrusters, Advanced Electric Propulsion Systems for Space Vehicles, Sputtering, A Thrust Generation Mechanism, Sputtering Phenomena, Possible Performance of Sputtering Thrusters, Energy Efficiency of the Sputtering Process, Analyses of an Elementary Mission with Different Electric Thrusters, General Consideration, Performance Formula for Electric Thrusters, Optimization with Electric Thrusters

**TOTAL: 60 PERIODS****COURSE OUTCOMES:**

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

**CO1:** Have knowledge on the basics and classification of space propulsion.

**CO2:** Comprehend the physics of ionized gases, their theories and particle collisions.

**CO3:** Demonstrate the working, types and performance of nuclear rockets with their design considerations.

**CO4:** Learn the basics of radioisotope propulsion with their performance studies.

**CO5:** Have knowledge on advanced methods of space propulsion systems with new thrust generation mechanisms.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	✓	✓	✓	✓			✓		✓			✓
<b>CO2</b>	✓	✓	✓			✓	✓					✓
<b>CO3</b>	✓	✓	✓	✓		✓	✓	✓	✓			✓
<b>CO4</b>	✓	✓	✓	✓			✓	✓				✓
<b>CO5</b>	✓	✓	✓			✓	✓	✓	✓		✓	✓

**REFERENCES:**

1. Bruno Claudio and Paul A. Czysz, "Future Spacecraft Propulsion Systems", Springer, Praxis Publishing Ltd, 2006.
2. George W. Sutton, "Engineering Magnetohydrodynamics", Dover Publications Inc., New York, 2005.
3. George P. Sutton & Oscar Biblarz, "Rocket Propulsion Elements, John Wiley & Sons Inc., NewYork, 9<sup>th</sup> Edition, 2016.
4. Martin Tajmar, "Advanced Space Propulsion Systems" Springer Verlag GmbH, 2003.
5. Robert G. Jahn, "Physics of Electric Propulsion", McGraw-Hill Series, New York, 1968.
6. William J. Emrich, "Principles of Nuclear Rocket Propulsion" Elsevier Science, 2016.

**AS5102****AEROSPACE STRUCTURAL ANALYSIS**

<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>3</b>	<b>1</b>	<b>0</b>	<b>4</b>

**COURSE OBJECTIVES:**

This course will enable students

1. To learn the important technical aspects on theory of bending.
2. To find the shear flow distribution and to locate the shear centre for open and closed sections.
3. To analyse the stability problems involved in aircraft structural components under various modes of loadings.
4. To impart knowledge on how to analyze aircraft structural components under various forms of loading.
5. To gain knowledge on the spacecraft structures and materials used.

*Attested*

*W. J.*  
**DIRECTOR**  
 Centre for Academic Courses  
 Anna University, Chennai-600 025

**UNIT I BENDING OF BEAMS****9+3**

Elementary theory of pure bending – Stresses in beams of symmetrical and unsymmetrical sections - Box beams – Generalized theory of bending – Methods of bending stress determination – Principal axes method – Neutral axis method – ‘k’ method – Deflection of unsymmetrical beams – Stresses in Composite Beams – Deflection of Sandwich Beams – Design Principles.

**UNIT II SHEAR FLOW ANALYSIS****9+3**

Concept of shear flow in thin walled open & closed sections – Determination of the shear centre in symmetrical and unsymmetrical cross-sections – Flexural shear flow in multi-flange box beams – Shear flow due to combined bending & torsion in closed sections – Torsion of thin-walled open section members – Stress analysis of aerospace components – Tapered wing spar.

**UNIT III DESIGN OF COMPRESSION MEMBERS****9+3**

Analysis of solid columns – Governing Equations – Critical Loads & Buckled Modes – Thin-walled Compressions Members – Stability Analysis – Design Criterion – Buckling of sheets under compression – Plate buckling coefficient – Inelastic buckling of plates – Sheet-stiffener panels – Effective width – Failure stress in plates and stiffened panels – Local Buckling – Crippling Load Estimation.

**UNIT IV ANALYSIS OF AEROSPACE STRUCTURAL COMPONENTS****9+3**

Loads on an aircraft – Aerodynamic loads – Manoeuvre loads – Load factor determination – The flight envelope – Shear force, bending moment and torque distribution along the span of the wing and fuselage – Structural parts of wing and fuselage and their functions – Introduction to aeroelasticity – Sources of launch vehicles loads – Launch vehicle categories – Load and acceleration time-line profile.

**UNIT V REQUIREMENTS OF SPACECRAFT STRUCTURES****9+3**

Introduction & General Aspects – The Satellite Primary Structure – Load Classification – Typical Requirements – Strength – Failure Theories – Buckling – Sources of Vibration – Frequency Limits – Stiffness, Damping & Mass Distribution – Satellite Vibration Analysis – Response Spectrum – Design Requirements – Materials Used for Construction – Mechanical Interfaces.

**L : 45, T : 15, TOTAL: 60 PERIODS****COURSE OUTCOMES:**

Upon completion of the course, students will be able to

- CO1:** Apply the concept of normal stress variation on unsymmetrical sections subjected to bending moments on practical problems.
- CO2:** Find the shear flow variation in thin walled open sections with skin effective and ineffective in bending.
- CO3:** Evaluate the shear flow variation in single cell and multi-cell tubes subjected to shear and torque loads.
- CO4:** Analyse the behaviour of buckling of simply supported plates and also to know the effective width of sheet stringers combination.
- CO5:** Analyse and design structural members subject to compression.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓		✓						✓
CO2	✓	✓	✓	✓	✓	✓	✓					✓
CO3	✓	✓	✓	✓	✓		✓					
CO4	✓	✓	✓	✓	✓	✓			✓			
CO5	✓	✓	✓	✓			✓	✓				✓

Attested

## REFERENCES:

1. Bruce.K.Donaldson, "Analysis of Aircraft Structures: An Introduction", Cambridge University Press, 2<sup>nd</sup> edition, 2008.
2. Bruhn. EF, "Analysis and Design of Flight Vehicle Structures", Tristate Offset Co, 1980.
3. Megson, TMG, "Aircraft Structures for Engineering Students", Elsevier Aerospace Engineering Series, 5<sup>th</sup> Edition, 2012.
4. Peery, DJ and Azar, JJ, "Aircraft Structures", 2<sup>nd</sup> Edition, McGraw-Hill, New York, 1993.
5. Rivello, RM, "Theory and Analysis of Flight Structures", McGraw-Hill, N.Y., 1993.
6. Sun. CT, "Mechanics of Aircraft Structures", Wiley publishers, 2<sup>nd</sup> edition, 2006.

AS5103

SPACE VEHICLE AERODYNAMICS

L T P C  
4 0 0 4

## COURSE OBJECTIVES:

This course will enable students to

1. Gain knowledge on the basics of low speed aerodynamics
2. Learn the physics involved in compressible flows.
3. Provide enough knowledge on boundary layers and their interactions.
4. Impart knowledge on the aerodynamic characteristics of missile components.
5. Gain an idea about aerodynamic heating phenomena.

<b>UNIT I</b>	<b>BASICS OF INCOMPRESSIBLE FLOW</b>	<b>12</b>
Aerodynamic forces and moments - Centre of pressure - Aerodynamic centre - Continuity equation - Momentum equation - Stream function - Potential function - Elementary flows - Flow over cylinder, sphere and cones.		
<b>UNIT II</b>	<b>COMPRESSIBLE FLOWS</b>	<b>12</b>
Compressibility - Speed of sound - Normal shock - Oblique shock - Expansion fan - Variable area ducts - Unsteady shock waves - Fanno flow - Rayleigh flow - Wave drag- Crocco's Theorem - Method of characteristics.		
<b>UNIT III</b>	<b>BOUNDARY LAYER THEORY</b>	<b>12</b>
Boundary layer thickness - Displacement thickness - Momentum thickness - Laminar boundary layer - Turbulent boundary layer - Blasius solution - Skin friction drag estimation - Shock wave-boundary layer interactions.		
<b>UNIT IV</b>	<b>AERODYNAMIC CHARACTERISTICS OF MISSILES</b>	<b>12</b>
Airframe components of missiles - Forebody shapes - Prediction of component characteristics - Wing planform for missiles Delta wing - Vortex break down - Compressibility effect on delta wing - Wing-body interference effects - Transonic and Supersonic drag reduction methods - Fin drag - Body drag.		
<b>UNIT V</b>	<b>AERODYNAMIC HEATING</b>	<b>12</b>
Heat transfer process - Basic parameters in aerodynamic heating - Reference temperature method - Aerodynamic heating on conical surfaces - Variable entropy effects - Heat transfer across junctures - Non isothermal wall effects - Swept shock interactions - Application of methodology in practical missile design.		

**TOTAL: 60 PERIODS**

## COURSE OUTCOMES:

At the end of the course, students will

- CO1:** Have through knowledge on the concepts of incompressible aerodynamics.
- CO2:** Be able to analyse practical problems involving Fanno and Rayleigh flow.
- CO3:** Have knowledge on the concepts of laminar and turbulent boundary layer flows and their interaction with shock waves.

*Attested*



**CO4:** Able to demonstrate and analyse different configurations of missiles and their characteristics.

**CO5:** Be able to design efficient re-entry vehicles by solving the problem of aerodynamic heating.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	✓	✓	✓		✓		✓					
<b>CO2</b>	✓	✓	✓	✓		✓						✓
<b>CO3</b>	✓	✓	✓	✓	✓	✓	✓					✓
<b>CO4</b>	✓	✓	✓	✓	✓			✓	✓			✓
<b>CO5</b>	✓	✓	✓	✓			✓	✓				

**REFERENCES:**

1. Anderson, JD, "Fundamentals of Aerodynamics", McGraw-Hill Book Co, 2010.
2. Chin SS, "Missile Configuration Design", Mc GrawHill, 1961.
3. Hermann Schlichting, "Boundary Layer Theory", Springer, 8<sup>th</sup> edition, 2000.
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5. Nielson, Jack N, Stever, Gutford, "Missile Aerodynamics", McGraw Hill, 1960.

**RM5151**

**RESEARCH METHODOLOGY AND IPR**

**L T P C**  
**2 0 0 2**

**COURSE OBJECTIVES:**

To impart knowledge and skills required for research and IPR:

- Problem formulation, analysis and solutions.
- Technical paper writing / presentation without violating professional ethics
- Patent drafting and filing patents.

**UNIT I RESEARCH PROBLEM FORMULATION**

**6**

Meaning of research problem- Sources of research problem, criteria characteristics of a good research problem, errors in selecting a research problem, scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, necessary instrumentations

**UNIT II LITERATURE REVIEW**

**6**

Effective literature studies approaches, analysis, plagiarism, and research ethics.

**UNIT III TECHNICAL WRITING /PRESENTATION**

**6**

Effective technical writing, how to write report, paper, developing a research proposal, format of research proposal, a presentation and assessment by a review committee.

**UNIT IV INTRODUCTION TO INTELLECTUAL PROPERTY RIGHTS (IPR)**

**6**

Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

**UNIT V INTELLECTUAL PROPERTY RIGHTS (IPR)**

**6**

Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications. New Developments in IPR: Administration of Patent System, IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

**TOTAL: 30 PERIODS**

## COURSE OUTCOMES:

1. Ability to formulate research problem
2. Ability to carry out research analysis
3. Ability to follow research ethics
4. Ability to understand that today's world is controlled by Computer, Information Technology, but tomorrow world will be ruled by ideas, concept, and creativity
5. Ability to understand about IPR and filing patents in R & D.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓										
CO2	✓											
CO3	✓							✓				
CO4	✓				✓							
CO5	✓					✓						✓

## REFERENCES:

1. Asimov, "Introduction to Design", Prentice Hall, 1962.
2. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007.
3. Mayall, "Industrial Design", McGraw Hill, 1992.
4. Niebel, "Product Design", McGraw Hill, 1974.
5. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for beginners" 2010

**AS5111 LAUNCH VEHICLE AERODYNAMICS LABORATORY**

**L T P C**  
**0 0 4 2**

## COURSE OBJECTIVES:

This laboratory course will enables students

1. To get exposure with a practical knowledge on various aerodynamic principles related to inviscid incompressible fluids.
2. To have a practical exposure on Aerodynamic measurement techniques.
3. To do testing of sub systems and components of aircraft at low speed.
4. To measure force and moments on missile models.
5. To calibrate subsonic and supersonic wind tunnels.

## LIST OF EXPERIMENTS:

1. Calibration of subsonic wind tunnel
2. Pressure distribution on a swept wing model
3. Pressure distribution on nose cone model at subsonic speeds
4. Pressure distribution on a sphere model
5. Force and moment measurements on D model using wind tunnel balance
6. Base drag measurements on missile model
7. Pressure distribution on backward step model
8. Thermal boundary layer measurements over a flat plate
9. Calibration of supersonic wind tunnel
10. Wall pressure measurements over a circular cone in a Supersonic flow
11. Wall pressure measurements on a semi wedge in a supersonic flow
12. Flow visualization of a bow shock in front of a bluff body
13. Flow visualization of shock boundary layer interaction
14. Wall pressure measurements in single expansion ramp nozzle

**TOTAL: 60 PERIODS**

Any 10 Experiments will be conducted.

*Attested*

  
**DIRECTOR**  
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Anna University, Chennai-600 025

**COURSE OUTCOMES:**

Upon completion of this course, students will be able

- CO1:** To operate and calibrate subsonic and supersonic wind tunnel
- CO2:** To comprehend the pressure distribution over the streamlined and bluff bodies.
- CO3:** To measure force and moments on aircraft models
- CO4:** To measure boundary layer thickness for various models
- CO5:** To carry out flow visualization at subsonic speeds.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	✓	✓		✓			✓		✓			✓
<b>CO2</b>	✓	✓	✓		✓				✓			
<b>CO3</b>	✓	✓	✓	✓					✓			
<b>CO4</b>	✓	✓	✓	✓	✓				✓			✓
<b>CO5</b>	✓	✓		✓	✓	✓			✓			✓

**LABORATORY EQUIPMENTS REQUIREMENTS**

1. Subsonic wind tunnel
2. Supersonic wind tunnel
3. Wind tunnel balance
4. Schlieren system
5. Pressure Transducers/ pressure scanner
6. Models for testing cone, wedge, bluff body, swept wing, missile, D model and SERN.

**AS5112****SPACE PROPULSION LABORATORY**
**L T P C**  
**0 0 4 2**
**COURSE OBJECTIVES:**

This course will enable students to

1. Visualize the shock pattern in supersonic flows
2. Provides an idea of wall pressure distribution on subsonic and supersonic inlets and nozzles.
3. Perform testing on compressor blades and basic knowledge on cold flow studies.
4. Develop ability to analyze and interpret the experimental data using software.
5. Perform experiments on cavity models.

**LIST OF EXPERIMENTS:**

1. Flow visualization of a secondary injection in a supersonic flow
2. Flow visualization of shock system in front of a supersonic inlet
3. Wall pressure measurements in a supersonic nozzle
4. Wall pressure measurements in a supersonic diffuser
5. Total pressure measurements in the radial direction of a supersonic circular jet
6. Total pressure measurements along the jet axis of a circular supersonic jet
7. Cold flow studies of a wake region behind flame holders
8. Wall pressure measurements of a noncircular combustor
9. Wall pressure measurements of a subsonic diffuser
10. Cascade testing of compressor blades.
11. Pressure distribution on cavity model with injections.

**TOTAL: 60 PERIODS**

## COURSE OUTCOMES:

At the end of the course, student will be able

- CO1:** To perform wall pressure distribution on subsonic and supersonic nozzles
- CO2:** To acquire knowledge on fundamental concepts of low speed and high speed jets and experimental techniques pertains to measurements.
- CO3:** To gain adequate knowledge on pressure distribution on cavity models
- CO4:** To have exposure on wake survey methods.
- CO5:** To carry out flow visualization at supersonic speeds.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	✓	✓	✓						✓			
<b>CO2</b>	✓	✓	✓	✓	✓		✓		✓			✓
<b>CO3</b>	✓	✓	✓		✓				✓			✓
<b>CO4</b>	✓	✓	✓				✓		✓			
<b>CO5</b>	✓	✓	✓	✓	✓		✓		✓			✓

## LABORATORY EQUIPMENTS REQUIREMENTS

1. Supersonic nozzle and supersonic diffuser
2. Total pressure probes
3. Symmetrical Cambered aerofoil
4. Models of flame holders and non circular combustor
5. Traversing mechanism (at least 2-D)
6. Pressure Transducers/ pressure scanner
7. Cascade model for compressor blades
8. Multitube manometers

**AS5251**

**HYPERSONIC AERODYNAMICS**

**L T P C**  
**3 0 0 3**

## COURSE OBJECTIVES:

This course will enables students

1. To realise the importance of studying the peculiar hypersonic speed flow characteristics pertaining to flight vehicles.
2. To provide knowledge on various surface inclination methods for hypersonic inviscid flows.
3. To arrive at the approximate solution methods for hypersonic flows.
4. To impart knowledge on hypersonic viscous interactions.
5. To impart knowledge on the effect on aerodynamic heating on hypersonic vehicles.

### UNIT I INTRODUCTION TO HYPERSONIC AERODYNAMICS

**9**

Peculiarities of Hypersonic flows - Thin shock layers – entropy layers – low density and high density flows – hypersonic flight similarity parameters – shock wave and expansion wave relations of inviscid hypersonic flows – velocity vs altitude map for hypersonic vehicles.

### UNIT II SURFACE INCLINATION METHODS FOR HYPERSONIC INVISCID FLOWS

**8**

Local surface inclination methods – modified Newtonian Law – Newtonian theory – tangent wedge tangent cone and shock expansion methods – Calculation of surface flow properties – practical application of surface inclination methods – hypersonic independence principle.

**UNIT III APPROXIMATE METHODS FOR INVISCID HYPERSONIC FLOWS 10**

Assumptions in approximate methods hypersonic small disturbance equation and theory – Maslen’s theory– blast wave theory – hypersonic equivalence principle- entropy effects - rotational method of characteristics - hypersonic shock wave shapes and correlations.

**UNIT IV VISCOUS HYPERSONIC FLOW THEORY 10**

Peculiarities of hypersonic boundary layers - boundary layer equations r – hypersonic boundary layer theory and non similar hypersonic boundary layers – hypersonic aerodynamic heating and entropy layers effects on aerodynamic heating – heat flux and skin friction estimation.

**UNIT V VISCOUS INTERACTIONS AND TRANSITION 8**

Strong and weak viscous interactions – hypersonic shockwaves and boundary layer interactions – Parameters affecting hypersonic boundary layer transition - Estimation of hypersonic boundary layer transition- Role of similarity parameter for laminar viscous interactions in hypersonic viscous flow.

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES:**

Upon completion of the course, students will

- CO1:** Be able to arrive at the solution for problems involving inviscid and viscous hypersonic flows.
- CO2:** Have thorough knowledge on high temperature effects in hypersonic aerodynamics.
- CO3:** Be able to arrive at various solution methods to overcome aerodynamic heating problem on hypersonic vehicles.
- CO4:** To gain ideas on the design issues associated with hypersonic vehicles.
- CO5:** Able to realize the importance and use of the relevant equations for viscous hypersonic flows.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	✓	✓	✓	✓	✓		✓					✓
<b>CO2</b>	✓	✓	✓	✓			✓	✓				
<b>CO3</b>	✓	✓	✓	✓	✓		✓	✓	✓			✓
<b>CO4</b>	✓	✓	✓	✓	✓		✓			✓		
<b>CO5</b>	✓	✓	✓	✓			✓					✓

**REFERENCES:**

1. Anderson, JD, “Hypersonic and High Temperature Gas Dynamics”, AIAA Education Series, 2<sup>nd</sup> edition, 2006.
2. Anderson, JD, “Modern compressible flow: with Historical Perspective”, McGraw Hill Education, 3<sup>rd</sup> edition, 2017.
3. William H. Heiser and David T. Pratt, Hypersonic Air Breathing propulsion, AIAA Education Series, 1994.
4. John T. Bertin, Hypersonic Aerothermodynamics, AIAA Education Series, 1993.

*Attested*

*[Signature]*

**DIRECTOR**  
Centre for Academic Courses  
Anna University, Chennai-600 025

**COURSE OBJECTIVES:**

This course will enable students

1. To have a basic knowledge on the peculiarities of space environment and to realize the importance of manned space missions.
2. To get introduced with the characteristics of various orbits and the importance of orbital elements.
3. To get familiarize with the basic aspects of satellite injection and the types of satellite perturbations.
4. To compute trajectory for interplanetary travel and flight of ballistic missiles based on the fundamental concepts of orbital mechanics.
5. To provide basic knowledge on the ballistic missile trajectories.

**UNIT I SPACE ENVIRONMENT****12**

Peculiarities of space environment and its description– effect of space environment on materials of spacecraft structure and astronauts- manned space missions – effect on satellite life time.

**UNIT II CHARACTERISTICS OF VARIOUS ORBITS****12**

Properties of elliptic, Parabolic and hyperbolic properties in terms of orbital elements – relations between position and time – Barker's theorem – Whittaker's theory – Sphere of influence.

**UNIT III SATELLITE INJECTION AND SATELLITE PERTURBATIONS****12**

General aspects of satellite injection – satellite orbit transfer – various cases – orbit deviations due to injection errors – special and general perturbations – Cowell's method and Enake's method – method of variations of orbital elements – general perturbations approach.

**UNIT IV INTERPLANETARY TRAJECTORIES****12**

Two-dimensional interplanetary trajectories – fast interplanetary trajectories – three dimensional interplanetary trajectories – launch of interplanetary spacecraft – trajectory estimation about the target planet – concept of sphere of influence – Lambert's theorem.

**UNIT V BALLISTIC MISSILE TRAJECTORIES****12**

Introduction to ballistic missile trajectories – boost phase – the ballistic phase – trajectory geometry – optimal flights – time of flight – re-entry phase – the position of impact point – influence coefficients.

**TOTAL: 60 PERIODS****COURSE OUTCOMES:**

At the end of this course, students will be able

- CO1:** To acquire knowledge on the peculiarities of space environment and its effect on spacecraft materials.
- CO2:** To estimate the time and position of an object in various orbits.
- CO3:** To acquire knowledge on the basic concepts of satellite injection and satellite perturbations.
- CO4:** To calculate orbital parameters and to perform conceptual trajectory designs for geocentric or interplanetary missions.
- CO5:** To estimate the time of flight and the position of impact point of ballistic missiles.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓			✓				✓	✓
CO2	✓	✓	✓		✓	✓	✓	✓			✓	
CO3	✓	✓	✓	✓		✓	✓					✓
CO4	✓	✓	✓		✓	✓	✓					✓
CO5	✓	✓	✓	✓	✓	✓	✓	✓				

## REFERENCES:

1. Cornelisse, JW, Schoyer, HFR & Wakker, KF, "Rocket Propulsion and Space Dynamics", Pitman Publishing, 1979.
2. Howard D. Curtis, "Orbital Mechanics for Engineering Students", 3<sup>rd</sup> Edition, Butterworth-Heinemann, 2013.
3. Parker, ER, "Materials for Missiles and Spacecraft", Mc.Graw Hill Book Co. Inc., 1982.
4. Suresh. BN & Sivan. K, "Integrated Design for Space Transportation System", Springer India, 2015.
5. Sutton, G.P. "Rocket Propulsion Elements", John Wiley & Sons Inc., New York, 9th Edition, 2016.

AL5251

CFD FOR AEROSPACE APPLICATIONS

L T P C  
3 0 0 3

## COURSE OBJECTIVES:

This course will make the students

1. To get familiarize with the procedure to obtain numerical solution to fluid dynamic problems.
2. To gain knowledge on the important aspects of grid generation for practical problems.
3. To get exposure on time dependant and panel methods.
4. To learn the techniques pertaining to transonic small perturbation force.
5. To make use of commercial CFD software for aerospace applications.

## UNIT I NUMERICAL SOLUTIONS OF SOME FLUID DYNAMICAL PROBLEMS 9

Basic fluid dynamics equations, Equations in general orthogonal coordinate system, Body fitted coordinate systems, mathematical properties of fluid dynamic equations and classification of partial differential equations - Finding solution of a simple gas dynamic problem, Local similar solutions of boundary layer equations, Numerical integration and shooting technique. Numerical solution for CD nozzle isentropic flows and local similar solutions of boundary layer equations- Panel methods.

## UNIT II GRID GENERATION 9

Need for grid generation – Various grid generation techniques – Algebraic, conformal and numerical grid generation – importance of grid control functions – boundary point control – orthogonality of grid lines at boundaries. Elliptic grid generation using Laplace's equations for geometries like aerofoil and CD nozzle. Unstructured grids, Cartesian grids, hybrid grids, grid around typical 2D and 3D geometries – Overlapping grids – Grids around multi bodies.

## UNIT III TIME DEPENDENT METHODS 9

Stability of solution, Explicit methods, Time split methods, Approximate factorization scheme, Unsteady transonic flow around airfoils. Some time dependent solutions of gas dynamic problems. Numerical solution of unsteady 2-D heat conduction problems using SLOR methods.

## UNIT IV FINITE VOLUME METHOD 9

Introduction to Finite volume Method - Different Flux evaluation schemes, central, upwind and hybrid schemes - Staggered grid approach - Pressure-Velocity coupling - SIMPLE, SIMPLER algorithms- pressure correction equation (both incompressible and compressible forms) - Application of Finite Volume Method -artificial diffusion.

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**UNIT V CFD FOR INDUSTRIAL APPLICATIONS****9**

Various levels of approximation of flow equations, turbulence modelling for viscous flows, verification and validation of CFD code, application of CFD tools to 2D and 3D configurations. CFD for kinetic heating analysis – Coupling of CFD code with heat conduction code, Unsteady flows – Grid movement method, Oscillating geometries, Computational aeroelasticity – Coupling of CFD with structural model – Aeroelasticity of airfoil geometry, Introduction to commercial CFD software for aerospace applications, High performance computing for CFD applications – Parallelization of codes –domain decomposition.

**TOTAL: 60 PERIODS****COURSE OUTCOMES:**

At the end of this course, students will be able

**CO1:** To arrive at the numerical solutions to boundary layer equations.

**CO2:** To perform numerical grid generation and have knowledge about the mapping techniques.

**CO3:** To familiarise himself/herself with high performance computing for CFD applications.

**CO4:** To implement the explicit time dependent methods and their factorization schemes.

**CO5:** To do the stability analysis and linearization of the implicit methods.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	✓	✓	✓	✓	✓	✓						
<b>CO2</b>	✓	✓	✓	✓	✓				✓			✓
<b>CO3</b>	✓	✓	✓	✓	✓			✓				✓
<b>CO4</b>	✓	✓	✓	✓	✓							✓
<b>CO5</b>	✓	✓	✓	✓	✓		✓					

**REFERENCES:**

1. Bose. TK, "Numerical Fluid Dynamics", Narosa Publishing House, 2001.
2. Chung. TJ, "Computational Fluid Dynamics", Cambridge University Press, 2010.
3. Hirsch,AA, "Introduction to Computational Fluid Dynamics", McGraw-Hill, 1989.
4. John D. Anderson, "Computational Fluid Dynamics", McGraw Hill Education, 2017.
5. Sedat Biringen & Chuen-Yen Chow, "Introduction to Computational Fluid Dynamics by Example", Wiley publishers, 2<sup>nd</sup> edition, 2011.
6. Wirz, HJ & Smeldern, JJ, "Numerical Methods in Fluid Dynamics", McGraw-Hill & Co., 1978.

**AS5211****AEROSPACE STRUCTURES LABORATORY****L T P C****0 0 4 2****COURSE OBJECTIVES:**

This laboratory course will make students

1. To impart practical knowledge on calibration of photoelastic materials.
2. To determine the elastic constant for composite lamina,
3. To find the symmetrical and unsymmetrical bending of beams.
4. To determine the shear centre locations for closed and open sections.
5. To find the buckling of columns with different end conditions.

**LIST OF EXPERIMENTS:**

1. Symmetrical & Unsymmetrical Bending of Beams
2. Buckling of Columns with Different End Conditions
3. Shear Centre Location of Thin-Walled Beams
4. Influence Coefficients & Flexibility Matrix Determination
5. Stresses Due to Combined Loading
6. Calibration of Photo Elastic Materials / Experiments in Photoelasticity
7. Experimental Modal Analysis / Free Vibration Tests
8. Resonance Testing of Structural Parts

*Attested*

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9. Fabrication of Composite Laminates
10. Mechanical Testing & Characterization of Composite Material
11. Non-Destructive Characterization of Materials
12. Non-Destructive Evaluation of Flaws using Acoustic Emission / Ultrasonics
13. Modelling and Static Analysis of an Aircraft Component using FE software
14. Fatigue Testing and Inspection of Failure Surface

**NOTE:** Any TEN experiments will be conducted out of 14.

**TOTAL: 60 PERIODS**

**COURSE OUTCOMES:**

Upon completion of this course, a student will be able

- CO1:** To conduct tests on beams and columns.
- CO2:** To design an experimental evaluation technique for a given application.
- CO3:** To carry out non-destructive testing.
- CO4:** To fabricate a composite laminate and characterize it.  
To carry out structural analysis using finite element software.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	✓	✓	✓						✓			
<b>CO2</b>	✓	✓	✓		✓	✓			✓			✓
<b>CO3</b>	✓	✓	✓		✓	✓			✓			✓
<b>CO4</b>	✓	✓	✓		✓				✓			✓
<b>CO5</b>	✓	✓	✓						✓			

**LABORATORY EQUIPMENTS REQUIREMENTS**

1. Constant strength beam setup
2. Column setup
3. Unsymmetrical Bending setup
4. Experimental setup for location of shear centre (open & close section)
5. Cantilever beam setup
6. Experimental setup for bending and torsional loads
7. Diffuser transmission type polariscope with accessories
8. Experimental setup for vibration of beams
9. Universal Testing Machine
10. Wagner beam setup



**AL5261**

**COMPUTATION LABORATORY**  
**(Consists of FEM & CFD experiments)**

**L T P C**  
**0 0 4 2**

**COURSE OBJECTIVES:**

1. This course is intended to make students familiar with different types of structural analysis using finite element software
2. This course helps students to correctly interpret the results of simulation.
3. To equip with the knowledge base essential for application of computational fluid dynamics to engineering flow problems.
4. To provide the essential numerical background for solving the partial differential equations governing the fluid flow.
5. To develop students' skills of using a commercial software package

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## EXPERIMENTS IN FEM

### LIST OF EXPERIMENTS:

1. Static analysis of a uniform bar subject to different loads -1-D element
2. Thermal stresses in a uniform and tapered member - 1-D element
3. Static analysis of trusses / frames under different loads
4. Stress analysis & deformation of a beam using 1-D element & 2-D – incorporation of discrete, distributed, and user-defined loads
5. Static analysis of a beam with additional spring support
6. Stress concentration in an infinite plate with a small hole
7. Bending of a plate with different support conditions
8. Stability analysis of a plate under in-plane loads
9. Buckling of solid and thin-walled columns under different end conditions
10. Free vibration analysis of a bar / beam
11. Forced response of a bar / beam under harmonic excitation
12. Heat transfer analysis using 1-D & 2-D elements - conduction and convection
13. Modelling and analysis of a laminated plate
14. Impact analysis of a laminated plate

## EXPERIMENTS IN CFD

### LIST OF EXPERIMENTS:

1. Numerical simulation of 1-D diffusion and conduction in fluid flows
2. Numerical simulation of 1-D convection-diffusion problems
3. Numerical simulation of 2-D unsteady state heat conduction problem
4. Numerical simulation of 2-D diffusion and 1-D convection combined problems
5. Structured grid generation over airfoil section
6. 3-D numerical simulation of flow through CD nozzles
7. 3-D numerical simulation of flow development of a subsonic and supersonic jets
8. Numerical simulation of boundary layer development
9. Numerical simulation of subsonic combustion in a ramjet combustor
10. Numerical simulation of transonic flow over airfoils

(note) Experiments 6-10 can be done by using CFD Software tools

**TOTAL: 60 PERIODS**

### COURSE OUTCOMES:

At the end of this course, students will be

**CO1:** Able to get solution of aerodynamic flows.

**CO2:** Able to perform stability analysis of structural components.

**CO3:** To define and setup flow problem properly within CFD context, performing solid modelling using CAD package and producing grids via meshing tool.

**CO4:** Able to comprehend both flow physics and mathematical properties of governing Navier-Stokes equations and define proper boundary conditions for solution.


**CO5:** Able to use CFD software to model relevant engineering flow problems.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓				✓			
CO2	✓	✓	✓	✓	✓				✓			✓
CO3	✓	✓	✓	✓	✓	✓			✓			✓
CO4	✓	✓	✓	✓	✓				✓		✓	✓
CO5	✓	✓	✓	✓	✓				✓			✓

### LABORATORY EQUIPMENTS REQUIREMENTS

1. Desktop computers
2. MS visual C++
3. CFD software

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**AS5212**

**MINI PROJECT WITH SEMINAR**

**L T P C**  
**0 0 4 2**

Seminar is to be given by the student after the completion of a mini project chosen by the student. Topics for the mini projects can be from the aeronautical engineering and allied fields. The mini project can be based on either numerical or analytical solution or design or fully experimental; or a combination of these tasks.

**AS5072**

**ELEMENTS OF SATELLITE TECHNOLOGY**

**L T P C**  
**3 0 0 3**

**COURSE OBJECTIVES:**

This course will make students

1. To learn the satellite mission and configurations,
2. To have an basic idea on power system of satellites
3. To learn the attitude and orbit control systems of satellites.
4. To gain knowledge on basic of propulsion systems, structures, and thermal controls involved in satellites.
5. To learn the basic aspects of telemetry systems.

**UNIT I SATELLITE MISSION AND CONFIGURATION 9**

Mission Overview – Requirements for different missions – Space Environment, Spacecraft configuration-Spacecraft Bus–Payload–Requirements and constraints– Initial configuration decisions and Trade-offs–Spacecraft configuration process– Broad design of Spacecraft Bus–Subsystem layout–Types of Satellites–Constellations– Applications.

**UNIT II POWER SYSTEM 8**

Power sources–Energy storage–Solar panels–Deployable solar panels–Spacecraft Power management –Power distribution–Deep Space Probes.

**UNIT III ATTITUDE AND ORBIT CONTROL SYSTEM (AOCS) 9**

Coordinate system –AOCS requirements–Environment effects – Attitude stabilization – Attitude sensors –Actuators–Design of control algorithms.

**UNIT IV PROPULSION SYSTEMS, STRUCTURES AND THERMAL CONTROL 10**

Systems Trade-off–Mono-propellant systems –Thermal consideration–System integration design factors – Pre-flight test requirements–System reliability Configuration design of Spacecraft structure– Structural elements–Material selection–Environmental Loads–Vibrations– Structural fabrication– Orbital environments -Average temperature in Space–Transient temperature evaluation– Thermal control techniques– Temperature calculation for a spacecraft– Thermal design and analysis program structure –Thermal design verification–Active thermal control techniques.

**UNIT V TELEMETRY SYSTEMS 9**

Base Band Telemetry system– Modulation– TT & CRF system–Telecommand system–Ground Control Systems

**TOTAL: 45 PERIODS**

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**COURSE OUTCOMES:**

Upon completion of this course, Students will

**CO1:** Be able to describe the main components of a satellite and its importance.

**CO2:** Compare the merits and demerits of various power systems used.

**CO3:** Be able to learn the dynamics of the satellite.

**CO4:** Be able to study the design of propulsion systems, structures needed for satellites.

**CO5:** Acquire knowledge on satellite orbit control and telemetry systems.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	✓	✓	✓		✓	✓	✓		✓			✓
<b>CO2</b>	✓	✓	✓			✓					✓	
<b>CO3</b>	✓	✓			✓		✓					✓
<b>CO4</b>	✓	✓	✓	✓	✓	✓		✓				
<b>CO5</b>	✓	✓					✓					✓

**REFERENCES:**

1. James R.Wertz, "Spacecraft Attitude Determination and Control", Kluwer Academic Publisher, 1988.
2. James R Wertz & Wiley J. Larsen, "Space Mission Analysis and Design", (Space Technology Library, Vol. 8, Microcosm Publisher, 1999.
3. Marcel J.Sidi, "Spacecraft Dynamics and Control- A Practical Engineering Approach", Cambridge University press, 2000.
4. Lecture notes on "Satellite Architecture", ISRO Satellite Centre Bangalore-560017.

**AS5001****CRYOGENIC TECHNOLOGY****L T P C  
3 0 0 3****COURSE OBJECTIVES:**

This course will enable students

1. To learn various thermodynamic cycles for cryogenic plants.
2. To analyse the problems associated with a cryopropellants.
3. To calculate the efficiencies of cryogenic systems.
4. To gain knowledge on the various cycles of cryogenic plants.
5. To compare the performance of cryogenic engines with non-cryogenic engines.

**UNIT I FUNDAMENTALS OF CRYOGENICS****10**

Theory behind the production of low temperature - expansion engine - heat exchangers - Cascade process - Joule Thomson and magnetic effects - cryogenic liquids as cryogenic propellants for cryogenic rocket engines - properties of various cryogenic propellants - handling problems associated with cryogenic propellants.

**UNIT II CRYOGENIC SYSTEMS EFFICIENCY****8**

Types of losses and efficiency of cycles - amount of cooling - the features of liquefaction process - cooling coefficient of performance - Thermodynamic efficiency - The energy balancing method.

**UNIT III THERMODYNAMIC CYCLES FOR CRYOGENIC PLANTS****8**

Classification of cryogenic cycles - The structure of cycles Throttle expansion cycles - Expander cycles - Mixed throttle expansion and expander cycles - Thermodynamic analysis - Numerical problems.

*Attested*

**UNIT IV PROBLEMS ASSOCIATED WITH CRYOPROPELLANTS 10**

Storage problems of cryogenic propellants - zero gravity problems associated with cryopropellants - phenomenon of tank collapse - geysering effect - material strength considerations.

**UNIT V CRYOGENIC ROCKET ENGINES 9**

Peculiar design difficulties associated with the design of feed system, injector and thrust chamber of cryogenic rocket engines - Relative performance of cryogenic engines when compared to non-cryo engines.

**TOTAL: 45 PERIODS****COURSE OUTCOMES:**

Upon completion of this course, Students will be able

**CO1:** To acquire knowledge on the fundamental requirements that are peculiar to cryogenic rocket engines.

**CO2:** To determine the thermodynamic efficiency of cryogenic systems.

**CO3:** To carry out thermodynamic analysis for cryogenic plants.

**CO4:** To demonstrate the peculiar problems associated with cryopropellants.

**CO5:** To acquire knowledge on cryogenic propulsion systems

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓		✓		✓		✓			
CO2	✓	✓	✓	✓		✓	✓	✓				✓
CO3	✓	✓	✓	✓	✓	✓	✓	✓				✓
CO4	✓	✓	✓	✓				✓	✓			✓
CO5	✓	✓	✓	✓	✓			✓	✓			

**REFERENCES:**

1. Barron.RF, "Cryogenic systems", Oxford University, 1985.
2. Dieter K. Huzel & David H. Huang, "Modern Engineering for Design of Liquid-Propellant Rocket Engines", AIAA Series, 1992.
3. Haseldom.G, "Cryogenic Fundamentals", Academic press, 2001.
4. Sarner.S.F, "Propellant Chemistry", Reinhold Publishing Corporation New York, 1966.
5. Sutton, G.P. "Rocket Propulsion Elements", John Wiley & Sons Inc., New York, 9<sup>th</sup> edition, 2016.

**AS5002****EXPERIMENTAL TECHNIQUES****L T P C  
3 0 0 3****COURSE OBJECTIVES:**

This course will enable students

1. To learn the basic concepts on measurements.
2. To have an idea on electrical strain strain gages and its circuits.
3. To calibrate low speed and high speed wind tunnels,
4. To calculate power losses in wind tunnels
5. To gain knowledge on various flow visualization techniques.

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**UNIT I BASIC CONCEPTS 9**

Stresses, Strains and Displacements - Determination of Principal Values of Stresses and Strains in 2-D & 3-D - Maximum Shear Stress - Strain Measurement Using Mechanical Extensometers - Principles of Measurements - Basic Characteristics and Requirements of a Measuring System – Sources of error - Statistical Analysis of Experimental Data - Non-Contact Measurement.

**UNIT II ELECTRICAL-RESISTANCE STRAIN GAGES 9**

Strain Sensitivity in Metallic Alloys - Gage Construction - Gage Sensitivities and Gage Factor - Performance Characteristics of Foil Strain Gages - Environmental Effects - The Three-Element Rectangular Rosette - Corrections for Transverse Strain Effects – Other Types of Strain Gages - Semiconductor Strain Gages – Grid & Brittle Coating Methods of Strain Analysis.

**UNIT III STRAIN-GAGE CIRCUITS & INSTRUMENTATION 9**

The Potentiometer Circuit and Its Application to Strain Measurement – Variants From The Basic Potentiometer Circuit – Circuit Output - The Wheatstone Bridge Constant Current and Constant Voltage Circuits – Circuit Sensitivity – Calibrating Strain-Gage Circuits - Effects of Lead Wires and Switches - Electrical Noise Reduction – Strain Measurement in Bars, Beams and Shafts.

**UNIT IV WIND TUNNEL MEASUREMENTS 10**

Objective of experimental studies, Types of wind tunnels, Low speed tunnel, Energy ratio, Power losses in a wind tunnel – Calibration of subsonic wind tunnels - Speed Setting - Flow Direction – Three-Hole and Five-Hole Yaw Probes - Turbulence - Transonic wind tunnel – Transonic Test Section - Supersonic wind tunnels – Losses in Supersonic Tunnels – Supersonic Wind Tunnel Diffusers - Effects of Second Throat – Runtime calculation - Calculating Air Flow Rates - Calibration of Supersonic Wind Tunnels – Hypersonic wind tunnel and Calibration -Wind tunnel balance – Water tunnel.

**UNIT V FLOW VISUALIZATION TECHNIQUES 8**

Visualization techniques – Smoke tunnel – Dye Injection - Bubble Techniques – Surface Flow Visualization techniques – oil – Tufts - China Clay - Ultraviolet Fluorescence Photography - Interferometer – Fringe-Displacement method – Shadowgraph - Schlieren system – Background Oriented Schlieren (BOS) system - Laser sheet flow visualization.

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES:**

Upon completion of this course, students will be able

- CO1:** To identify the types of errors involved in measurements.
- CO2:** To analyse the strain gage circuits and can perform tests.
- CO3:** To characterize the performance of electrical strain gages
- CO4:** To perform various test using wind tunnels
- CO5:** To demonstrate various flow visualization techniques.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓				✓			✓
CO2	✓	✓		✓			✓		✓			
CO3	✓	✓		✓	✓	✓						✓
CO4	✓	✓	✓	✓			✓		✓			✓
CO5	✓	✓	✓	✓	✓	✓	✓					

**REFERENCES:**

1. Allan Pope and Kenneth L Goin, “High Speed Wind Tunnel Testing”, Krieger Publishing Company, 1978.
2. James W. Dally, William F. Riley, “Experimental Stress Analysis”, McGraw-Hill College, 1991.

*Attested*

3. James F. Doyle and James W. Phillips, "Manual on Experimental Stress Analysis", 5<sup>th</sup> Edition, Society for Experimental Mechanics, 1989.
4. Rathakrishnan, E., "Instrumentation, Measurements, and Experiments in Fluids", CRC Press – Taylor & Francis, 2007.
5. Robert B Northrop, "Introduction to Instrumentation and Measurements", Second Edition, CRC Press, Taylor & Francis, 2006.
6. Sharpe Jr, William N, "Handbook of Experimental Solid Mechanics", Springer, 2008.

**AS5003**

**FUNDAMENTALS OF COMBUSTION**

**L T P C**  
**3 0 0 3**

**COURSE OBJECTIVES:**

This course will enable students

1. To impart knowledge to students on basic fuel and oxidizer characteristics.
2. To impart the concept of various governing equation and role of chemical kinetic in combustion process.
3. To make the students to understand various kinds flame and factors affecting flame.
4. The concept of diffusion flames.
5. Application of calculation in the field of Aerospace engineering.

**UNIT I THERMODYNAMICS OF COMBUSTION 9**

Combustion, types of fuels and oxidizers, calorific value measurements, flash point, fire point, smoke point, specific gravity, auto ignition temperature, Proximate analysis, ultimate analysis, Ideal gas law, gas mixture, sensible enthalpy, stoichiometry, equivalence ratio, heat of reaction, heat of combustion, heat of formation, adiabatic flame temperature, determination of equilibrium composition.

**UNIT II TRANSPORT PHENOMENA AND CHEMICAL KINETIC OF COMBUSTION 9**

Mass Transfer Rate Laws, Species Conservation, Some Applications of Mass Transfer, Global Versus Elementary Reactions, Rates of Reaction for Multistep Mechanisms, Net Production Rates, Compact Notation, Relation Between Rate Coefficients and Equilibrium Constants, Steady-State Approximation, The Mechanism for unimolecular Reactions, Chain and Chain-Branching Reactions, Chemical Time Scales, Partial Equilibrium, Reduced Mechanisms.

**UNIT III PREMIXED FLAMES 10**

Physical Description, detonation and deflagration, Hugoniot curve, Determination of CJ points, Governing Equations, Boundary Conditions, Structure of CH<sub>4</sub>–Air Flame, Factors Influencing Flame Velocity and Thickness, Flame Speed Correlations, Quenching, Flammability, and Ignition, Quenching by a Cold Wall Flammability Limits Ignition, Flame Stabilization.

**UNIT IV LAMINAR DIFFUSION FLAMES 9**

Non-reacting Constant-Density Laminar Jet, Physical Description, Conservation Laws, Boundary Conditions, Solution, Jet Flame Physical Description, Simplified Theoretical Descriptions, Flame Lengths for Circular-Port and Slot Burners, Roper's Correlations, Flow rate and Geometry Effects, Factors Affecting Stoichiometry, Soot Formation and Destruction Counter flow.

**UNIT V DROPLET EVAPORATION AND BURNING 8**

Simple Model of Droplet Evaporation, Gas-Phase Analysis, Droplet, Simple Model of Droplet Burning, Burning Rate Constant and Droplet, Lifetimes, Extension to Convective Environments, Additional Factors, One-Dimensional Vaporization-Controlled Combustion.

**TOTAL: 45 PERIODS**

## COURSE OUTCOMES:

Upon completion of this course, students will be

- CO1:** Exposed to different kinds of fuel and oxidizer characteristics.
- CO2:** Able to realize basic chemical kinetics and mechanisms behind exothermic reactions.
- CO3:** Exposed to the significance of premixed flames.
- CO4:** To acquire knowledge on characteristics of diffusion flames, soot formations etc.
- CO5:** To familiarize in the field of droplet and evaporation theory.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	✓	✓	✓		✓		✓	✓	✓			✓
<b>CO2</b>	✓	✓	✓		✓		✓					✓
<b>CO3</b>	✓	✓	✓	✓			✓	✓	✓			✓
<b>CO4</b>	✓	✓	✓	✓	✓			✓				✓
<b>CO5</b>	✓	✓	✓				✓	✓	✓			✓

## REFERENCES:

1. Kenneth K.Kuo, "Principles of combustion", John Wiley & sons Inc, 2<sup>nd</sup> edition, 2012.
2. Mishra, DP, "Fundamentals of Combustion", PHI publishers, 2008.
3. Mukunda,HS, "Understanding combustion", Orient Blackswan, 2<sup>nd</sup> edition, 2009.
4. Stephen Turns , "An Introduction to Combustion: Concepts and Applications", McGrawHill, 3<sup>rd</sup> edition, 2017.
5. Vasudevan Raghavan, "Combustion Technology: essentials of flames and burners", Ane Books Pvt. Ltd, 1<sup>st</sup> edition, 2016.

**AS5071**

**COMPUTATIONAL HEAT TRANSFER**

**L T P C**  
**3 0 0 3**

## COURSE OBJECTIVES:

This course will enable students

1. To get insights into the basic aspects of various discretization methods.
2. To provide basic ideas on the types of PDE's and its boundary conditions to arrive at its solution.
3. To impart knowledge on solving conductive, transient conductive and convective problems using computational methods.
4. To solve radiative heat transfer problems using computational methods.
5. To provide a platform for students in developing numerical codes for solving heat transfer problems.

## UNIT I INTRODUCTION

**9**

Finite Difference Method-Introduction-Taylor's series expansion-Discretization Methods Forward, backward and central differencing scheme for first order and second order Derivatives – Types of partial differential equations-Types of errors-Solution to algebraic equation-Direct Method and Indirect Method-Types of boundary condition-FDM - FEM - FVM.

## UNIT II CONDUCTIVE HEAT TRANSFER

**9**

General 3D-heat conduction equation in Cartesian, cylindrical and spherical coordinates. Computation (FDM) of One –dimensional steady state heat conduction –with Heat generation-without Heat generation- 2D-heat conduction problem with different boundary conditions-Numerical treatment for extended surfaces- Numerical treatment for 3D- Heat conduction-Numerical treatment to 1D-steady heat conduction using FEM.

*Attested*



**UNIT III      TRANSIENT HEAT CONDUCTION****9**

Introduction to Implicit, explicit Schemes and Crank-Nicolson Schemes Computation (FDM) of One-dimensional unsteady heat conduction –with heat Generation-without Heat generation - 2D-transient heat conduction problem with different boundary conditions using Implicit, explicit Schemes-Importance of Courant number- Analysis for 1-D,2-D transient heat Conduction problems.

**UNIT IV      CONVECTIVE HEAT TRANSFER****9**

Convection- Numerical treatment (FDM) of steady and unsteady 1-D and 2-d heat convection-diffusion steady-unsteady problems- Computation of thermal and Velocity boundary layer flows. Upwind scheme-Stream function-vorticity approach-Creeping flow.

**UNIT V      RADIATIVE HEAT TRANSFER****9**

Radiation fundamentals-Shape factor calculation-Radiosity method- Absorption Method - Monte Carlo method-Introduction to Finite Volume Method- Numerical treatment of radiation enclosures using finite Volume method. Developing a numerical code for 1D, 2D heat transfer problems.

**TOTAL: 45 PERIODS****COURSE OUTCOMES:**

Upon completion of this course, Students will

**CO1:** Have an Idea about discretization methodologies for solving heat transfer problems.

**CO2:** Be able to solve 2-D conduction and convection problems.

**CO3:** Have an ability to develop solutions for transient heat conduction in simple geometries.

**CO4:** Be capable of arriving at numerical solutions for conduction and radiation heat transfer problems.

**CO5:** Have knowledge on developing numerical codes for practical engineering heat transfer problems.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	✓	✓	✓	✓	✓							
<b>CO2</b>	✓	✓	✓	✓	✓		✓					✓
<b>CO3</b>	✓	✓	✓	✓	✓	✓	✓					✓
<b>CO4</b>	✓	✓	✓	✓	✓							✓
<b>CO5</b>	✓	✓	✓	✓	✓			✓				

**REFERENCES:**

1. Chung,TJ, "Computational Fluid Dynamics", Cambridge University Press, 2002.
2. Holman,JP, "Heat Transfer", McGraw-Hill Book Co, Inc., McGraw-Hill College; 8<sup>th</sup> / Disk edition, 1997.
3. John D. Anderson, "Computational Fluid Dynamics", McGraw Hill Education, 2017.
4. John H. Lienhard, "A Heat Transfer", Text Book, Dover Publications, 4th edition, 2013.
5. Richard H. Pletcher, John C. Tannehill & Dale Anderson, "Computational Fluid Mechanics and Heat Transfer", 3<sup>rd</sup> edition, CRC Press, 2012
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Attested



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**COURSE OBJECTIVES:**

This course will make students

1. To impart knowledge on the basic aspects on the classification of missiles and its aerodynamics characteristics.
2. To provide idea about the missile configurations and preliminary drag estimation.
3. To analyse the aerodynamic characteristics of slender and blunt bodies.
4. To get insight into the basic aspects of launching phase of missiles.
5. To demonstrate the stability aspects of missile configuration and various control methods of missiles.

**UNIT I BASICS ASPECTS OF MISSILE AERODYNAMICS 9**

Classification of missiles-Aerodynamics characteristics and requirements of air to air missiles, air to surface missiles and surface to air missiles-Missile trajectories-fundamental aspects of hypersonic aerodynamics.

**UNIT II MISSILE CONFIGURATIONS AND DRAG ESTIMATION 9**

Various configurations-components-forces on the vehicle during atmospheric flight-nose cone design and drag estimation – Various types of drag and their origin – methods of minimize the drag types.

**UNIT III AERODYNAMICS OF SLENDER AND BLUNT BODIES 9**

Aerodynamics of slender and blunt bodies, wing-body interference effects-Asymmetric flow separation and vortex shedding-unsteady flow characteristics of launch vehicles- determination of aero elastic effects.

**UNIT IV AERODYNAMIC ASPECTS OF LAUNCHING PHASE 9**

Booster separation-cross wind effects-specific considerations in missile launching-missile integration and separation-methods of evaluation and determination- Wind tunnel tests – Comparison with CFD Analysis.

**UNIT V STABILITY AND CONTROL OF MISSILES 9**

Forces and moments acting on missiles-Lateral, rolling and longitudinal moments-missile dispersion-stability aspects of missile configuration-Aerodynamic control methods-Jet control methods-Stability derivatives.

**TOTAL: 45 PERIODS****COURSE OUTCOMES:**

Upon completion of this course, Students will be able

- CO1:** To apply the concepts of high speed aerodynamics on missiles.
- CO2:** To acquire knowledge on aerodynamics characteristics of missiles of various types.
- CO3:** To estimate drag for various missile configurations and methods to reduce it.
- CO4:** To estimate the forces and moments acting on missiles.
- CO5:** To apply slender body aerodynamics knowledge during launching phase and stability and control aspects of missiles.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓		✓						✓
CO2	✓	✓	✓	✓								✓
CO3	✓	✓	✓	✓	✓							✓
CO4	✓	✓	✓		✓	✓	✓	✓				✓
CO5	✓	✓	✓		✓	✓	✓		✓			✓

Attested

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2. Anderson JD, "Modern compressible flow: with Historical Perspective", McGraw Hill Education, 3<sup>rd</sup> edition, 2017.
3. Chin SS, "Missile Configuration Design", McGraw Hill, New York, 1961.
4. Jack Nielson, "Missile Aerodynamics", AIAA; 1<sup>st</sup> edition, 1988.

**AS5005**

**SPACECRAFT ATTITUDE DYNAMICS AND CONTROL**

**L T P C**  
**3 0 0 3**

## COURSE OBJECTIVES:

This course will enable students

1. To get introduced with the basics of attitude sensors and its types.
2. To gain knowledge on the basic principles of operation of thrusters.
3. To learn rigid body dynamics and various disturbing forces in space.
4. To gain in-depth knowledge on attitude stabilization schemes & orbit maneuvers.
5. To be familiar with the concepts of operating principles and design of guidance laws.

### UNIT I ATTITUDE SENSORS

**8**

Relative Attitude sensors – Gyroscopes, Motion reference Units, Absolute Attitude sensors – Horizon sensor, Orbital Gyrocompass, Earth sensors, sun sensors (Digital and analog), star sensor- Magnetometer

### UNIT II CONTROL ACTUATORS

**9**

Fundamental principles of operation of Thrusters- Momentum Wheel-Control Moment Gyros- Reaction wheel- Magnetic Torques- Reaction Jets- Ion Propulsion- Electric propulsion- solar sails

### UNIT III ATTITUDE DYNAMICS, ATTITUDE AND ORBITAL DISTURBANCES

**9**

Rigid Body Dynamics - Flexible body Dynamics - Slosh Dynamics- disturbing forces due to Drag, Solar radiation Pressure and forces - Disturbances due to Celestial bodies

### UNIT IV ATTITUDE STABILIZATION SCHEMES & ORBIT MANEUVERS

**10**

Spin, Dual spin - Gravity gradient - Zero momentum system - Momentum Biased system - Reaction control system - Single and Multiple Impulse orbit Adjustment - Hohmann Transfer- Station Keeping and fuel Budgeting

### UNIT V MISSILE AND LAUNCH VEHICLE GUIDANCE

**9**

Operating principles and design of guidance laws - homing guidance laws- short range - Medium range and BVR missiles - Launch Vehicle- Introduction - Mission requirements- Implicit guidance schemes - Explicit guidance - Q guidance schemes

**TOTAL: 45 PERIODS**

## COURSE OUTCOMES:

Upon completion of this course, students will be able to

**CO1:** Get basic idea on the working principles of attitude sensors and its applications.

**CO2:** Familiarize with control actuators used for satellite applications.

**CO3:** Comprehend the application of rocket vehicle guidance laws.

**CO4:** Demonstrate satellite orbit stabilization schemes and methods of satellite orbit transfer.

**CO5:** Familiarize with orbit manoeuvres of satellites and rocket vehicle guidance. *Attested*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓									
CO2	✓	✓	✓	✓	✓							
CO3	✓	✓	✓	✓					✓			
CO4	✓	✓		✓	✓							
CO5	✓	✓					✓	✓				

#### REFERENCES:

1. Blake Lock, J.H Automatic control of Aircraft and missiles, John Wiley Sons, New York, 1990.
2. James R Wertz, Spacecraft Attitude Determination and control, Reidel Publications.2001.
3. Kaplan M, Modern Spacecraft Dynamics and control, Wiley Press, 1979.
4. Marcel J. Sidi, Spacecraft Dynamics and control, A Practical Engineering Approach, Cambridge University Press.2000.
5. Meyer Rudolph X, Elements of Space Technology for Aerospace Engineers, Academic Press, 1999.
6. Vladimir A Chobotov, Spacecraft Attitude Dynamics and Control (Orbit)", Krieger Publishing Company Publishers, 1991.

**AS5006**

**CHEMICAL ROCKET TECHNOLOGY**

**L T P C**  
**3 0 0 3**

#### COURSE OBJECTIVES:

This course will make students

1. To classify the rockets and can develop the thrust equation.
2. To impart knowledge to the students on solid, liquid and hybrid rocket propulsion.
3. To provide knowledge on the types of igniters and injectors used in solid and liquid rocket systems.
4. To conduct various rocket testing and to analyse various modes of combustion instabilities.
5. To describe and understand types of rocket testing, safety and environmental concerns.

#### UNIT I ROCKET PERFORMANCE

**9**

Classification of Rockets - Propellants classification -Thrust equation, specific impulses, total impulse, characteristic velocity – Thrust coefficient – Efficiency: Real and ideal nozzle characteristic, Adiabatic flame temperature and its calculation, Criterion for Choice of propellants.

#### UNIT II SOLID ROCKET MOTORS

**9**

Viscous subsystems of solid rocket motor and their function – Igniters - Type of igniters – Internal ballistics properties– Burning rate - Factor affecting burning rate - Equilibrium Chamber pressure– Propellant grain geometry design, Erosive burning – Pressure vs Time curve- thrust vs time curve – Special problems of solid rocket nozzle – Combustion mechanism of solid propellants – Solid rocket motor design.

#### UNIT III LIQUID ROCKET ENGINES

**10**

Classification of liquid rocket engine — Injectors and its types - various of types of feeding system - performance and choice of feed system cycle – Propellants tank and propellant slosh - Gas requirement for propellant draining - Thrust chamber – Thrust chamber cooling – Cryogenic propellants – Problems peculiar to cryogenic engine -- Turbo pumps – Ignition system - Combustion of liquid rocket – Thrust chamber design.

**UNIT IV HYBRID PROPULSION SYSTEM****8**

Standard and reverse hybrid rocket – Application – Limitation - Advance fuel – Combustion mechanism of hybrid rocket – Regression rate measurement – Methods for improving regression rate.

**UNIT V ROCKET TESTING AND COMBUSTION INSTABILITIES****9**

Burning rate measurement techniques - Rocket testing – Static testing of rockets – Instrumentation and safety procedures – Ignition delay testing – Combustion instability - L\* instability – different modes of combustion instability – Bulk and wave mode of combustion instability in solid and liquid rockets – Pogo instability.

**TOTAL :45 PERIODS****COURSE OUTCOMES**

At the end of the course, students will be able to

**CO1:** To identify the rocket propulsion system and its applications.

**CO2:** Analyze the performance of thrust chambers.

**CO3:** Describe and classify solid propellant rocket motors and its components.

**CO4:** Analyse propellants properties and associated physical and chemical processes.

**CO5:** Describe and classify liquid propellant rocket motors, its components and various associated systems.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓		✓						
CO2	✓	✓	✓	✓	✓		✓					✓
CO3	✓	✓	✓	✓	✓	✓		✓				✓
CO4	✓	✓	✓		✓			✓			✓	✓
CO5	✓	✓	✓									✓

**REFERENCES:**

1. Martin J. Chiaverini & Kenneth K. Kuo, "Fundamentals of Hybrid Rocket Combustion and Propulsion", Progress in Astronautics and Aeronautics (book218), 1<sup>st</sup> edition, 2007.
2. Ramamurthi,K, "Rocket Propulsion", Laxmi Publications Private Limited, 1<sup>st</sup> edition, 2016.
3. Sutton,GP "Rocket Propulsion Elements", John Wiley & Sons Inc., New York, 9<sup>th</sup> Edition, 2016.

**AL5071****AEROSPACE MATERIALS****L T P C  
3 0 0 3****COURSE OBJECTIVES:**

This course will enable students

1. To get insights into the basic aspects of material science.
2. To provide basic idea on the mechanical behaviour of materials.
3. To impart knowledge on the macro mechanics of composite materials,
4. To gain knowledge on the analysis and manufacturing methods of composite materials.
5. To learn about the sandwich construction.

**UNIT I MATERIAL SCIENCE****9**

Crystallography of metals & metallic alloys – Imperfections – Dislocations in Different Crystal Systems – Effect on plasticity – Strengthening Mechanisms Due to Interaction of Dislocations with Interfaces – Other Strengthening Methods – Dislocation Generation Mechanisms

*Attested*

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**UNIT II MECHANICAL BEHAVIOUR 9**

Stress-strain curve and mechanical behaviour of materials – linear elasticity and plasticity – failure of ductile and brittle materials – use of failure theories – maximum normal stress and maximum shear stress failure theories – importance of the octahedral stress failure theory – failure theories based on strain energy – cyclic loading and fatigue of materials – the S-N curve

**UNIT III METALLIC ALLOYS 9**

Metals and alloys used for different aerospace applications – Properties of conventional and advanced aerospace alloys – Effect of alloying elements – Summary of conventional and state-of-the-art manufacturing processes – Types of heat treatment and their effect – other processing parameters – Materials for aerospace application – Design requirements & standards

**UNIT IV HIGH TEMPERATURE MATERIALS 9**

Carbon-Carbon Composites and Ceramic Materials For High Temperature Aerospace Application – Manufacturing Technologies & Controlling Parameters – Mechanical and Thermal Properties of These Material Systems – Thermal Protection Material System for a Re-Entry Vehicle – Use of Superalloys – Metal Matrix Composites & Cermets – Properties and Applications – Mechanical and Thermal Fatigue

**UNIT V MATERIALS FOR SANDWICH CONSTRUCTION 9**

Aerospace application of honeycomb and sandwich type construction – Materials used – Typical properties – Fabrication techniques – Design principles involved in beams and panels of sandwich type construction – Numerical examples – Failure modes of sandwich panels – Inspection Techniques

**TOTAL : 45 PERIODS**

**COURSE OUTCOMES:**

Upon completion of this course, students will

**CO1:** Be able to investigate the physical and mechanical behaviour of different materials.

**CO2:** Have exposure on dislocation theories and their importance.

**CO3:** Have general knowledge of the properties of different aerospace materials

**CO4:** Be able to apply failure theories appropriately.

**CO5:** Be able to select good materials for a specific aerospace application.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	✓		✓				✓					
<b>CO2</b>	✓	✓	✓	✓	✓	✓						✓
<b>CO3</b>	✓	✓	✓	✓	✓	✓						✓
<b>CO4</b>	✓	✓	✓	✓	✓							✓
<b>CO5</b>	✓		✓				✓	✓				✓

**REFERENCES**

1. Adrian Mouritz, "Introduction to Aerospace Materials", Woodhead Publishing, 1<sup>st</sup> edition, 2012.
2. Jones. R M, "Mechanics of Composite Materials", 2nd Edition, CRC Press, Taylor & Francis Group, 1998.
3. Prasad, N. Eswara, Wanhill, RJH, "Aerospace Materials and Material Technologies Volume 1: Aerospace Materials", Springer Singapore, 2017.
4. Sam Zhang & Dongliang Zhao, "Aerospace Materials Handbook", CRC Press, Taylor & Francis Group, 2012.

*Attested*

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**COURSE OBJECTIVES:**

This course will make students

1. To provide knowledge on the basic aspects of space vehicle operation environment.
2. To give an idea about the structural loads acting on space vehicles
3. To introduce the space vehicle design aspects, its complex issues requiring expertise from many different areas of Aerospace Engineering.
4. To impart knowledge on various parameters that influences the design of space vehicles including their mission, orbital mechanics and the space environment.
5. To get insight into the basic aspects of re-entry motion.

**UNIT I SPACE VEHICLE BASICS 9**

Earth environment - Launch environment – Atmospheric environment – Rocket performance and staging – Selection criteria of space vehicles - Expendable launch vehicles- Advanced mission concepts.

**UNIT II STRUCTURAL DESIGN 9**

Design drivers – Mission goals – Payload and instrument requirements – factors in structural concept selection - Deployable Structures – Vehicle mass – Vehicle centre of mass – Moment of inertia – Sources of structural loads – Analysis of structural loads – Load alleviation – Stress levels and safety factors – Structural materials.

**UNIT III CONFIGURATION ASPECTS 9**

Propulsion system aspects – Vehicle configuration – Number of stages/boosters – Vehicle layout – Recovery system selection – Launch sites – Guidance strategy - Ascent guidance – Flyback guidance systems – Attitude controller.

**UNIT IV POWER SYSTEM DESIGN 9**

Power system functions – Power system design drivers – Power system elements – Solar array design – Fuel cells – Power conditioning and control – Future concepts in space propulsion.

**UNIT V RE-ENTRY MOTION 9**

Re-entry Motion - Trade-offs for Re-entry Design - Significant Forces on a Re-entry vehicle - Ballistic Coefficient - Re-entry Motion Analysis - Trajectory and Deceleration - Trajectory and Heating - Trajectory and the Re-entry Corridor - Vehicle Shape design.

**TOTAL: 45 PERIODS****COURSE OUTCOMES:**

Upon the completion of this course, students will be

**CO1:** Familiar with the selection criteria of space launch vehicles.

**CO2:** Able to design space vehicles considering the various structural loads.

**CO3:** In a position to wisely select suitable configuration of space launch vehicle for given requirements.

**CO4:** Able to perform the design of power system for space vehicles.

**CO5:** Able to analyze re-entry motion of vehicles.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓		✓		✓		✓			
CO2	✓	✓	✓	✓								✓
CO3	✓	✓	✓	✓	✓				✓			✓
CO4	✓	✓				✓						
CO5	✓	✓		✓	✓	✓	✓		✓			✓

Attested

## REFERENCES:

1. Alan C. Tribble, "The Space Environment: Implications for Spacecraft Design", 2<sup>nd</sup> edition, Princeton University Press, 2003.
2. Michael D. Griffin, James R. French, "Space Vehicle Design", AIAA Education Series, Second edition, 1991.
3. Mukund R. Patel, "Spacecraft Power Systems", CRC Press, 2005.
4. Pasquale M Sforza, "Manned Spacecraft Design Principles", Butterworth - Heinemann, 2015.
5. Peter Fortescue, John Stark and Graham Swinerd, "Spacecraft Systems Engineering", Wiley, 3<sup>rd</sup> Edition, 2003.

AS5008

MISSILE GUIDANCE AND CONTROL

L T P C  
3 0 0 3

## COURSE OBJECTIVES:

This course will make students

1. To provide basic introduction to missiles systems
2. To impart knowledge to students on basic missile configurations and preliminary drag estimation.
3. To introduce slender body aerodynamics, aerodynamic aspects during launching phase and stability and control aspects of missile.
4. To provide knowledge on strategic missiles.
5. To get insight into the basic aspects of weapon delivery systems.

### UNIT I MISSILE SYSTEMS INTRODUCTION 8

History of guided missile for defence applications- Classification of missiles- The Generalized Missile Equations of Motion- Coordinate Systems- Lagrange's Equations for Rotating Coordinate Systems-Rigid-Body Equations of Motion-missile system elements, missile ground systems.

### UNIT II MISSILE AIRFRAMES, AUTOPILOTS AND CONTROL 9

Missile aerodynamics- Force Equations, Moment Equations, Phases of missile flight. Missile control configurations. Missile Mathematical Model. Autopilots — Definitions, Types of Autopilots, Example Applications. Open-loop autopilots. Inertial instruments and feedback. Autopilot response, stability, and agility- Pitch Autopilot Design, Pitch-Yaw-Roll Autopilot Design.

### UNIT III MISSILE GUIDANCE LAWS 10

Tactical Guidance Intercept Techniques, Derivation of the Fundamental Guidance Equations, explicit, Proportional Navigation, Augmented Proportional Navigation, beam riding, bank to turn missile guidance, Three-Dimensional Proportional Navigation, comparison of guidance system performance, Application of Optimal Control of Linear Feedback Systems.

### UNIT IV STRATEGIC MISSILES 10

Introduction, The Two-Body Problem, Lambert's Theorem, First-Order Motion of a Ballistic Missile-Correlated Velocity and Velocity-to-Be-Gained Concepts, Derivation of the Force Equation for Ballistic Missiles, Atmospheric Reentry, Ballistic Missile Intercept, Missile Tracking Equations of Motion, Introduction to Cruise Missiles, The Terrain-Contour Matching (TERCOM) Concept.

### UNIT V WEAPON DELIVERY SYSTEMS 8

Weapon Delivery Requirements, Factors Influencing Weapon Delivery Accuracy, Unguided Weapons, The Bombing Problem, Guided Weapons, Integrated Flight Control in Weapon



**COURSE OUTCOMES:**

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

- CO1:** Have through knowledge with the advanced concepts of missile guidance and control to the engineers.
- CO2:** Provide the necessary mathematical knowledge that is needed in understanding the physical processes.
- CO3:** Derive fundamental guidance equations and to compare guidance system performance.
- CO4:** Explain the importance of strategic missiles and tracking equation of motions.
- CO5:** Provide concepts on weapon delivery systems and also the factors influences weapon delivery system.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	✓	✓	✓	✓							✓	✓
<b>CO2</b>	✓	✓	✓	✓	✓		✓			✓	✓	✓
<b>CO3</b>	✓	✓	✓	✓	✓		✓			✓		✓
<b>CO4</b>	✓	✓	✓		✓	✓					✓	
<b>CO5</b>	✓	✓	✓		✓	✓				✓		✓

**REFERENCES:**

1. Blakelock, JH, "Automatic Control of Aircraft and Missiles", 2<sup>nd</sup> edition, John Wiley & Sons, 1991.
2. Fleeman, Eugene L, "Tactical Missile Design", 2<sup>nd</sup> edition, AIAA Education series, 2006.
3. Garnell, P, "Guided Weapon Control Systems", 2nd Edition, Pergamon Press, 1980.
4. Joseph Ben Asher and Isaac Yaesh, "Advances in Missile Guidance Theory" AIAA Education series, 1998.
5. Paul Zarchan, "Tactical and Strategic Missile Guidance", AIAA Education series, 6th edition, 2013.
6. Siouris, GM, "Missile Guidance and control systems", Springer, 2004.

**AL5078**

**THEORY OF BOUNDARY LAYERS**

**L T P C**  
**3 0 0 3**

**COURSE OBJECTIVES:**

1. This course imparts knowledge to students on growth of boundary layer and its effect on the aerodynamic design of airframe of flight vehicles.
2. This course will introduce them the solution methods for boundary layer problems.
3. This course enables the students to understand the importance of viscosity and boundary layer in fluid flow.
4. This course also introduces the theory behind laminar and turbulent boundary layers.
5. This course will make students to learn the concepts of boundary layer transition and separation.

**UNIT I THEORY OF VISCOUS FLOW**

**8**

Fundamental equations of viscous flow, Conservation of mass, Conservation of Momentum-Navier-Stokes equations, Energy equation, Mathematical character of basic equations, Dimensional parameters in viscous flow, Non-dimensionalising the basic equations and boundary conditions, vorticity considerations, creeping flow, boundary layer flow.

*Attested*

**UNIT II INCOMPRESSIBLE VISCOUS FLOWS AND BOUNDARY LAYER 10**

Solutions of viscous flow equations, Couette flows, Hagen-Poiseuille flow, Flow between rotating concentric cylinders, Combined Couette-Poiseuille Flow between parallel plates, Creeping motion, Stokes solution for an immersed sphere, Development of boundary layer, Displacement thickness, momentum and energy thickness.

**UNIT III LAMINAR BOUNDARY LAYER THEORY 10**

Laminar boundary layer equations, Flat plate Integral analysis of Karman – Integral analysis of energy equation – Laminar boundary layer equations – boundary layer over a curved body-Flow separation- similarity solutions, Blasius solution for flat-plate flow, Falkner-Skan wedge flows, Boundary layer temperature profiles for constant plate temperature –Reynold’s analogy, Integral equation of Boundary layer – Pohlhausen method – Thermal boundary layer calculations.

**UNIT IV THEORY OF TURBULENT BOUNDARY LAYER 9**

Turbulence-physical and mathematical description, Two-dimensional turbulent boundary layer equations — Velocity profiles – The law of the wall – The law of the wake – Turbulent flow in pipes and channels – Turbulent boundary layer on a flat plate – Boundary layers with pressure gradient, Eddy Viscosity, mixing length , Turbulence modelling.

**UNIT V BOUNDARY LAYER TRANSITION AND SEPARATION 8**

Boundary layer control in laminar flow-Methods of Boundary layer control: Motion of the solid wall- Acceleration of the boundary layer-Suction- Injection of different gas-Prevention of transition- Cooling of the wall-Boundary layer suction-Injection of a different gas.

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES:**

Upon completion of this course, students will be able

- CO1:** To apply proper governing equations for various types of viscous flows in engineering applications.
- CO2:** To obtain solutions for various viscous flow problems in engineering.
- CO3:** To estimate skin friction over solid surfaces, over which laminar boundary layer persists.
- CO4:** To arrive at the solutions for turbulent boundary layer and the resulting drag.
- CO5:** To gain insights on the techniques for boundary layer control.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	✓	✓	✓	✓	✓			✓				
<b>CO2</b>	✓	✓	✓	✓	✓	✓						✓
<b>CO3</b>	✓	✓	✓	✓			✓	✓				
<b>CO4</b>	✓	✓	✓	✓	✓			✓				✓
<b>CO5</b>	✓	✓	✓	✓		✓	✓					✓

**REFERENCES:**

1. White, F. M., Viscous Fluid Flow, McGraw-Hill & Co., Inc., New York, 2008.
2. Schlichting, H., Boundary Layer Theory, McGraw-Hill, New York, 1979.
3. Reynolds, A, J., Turbulent Flows Engineering, John Wiley and Sons, 1980.

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**COURSE OBJECTIVES:**

This course will enable the students

1. To learn the concepts of finite element methods and the various solution schemes available.
2. To impart knowledge to solve plane stress and plane strain problems.
3. To solve heat transfer and fluid mechanics problems using Finite element methods.
4. To formulate mass and stiffness element matrices for vibration problems.
5. To be familiar in obtaining solutions to fluid flow problems.

**UNIT I INTRODUCTION 9**

Review of various approximate methods – Rayleigh-Ritz, Galerkin and Finite Difference Methods – Problem Formulation – Application to Structural Elements & Practical Problems – Derivation of Stiffness and Flexibility Matrices – Spring Systems – Role of Energy Principles – Basic Concepts of Finite Element Method – Interpolation, Nodes, Degrees of Freedom – Solution Schemes.

**UNIT II DISCRETE ELEMENTS 9**

Finite Element Structural Analysis Involving 1-D Bar and Beam Elements – Tapered Bar – Temperature Effects – Static Loading – Formulation of the Load Vector for 1-D Elements – Methods of Stiffness Matrix Formulation – Interpolation & Shape Functions – Boundary Conditions – Determination of Displacements & Reactions – Constitutive Relations – Determination of Nodal Loads & Stresses.

**UNIT III CONTINUUM ELEMENTS 9**

Plane Stress & Plane strain Loading – CST Element – LST Element – Element Characteristics – Problem Formulation & Solution Using Finite Elements – Axisymmetric Bodies & Axisymmetric Loading – Consistent and Lumped Load Vectors – Use of Local, Area and Volume Co-ordinates – Isoparametric Formulation – Shape Functions – Role of Numerical Integration – Load Consideration – Complete FE Solution.

**UNIT IV VIBRATION & BUCKLING 9**

Formulation of the Mass and Stiffness Element Matrices for Vibration Problems – Bar and Beam Elements – Derivation of the Governing Equation – Natural Frequencies and Modes – Damping Considerations – Harmonic Response – Response Calculation Using Numerical Integration – Buckling of Columns – Problem Formulation – Solution – Determination of Buckling Loads and Modes.

**UNIT V HEAT TRANSFER & FLUID MECHANICS 9**

One Dimensional Heat Transfer Analysis – Formulation of the Governing Equations in Finite Element Form – Equivalent Load Vector – Solution & Temperature Distribution – Finite Element Formulation & Solution for Sample Problems Involving Fluid Mechanics.

**TOTAL: 45 PERIODS****COURSE OUTCOMES:**

At the end of this course, students will have

- CO1:** An ability to frame governing equations involving different type of finite elements.  
**CO2:** Knowledge on the general finite element methodology for a variety of practical problems.  
**CO3:** An ability to solve simple 1-D and 2-D problems using the finite element method.  
**CO4:** Knowledge on how to apply numerical integration techniques effectively in finite elements solutions.  
**CO5:** An ability to frame and solve heat transfer and fluid mechanics problems using the FE method.

*Attested*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓							
CO2	✓	✓	✓	✓	✓				✓			✓
CO3	✓	✓	✓	✓	✓		✓					✓
CO4	✓	✓	✓	✓	✓							✓
CO5	✓	✓	✓	✓	✓			✓				

#### REFERENCES:

1. Bathe, KJ & Wilson, EL, Numerical Methods in Finite Elements Analysis, Prentice Hall of India Ltd., 1983.
2. Dhanaraj, R & K.Prabhakaran Nair, K, Finite Element Method, Oxford university press, India, 2015.
3. Krishnamurthy, CS, Finite Elements Analysis, Tata McGraw - Hill, 1987.
4. Rao, SS Finite Element Method in Engineering, Butterworth, Heinemann Publishing, 3<sup>rd</sup> Edition, 1998.
5. Robert D. Cook, David S. Malkus, Michael E. Plesha and Robert J. Witt, Concepts and Applications of Finite Element Analysis, John Wiley & Sons, 4<sup>th</sup> Edition, 2002.
6. Segerlind, LJ, Applied Finite Element Analysis, , John Wiley and Sons Inc., New York, 2<sup>nd</sup> Edition, 1984.
7. Tirupathi R. Chandrupatla & Ashok D. Belegundu, Introduction to Finite Elements in Engineering, Prentice Hall, 2002.

AL5072

### ANALYSIS OF COMPOSITE STRUCTURES

L T P C  
3 0 0 3

#### COURSE OBJECTIVES:

This course will make students

1. To impart knowledge on the macro mechanics of composite materials.
2. To determine stresses and strains in composites and also imparts an idea about the manufacturing methods of composite materials.
3. To get an idea on failure theories of composites.
4. To provide the basic knowledge on the properties of fibre and matrix materials used in commercial composites as well as some common manufacturing techniques.
5. To gain knowledge on the basic concepts of acoustic emission technique.

#### UNIT I FIBERS, MATRICES, AND FABRICATION METHODS

9

Production & Properties of Glass, Carbon and Aramid Fibers – Thermosetting and Thermoplastic Polymers – Polymer Properties of Importance to the Composite, Summary of Fabrication Processes – Scope of Composite Materials for Various Aerospace Application.

#### UNIT II MICROMECHANICS OF A UNIDIRECTIONAL COMPOSITE

9

Volume and Weight Fractions in a Composite Specimen – Longitudinal Behaviour of Unidirectional Composites – Load Sharing – Failure Mechanism and Strength – Factors Influencing Longitudinal Strength and Stiffness – Transverse Stiffness and Strength – Prediction of Elastic Properties Using Micromechanics – Typical Unidirectional Fiber Composite Properties – Minimum and Critical Fiber Volume Fractions.

Attested

**UNIT III MACROMECHANICS APPROACH****9**

Stress Analysis of an Orthotropic Lamina – Hooke's Law – Stiffness and Compliance Matrices – Specially Orthotropic Material – Transversely Isotropic Material & Specially Orthotropic Material under Plane Stress – Determination of  $E_x$ ,  $E_y$ ,  $G_{xy}$  – Stress & Strain Transformations – Transformation of Stiffness and Compliance Matrices – Strengths of an Orthotropic Lamina Using Different Failure Theories.

**UNIT IV ANALYSIS OF LAMINATED COMPOSITES****10**

Laminate Strains - Variation of Stresses in a Laminate - Resultant Forces and Moments - Synthesis of Stiffness Matrix - Laminate Description System - Construction and Properties of Special Laminates - Symmetric Laminates – Balanced Laminate - Cross-Ply, and Angle-Ply Laminates - Quasi-isotropic Laminates - Determination of Laminae Stresses and Strains – Determination of Hygrothermal Stresses - Analysis of Laminates after Initial Failure.

**UNIT V ANALYSIS OF LAMINATED PLATES AND BEAMS****8**

Governing Equations For Laminated Composite Plates -- Governing Equations for Laminated Beams - Application of Theory – Bending, Buckling and Vibration of Laminated Beams and Plates repair- Analysis of sandwich construction-AE technique.

**TOTAL: 45 PERIODS****COURSE OUTCOMES:**

Upon completion of this course, students will be able

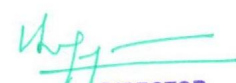
- CO1:** To calculate the elastic and strength properties of unidirectional laminates using micromechanics theory.
- CO2:** To analyze a composite laminate using the different failure theories.
- CO3:** To select the most appropriate manufacturing process for fabricating composite components.
- CO4:** To demonstrate understanding of the different materials (fibres, resins, cores) used in composites.
- CO5:** To gain knowledge on non-destructive inspection (NDI) and structural health monitoring of composites.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	✓	✓	✓			✓	✓		✓			
<b>CO2</b>	✓	✓	✓		✓	✓						✓
<b>CO3</b>	✓	✓	✓	✓		✓						✓
<b>CO4</b>	✓	✓	✓	✓								✓
<b>CO5</b>	✓	✓	✓	✓	✓			✓	✓			

**REFERENCES:**

1. Agarwal, BD and Broutman, LJ, "Analysis and Performance of Fibre Composites", John Wiley & Sons, 3<sup>rd</sup> edition, 2006.
2. Allen Baker, "Composite Materials for Aircraft Structures", AIAA Series, 2<sup>nd</sup> Edition, 2004.
3. Autar K Kaw, "Mechanics of Composite Materials", CRC Press, 2<sup>nd</sup> edition, 2005.
4. Calcote, LR, "The Analysis of laminated Composite Structures", Von – Nostrand Reinhold Company, New York, 1998.
5. Isaac M. Daniel & Orilshai, "Mechanics of Composite Materials", OUP USA publishers, 2<sup>nd</sup> edition, 2005.
6. Lubing, "Handbook on Advanced Plastics and Fibre Glass", Von Nostran Reinhold Co., New York, 1989.

Attested



**DIRECTOR**  
Centre for Academic Courses  
Anna University, Chennai-600 025

**COURSE OBJECTIVES:**

This course will make students

1. To learn the fundamentals aspects of fatigue & fracture mechanics.
2. To gain knowledge on the statistical aspects of fatigue behaviour of materials.
3. To get insights into the physical aspects of fatigue.
4. To evaluate the strength of the cracked bodies.
5. To provide knowledge on fatigue design and testing of aerospace structures.

**UNIT I BASIC CONCEPTS & OVERVIEW****9**

Historical Perspective – Case Studies – Review of Material Behaviour – Linear & Non-Linear Response – Temperature and Strain Rate Effect – Strain Hardening – Different Mechanisms of Failure – Typical Defects & Elements of Dislocation Theories – Atomic View of Fracture – Fractographic Examination of Failure Surfaces of Different Materials – Overview of Design Approach – Safe Life Design.

**UNIT II FATIGUE OF STRUCTURES****9**

S.N. curves – Endurance limit – Effect of mean stress – Goodman, Gerber and Soderberg relations and diagrams – Notches and stress concentrations – Stress concentration factors – Notched S-N curves – Low cycle and high cycle fatigue – Coffin-Manson's relation – Transition life – Cyclic Strain hardening and softening – Load History Analysis – Cycle counting techniques – Cumulative damage theory

**UNIT III PHYSICAL ASPECTS OF FATIGUE****9**

Fracture mechanism in metals - Phase in fatigue life – Crack source – Cleavage initiation – Crack growth – Ductile-brittle transition – Final fracture – Dislocations – Fatigue fracture surface of inter and intra-granular fracture – Environmental effects – Terminology and classification – Corrosion principles – Stress corrosion cracking – Hydrogen embrittlement – Influencing parameters on crack behaviour

**UNIT IV LINEAR ELASTIC FRACTURE MECHANICS****9**

Stress analysis and strength of a cracked body – Stress concentration – potential energy and surface energy – Energy release rate – Griffith's theory – Irwin extension of Griffith's theory to ductile materials – Plastic zone shape – Effect of thickness on fracture toughness – Stress intensity factors for typical geometries – Instability of the R-curve – K-controlled fracture – Plane strain fracture toughness – Mixed mode – Interaction of cracks – Limitations of the linear elastic fracture theory

**UNIT V FRACTURE TOUGHNESS TESTING****9**

General considerations for metallic specimens – Specimen configuration – Stress intensity factors – Pre-cracking – Grooving – ASTM E-399 and similar standards – K-R curve – J-testing on metals – Determination of crack parameters – CTOD testing – Testing of metals in the ductile-brittle transition region – Quantitative toughness tests – Charpy & Izod tests – Mathematical modelling concepts

**TOTAL: 45 PERIODS****COURSE OUTCOMES:**

Upon completion of this course, students will be able

- CO1:** To identify and describe the basic fracture and fatigue mechanisms and apply that knowledge to failure analysis.
- CO2:** To correctly apply linear elastic fracture to predict material failure.
- CO3:** To predict lifetimes for fatigue and environmentally assisted cracking.
- CO4:** To demonstrate fatigue design and testing of structures.
- CO5:** To realise the importance of composite materials in Aerospace structures.

Attested

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓				✓					
CO2	✓	✓	✓			✓	✓					
CO3	✓	✓	✓			✓	✓					✓
CO4	✓	✓	✓			✓		✓				
CO5	✓	✓	✓			✓	✓					

#### REFERENCES:

1. Barrois, W & Ripley, L, "Fatigue of Aircraft Structures", Pergamon Press, Oxford, 1983.
2. Brock, D, "Elementary Engineering Fracture Mechanics", Noordhoff International Publishing Co., London, 1994.
3. Knott, JF, "Fundamentals of Fracture Mechanics", Butterworth & Co. Ltd., London, 1983.
4. Sih, CG, "Mechanics of Fracture, Vol.1", Sijthoff and Noordhoff International Publishing Co., Netherland, 1989.

AL5079

### VIBRATION ISOLATION AND CONTROL

L T P C  
3 0 0 3

#### COURSE OBJECTIVES:

This course will enable students

1. To get insight into the basic aspects of vibration theory.
2. To get in-depth knowledge on different types of isolators and its effectiveness.
3. To provide the basic knowledge on dynamic vibration absorber.
4. To realize the importance of materials selection for appropriate applications.
5. To get knowledge on the principles of active vibration control.

#### UNIT I BASIC VIBRATION THEORY 9

Free Vibration Theory – Determination of Natural Frequency of a Single Degree Of Freedom – System– Response of a Damped Single Degree of Freedom System – Role of Damping – Forced Vibrations of Discrete Systems – Continuous Systems – Vibrations of Beams and Shafts – Idealization of a Real System Into a Discrete Model – Resonance – An Overview of the Different Methods of Vibration Control

#### UNIT II VIBRATION ISOLATION 9

Transmissibility – Numerical Examples – Necessity of Vibration Isolation – Vibration Reduction at Source – System Redesign – Different Types of Isolators & Their Effectiveness – Pneumatic Suspension – Excitation Reduction at Source and Factors Affecting Vibration Level – Source Classification – Control of Flow Induced & Self-Excited Systems

#### UNIT III DYNAMIC VIBRATION ABSORBER 9

Dynamic Vibration Neutralizers – Self-tuned Pendulum Neutralizer - Optimum Design of Damped Absorbers – Absorber with ideal spring and viscous dashpot – Gyroscopic vibration absorbers – Impact Absorbers – Absorbers attached to continuous systems – Field Balancing of Rotors – Resonance: Detuning and Decoupling – Remedial Measures

#### UNIT IV SELECTION OF MATERIALS 9

Dynamic Properties of Viscoelastic Material – Selection of Materials – Damping-Stress Relationship – Selection Criteria for Linear Hysteretic Material – Design for enhanced material damping – Linear Viscoelastic Model – Constrained Layer Damping – Relaxation – Frequency and Temperature Dependence of the Complex Modulus – Overview and Role of Smart Materials

*Haesied*

**UNIT V PRINCIPLES OF ACTIVE VIBRATION CONTROL****9**

Conceptual Understanding – Shape Memory Actuators for Vibration Control – Shape Memory Materials – Tuned Vibration Absorbers using SMA – Basics of Electro-and Magneto-Rheological Fluids – Active Vibration Isolation using ERF and MRF – Methods of Active Vibration Control Using Piezoelectric Materials – Derivation of Governing Equations – Response of the Structure

**TOTAL: 45 PERIODS****COURSE OUTCOMES:**

At the end of this course, students will be able

**CO1:** To realise the importance of vibration theory & its practical applications

**CO2:** To work out response calculations

**CO3:** To analyse and compare the different methods of vibration control

**CO4:** To exposure on vibration control using smart materials

**CO5:** To design a vibration control unit.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	✓	✓	✓	✓			✓					
<b>CO2</b>	✓	✓	✓		✓	✓						✓
<b>CO3</b>	✓	✓	✓	✓		✓						✓
<b>CO4</b>	✓	✓	✓	✓	✓		✓					✓
<b>CO5</b>	✓	✓	✓				✓	✓				

**REFERENCES:**

1. Malcolm J. Crocker, "Handbook of Noise and Vibration Control", Wiley; 1st edition, 2007.
2. Mallik, AK, "Principles of Vibration Control", Affiliated East-West Press, India, 1990.
3. Mead,DJ, "Passive Vibration Control", Wiley, 1st edition, 1999.
4. Preumont,A "Vibration Control of Active Structures", Springer Netherlands, 3rd edition, 2011.

**AL5075****NON-DESTRUCTIVE EVALUATION****L T P C****3 0 0 3****COURSE OBJECTIVES:**

This course will make students

1. To impart knowledge on the fundamentals of nondestructive testing methods and techniques, aircraft inspection methodology using NDT methods
2. To get insights into the basic aspects of electron microscopy.
3. To learn modern NDT techniques like acoustic emission, ultrasonic and thermographic testing methods.
4. To inspect the aircraft structures using NDT techniques.
5. To get basic knowledge on the structural health monitoring of aerospace structures.

**UNIT I INTRODUCTION****9**

Need for non-destructive evaluation (NDT) – Applications – Structural inspection – Structural deterioration due to corrosion and fatigue – Crack growth – Fabrication defects – Overloading – Detailed visual inspection – Aircraft wing and fuselage inspection using various NDT techniques – Overview and relative comparison of NDT methods – Jet engine inspection – Critical locations

**UNIT II ELECTRON MICROSCOPY****9**

Fundamentals of optics – Optical microscope and its instrumental details – Variants in the optical microscopes and image formation – Polarization light effect – Sample preparation and applications of optical microscopes – Introduction to Scanning electron microscopy (SEM) – Instrumental details and image formation of SEM – Introduction to transmission electron microscopy (TEM) – Imaging techniques and spectroscopy – Sample preparation for SEM and TEM

*Attested*



**UNIT III ACOUSTIC EMISSION AND ULTRASONICS 9**

Sources of acoustic emission – Physical principals involving acoustic emission and ultrasonics – Configuration of ultrasonic sensors – Phased array ultrasonics – Instrument parts and features for acoustic emission and ultrasonics – Defect characterization – Inspection of cracks and other flaws in metals and composites – Interpretation of data – Image processing – Concepts and application

**UNIT IV AIRCRAFT INSPECTION 9**

Inspection Levels – General Visual Inspection – During pre, or post flight – Detailed Visual Inspection (DET) – Periodic inspection – Special Detailed Inspection (SDET) – Uses of NDT Methods – Jet Engine Inspection – Engine overhaul – Fluorescent penetrate inspection – Airframe Loading – Fuselage Inspection – Critical Locations – Comparison of different methods of NDT – Visual – Radiography – Eddy Current Testing – Liquid Penetrant Testing – Remote Testing - Landing Gear Inspection

**UNIT V STRUCTURAL HEALTH MONITORING 9**

An Overview of Structural Health Monitoring – Structural Health Monitoring and Role of Smart Materials – Structural Health Monitoring versus Non-Destructive Evaluation – A Broad Overview of Smart Materials Applications – Notable Applications of SHM in Aerospace Engineering – Structural health monitoring of composites – Repair investigation using SHM – Current limits and future trends.

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES:**

At the end of this course, students will be able

- CO1:** To realize the importance of various NDT techniques.
- CO2:** To identify suitable NDT technique for a particular application.
- CO3:** To demonstrate the physical principles involved in acoustic emission and ultrasonics.
- CO4:** To have knowledge on the physical principles involved in the various other techniques of NDT.
- CO5:** To realise the state-of-the-art in NDT testing and structural health monitoring.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	✓	✓	✓		✓	✓	✓					
<b>CO2</b>	✓	✓	✓		✓	✓	✓					
<b>CO3</b>	✓	✓	✓		✓		✓					✓
<b>CO4</b>	✓	✓	✓	✓			✓					✓
<b>CO5</b>	✓	✓	✓		✓		✓					✓

**REFERENCES:**

1. Cullity, BD & Stock, SR, "Elements of X-ray diffraction", Prentice Hall, Inc. USA, 2001.
2. Daniel Balageas, Claus-Peter Fritzen, Alfredo Güemes, "Structural Health Monitoring", Wiley-ISTE, 2006.
3. Douglas E Adams, "Health Monitoring of Structural Materials and Components-Methods with Applications", John Wiley and Sons, 2007.
4. Douglas B. Murphy, "Fundamentals of light microscopy and electronic imaging", Wiley-Liss, Inc. USA, 2001.
5. Richard Brundle. C, Charles A. Evans, Jr., Shaun Wilson, "Encyclopedia of Materials Characterization, Surfaces, Interfaces, Thin Films", Butterworth-Heinemann, Boston, USA, 1992.
6. Williams, DB & Barry Carter,C, "Transmission electron microscopy, vol. 4", Springer, USA, 1996.
7. Non-destructive Testing Handbook – ASNT Series – Volume 1 – 6.

*Attested*

*W. J. J.*  
DIRECTOR

**COURSE OBJECTIVES:**

This course will make students

1. To impart knowledge to students on basic plasma and its application in aerospace engineering.
2. To learn about the motion of charged particles.
3. To get inference about the collision of charged particles and energy Equilibrium.
4. To learn about the MHD plasma and its stability.
5. To get information about electromagnetic waves, kinetic of plasma and some of the damping mechanism.

**UNIT I INTRODUCTION TO PLASMA 8**

Plasma, An Ionized Gas, Plasmas are Quasi-Neutral, Plasma Shielding, Elementary Derivation of the Boltzmann Distribution, Plasma Density in Electrostatic Potential, Debye Shielding, Plasma-Solid Boundaries (Elementary), Thickness of the Sheath, the 'Plasma Parameter', Occurrence of Plasmas, Different Descriptions of Plasma, Equations of Plasma Physics.

**UNIT II MOTION OF CHARGED PARTICLES IN FIELDS 9**

Uniform B field,  $E = 0$ , Uniform B and Non-zero E, Drift Due to Gravity or Other Forces, Non-uniform B Field, Curvature Drift, Interlude: Toroidal Confinement of Single Particles, The Mirror Effect of Parallel Field Gradients:  $E = 0$ ,  $\nabla B \parallel B$ , Time Varying B Field (E Inductive), Time Varying E-field (E, B Uniform), Direct Derivation of  $[(dE)/dt]$  Effect: 'Polarization Drift', Non Uniform E (Finite Larmor Radius)

**UNIT III COLLISIONS IN PLASMAS 9**

Binary Collisions between Charged Particles, Scattering Angle, Differential Cross-Section for Scattering by Angle, Relaxation Processes, Energy Loss, Cut-offs Estimate, Momentum Loss, Thermal Distribution Collisions, Thermal Collision Frequencies, Applications of Collision Analysis, Energy Equilibration

**UNIT IV FLUID DESCRIPTION OF PLASMA 9**

Particle Conservation (In 2-d Space), Fluid Motion, Lagrangian & Eulerian Viewpoints, Two-fluid Equilibrium: Diamagnetic Current, Reduction of Fluid Approach to the Single Fluid Equations, Single Fluid Equations: M.H.D, Heuristic Derivation/Explanation, Maxwell's Equations for MHD Us, MHD Equilibria, General Properties of MHD Equilibria, Low  $\beta$  equilibria: Force-Free Plasmas, Toroidal Equilibrium, MHD Stability, General Principles Governing Instabilities.

**UNIT V ELECTROMAGNETIC WAVES IN PLASMAS 10**

Linear Waves in Anisotropic Medium, Isotropic Medium, High Frequency Plasma Conductivity, Cold Plasma Waves, Thermal Effects on Plasma Waves, Electrostatic Approximation Waves, Simple Example of MHD Dynamics: Alfvén Waves, Non-uniform Plasmas and Wave Propagation, Two Stream Instability, Kinetic Theory of Plasma Waves, Vlasov Equation, Linearized Wave Solution of Vlasov Equation, Landau's Original Approach, Solution of Dispersion Relation, Direct Calculation of Collisionless Particle Heating, Damping Mechanisms, Ion Acoustic Waves and Landau Damping, Alternative Expressions of Dielectric Tensor Elements, Electromagnetic Waves in Unmagnetized Vlasov Plasma Experimental Verification of Landau Damping

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES:**

At the end of the course, students will be able

- CO1:** To acquire knowledge on the use of plasma and its application in field of Aerospace vehicles.
- CO2:** To realize the basic motion of charged particles and flow physics.
- CO3:** To get exposure on the significance of particle collision.
- CO4:** To acquire knowledge about the motion of MHD and its stability in the flow field.
- CO5:** To get through knowledge in the field of plasma wave kinetics.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓		✓	✓	✓					✓
CO2	✓	✓	✓	✓			✓		✓			
CO3	✓	✓	✓	✓	✓		✓	✓				✓
CO4	✓	✓	✓		✓				✓		✓	
CO5	✓	✓	✓	✓			✓		✓			✓

#### REFERENCES:

1. Dan M. Goebel, Ira Katz, "Fundamentals of Electric Propulsion: Ion and Hall Thrusters", Wiley publication, 1st edition, 2008.
2. George P. Sutton & Oscar Biblarz, "Rocket Propulsion Elements", Wiley publication, 9<sup>th</sup> Edition, 2016.
3. Prof. Hutchinson, "Introduction to Plasma Physics I", lecture notes, MIT open courseware.
4. Luis Conde, "An Introduction to Plasma Physics and its Space Applications, Volume 1", Morgan & Claypool Publishers as part of IOP Publishing- 2018.

AS5010

ROCKET AND MISSILE SYSTEMS

L T P C

3 0 0 3

#### COURSE OBJECTIVES:

This course will enable students

1. To get insight into the basic aspects of rockets and missile subsystems.
2. To impart knowledge on igniters system, injection system, thermal protection system.
3. To get knowledge on stage separation system and vehicle optimization.
4. To provide knowledge on thrust vector control methods.
5. To get in-depth knowledge on thermal protection system and high temperature materials for aerospace applications.

#### UNIT I ROCKET AND MISSILE SUBSYSTEM 9

Various subsystem of thrust chamber – igniters for solid propellants and liquid propellants – Pyrogen igniter - Pyrodyne igniter- Pelleted Pyrotechnic- Insulation system – Liner system – Injector system- Damping system for propellant slosh - Propellant hammer– Thermal insulating for cryogenic propellants – Cooling system.

#### UNIT II STAGE SEPARATION SYSTEM 9

Need of multi staging – Clustering – Staging method - stage separation techniques in atmosphere - Stage separation techniques in vacuum - Vehicle Optimization.

#### UNIT III THRUST VECTOR CONTROL 9

Thrust vector control – TVC mechanism in single nozzle – Gimbal – movable nozzle – jet vanes- jet tabs- jetavator – secondary injection of liquid and hot gas injection – small auxiliary thrust chamber – TVC with multiple thrust chamber – TVC testing

#### UNIT IV THERMAL PROTECTION SYSTEM 9

Principle of high temperature design – thermal environment – aerodynamic heating – solar heating – principles of thermal protection – thermal protection systems – systems based on heat dissipation – systems based on heat absorption- capabilities of thermal protection systems.

#### UNIT V HIGH TEMPERATURE MATERIAL FOR AEROSPACE APPLICATIONS 9

Component system analysis – re-entry component analysis – composite material systems- Ceramics reinforced with refractory metal fibres – high temperature material fabrication – Fracture of pressure vessels – temperature control of spacecrafts – ablation materials.

TOTAL:45 PERIODS

## COURSE OUTCOMES:

Upon completion of the course, students will be

**CO1:** Able to learn the principles of operation and design of various rocket systems.

**CO2:** Able to explore the design of multi-stage launch vehicles.

**CO3:** Able to acquire knowledge on the application and working of thrust vector control in rocket and missiles.

**CO4:** Aware of thermal protecting requirements and preventive measurements for aerodynamics heating.

**CO5:** Able to get attentiveness on high temperature material components analysis for aerospace applications.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓			✓				✓	✓
CO2	✓	✓	✓					✓	✓		✓	
CO3	✓	✓	✓	✓		✓			✓			✓
CO4	✓	✓	✓			✓			✓			✓
CO5	✓	✓	✓	✓			✓	✓				

## REFERENCES:

1. Cornelisse, JW, Schoyer, HFR & Wakker, F, "Rocket Propulsion and Space Dynamics", Pitman Publishing, 1979.
2. Earl R. Parker, "Materials for Missiles and Spacecraft", McGraw –Hill Book company, Inc.1982.
3. Howard D.Curtis, "Orbital Mechanics for Engineering Students", 3<sup>rd</sup> Edition, Butterworth-Heinemann, 2013.
4. Sutton, G.P, "Rocket Propulsion Elements", John Wiley & Sons Inc., New York, 9th Edition, 2016.

**AS5011**

**ELECTRIC PROPULSION SYSTEMS**

**L T P C**  
**3 0 0 3**

## COURSE OBJECTIVES:

This course will enables students

1. To get familiarize with the basic the operating principles of the various electrical thrusters.
2. To learn the concept of plasma kinetic theory
3. To gain idea on the elements of gas kinetics.
4. To impart knowledge on the classes of MPD thrusters.
5. To study the importance of electric propulsion for space applications.

### UNIT I PHYSICS OF IONIZED GASE

**8**

Atomic structure of gases - Ionization processes - Particle collisions in an ionized gas Electrical conductivity of an ionized gas - Kinetic Theory – Application of ionized gas flows.

### UNIT II INTRODUCTION TO THE BASIC PHYSICS OF ELECTRIC PROPULSION SYSTEMS

**9**

Historical outline - Definition of Electric Propulsion - High impulse Space Missions - Exhaust velocity and specific impulse - Power supply penalty – Electric charges and Electrostatic fields - Currents and Magnetic interactions - Time dependent fields and Electromagnetic wave propagation.

### UNIT III ELECTRO-THERMAL PROPULSION

**9**

One dimensional model - Enthalpy of high temperature gases - Frozen flow efficiency – Resistojets - Electrical discharges - Arcjets - Operation and Analysis - Materials - advantages and Disadvantages

**UNIT IV ELECTROSTATIC PROPULSION 9**

One dimensional space-charge flows - Basic relationships - The acceleration- deceleration concept - Ion engines - Design and Performance - Hall effect – Hall thrusters - Field emission electric propulsion (FEEP) - Colloid thrusters

**UNIT V ELECTROMAGNETIC PROPULSION 10**

The Lorentz force - Magnetogasdynamic channel flow - Ideal steady flow acceleration - Thermal and viscous losses - Geometry considerations - Self induced fields - Sources of the conducting gas - The magnetoplasdynamic arc - Magneto- plasmadynamic (MPD) thrusters - Pulsed plasma acceleration - Pulsed plasma thrusters (PPT) - Quasi steady acceleration - Pulsed inductive acceleration - Travelling wave acceleration

**TOTAL: 45 PERIODS****COURSE OUTCOMES:**

Upon completion of the course, students will be

- CO1:** Able to classify and describe the electric thrusters for space applications.
- CO2:** Able to perform the preliminary sizing of a test facility for electric propulsion.
- CO3:** Able to perform calculations of first approximation on plasmas of electric propulsion.
- CO4:** Able to set theory models for the study of electric propulsion systems.
- CO5:** Able to acquire knowledge on the basics of rarefied gas dynamics and plasma physics.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	✓	✓	✓	✓			✓		✓			✓
<b>CO2</b>	✓	✓	✓		✓	✓			✓			✓
<b>CO3</b>	✓	✓	✓	✓	✓	✓		✓	✓			✓
<b>CO4</b>	✓	✓	✓	✓	✓			✓				✓
<b>CO5</b>	✓	✓	✓	✓			✓	✓	✓		✓	

**REFERENCES:**

1. George W. Sutton, "Engineering Magnetohydrodynamics", Dover Publications Inc., New York, 2006.
2. Robert G. Jahn, "Physics of Electric Propulsion", Dover Publications, 2012.
3. Sutton,GP "Rocket Propulsion Elements", John Wiley & Sons Inc., New York, 9th Edition, 2016.

**AS5012****MANNED SPACE MISSIONS****L T P C  
3 0 0 3****COURSE OBJECTIVES:**

This course will make students

1. To get insights into the basic aspects of manned and unmanned missions.
2. To provide with the basic knowledge on the structure of atmosphere and the space environment.
3. To learn the complexities involved in sending human being into space missions.
4. To learn how the unmanned missions with respect to mission logistics and planning are different from manned missions.

**UNIT I INTRODUCTION 8**

The physics of space - Current missions: space station, Moon mission and Mars missions - Engineering challenges on Manned vs. unmanned missions - Scientific and technological gains from space programs - Salient features of Apollo and Space station missions – space shuttle mission

**UNIT II SPACE VS EARTH ENVIRONMENT 10**

Atmosphere: Structure and Composition - - Atmosphere: Air Pressure, Temperature, and Density - Atmosphere: Meteoroid, Orbital Debris & Radiation Protection - Human Factors of Crewed Spaceflight, . Safety of Crewed Spaceflight - Magnetosphere - Radiation Environment: Galactic Cosmic Radiation (GCR) , Solar Particle Events (SPE) - Radiation and the Human Body – Impact of microgravity and g forces on humans – space adaptation syndrome

**UNIT III LIFE SUPPORT SYSTEMS AND COUNTER MEASURES 8**

Life Support Systems and Space Survival Overview - - Environment Controlled Life Support Systems (ECLSS) - Human / Machine Interaction - - Human Factors in Control Design - Crew Accommodations

**UNIT IV MISSION LOGISTICS AND PLANNING 10**

Group Dynamics: Ground Communication and Support - Space Resources and Mission Planning - Space Mission Design: Rockets and Launch Vehicles - Orbital Selection and Astrodynamics , Entry, Descent, Landing, and Ascent, Designing and Sizing Space elements, Transfer, Entry, Landing, and Ascent Vehicles, Designing, Sizing, and Integrating a Surface Base, Planetary Surface Vehicles

**UNIT V ALLIED TOPICS 9**

Spacecraft Subsystems: Space Operations - Space Architecture, Attitude Determination and Control - Designing Power Systems - Extravehicular Activity (EVA) Systems - Space Robotics - Mission Operations for Crewed Spaceflight - Command, Control, and Communications Architecture.

**TOTAL:45 PERIODS**

**COURSE OUTCOMES:**

At the end of the course, students will be able

- CO1:** To get updated with technical status on current knowledge manned and unmanned missions.
- CO2:** To apply space element architectures, design and sizing principles and processes for on-orbit, ascent and re-entry operations. Apply sizing principles to estimate mass and power for a given set of requirements.
- CO3:** To apply basic principles of orbital mechanics and how they apply to human missions.
- CO4:** To familiarize with human spaceflight mission design principles, limitations and processes and apply them to develop goals, objectives as well as top level requirements
- CO5:** To characterize the scope, functions and physical architecture options for human spaceflight support systems such as Environmental Control and Life Support, Thermal Control, EVA Systems, and others.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	✓	✓			✓	✓	✓	✓	✓		✓	
<b>CO2</b>	✓			✓	✓		✓	✓				✓
<b>CO3</b>	✓		✓	✓					✓			✓
<b>CO4</b>	✓	✓	✓	✓	✓	✓					✓	✓
<b>CO5</b>	✓	✓	✓	✓		✓	✓		✓		✓	

**REFERENCES:**

1. Connors, MM, Harrison, AA, and Akins, FR,. “Living Aloft: Human Requirements for Extended Spaceflight”, University Press of the Pacific, Honolulu, 2005.
2. Eckart, P, “Spaceflight Life Support and Biospherics”, Springer publishers, 1<sup>st</sup> t edition, 2010.
3. Larson, WJ and Pranke, LK, “Human Spaceflight: Mission Analysis and Design”, McGraw-Hill Higher Education, Washington, DC, 1999.
4. McNamara, Bernard, “Into the Final Frontier: The Human Exploration of Space”, Brooks Cole Publishing, 1<sup>st</sup> edition, 2000.

**COURSE OBJECTIVES:**

This course will enable students

1. To realize the importance and influence of non-equilibrium real-gas effects in high temperature flows.
2. To know the physical mechanisms causing aerodynamic heating of high speed vehicles.
3. To study the parameters that influences the design of hypersonic vehicles.
4. To know the computational methods appropriate to high temperature flows.
5. To realize the effects of friction and heat addition to gas dynamic flow, typical in aerospace engines.

**UNIT I INTRODUCTION****8**

Nature of high temperature flows – Chemical effects in air – Real perfect gases – Gibb's free energy and entropy by chemical and non equilibrium – Chemically reacting mixtures and boundary layers.

**UNIT II STATISTICAL THERMODYNAMICS****8**

Introduction to statistical thermodynamics – Relevance to hypersonic flow - Microscopic description of gases – Boltzman distribution – Cartesian function

**UNIT III KINETIC THEORY AND HYPERSONIC FLOWS****9**

Chemical equilibrium calculation of equilibrium composition of high temperature air – equilibrium properties of high temperature air – collision frequency and mean free path – velocity and speed distribution functions.

**UNIT IV INVISCID HIGH TEMPERATURE FLOWS****10**

Equilibrium and non – equilibrium flows – governing equations for inviscid high temperature equilibrium flows – equilibrium normal and oblique shock wave flows – frozen and equilibrium flows – equilibrium conical and blunt body flows – governing equations for non equilibrium inviscid flows.

**UNIT V TRANSPORT PROPERTIES IN HIGH TEMPERATURE GASES****10**

Transport coefficients – mechanisms of diffusion – total thermal conductivity – transport characteristics for high temperature air – radiative transparent gases – radiative transfer equation for transport, absorbing and emitting and absorbing gases.

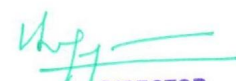
**TOTAL: 45 PERIODS****COURSE OUTCOMES:**

At the end of the course, students will be

- CO1:** Able to identify the critical physical phenomena in high temperature flows.
- CO2:** Realize the importance of kinetic theory of gases.
- CO3:** Having knowledge about the features and importance of high - enthalpy flows.
- CO4:** In a position to demonstrate the transport properties in High-Temperature gases.
- CO5:** Having knowledge on some of the basic phenomena in rarefied flows.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓		✓						✓
CO2	✓	✓	✓	✓			✓	✓				
CO3	✓	✓	✓	✓		✓	✓	✓	✓			✓
CO4	✓	✓	✓	✓			✓			✓		
CO5	✓	✓	✓	✓		✓						✓

Attested



## REFERENCES:

1. Anderson, JD, "Hypersonic and High Temperature Gas Dynamics", AIAA Education Series, 2<sup>nd</sup> edition, 2006.
2. Anderson J D, "Modern compressible flow : with Historical Perspective", McGraw Hill Education, 3<sup>rd</sup> edition, 2017.
3. Bose, TK, "High Temperature Gas Dynamics", Springer-Verlag Berlin Heidelberg, 1st edition, 2004.
4. John T. Bertin, "Hypersonic Aerothermodynamics", AIAA Education Series, 1993.
5. William H. Heiser & David T. Pratt, "Hypersonic Air Breathing propulsion", AIAA Education Series, 1994.

**AL5074**

**HIGH SPEED JET FLOWS**

**L T P C**  
**3 0 0 3**

## COURSE OBJECTIVES:

This course will make students

1. To get insight into the basic aspects of jets and types of jets.
2. To learn the basic properties of jets and its characteristics.
3. To get knowledge on various active and passive jet control methods.
4. To gain knowledge into the basic aspects of jet acoustics
5. To acquire in-depth knowledge on how and what type of control methods can be implemented practically.

### UNIT I INTRODUCTION

**9**

Properties of Turbulent Jets-Fundamental Concepts, Submerged Jets- Velocity Profiles in a Submerged Jet- Spread of a turbulent submerged jet- Lines of Constant Velocity in a Submerged Jet. Velocity Variation along the Axis of a Submerged jet, Velocity, Temperature, and Concentration Profiles in a Turbulent Jet Spreading into an External Stream of Fluid-Spread of a Turbulent Jet into a Co-flowing or Counter-flowing External Stream- Turbulence Characteristics in a Free Jet.

### UNIT II JETS

**9**

Types of Jets - Plane free-jets. Round jets. Plane jets in a co-flowing stream. Round jet in Co flowing stream- Swirling jets-Radial jets- Wall jets- Jet Characteristics & Entrainment, Mathematical treatment of jet profiles- Semi-empirical Theories. Mixing Layers- Computational and Experimental Techniques for Studying the Jets.

### UNIT III ACTIVE JET CONTROL METHODS

**9**

Active control methods- Actuators-Fluidic, Thermal, Acoustic, Piezoelectric, Electromagnetic, MEMS, Synthetic Jets, Controls and Sensors, Applications.

### UNIT IV PASSIVE JET CONTROL METHODS

**9**

Passive control techniques- Tabs, Grooves, Chevrons, non-circular nozzles, Notches & wires, vortex generators. Optical Flow Visualization, Applications.

### UNIT V JET ACOUSTICS

**9**

Introduction to Jet Acoustics – Types of jet noise – Source of generation- Travelling wave solution, standing wave solution – multi-dimensional acoustics-Theoretical Concepts of Jet Noise Generation and Suppression–Jet Noise suppression techniques – applications

**TOTAL: 45 PERIODS**

*Attested*

  
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## COURSE OUTCOMES:

Upon completion of this course, students will be able

**CO1:** To acquire knowledge on the unique features of jet flows.

**CO2:** To analyse the characteristics of jets.

**CO3:** To have through knowledge on active and passive control methods of jets.

**CO4:** To acquire knowledge on jet acoustics and methods for suppression of jet noise.

**CO5:** To demonstrate various experimental techniques to determine jet characteristics.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓			✓					✓
CO2	✓	✓	✓		✓		✓		✓			
CO3	✓	✓	✓	✓	✓	✓	✓					
CO4	✓	✓	✓		✓	✓	✓	✓	✓			
CO5	✓	✓	✓	✓			✓					✓

## REFERENCES:

1. Ethirajan Rathakrishnan, "Applied Gas Dynamics", John Wiley, New York, 2010.
2. Liepmann and Roshko, "Elements of Gas Dynamics", Dover Publishers, 2017.
3. Rathakrishnan E., "Gas Dynamics", Prentice Hall of India, New Delhi, 5<sup>th</sup> edition, 2014.
4. Shapiro, AH, "Dynamics and Thermodynamics of Compressible Fluid Flow, Vols. I & II", Ronald Press, New York, 1953.

## AL5077 SMART MATERIALS AND STRUCTURAL HEALTH MONITORING

L T P C  
3 0 0 3

### COURSE OBJECTIVES:

This course will enables students

1. To get basic idea on the fundamentals of structural health monitoring.
2. To impart knowledge in the areas of vibration based techniques in structural health monitoring, fibre optics and piezo electric sensors.
3. To gain knowledge on the fundamentals of fabrication, modelling, analysis, and design of smart materials and structures.
4. To get exposed to the state of the art of smart materials and systems,
5. To impart knowledge on spanning piezoelectrics, shape memory alloys, electro active polymers, mechanochromic materials and fibre optics.

### UNIT I STRUCTURAL HEALTH MONITORING

8

An Overview of Structural Health Monitoring, Structural Health Monitoring and Smart Materials, Structural Health Monitoring versus Non Destructive Evaluation A broad Overview of Smart Materials Overview of Application Potential of SHM Notable Applications of SHM – Aerospace Engineering. Structural health monitoring of composites – Repair investigation using SHM.

### UNIT II OVERVIEW OF SMART MATERIALS

10

Introduction to Smart Materials, Principles of Piezoelectricity, Perovskite Piezoceramic Materials, Single Crystals vs Polycrystalline Systems, Piezoelectric Polymers, Principles of Magnetostriction, Rare earth Magnetostrictive materials, Giant Magnetostriction and Magneto-resistance Effect, Introduction to Electro-active Materials, Electronic Materials, Electro-active Polymers, Ionic Polymer Matrix Composite (IPMC), Shape Memory Effect, Shape Memory Alloys, Shape Memory Polymers, Electro-rheological Fluids, Magneto Rheological Fluids.

Attested

**UNIT III SMART COMPOSITES****10**

Review of Composite Materials, Micro and Macro-mechanics, Modelling Laminated Composites based on Classical Laminated Plate Theory, Effect of Shear Deformation, Dynamics of Smart Composite Beam, Governing Equation of Motion, Finite Element Modelling of Smart Composite Beams, Vibration Control using SHM –introduction to FE formulation Constitutive Relationship - Element Stiffness Matrix for High Precision Finite Element -Element Mass Matrix for High Precision Finite Element - Developing Actuator and Sensor Influence Matrix .Delamination Sensing using Piezo Sensory Layer.

**UNIT IV INTELLIGENT SYSTEMS AND NEURAL NETWORKS****9**

Operational evaluation -.Data acquisition- Feature extraction-Statistical model development for feature discrimination -Data Cleansing – Normalization-Data Fusion – Compression – Statistical model building - Supervised pattern recognition - Unsupervised pattern recognition – Signal processing – Fuzzy C means- K means – Kohonen’s Self organization mapping- Fundamentals of Wavelet analysis –Life Prediction.

**UNIT V ADVANCES IN SMART STRUCTURES & MATERIALS****8**

Self-Sensing Piezoelectric Transducers, Energy Harvesting Materials, Autophagous Materials, Self-Healing Polymers, Intelligent System Design, Emergent System Design of Chemical and Bio-Chemical sensing in structural Assessment – Absorptive chemical sensors – Spectroscopes – Fibre Optic Chemical Sensing Systems and Distributed measurement.

**TOTAL: 45 PERIODS****COURSE OUTCOMES:**

Upon completion of this course, students will be able

**CO1:** To familiarize with the fundamentals of history of SHM.

**CO2:** To provide a systematic approach to SHM process.

**CO3:** To have knowledge of the various smart materials used for aerospace applications.

**CO4:** To familiarize with the non-destructive test techniques relevant to SHM.

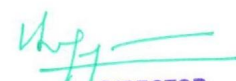
**CO5:** To provide hands-on experience with experimental modal analysis.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>	✓	✓	✓		✓		✓					✓
<b>CO2</b>	✓	✓	✓	✓		✓	✓					✓
<b>CO3</b>	✓	✓	✓	✓	✓		✓					✓
<b>CO4</b>	✓	✓	✓	✓	✓		✓	✓				✓
<b>CO5</b>	✓	✓	✓		✓		✓		✓			✓

**REFERENCES:**

1. Brian Culshaw, “Smart Structures, and Materials”, Artech House, 2000.
2. Daniel Balageas, Claus-Peter Fritzen, Alfredo Güemes, “Structural Health Monitoring”, Wiley - ISTE, 2006.
3. Douglas E Adams, “Health Monitoring of Structural Materials and Components-Methods with Applications”, John Wiley and Sons, 2007.
4. Gandhi and Thompson, “Smart Materials and Structures”, Springer Netherlands, 1992.
5. Laurene Fausett, “Fundamentals Of Neural Networks”, Pearson publishers, 1994
6. Victor Giurgutiu, “Structural Health Monitoring with Wafer Active Sensors”, Academic Press Inc, 2007.

Attested



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**COURSE OBJECTIVES:**

This course will enable students

1. To impart knowledge on the basic aspects of UAV and its types.
2. To realize the importance of airframe designs and types of propulsions in unmanned aerial vehicle.
3. Gain knowledge on various subsystems and testing procedure of an unmanned aerial vehicle.
4. To enhance the knowledge in the field of real time applications.
5. To get familiarize with the ground control procedures and operations.

**UNIT I INTRODUCTION TO UAV 9**

History of UAV –classification –basic terminology-models and prototypes –applications

**UNIT II BASICS OF AIRFRAME 9**

Airframe –dynamics –modeling- structures –wing design- engines and its types-equipment, maintenance and management-control surfaces-specifications.

**UNIT III DEVELOPMENT OF UAS SYSTEM 9**

System Development- Ground Testing-UAV component testing-Uav Sub-assembly and Sub-System Testing- Testing Complete UAV, Environmental testing – Testing Complete UAV- Control Station testing-Catapult Launch systems -System In flight Testing- Test sites-Test Crew training-Onsite preparation - System Certification.

**UNIT IV DEPLOYMENT OF UNMANNED AERIAL SYSTEM 9**

Operational trails-network centric operations-Radar confusion-Missile Decoy-radio relay-Electronic Intelligence-Covert Reconnaissance and surveillance Target designation by laser, NBC contamination Monitoring-Long Range reconnaissance and strike- Aerial photography-Information services-communication relay- landmine detection and Destruction-other applications

**UNIT V COMMUNICATION PAYLOADS AND PATH PLANNING 9**

Payloads-Telemetry-tracking-Aerial photography, Frequency range – Commands- Control, FPV videos - Flight computer sensor-displays, RF modems, Simulation and ground testing, Trouble shooting, waypoints navigation and ground control software.

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES:**

At the end of this course, students will be able

**CO1:** To classify UAVs based on different parameters.

**CO2:** To demonstrate ability to design an efficient structure for an UAV of specific application.

**CO3:** To perform ground testing of UAVs.

**CO4:** To apply the knowledge gained on electronic intelligence and target designation for successful development of UAS.

**CO5:** To understand the basic concepts in the different types of navigation schemes for UAS.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓			✓			✓			✓
CO2	✓	✓	✓	✓	✓	✓						✓
CO3	✓	✓	✓		✓	✓			✓			✓
CO4	✓		✓	✓		✓			✓			
CO5	✓		✓	✓	✓		✓		✓			✓

Attested

## REFERENCES:

1. Armand J. Chaput, "Design of Unmanned Air Vehicle Systems", Lockheed Martin Aeronautics Company, 2001.
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.
4. Reg Austin, "Unmanned Aircraft systems-UAVs Design, Development and Deployment", WILEY Publication, 2010.
5. Robert C. Nelson, "Flight Stability and Automatic Control", McGraw-Hill, Inc, 1998.
6. Swatton , PJ, "Ground studies for pilots' flight planning", 6<sup>th</sup> edition, 2008.



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## OPEN ELECTIVE COURSES (OEC)

OE5091

**BUSINESS DATA ANALYTICS**

**L T P C**  
**3 0 0 3**

### **COURSE OBJECTIVES:**

- To understand the basics of business analytics and its life cycle.
- To gain knowledge about fundamental business analytics.
- To learn modeling for uncertainty and statistical inference.
- To understand analytics using Hadoop and Map Reduce frameworks.
- To acquire insight on other analytical frameworks.

### **UNIT I OVERVIEW OF BUSINESS ANALYTICS**

**9**

Introduction – Drivers for Business Analytics – Applications of Business Analytics: Marketing and Sales, Human Resource, Healthcare, Product Design, Service Design, Customer Service and Support – Skills Required for a Business Analyst – Framework for Business Analytics Life Cycle for Business Analytics Process.

#### **Suggested Activities:**

- Case studies on applications involving business analytics.
- Converting real time decision making problems into hypothesis.
- Group discussion on entrepreneurial opportunities in Business Analytics.

#### **Suggested Evaluation Methods:**

- Assignment on business scenario and business analytical life cycle process.
- Group presentation on big data applications with societal need.
- Quiz on case studies.

### **UNIT II ESSENTIALS OF BUSINESS ANALYTICS**

**9**

Descriptive Statistics – Using Data – Types of Data – Data Distribution Metrics: Frequency, Mean, Median, Mode, Range, Variance, Standard Deviation, Percentile, Quartile, z-Score, Covariance, Correlation – Data Visualization: Tables, Charts, Line Charts, Bar and Column Chart, Bubble Chart, Heat Map – Data Dashboards.

#### **Suggested Activities:**

- Solve numerical problems on basic statistics.
- Explore chart wizard in MS Excel Case using sample real time data for data visualization.
- Use R tool for data visualization.

#### **Suggested Evaluation Methods:**

- Assignment on descriptive analytics using benchmark data.
- Quiz on data visualization for univariate, bivariate data.

### **UNIT III MODELING UNCERTAINTY AND STATISTICAL INFERENCE**

**9**

Modeling Uncertainty: Events and Probabilities – Conditional Probability – Random Variables – Discrete Probability Distributions – Continuous Probability Distribution – Statistical Inference: Data Sampling – Selecting a Sample – Point Estimation – Sampling Distributions – Interval Estimation – Hypothesis Testing.

#### **Suggested Activities:**

- Solving numerical problems in sampling, probability, probability distributions and hypothesis testing.
- Converting real time decision making problems into hypothesis.

*Attested*

**Suggested Evaluation Methods:**

- Assignments on hypothesis testing.
- Group presentation on real time applications involving data sampling and hypothesis testing.
- Quizzes on topics like sampling and probability.

**UNIT IV ANALYTICS USING HADOOP AND MAPREDUCE FRAMEWORK 9**

Introducing Hadoop – RDBMS versus Hadoop – Hadoop Overview – HDFS (Hadoop Distributed File System) – Processing Data with Hadoop – Introduction to MapReduce – Features of MapReduce – Algorithms Using Map-Reduce: Matrix-Vector Multiplication, Relational Algebra Operations, Grouping and Aggregation – Extensions to MapReduce.

**Suggested Activities:**

- Practical – Install and configure Hadoop.
- Practical – Use web based tools to monitor Hadoop setup.
- Practical – Design and develop MapReduce tasks for word count, searching involving text corpus etc.

**Suggested Evaluation Methods:**

- Evaluation of the practical implementations.
- Quizzes on topics like HDFS and extensions to MapReduce.

**UNIT V OTHER DATA ANALYTICAL FRAMEWORKS 9**

Overview of Application development Languages for Hadoop – PigLatin – Hive – Hive Query Language (HQL) – Introduction to Pentaho, JAQL – Introduction to Apache: Sqoop, Drill and Spark, Cloudera Impala – Introduction to NoSQL Databases – Hbase and MongoDB.

**Suggested Activities:**

- Practical – Installation of NoSQL database like MongoDB.
- Practical – Demonstration on Sharding in MongoDB.
- Practical – Install and run Pig
- Practical – Write PigLatin scripts to sort, group, join, project, and filter data.
- Design and develop algorithms to be executed in MapReduce involving numerical methods for analytics.

**Suggested Evaluation Methods:**

- Mini Project (Group) – Real time data collection, saving in NoSQL, implement analytical techniques using Map-Reduce Tasks and Result Projection.

**TOTAL: 45 PERIODS****COURSE OUTCOMES:**

On completion of the course, the student will be able to:

- Identify the real world business problems and model with analytical solutions.
- Solve analytical problem with relevant mathematics background knowledge.
- Convert any real world decision making problem to hypothesis and apply suitable statistical testing.
- Write and Demonstrate simple applications involving analytics using Hadoop and MapReduce
- Use open source frameworks for modeling and storing data.
- Apply suitable visualization technique using R for visualizing voluminous data.

**REFERENCES:**

1. Vignesh Prajapati, "Big Data Analytics with R and Hadoop", Packt Publishing, 2013.
2. Umesh R Hodeghatta, Umesha Nayak, "Business Analytics Using R – A Practical Approach", Apress, 2017.
3. Anand Rajaraman, Jeffrey David Ullman, "Mining of Massive Datasets", Cambridge University Press, 2012.

4. Jeffrey D. Camm, James J. Cochran, Michael J. Fry, Jeffrey W. Ohlmann, David R. Anderson, "Essentials of Business Analytics", Cengage Learning, second Edition, 2016.
5. U. Dinesh Kumar, "Business Analytics: The Science of Data-Driven Decision Making", Wiley, 2017.
6. A. Ohri, "R for Business Analytics", Springer, 2012
7. Rui Miguel Forte, "Mastering Predictive Analytics with R", Packt Publication, 2015.

**OE5092**

**INDUSTRIAL SAFETY**

**L T P C**  
**3 0 0 3**

**COURSE OBJECTIVES:**

- Summarize basics of industrial safety
- Describe fundamentals of maintenance engineering
- Explain wear and corrosion
- Illustrate fault tracing
- Identify preventive and periodic maintenance

**UNIT I INTRODUCTION 9**

Accident, causes, types, results and control, mechanical and electrical hazards, types, causes and preventive steps/procedure, describe salient points of factories act 1948 for health and safety, wash rooms, drinking water layouts, light, cleanliness, fire, guarding, pressure vessels, etc, Safety color codes. Fire prevention and firefighting, equipment and methods.

**UNIT II FUNDAMENTALS OF MAINTENANCE ENGINEERING 9**

Definition and aim of maintenance engineering, Primary and secondary functions and responsibility of maintenance department, Types of maintenance, Types and applications of tools used for maintenance, Maintenance cost & its relation with replacement economy, Service life of equipment.

**UNIT III WEAR AND CORROSION AND THEIR PREVENTION 9**

Wear- types, causes, effects, wear reduction methods, lubricants-types and applications, Lubrication methods, general sketch, working and applications, i. Screw down grease cup, ii. Pressure grease gun, iii. Splash lubrication, iv. Gravity lubrication, v. Wick feed lubrication vi. Side feed lubrication, vii. Ring lubrication, Definition, principle and factors affecting the corrosion. Types of corrosion, corrosion prevention methods.

**UNIT IV FAULT TRACING 9**

Fault tracing-concept and importance, decision tree concept, need and applications, sequence of fault finding activities, show as decision tree, draw decision tree for problems in machine tools, hydraulic, pneumatic, automotive, thermal and electrical equipment's like, I. Any one machine tool, ii. Pump iii. Air compressor, iv. Internal combustion engine, v. Boiler, vi. Electrical motors, Types of faults in machine tools and their general causes.

**UNIT V PERIODIC AND PREVENTIVE MAINTENANCE 9**

Periodic inspection-concept and need, degreasing, cleaning and repairing schemes, overhauling of mechanical components, overhauling of electrical motor, common troubles and remedies of electric motor, repair complexities and its use, definition, need, steps and advantages of preventive maintenance. Steps/procedure for periodic and preventive maintenance of: I. Machine tools, ii. Pumps, iii. Air compressors, iv. Diesel generating (DG) sets, Program and schedule of preventive maintenance of mechanical and electrical equipment, advantages of preventive maintenance. Repair cycle concept and importance

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES:**

- CO1: Ability to summarize basics of industrial safety  
 CO2: Ability to describe fundamentals of maintenance engineering  
 CO3: Ability to explain wear and corrosion  
 CO4: Ability to illustrate fault tracing  
 CO5: Ability to identify preventive and periodic maintenance

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓											
CO2	✓											
CO3	✓	✓	✓									
CO4	✓	✓	✓									
CO5	✓	✓	✓									

**REFERENCES:**

1. Audels, Pump-hydraulic Compressors, Mcgrew Hill Publication, 1978.
2. Garg H P, Maintenance Engineering, S. Chand and Company, 1987.
3. Hans F. Winterkorn, Foundation Engineering Handbook, Chapman & Hall London, 2013.
4. Higgins & Morrow, Maintenance Engineering Handbook, Eighth Edition, 2008

OE5093

**OPERATIONS RESEARCH**
**L T P C**  
**3 0 0 3**
**COURSE OBJECTIVES:**

- Solve linear programming problem and solve using graphical method.
- Solve LPP using simplex method
- Solve transportation, assignment problems
- Solve project management problems
- Solve scheduling problems

**UNIT I LINEAR PROGRAMMING****9**

Introduction to Operations Research – assumptions of linear programming problems -  
 Formulations of linear programming problem – Graphical method

**UNIT II ADVANCES IN LINEAR PROGRAMMING****9**

Solutions to LPP using simplex algorithm- Revised simplex method - primal dual relationships –  
 Dual simplex algorithm - Sensitivity analysis

**UNIT III NETWORK ANALYSIS – I****9**

Transportation problems -Northwest corner rule, least cost method, Voges's approximation  
 method - Assignment problem -Hungarian algorithm

**UNIT IV NETWORK ANALYSIS – II****9**

Shortest path problem: Dijkstra's algorithms, Floyds algorithm, systematic method -CPM/PERT

**UNIT V NETWORK ANALYSIS – III****9**

Scheduling and sequencing - single server and multiple server models - deterministic inventory  
 models - Probabilistic inventory control models

**TOTAL: 45 PERIODS***Attested*



## COURSE OUTCOMES:

CO1: To formulate linear programming problem and solve using graphical method.

CO2: To solve LPP using simplex method

CO3: To formulate and solve transportation, assignment problems

CO4: To solve project management problems

CO5: To solve scheduling problems

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓											
CO2	✓											
CO3	✓	✓	✓									
CO4	✓	✓	✓									
CO5	✓	✓	✓									

## REFERENCES:

1. Harvey M Wagner, Principles of Operations Research: Prentice Hall of India 2010
2. Hitler Libermann, Operations Research: McGraw Hill Pub. 2009
3. Pant J C, Introduction to Optimisation: Operations Research, Jain Brothers, Delhi, 2008
4. Pannerselvam, Operations Research: Prentice Hall of India 2010
5. Taha H A, Operations Research, An Introduction, PHI, 2008

OE5094

**COST MANAGEMENT OF ENGINEERING PROJECTS**

**L T P C**  
**3 0 0 3**

## COURSE OBJECTIVES:

- Summarize the costing concepts and their role in decision making
- Infer the project management concepts and their various aspects in selection
- Interpret costing concepts with project execution
- Develop knowledge of costing techniques in service sector and various budgetary control techniques
- Illustrate with quantitative techniques in cost management

### UNIT I INTRODUCTION TO COSTING CONCEPTS

9

Objectives of a Costing System; Cost concepts in decision-making; Relevant cost, Differential cost, Incremental cost and Opportunity cost; Creation of a Database for operational control.

### UNIT II INTRODUCTION TO PROJECT MANAGEMENT

9

Project: meaning, Different types, why to manage, cost overruns centres, various stages of project execution: conception to commissioning. Project execution as conglomeration of technical and nontechnical activities, Detailed Engineering activities, Pre project execution main clearances and documents, Project team: Role of each member, Importance Project site: Data required with significance, Project contracts.

### UNIT III PROJECT EXECUTION AND COSTING CONCEPTS

9

Project execution Project cost control, Bar charts and Network diagram, Project commissioning: mechanical and process, Cost Behavior and Profit Planning Marginal Costing; Distinction between Marginal Costing and Absorption Costing; Break-even Analysis, Cost-Volume-Profit Analysis, Various decision-making problems, Pricing strategies: Pareto Analysis, Target costing, Life Cycle Costing.

### UNIT IV COSTING OF SERVICE SECTOR AND BUDGETERY CONTROL

9

Just-in-time approach, Material Requirement Planning, Enterprise Resource Planning, Activity-Based Cost Management, Bench Marking; Balanced Score Card and Value-Chain Analysis, Budgetary Control: Flexible Budgets; Performance budgets; Zero-based budgets.

**UNIT V QUANTITATIVE TECHNIQUES FOR COST MANAGEMENT****9**

Linear Programming, PERT/CPM, Transportation problems, Assignment problems, Learning Curve Theory.

**TOTAL: 45 PERIODS****OUTCOMES**

- CO1 – Understand the costing concepts and their role in decision making
- CO2 – Understand the project management concepts and their various aspects in selection
- CO3 – Interpret costing concepts with project execution
- CO4 – Gain knowledge of costing techniques in service sector and various budgetary control techniques
- CO5 – Become familiar with quantitative techniques in cost management

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓		✓			✓	✓		✓	✓
CO2	✓	✓	✓		✓				✓		✓	✓
CO3	✓	✓	✓		✓	✓					✓	✓
CO4	✓	✓	✓		✓		✓				✓	✓
CO5	✓	✓	✓		✓	✓	✓				✓	✓

**REFERENCES:**

1. Ashish K. Bhattacharya, Principles & Practices of Cost Accounting A. H. Wheeler publisher, 1991
2. Charles T. Horngren and George Foster, Advanced Management Accounting, 1988
3. Charles T. Horngren et al Cost Accounting A Managerial Emphasis, Prentice Hall of India, New Delhi, 2011
4. Robert S Kaplan Anthony A. Alkinson, Management & Cost Accounting, 2003
5. Vohra N.D., Quantitative Techniques in Management, Tata McGraw Hill Book Co. Ltd, 2007

**OE5095****COMPOSITE MATERIALS****L T P C  
3 0 0 3****COURSE OBJECTIVES:**

- Summarize the characteristics of composite materials and effect of reinforcement in composite materials.
- Identify the various reinforcements used in composite materials.
- Compare the manufacturing process of metal matrix composites.
- Understand the manufacturing processes of polymer matrix composites.
- Analyze the strength of composite materials.

**UNIT I INTRODUCTION****9**

Definition – Classification and characteristics of Composite materials - Advantages and application of composites - Functional requirements of reinforcement and matrix - Effect of reinforcement (size, shape, distribution, volume fraction) on overall composite performance.

**UNIT II REINFORCEMENTS****9**

Preparation-layup, curing, properties and applications of glass fibers, carbon fibers, Kevlar fibers and Boron fibers - Properties and applications of whiskers, particle reinforcements - Mechanical Behavior of composites: Rule of mixtures, Inverse rule of mixtures - Isostrain and Isostress conditions.

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**UNIT III MANUFACTURING OF METAL MATRIX COMPOSITES 9**

Casting – Solid State diffusion technique - Cladding – Hot isostatic pressing - Properties and applications. Manufacturing of Ceramic Matrix Composites: Liquid Metal Infiltration – Liquid phase sintering. Manufacturing of Carbon – Carbon composites: Knitting, Braiding, Weaving - Properties and applications.

**UNIT IV MANUFACTURING OF POLYMER MATRIX COMPOSITES 9**

Preparation of Moulding compounds and prepregs – hand layup method – Autoclave method – Filament winding method – Compression moulding – Reaction injection moulding - Properties and applications.

**UNIT V STRENGTH 9**

Laminar Failure Criteria-strength ratio, maximum stress criteria, maximum strain criteria, interacting failure criteria, hygrothermal failure. Laminate first ply failure-insight strength; Laminate strength-ply discount truncated maximum strain criterion; strength design using caplet plots; stress concentrations.

**TOTAL: 45 PERIODS****COURSE OUTCOMES:**

- CO1 - Know the characteristics of composite materials and effect of reinforcement in composite materials.
- CO2 – Know the various reinforcements used in composite materials.
- CO3 – Understand the manufacturing processes of metal matrix composites.
- CO4 – Understand the manufacturing processes of polymer matrix composites.
- CO5 – Analyze the strength of composite materials.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1		✓	✓	✓								
CO2		✓	✓	✓	✓						✓	
CO3			✓	✓	✓		✓				✓	
CO4			✓	✓	✓		✓				✓	
CO5				✓	✓		✓					

**REFERENCES:**

1. Cahn R.W. - Material Science and Technology – Vol 13 – Composites, VCH, West Germany.
2. Callister, W.D Jr., Adapted by Balasubramaniam R, Materials Science and Engineering, An introduction, John Wiley & Sons, NY, Indian edition, 2007.
3. Chawla K.K., Composite Materials, 2013.
4. Lubin.G, Hand Book of Composite Materials, 2013.

**OE5096****WASTE TO ENERGY****L T P C  
3 0 0 3****COURSE OBJECTIVES:**

- Interpret the various types of wastes from which energy can be generated
- Develop knowledge on biomass pyrolysis process and its applications
- Develop knowledge on various types of biomass gasifiers and their operations
- Invent knowledge on biomass combustors and its applications on generating energy

- Summarize the principles of bio-energy systems and their features

**UNIT I INTRODUCTION TO EXTRACTION OF ENERGY FROM WASTE 9**  
 Classification of waste as fuel – Agro based, Forest residue, Industrial waste - MSW – Conversion devices – Incinerators, gasifiers, digestors

**UNIT II BIOMASS PYROLYSIS 9**  
 Pyrolysis – Types, slow fast – Manufacture of charcoal – Methods - Yields and application – Manufacture of pyrolytic oils and gases, yields and applications.

**UNIT III BIOMASS GASIFICATION 9**  
 Gasifiers – Fixed bed system – Downdraft and updraft gasifiers – Fluidized bed gasifiers – Design, construction and operation – Gasifier burner arrangement for thermal heating – Gasifier engine arrangement and electrical power – Equilibrium and kinetic consideration in gasifier operation.

**UNIT IV BIOMASS COMBUSTION 9**  
 Biomass stoves – Improved chullahs, types, some exotic designs, Fixed bed combustors, Types, inclined grate combustors, Fluidized bed combustors, Design, construction and operation - Operation of all the above biomass combustors.

**UNIT V BIO ENERGY 9**  
 Properties of biogas (Calorific value and composition), Biogas plant technology and status - Bio energy system - Design and constructional features - Biomass resources and their classification - Biomass conversion processes - Thermo chemical conversion - Direct combustion - biomass gasification - pyrolysis and liquefaction - biochemical conversion - anaerobic digestion - Types of biogas Plants – Applications - Alcohol production from biomass - Bio diesel production -Urban waste to energy conversion - Biomass energy programme in India.

**TOTAL: 45 PERIODS**

**OUTCOMES:**

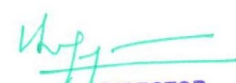
- CO1 – Understand the various types of wastes from which energy can be generated
- CO2 – Gain knowledge on biomass pyrolysis process and its applications
- CO3 – Develop knowledge on various types of biomass gasifiers and their operations
- CO4 – Gain knowledge on biomass combustors and its applications on generating energy
- CO5 – Understand the principles of bio-energy systems and their features

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓		✓									✓
CO2	✓		✓									✓
CO3	✓	✓	✓		✓							✓
CO4	✓	✓	✓		✓		✓					✓
CO5	✓	✓	✓		✓							✓

**REFERENCES:**

- Biogas Technology - A Practical Hand Book - Khandelwal, K. C. and Mahdi, S. S., Vol. I & II, Tata McGraw Hill Publishing Co. Ltd., 1983.
- Biomass Conversion and Technology, C. Y. WereKo-Brobby and E. B. Hagan, John Wiley & Sons, 1996.
- Food, Feed and Fuel from Biomass, Challal, D. S., IBH Publishing Co. Pvt. Ltd., 1991.
- Non Conventional Energy, Desai, Ashok V., Wiley Eastern Ltd., 1990.

Attested



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## AUDIT COURSES (AC)

**AX5091**

**ENGLISH FOR RESEARCH PAPER WRITING**

**L T P C**  
**2 0 0 0**

### **COURSE OBJECTIVES:**

- Teach how to improve writing skills and level of readability
- Tell about what to write in each section
- Summarize the skills needed when writing a Title
- Infer the skills needed when writing the Conclusion
- Ensure the quality of paper at very first-time submission

### **UNIT I INTRODUCTION TO RESEARCH PAPER WRITING**

**6**

Planning and Preparation, Word Order, Breaking up long sentences, Structuring Paragraphs and Sentences, Being Concise and Removing Redundancy, Avoiding Ambiguity and Vagueness

### **UNIT II PRESENTATION SKILLS**

**6**

Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticizing, Paraphrasing and Plagiarism, Sections of a Paper, Abstracts, Introduction

### **UNIT III TITLE WRITING SKILLS**

**6**

Key skills are needed when writing a Title, key skills are needed when writing an Abstract, key skills are needed when writing an Introduction, skills needed when writing a Review of the Literature, Methods, Results, Discussion, Conclusions, The Final Check

### **UNIT IV RESULT WRITING SKILLS**

**6**

Skills are needed when writing the Methods, skills needed when writing the Results, skills are needed when writing the Discussion, skills are needed when writing the Conclusions

### **UNIT V VERIFICATION SKILLS**

**6**

Useful phrases, checking Plagiarism, how to ensure paper is as good as it could possibly be the first-time submission

**TOTAL: 30 PERIODS**

### **COURSE OUTCOMES:**

- CO1 – Understand that how to improve your writing skills and level of readability  
CO2 – Learn about what to write in each section  
CO3 – Understand the skills needed when writing a Title  
CO4 – Understand the skills needed when writing the Conclusion  
CO5 – Ensure the good quality of paper at very first-time submission

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
<b>CO1</b>										✓		✓
<b>CO2</b>										✓		✓
<b>CO3</b>										✓		✓
<b>CO4</b>										✓		✓
<b>CO5</b>										✓		✓

### **REFERENCES**

1. Adrian Wallwork , English for Writing Research Papers, Springer New York Dordrecht Heidelberg London, 2011
2. Day R How to Write and Publish a Scientific Paper, Cambridge University Press 2006
3. Goldbort R Writing for Science, Yale University Press (available on Google Books) 2006
4. Highman N, Handbook of Writing for the Mathematical Sciences, SIAM. Highman's

book 1998.

**AX5092**

**DISASTER MANAGEMENT**

**L T P C**  
**2 0 0 0**

**COURSE OBJECTIVES :**

- Summarize basics of disaster
- Explain a critical understanding of key concepts in disaster risk reduction and humanitarian response.
- Illustrate disaster risk reduction and humanitarian response policy and practice from multiple perspectives.
- Describe an understanding of standards of humanitarian response and practical relevance in specific types of disasters and conflict situations.
- Develop the strengths and weaknesses of disaster management approaches

**UNIT I INTRODUCTION 6**

Disaster: Definition, Factors and Significance; Difference between Hazard And Disaster; Natural and Manmade Disasters: Difference, Nature, Types and Magnitude.

**UNIT II REPERCUSSIONS OF DISASTERS AND HAZARDS 6**

Economic Damage, Loss of Human and Animal Life, Destruction Of Ecosystem. Natural Disasters: Earthquakes, Volcanisms, Cyclones, Tsunamis, Floods, Droughts And Famines, Landslides And Avalanches, Man-made disaster: Nuclear Reactor Meltdown, Industrial Accidents, Oil Slicks And Spills, Outbreaks Of Disease And Epidemics, War And Conflicts.

**UNIT III DISASTER PRONE AREAS IN INDIA 6**

Study of Seismic Zones; Areas Prone To Floods and Droughts, Landslides and Avalanches; Areas Prone To Cyclonic and Coastal Hazards with Special Reference To Tsunami; Post-Disaster Diseases and Epidemics

**UNIT IV DISASTER PREPAREDNESS AND MANAGEMENT 6**

Preparedness: Monitoring Of Phenomena Triggering a Disaster or Hazard; Evaluation of Risk: Application of Remote Sensing, Data from Meteorological And Other Agencies, Media Reports: Governmental and Community Preparedness.

**UNIT V RISK ASSESSMENT 6**

Disaster Risk: Concept and Elements, Disaster Risk Reduction, Global and National Disaster Risk Situation. Techniques of Risk Assessment, Global Co-Operation in Risk Assessment and Warning, People's Participation in Risk Assessment. Strategies for Survival

**TOTAL : 30 PERIODS**

**COURSE OUTCOMES:**

- CO1: Ability to summarize basics of disaster  
CO2: Ability to explain a critical understanding of key concepts in disaster risk reduction and humanitarian response.  
CO3: Ability to illustrate disaster risk reduction and humanitarian response policy and practice from multiple perspectives.  
CO4: Ability to describe an understanding of standards of humanitarian response and practical relevance in specific types of disasters and conflict situations.  
CO5: Ability to develop the strengths and weaknesses of disaster management approaches

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓											
CO2	✓											
CO3	✓	✓	✓									Attested

CO4	✓	✓	✓									
CO5	✓	✓	✓									

## REFERENCES

1. Goel S. L., Disaster Administration And Management Text And Case Studies”, Deep & Deep Publication Pvt. Ltd., New Delhi, 2009.
2. Nishitha Rai, Singh AK, “Disaster Management in India: Perspectives, issues and strategies “New Royal book Company, 2007.
3. Sahni, Pardeep Et. Al. ,” Disaster Mitigation Experiences And Reflections”, Prentice Hall Of India, New Delhi, 2001.

**AX5093**

**SANSKRIT FOR TECHNICAL KNOWLEDGE**

**L T P C**  
**2 0 0 0**

### COURSE OBJECTIVES:

- Illustrate the basic sanskrit language.
- Recognize sanskrit, the scientific language in the world.
- Appraise learning of sanskrit to improve brain functioning.
- Relate sanskrit to develop the logic in mathematics, science & other subjects enhancing the memory power.
- Extract huge knowledge from ancient literature.

#### UNIT I ALPHABETS

Alphabets in Sanskrit

6

#### UNIT II TENSES AND SENTENCES

Past/Present/Future Tense - Simple Sentences

6

#### UNIT III ORDER AND ROOTS

Order - Introduction of roots

6

#### UNIT IV SANSKRIT LITERATURE

Technical information about Sanskrit Literature

6

#### UNIT V TECHNICAL CONCEPTS OF ENGINEERING

Technical concepts of Engineering-Electrical, Mechanical, Architecture, Mathematics

6

**TOTAL: 30 PERIODS**

### COURSE OUTCOMES:

- CO1 - Understanding basic Sanskrit language.
- CO2 - Write sentences.
- CO3 - Know the order and roots of Sanskrit.
- CO4 - Know about technical information about Sanskrit literature.
- CO5 - Understand the technical concepts of Engineering.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1										✓		✓
CO2										✓		✓
CO3												✓
CO4												✓
CO5												✓

## REFERENCES

1. “Abhyaspustakam” – Dr. Vishwas, Samskrita-Bharti Publication, New Delhi

*Attested*

*W. J.*  
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2. "Teach Yourself Sanskrit" Prathama Deeksha-Vempati Kutumbshastri, Rashtriya Sanskrit Sansthanam, New Delhi Publication
3. "India's Glorious Scientific Tradition" Suresh Soni, Ocean books (P) Ltd., New Delhi, 2017.

**AX5094**

**VALUE EDUCATION**

**L T P C**  
**2 0 0 0**

**COURSE OBJECTIVES:**

Students will be able to

- Understand value of education and self-development
- Imbibe good values in students
- Let the should know about the importance of character

**UNIT I**

Values and self-development–Social values and individual attitudes. Work ethics, Indian vision of humanism. Moral and non-moral valuation. Standards and principles. Value judgements

**UNIT II**

Importance of cultivation of values. Sense of duty. Devotion, Self-reliance. Confidence, Concentration. Truthfulness, Cleanliness. Honesty, Humanity. Power of faith, National Unity. Patriotism. Love for nature, Discipline

**UNIT III**

Personality and Behavior Development-Soul and Scientific attitude. Positive Thinking. Integrity and discipline. Punctuality, Love and Kindness. Avoid fault Thinking. Free from anger, Dignity of labour.

Universal brother hood and religious tolerance. True friendship. Happiness Vs suffering, love for truth. Aware of self-destructive habits. Association and Cooperation. Doing best for saving nature

**UNIT IV**

Character and Competence–Holy books vs Blind faith. Self-management and Good health. Science of reincarnation. Equality, Nonviolence, Humility, Role of Women. All religions and same message. Mind your Mind, Self-control. Honesty, Studying effectively.

**TOTAL: 30 PERIODS**

**COURSE OUTCOMES:**

Students will be able to

- Knowledge of self-development.
- Learn the importance of Human values.
- Developing the overall personality.

**SUGGESTED READING**

1. Chakroborty, S.K. "Values and Ethics for organizations Theory and practice", Oxford University Press, New Delhi

**AX5095**

**CONSTITUTION OF INDIA**

**L T P C**  
**2 0 0 0**

**COURSE OBJECTIVES:**

Students will be able to:

- Understand the premises informing the twin themes of liberty and freedom from a civil rights perspective.
- To address the growth of Indian opinion regarding modern Indian intellectuals' constitutional



- Role and entitlement to civil and economic rights as well as the emergence nation hood in the early years of Indian nationalism.
- To address the role of socialism in India after the commencement of the Bolshevik Revolution in 1917 and its impact on the initial drafting of the Indian Constitution.

**UNIT I HISTORY OF MAKING OF THE INDIAN CONSTITUTION:**

History, Drafting Committee, (Composition & Working)

**UNIT II PHILOSOPHY OF THE INDIAN CONSTITUTION:**

Preamble, Salient Features

**UNIT III CONTOURS OF CONSTITUTIONAL RIGHTS AND DUTIES:**

Fundamental Rights, Right to Equality, Right to Freedom, Right against Exploitation, Right to Freedom of Religion, Cultural and Educational Rights, Right to Constitutional Remedies, Directive Principles of State Policy, Fundamental Duties.

**UNIT IV ORGANS OF GOVERNANCE:**

Parliament, Composition, Qualifications and Disqualifications, Powers and Functions, Executive, President, Governor, Council of Ministers, Judiciary, Appointment and Transfer of Judges, Qualifications, Powers and Functions.

**UNIT V LOCAL ADMINISTRATION:**

District's Administration head: Role and Importance, Municipalities: Introduction, Mayor and role of Elected Representative, CEO, Municipal Corporation. Pachayati raj: Introduction, PRI: Zila Pachayat. Elected officials and their roles, CEO Zila Pachayat: Position and role. Block level: Organizational Hierarchy (Different departments), Village level: Role of Elected and Appointed officials, Importance of grass root democracy.

**UNIT VI ELECTION COMMISSION:**

Election Commission: Role and Functioning. Chief Election Commissioner and Election Commissioners - Institute and Bodies for the welfare of SC/ST/OBC and women.

**TOTAL: 30 PERIODS**

**COURSE OUTCOMES:**

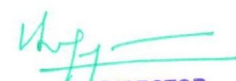
Students will be able to:

- Discuss the growth of the demand for civil rights in India for the bulk of Indians before the arrival of Gandhi in Indian politics.
- Discuss the intellectual origins of the framework of argument that informed the conceptualization of social reforms leading to revolution in India.
- Discuss the circumstances surrounding the foundation of the Congress Socialist Party [CSP] under the leadership of Jawaharlal Nehru and the eventual failure of the proposal of direct elections through adult suffrage in the Indian Constitution.
- Discuss the passage of the Hindu Code Bill of 1956.

**SUGGESTED READING**

1. The Constitution of India, 1950 (Bare Act), Government Publication.
2. Dr. S.N. Busi, Dr. B. R. Ambedkar framing of Indian Constitution, 1<sup>st</sup> Edition, 2015.
3. M.P. Jain, Indian Constitution Law, 7<sup>th</sup> Edn., Lexis Nexis, 2014.
4. D.D. Basu, Introduction to the Constitution of India, Lexis Nexis, 2015.

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**COURSE OBJECTIVES**

Students will be able to:

- Review existing evidence on their view topic to inform programme design and policy
- Making under taken by the DfID, other agencies and researchers.
- Identify critical evidence gaps to guide the development.

**UNIT I INTRODUCTION AND METHODOLOGY:**

Aims and rationale, Policy background, Conceptual framework and terminology - Theories of learning, Curriculum, Teacher education - Conceptual framework, Research questions - Overview of methodology and Searching.

**UNIT II INTRODUCTION AND METHODOLOGY:**

Aims and rationale, Policy background, Conceptual framework and terminology - Theories of learning, Curriculum, Teacher education - Conceptual framework, Research questions - Overview of methodology and Searching.

**UNIT III THEMATIC OVERVIEW**

Pedagogical practices are being used by teachers in formal and informal classrooms in developing countries - Curriculum, Teacher education.

**UNIT IV EVIDENCE ON THE EFFECTIVENESS OF PEDAGOGICAL PRACTICES**

Methodology for the in depth stage: quality assessment of included studies - How can teacher education (curriculum and practicum) and the school curriculum and guidance materials best support effective pedagogy? - Theory of change - Strength and nature of the body of evidence for effective pedagogical practices - Pedagogic theory and pedagogical approaches - Teachers' attitudes and beliefs and Pedagogic strategies.

**UNIT V PROFESSIONAL DEVELOPMENT**

Professional development: alignment with classroom practices and follow up support - Peer support - Support from the head teacher and the community - Curriculum and assessment - Barriers to learning: limited resources and large class sizes

**UNIT VI RESEARCH GAPS AND FUTURE DIRECTIONS**

Research design – Contexts – Pedagogy - Teacher education - Curriculum and assessment - Dissemination and research impact.

**TOTAL: 30 PERIODS****COURSE OUTCOMES:**

Students will be able to understand:

- What pedagogical practices are being used by teachers informal and informal classrooms in developing countries?
- What is the evidence on the effectiveness of these pedagogical practices, in what conditions, and with what population of learners?
- How can teacher education (curriculum and practicum) and the school curriculum and guidance materials best support effective pedagogy?

**SUGGESTED READING**

1. Ackers J, Hardman F (2001) Classroom interaction in Kenyan primary schools, Compare, 31(2): 245-261.
2. Agrawal M (2004) Curricular reform in schools: The importance of evaluation, Journal of *Attended*

- Curriculum Studies, 36(3):361-379.
3. Akyeampong K (2003) Teacher training in Ghana-does it count? Multi-site teacher education research project (MUSTER) country report 1.London:DFID.
  4. Akyeampong K, Lussier K, Pryor J, Westbrook J (2013) Improving teaching and learning of basic maths and reading in Africa: Does teacher preparation count? International Journal Educational Development, 33(3): 272–282.
  5. Alexander RJ(2001) Culture and pedagogy: International comparisons in primary education. Oxford and Boston: Blackwell.
  6. Chavan M(2003) Read India: Amass scale, rapid, 'learning to read' campaign.
  7. www.pratham.org/images/resource%20working%20paper%202.pdf

**AX5097**

**STRESS MANAGEMENT BY YOGA**

**L T P C**  
**2 0 0 0**

**COURSE OBJECTIVES**

- To achieve overall health of body and mind
- To overcome stress

**UNIT I**

Definitions of Eight parts of yoga.(Ashtanga)

**UNIT II**

Yam and Niyam - Do`s and Don`t`s in life - i) Ahinsa, satya, astheya, bramhacharya and aparigraha, ii) Ahinsa, satya, astheya, bramhacharya and aparigraha.

**UNIT III**

Asan and Pranayam - Various yog poses and their benefits for mind & body - Regularization of breathing techniques and its effects-Types of pranayam

**TOTAL: 30 PERIODS**

**COURSE OUTCOMES**

Students will be able to:

- Develop healthy mind in a healthy body thus improving social health also
- Improve efficiency

**SUGGESTED READING**

1. 'Yogic Asanas for Group Training-Part-I':Janardan Swami Yoga bhyasi Mandal, Nagpur
2. "Rajayoga or conquering the Internal Nature" by Swami Vivekananda, Advaita Ashrama (Publication Department), Kolkata

**AX5098**

**PERSONALITY DEVELOPMENT THROUGH  
LIFE ENLIGHTENMENT SKILLS**

**L T P C**  
**2 0 0 0**

**COURSE OBJECTIVES:**

- To learn to achieve the highest goal happily
- To become a person with stable mind, pleasing personality and determination
- To awaken wisdom in students

**UNIT I**

Neetisatakam-holistic development of personality - Verses- 19,20,21,22 (wisdom) - Verses- 29,31,32 (pride & heroism) – Verses- 26,28,63,65 (virtue) - Verses- 52,53,59 (dont`s) - Verses- 71,73,75,78 (do`s)

**UNIT II**

*Attested*

Approach to day to day work and duties - Shrimad Bhagwad Geeta: Chapter 2-Verses 41, 47,48 - Chapter 3-Verses 13, 21, 27, 35 Chapter 6-Verses 5,13,17,23, 35 - Chapter 18-Verses 45, 46, 48.

### UNIT III

Statements of basic knowledge - Shrimad Bhagwad Geeta: Chapter2-Verses 56, 62, 68 Chapter 12 -Verses 13, 14, 15, 16,17, 18 - Personality of role model - shrimad bhagwad geeta - Chapter2-Verses 17, Chapter 3-Verses 36,37,42 - Chapter 4-Verses 18, 38,39 Chapter18 – Verses 37,38,63

**TOTAL: 30 PERIODS**

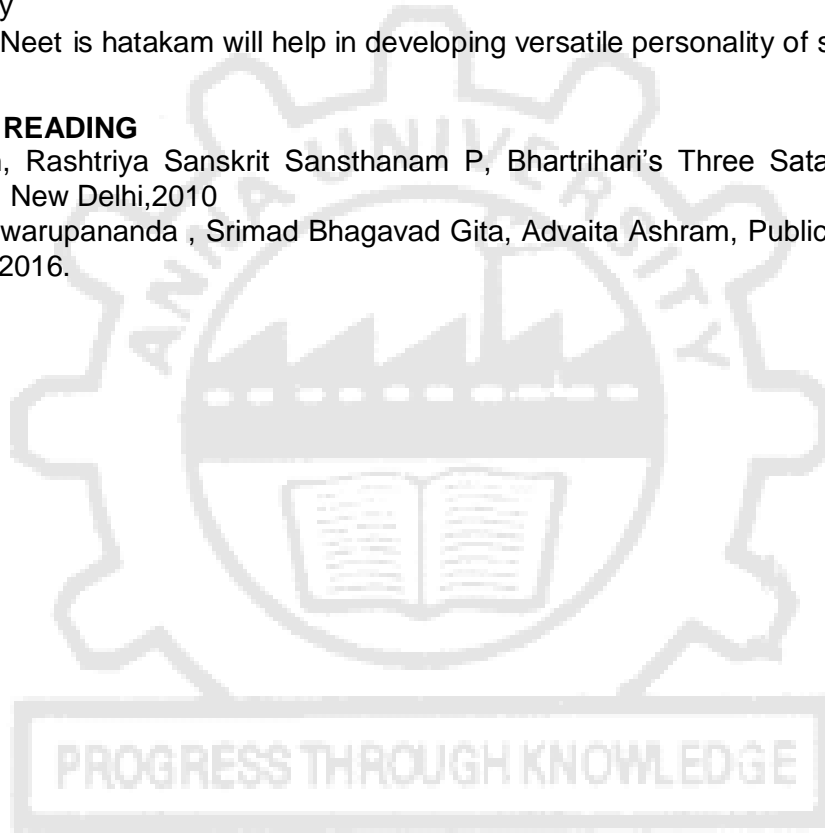
### COURSE OUTCOMES:

Students will be able to

- Study of Shrimad-Bhagwad-Geeta will help the student in developing his personality and achieve the highest goal in life
- The person who has studied Geeta will lead the nation and mankind to peace and prosperity
- Study of Neet is hatakam will help in developing versatile personality of students.

### SUGGESTED READING

1. Gopinath, Rashtriya Sanskrit Sansthanam P, Bhartrihari's Three Satakam, Niti-sringar-vairagya, New Delhi,2010
2. Swami Swarupananda , Srimad Bhagavad Gita, Advaita Ashram, Publication Department, Kolkata, 2016.



*Attested*

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