INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)
Dundigal, Hyderabad - 500 043

AERONAUTICAL ENGINEERING

COURSE DESCRIPTION FORM

Course Title	**AIRFRAME STRUCTURAL DESIGN**			
Course Code	**A72118**			
Regulation	**R15-JNTUH**			
Class	**IV-B.Tech I Semester**			
Course Structure	**Lectures**	**Tutorials**	**Practicals**	**Credits**
	4	**1**	**-**	**4**
Course Coordinator	**Ms. M Mary Thraza Assistant professor, Dept of AE.**			
Team of Instructors	**Ms. M Mary Thraza Assistant professor, Dept of AE.** **Mr. G Ram Vishal Assistant professor, Dept of AE.**			

I. COURSE OVERVIEW

The course is structured to provide a thorough understanding of the different design concerns, loads, and analysis techniques that are associated with light-weight air vehicle (aircraft, helicopters) and space vehicles (launch vehicles, spacecraft). The course builds upon a student ability to apply principles of mathematics, strength of materials, and structural mechanics to design and analyze aerospace structural components, assemblies and systems.

II. PREREQUISITE(S)

Level	Credits	Periods	Prerequisite
UG	4	5	Engineering mechanics
UG	4	5	Solid mechanics
UG	4	5	Aerospace structures

III. MARKS DISTRIBUTION

Sessional Marks	University End Exam Marks	Total Marks
Mid Semester Test There shall be 2 midterm examinations. Each midterm examination consists of subjective test. The subjective test is for 20 marks, with duration of 2 hours. Subjective test of each semester shall contain 5 one mark compulsory questions in part-A and part-B contains 5 questions, the student has to answer 3 questions, each carrying 5 marks. First midterm examination shall be conducted for the first two and half units of syllabus and second midterm examination shall be conducted for the remaining portion. **Assignment** Five marks are earmarked for assignments. There shall be two assignments in every theory course. Marks shall be awarded considering the average of two assignments in each course.	75	100

IV. EVALUATION SCHEME

S.No	Component	Duration	Marks
1	I Mid examination	80 minutes	20
2	I Assignment	--	05
3	II Mid examination	80 minutes	20
4	II Assignment	--	05
5	External examination	3 hours	75

V. COURSE OBJECTIVES

The objective of the teacher is to impart knowledge and abilities to the students to:

I. Familiarize students with the important issues and methodologies of aircraft design.
II. Illustrate the process of aircraft synthesis as an outcome of the integration of the disciplines of aerodynamics, performance, stability and control, propulsion, structures and aero elasticity.
III. Understand role and lay-out of main structural members of load carrying airframe components as well as the relevant basic design philosophies.
IV. Develop the ability to function as a member of a team in a design setting; including the ability to conduct a peer review of the other team members.
V. Familiarize students with Federal Aviation Regulations as a means for ensuring passenger safety.

VI. COURSE OUTCOMES

After completing this course the student must demonstrate the knowledge and ability to

1. Understand the role of Airworthiness requirements based on the Structural design and sizing- stages- Principal structural components of aircraft.
2. Remember the Structural design loads, safety margins, material properties, methods of estimation- construction, operation, maintenance, training- procedures. Critical load conditions
3. Solve the specific Load carrying structural members of airframes Wing loads- air load span wise distribution, effect of fuselage, engine nacelle, wing stores, control surfaces, landing, taxi, dynamic gust loads
4. Analyze Design requirements for wing, fuselage Empennage, concepts and philosophies. landing gear, engine mounts
5. Understand the Airframe materials and selection criteria using Fasteners and fittings- role, significance, general design considerations, criteria for allowable strength to reach the margins of safety.
6. Describe Loading actions, bending, torsion and shear.
7. Demonstrate Stress analysis of thin walled open and closed beams under bending and torsion
8. Stress analysis of shear webs
9. Buckling analysis of plates and stiffened shells.
10. Forward fuselage, aft fuselage structures, fuselage openings- windows, doors- design considerations.
11. Ultimate strength of stiffened cylindrical structure-review.
12. Demonstrate the Wing layout- location of spars, ailerons and flaps, rib spacing and direction
13. Summarize the Landing gear- purpose, types, general arrangement, loads- design considerations- ground handling, take-off, landing.
14. Understand concept of Fatigue life, damage tolerance, fail-safe design- weight controand balance
15. Generalized the pavement loading, support structure. Stowage and retraction.

VII. HOW PROGRAM OUTCOMES ARE ASSESSED

Program Outcomes (POs)		Level	Proficiency assessed by
PO1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	S	Assignments
PO2	**Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	H	Assignments
PO3	**Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	H	Micro projects
PO4	**Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.	S	Micro Projects
PO5	**Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.	H	Micro Projects
PO6	**The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.	--	--
PO7	**Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.	--	--
PO8	**Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.	--	--
PO9	**Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.	S	Micro Projects
PO10	**Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.	--	--
PO11	**Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.	--	----
PO12	**Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.	--	----

S - Supportive **H – Highly Related**

VIII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED

Program Specific Outcomes		Level	Proficiency Assessed by
PSO 1	**Professional Skills:** Able to utilize the knowledge of aeronautical/aerospace engineering in innovative, dynamic and challenging environment for design and development of new products.	H	Lectures and Assignments
PSO 2	**Problem-solving skills:** imparted through simulation language skills and general purpose CAE packages to solve practical, design and analysis problems of components to complete the challenge of airworthiness for flight vehicles.	S	Tutorials
PSO 3	**Practical implementation and testing skills:** Providing different types of in house and training and industry practice to fabricate and test and develop the products with more innovative technologies.	S	Seminars and Projects
PSO 4	**Successful career and entrepreneurship:** To prepare the students with broad aerospace knowledge to design and develop systems and subsystems of aerospace and allied systems and become technocrats.	H	Structural design of aircraft model

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IX. SYLLABUS

UNIT – I

INTRODUCTION AIRWORTHINESS REQUIREMENTS

Structural design and sizing- stages- Principal structural components of aircraft. Design requirements- structural integrity, stiffness, service life. Constraints- baseline aerodynamic configuration, external loading, weight, operating conditions, conformity to government regulations. Design for durability, damage tolerance.

Airworthiness requirements - loads, safety margins, material properties, methods of estimation- construction, operation, maintenance, training- procedures. Critical load conditions. Limit and ultimate loads- definition, significance. Aircraft materials- mechanical properties- design data- allowable, allowable bases. Failure theory. Flight loads- atmospheric, maneuver- construction of flight envelope.

UNIT- II

EXTERNAL LOADS-ESTIMATION, FASTENERS AND STRUCTURAL JOINTS

Wing loads- air load span wise distribution, effect of fuselage, engine nacelle, wing stores, control surfaces, landing, taxi, dynamic gust loads, wing weight distribution. Empennage loads- gust, maneuver, control surface. Fuselage loads- distribution of weight, fore body loads, after body loads, internal pressure, propulsion loads. Landing gear loads- landing conditions, ground handling loads, retraction loads. Miscellaneous loads. Airplane weight data, stiffness data, theories of failure.

Fasteners and fittings- role, significance, general design considerations, criteria for allowable strength. Margins of safety. Fastener systems, types, fastener information, dimensions, material, allowable strength-tensile, shear, bending, bearing, Rivets, bolts and screws, nuts- detail design considerations. Fastener selection. Fittings- lugs, bushings and bearings- loading, design and analysis. Joints- spliced, eccentric, gusset, welded, brazed, bonded- types, methods of joining, failure modes. Fatigue design considerations. Stress concentration- causes, methods of reduction. Fastener load distribution and by-pass load- severity factor, structural joint life prediction. Shim control and requirement.

UNIT- III

DESIGN OF WING, TAIL UNIT STRUCTURES

The wing- role- summary of wing loads, structural components- wing box, leading and trailing edges. Wing layout- location of spars, ailerons and flaps, rib spacing and direction, root rib bulkhead, span wise stiffeners, wing covers- skin-stringer panels, integrally stiffened panels, access holes, attachment of leading edge and trailing edge panels. Spars- general rules of spar design. Ribs and bulkheads- rib spacing and arrangement. Wing root joints, carry through structure. Fighter wing design- problems with swept wings.

Wing box, root rib bulkhead- estimation of loads, stress analysis, design parameters, optimisation, sizing, margins of safety. Leading and trailing edge assembly- control surfaces, flaps- structure

UNIT- IV

DESIGN OF FUSELAGE, LANDING GEAR, ENGINE MOUNTS

Function of fuselage- loading, general requirements. Ultimate strength of stiffened cylindrical structure-review, Principal structural components- skin and stringers, frame and floor beam, pressure bulkhead, wing and fuselage intersection- lay out, loading, stress analysis, sizing. Forward fuselage, aft fuselage structures, fuselage openings- windows, doors- design considerations.

Landing gear- purpose, types, general arrangement, loads- design considerations- ground handling, take-off, landing, braking, pavement loading, support structure. Stowage and retraction, gear lock- kinematic design. Shock absorbers- function, types, components, operation, loads, materials, design. Wheels and brakes, tire selection. Engine mounts- types- wing pod, rear fuselage, tail, fuselage mount, loads, design considerations

UNIT- V

FATIGUE LIFE, DAMAGE TOLERANCE, FAIL-SAFE DESIGN- WEIGHT CONTROAND BALANCE

Catastrophic effects of fatigue failure- examples- modes of failure- design criteria- fatigue stress, fatigue performance, fatigue life. Fatigue design philosophy- fail-safe, safe life. Service behaviour of aircraft structures- effect of physical and load environment design and of detail of fabrication Structural life- methods of estimation- the scatter factor- significance Fail-safe design- the concept, requirements, damage tolerance-estimation of fatigue strength

Text Books

1. Niu, M.C., Airframe Structural Design, second edition, Hongkong Conmlit Press, 1988, ISBN: 962-7128-09-0.
2. Niu, M.C., Airframe Stress Analysis and Sizing, second edition, Hongkong Conmlit Press, 1997, ISBN: 962-7128-08-2.

References

1. Bruhn, E.H., Analysis and Design of Flight Vehicles Structures, Tri -state Offset Company, USA, 1965.
2. Peery, D.J, and Azar, J.J., Aircraft Structures, second edition, Mc Graw-Hill, N.Y., 1993.
3. Megson, T.H.G., Aircraft Structures for Engineering Students, Butterworth-Heinemann/ Elsevier, 2007.
4. Fielding, J.P., Introduction to Aircraft Design, Cambridge University Press, 2005, ISBN: 0-521-657222-9.

X. COURSE PLAN:

The course plan is meant as a guideline. There may probably be changes.

Lecture No.	Course Learning Outcomes	Topics to be covered	Reference
1	Define structural design and sizing.	**UNIT-I INTRODUCTION AND AIRWORTHINESS REQUIREMENTS** Structural design.	T1:1.1
2	Define structural design and sizing.	sizing – stages – preliminary, detail-significance-scope of the course-preliminary	T1:1.1
3	Explain design requirements, structural integrity	Principal structural components of aircraft. Design requirements- structural integrity	T1:1.2
4	Explain design requirements,	Stiffness, service life. Constraints-baseline aerodynamic	T1:1.2

	structural integrity	configuration	
5	Explain design requirements, structural integrity	External loading, weight, operating conditions	T1:1.2
6	Explain design considerations	Conformity to government regulations	T1: 2.1.1
7	Explain damage tolerance	Other considerations-design for durability, damage tolerance, stretching	
8-9	Explain airworthiness requirements	Airworthiness requirements - loads, safety margins, material properties, methods of estimation construction, operation, maintenance, training-procedures	T1: 9.2.2
10-12	Define load conditions, failure theory	Critical load conditions. Limit and ultimate loads-definition, significance. Aircraft materials-mechanical properties-design data-allowable, allowable bases. Failure theory. Flight loads-atmospheric, maneuver-construction of flight envelope.	T1:9.2.3
13-15	Describe different types of loads on wing, landing gear	**UNIT-II** **EXTERNAL LOADS-ESTIMATION, FASTENERSANDSTRUCTURALJOINTS** Wing loads-air load span wise distribution, effect of fuselage, engine nacelle, wing stores, control surfaces, landing, taxi, dynamic gust loads, wing weight distribution. Empennage loads-gust, manoeuvre, control surface.	T1: 2.1
16-18	Describe different types of loads on propulsion systems	Fuselage loads distribution of weight, fore body loads, after body loads, internal pressure, propulsion loads. Landing gear loads-landing conditions, ground handling loads, retraction loads. Miscellaneous loads. Airplane weight data, stiffness data	T1:2.2
19-21	Describe different types of fasteners	Theories of failure, Fasteners and fittings-role, significance, general design considerations, criteria for allowable strength. Margins of safety. Fastener systems, types, fastener information, dimensions, material, allowable strength-tensile, shear, bending, bearing, Rivets, bolts and screws, nuts	T1:2.3-2.7
22-23	Analyze loads on fasteners, joints and its selection	Detail design considerations. Fastener selection. Fittings-lugs, bushings and bearings -loading, design and analysis. Joints-spliced, eccentric, gusset, welded, brazed, bonded-types, methods of joining, failure modes.	T1:2.8,2.9
24-26	Explain fatigue design considerations and analyze fastener loads	Fatigue design considerations. Stress concentration-causes, methods of reduction. Fastener load distribution and by-pass load-severity factor, structural joint life prediction. Shim control and requirement	T2:6.1
27-28	Describe wing structure	**UNIT-III** **DESIGNOFWING,TAILUNITSTRUCTURES** The wing-role-summary of wing loads	T2:6.2
29-30	Describe components of wing	Structural components-wing box, leading and trailing edges. Wing layout-location of spars, ailerons and flaps, rib spacing and direction, root rib bulkhead, span wise stiffeners	T2:6.3
31-33	Evaluate different loads on spars, ribs, bulkheads	Wing covers-skin-stringer panels, integrally stiffened panels, access holes, attachment of leading edge and trailing edge panels. Spars-general rules of spar design. Ribs and bulkheads-rib spacing and arrangement. Wing root joints, carry through structure. Fighter wing design-problems with swept wings	T1:5.1
34-36	Analyze loads on rib, bulkheads	Wing box, root rib bulk head-estimation of loads, stress analysis, design parameters, optimization, sizing, margins of safety. Leading and trailing edge assembly-control surfaces, flaps-structure	T1:5.2

37-38	Explain structure of fuselage and its loads	**UNIT-IV** **DESIGN OF FUSELAGE, LANDING GEAR AND ENGINEMOUNTS** Function of fuselage-loading, general requirements. Ultimate strength of stiffened cylindrical structure review	T1:5.2
39-40	Describe structural components of fuselage	Principal structural components-skin and stringers, frame and floor beam, pressure bulkhead, wing and fuselage intersection-layout, loading	T1:5.3
41-43	Analyze the structures of fuselage	Stress analysis, sizing. Forward fuselage, aft fuselage structures, fuselage openings-windows, doors-design considerations.	T1:6.5
44-46	Analyze the structures landing gear	Landing gear-purpose, types, general arrangement, loads-design considerations- ground handling, take-off, landing, braking, pavement loading	T1:6.5
47-49	Explain functions and loads of landing gear	Support structure. Stowage and retraction, gear lock-kinematic design. Shock absorbers-function, types, components, operation, loads, materials, design. Wheels and brakes, tire selection	T1:6.1
50-52	Describe engine mounts of wing	Engine mounts -types- wing pod, rear Fuselage, tail, fuselage mount ,loads, design considerations	T1:6.1.2
53-55	Describe fatigue failure	**UNIT-V** **FATIGUE LIFE,DAMAGE TOLERANCE, FAIL-SAFE DESIGN-WEIGHT CONTROL AND BALANCE** Catastrophic effects of fatigue failure-examples-modes of failure	T1:6.2
56-59	Explain fatigue conditions	Design criteria-fatigue stress, fatigue performance, fatigue life. Fatigue design philosophy-fail-safe, safe life.	T1:6.2
60-62	Describe service life of aircraft	Service behavior of aircraft structures-effect of physical and load environment design and of detail of fabrication Structural life-methods of estimation	T1:6.2.3
63-65	Describe the concepts of fail-safe design	The scatter factor-significance Fail-safe design-the concept, requirements, damage tolerance-estimation of fatigue strength	T1:6.3

XI. MAPPING COURSE OBJECTIVES LEADING TO THE ACHIEVEMENT OF THE PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

Course Objectives	Program Outcomes												Program Specific Outcomes			
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
I	H	S			S								H			
II			S		S				S						S	
III	H	S	S										H			
IV		S			S								H		S	
V					S											

S = Supportive **H = Highly related**

XII. MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF TSHE PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

Course Objectives	Program Outcomes												Program Specific Outcomes			
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
1	H			S									H			H
2			S						S				S			
3		H														
4													S		H	
5				H	S											
6	H			S												H
7			S						S				S			
8		H		S											H	
9													S			
10				H	S											
11	H			S									H			H
12			S						S							
13		H		S												
14	H												S			H
15				H	S											

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