# INSTITUTE OF AERONAUTICAL ENGINEERING

**(Autonomous)**

Dundigal, Hyderabad - 500 043

## AERONAUTICAL ENGINEERING

## COURSE DESCRIPTION FORM

| | | | | |
|---|---|---|---|---|
| **Course Title** | **CONCEPTUAL DESIGN OF FLIGHT VEHICLES** | | | |
| **Course Code** | **A62115** | | | |
| **Regulation** | **R15 - JNTUH** | | | |
| **Course Structure** | **Lectures** | **Tutorials** | **Practical's** | **Credits** |
| | 4 | - | - | 4 |
| **Course Coordinator** | Ms. M Snigdha, Assistant Professor, Dept of AE | | | |
| **Team of Instructors** | Ms. G Swathi, Assistant Professor, Dept of AE | | | |

### I. COURSE OVERVIEW

The aim is to introduce students the overview of the design process**.** The course covers basic principles of conceptual design process of an aircraft and the related details of all design techniques. After completion of the course the student gains adequate knowledge to design all the different phase of an aircraft design.

### II. PREREQUISITE(S)

| Level | Course Code | Semester | Prerequisite | Credits |
|---|---|---|---|---|
| UG | AME002 | II | Engineering Mechanics | 4 |
| UG | AAE002 | III | Mechanics of Solids | 4 |
| UG | A42103 | II | Aircraft Vehicle Structures | 4 |
| UG | A42105 | II | Flight Mechanics | 4 |
| UG | A42102 | II | Aerodynamics | 4 |

### III. MARKS DISTRIBUTION

| Session Marks | University End Exam Marks | Total Marks |
|---|---|---|
| **Mid Semester Test**<br>There shall be two midterm examinations. Each midterm examination consists of essay paper, objective paper and assignment.<br>The essay paper is for 10 marks of 60 minutes duration and shall contain 4 questions. The student has to answer 2 questions, each carrying 5 marks.<br>The objective paper is for 10 marks of 20 minutes duration. It consists of 10 multiple choice and 10 fill-in-the blank questions, the student has to answer all the questions and each carries half mark.<br>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.<br>**Assignment**<br>Five marks are marked for assignments. There shall be two assignments in every theory course. Assignments are usually issued at the time of commencement of the semester. These are of problem solving in nature with critical thinking. Marks shall be awarded considering the average of two midterm tests 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 course enables the students to:**

I. Discuss the importance of conceptual design process and studying different phases of design process involved in the design.
II. Understand the levels of integrated product development and principles of the baseline design-stability & control, performance and constraint analysis.
III. Analyze cost estimation, parametric analysis, optimization, and refined sizing and trade studies.
IV. Interpret unique design concepts in different phases of aircraft.
V. Observe different designing processes and how an aircraft production company works on it.

## VI. COURSE OUTCOMES

**At the end of the course the students are able to:**

1. Understand the importance of conceptual design process and phases involved in the design process.
2. Understand the different types of product development and principles of design.
3. Estimate and evaluate the initial sizing and configuration layout, crew station, no of passengers and payload.
4. Get sufficient knowledge on Aircraft conceptual design process.
5. Memorize different processes involved in the design of aircraft.
6. Discuss the integrated product development and aircraft design.
7. Understand the different sizing stages of conceptual design.
8. Discuss trade studies - design trades and requirement trades.
9. Discuss the case studies and design of unique aircraft concepts.
10. Estimate the aerodynamic considerations in configuration layout.
11. Estimate the cost, parametric analysis, optimization, and refined sizing and trade studies.
12. Evaluate the sizing with fixed engine and rubber engine.
13. Analyze and discuss the baseline design-stability & control, performance and constraint analysis.
14. Estimate the geometry sizing of fuselage, wing, tail, control surfaces.
15. Analyze and discuss the baseline design – performance and flight mechanics.

## VII. HOW PROGRAM OUTCOMES ARE ASSESSED

| Program outcomes | | Level | Proficiency assessed by |
|---|---|---|---|
| **PO1** | **Engineering knowledge**: Knowledge in fundamentals of mathematics, science and engineering. | H | Assignments |
| **PO2** | **Problem analysis**: An ability to identify, formulate and solve problems in key areas of Aerodynamics, Structures, Propulsion, Flight Dynamics and Control, Design, Testing, Space and Missile Technologies and Aviation of Aeronautical Engineering discipline. | H | Lectures |
| **PO3** | **Design/development of solutions**: An ability to design and conduct experiments, analyze and interpret data related to various areas of Aeronautical Engineering. | H | Lectures |

| | | | |
|---|---|---|---|
| **PO4** | **Conduct investigations of complex problems**: An ability in conducting investigations to solve problems using research based knowledge and methods to provide logical conclusions. | H | Lectures |
| **PO5** | **Modern tool usage:** Skills to use modern engineering and IT tools, software and equipment to analyze the problems in Aeronautical Engineering. | S | Seminars |
| **PO6** | **The engineer and society**: Understanding of impact of engineering solutions on the society to assess health, safety, legal, and social issues in Aeronautical Engineering. | | |
| **PO7** | **Environment and sustainability**: The impact of professional engineering solutions in environmental context and to be able to respond effectively to the needs of sustainable development. | | |
| **PO8** | **Ethics:** The knowledge of Professional and ethical responsibilities. | | |
| **PO9** | **Individual and team work**: An ability to work effectively as an individual and as a team member/leader in multidisciplinary areas. | H | Discussions |
| **PO10** | **Communication**: An ability to critique writing samples (abstract, executive summary, project report), and oral presentations. | | |
| **PO11** | **Project management and finance:** The need of self education and ability to engage in life - long learning. | H | Seminars |
| **PO12** | **Life-long learning**: Knowledge of management principles and apply these to manage projects in multidisciplinary environments. | H | Discussions |

**S – Supportive** **H – Highly Related**

## VIII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED

| Program Specific Outcomes | | Level | Proficiency assessed by |
|---|---|---|---|
| **PSO1** | **Professional skills:** Able to utilize the knowledge of aeronautical/aerospace engineering in innovative, dynamic and challenging environment for design and development of new products. | S | Seminars, Projects |
| **PSO2** | **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. | H | Lectures, Tutorials |
| **PSO3** | **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 | Projects |
| **PSO4** | **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. | S | Discussions |

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## IX. SYLLABUS

### UNIT – I

### OVERVIEW OF THE DESIGN PROCESS, SIZING FROM A CONCEPTULA SKETCH, AIRFOIL AND GEOMETRY SELECTION, THRUST TO WEIGHT RATIO, WING LOADING

Phases of aircraft design, Aircraft conceptual design process, project brief / request for proposal, problem definition, information retrieval, aircraft requirements, configuration options, integrated product development and aircraft design, the initial conceptual sketches, L/D estimation, initial takeoff weight build-up, empty weight estimation–historical trends, fuel fraction estimation, mission profiles, mission segment weight fractions, airfoil selection, airfoil design, design lift coefficient, stall, airfoil thickness ratio and other airfoil considerations, wing geometry and wing vertical location, wing tip shapes, tail geometry and arrangements, thrust to weight ratio-statistical estimation, thrust matching, wing loading–performance constraints., selection of thrust-to-weight ratio and wing loading.

## UNIT- II

## INITIAL SIZING & CONFIGURATION LAYOUT

Sizing with fixed engine and with rubber engine, geometry sizing of fuselage, wing, tail, control surfaces, development of configuration lay out from conceptual sketch, the inboard profile drawing, wetted area, volume distribution and fuel volume plots, lofting- definition, significance and methods, flat wrap lofting, special consideration in configuration lay out, isobar tailoring, Sears-Haack volume distribution, structural load paths, radar, IR, visual detect-ability, aural signature, considerations of vulnerability, crashworthiness, produce-ability, maintainability, fuselage design- crew station, passenger compartment, cargo provisions, weapons carriage, gun installation.

## UNIT- III

## PROPULSION AND FUEL SYSTEM ONTEGRATION, LANDING GEAR AND SUBSYSTEMS

Propulsion selection, jet engine integration, engine dimensions, inlet geometry, inlet location, capture area calculation, boundary layer diverters, nozzle integration, engine cooling provisions, engine size estimation, fuel system design and integration, landing gear arrangements, guidelines for lay out, shock absorbers– types, sizing, stroke determination, gear load factors, gear retraction geometry, aircraft subsystems, significance to configuration lay out, the baseline design layout and report of initial specifications.

## UNIT- IV

## BASELINE DESIGN ANALYSIS-AERODYNAMICS AND PROPULSION, STRUCTURES AND WEIGHT AND BALANCE

Estimation of lift curve slope, maximum lift coefficient, complete drag build up, installed performance of an engine, installed thrust methodology, net propulsive force, part power operation, aircraft loads, categories–maneuver, gust, inertial, power plant, landing gear loads, limit loads, the v-n diagram, air load distribution on lifting surfaces, review of methods of structural analysis, material selection, weights and moments-statistical group estimation method, centre of gravity excursion control.

## UNIT- V

## BASELINE DESIGN-STABILITY AND CONTROL, PERFORMANCE AND CONSTRAINT ANALYSIS

Estimation of static pitch stability, velocity stability and trim, estimation of stability and control derivatives, static lateral-directional stability & trim, estimation of aircraft dynamical characteristics, handling qualities, Cooper – Harper scale, relation to aircraft dynamic characteristics.
Performance analysis and constraint analysis–steady level flight, minimum thrust required for level flight, range and loiter endurance, steady climbing and descending flight, best angle and rate of climb, time to climb and fuel to climb, level turning flight, instantaneous turn rate, sustained turn rate, energy maneuverability methods of optimal climb trajectories and turns, the aircraft operating envelope, take off analysis, balanced field length, landing analysis, fighter performance measures of merit, effects of wind on aircraft performance, initial technical report of baseline design analysis and evaluation, refined baseline design and report of specifications.

## TEXT BOOKS:


1. Raymer, D.P., Aircraft Design: A Conceptual Approach, 3rd edn., AIAA Education Series, AIAA, 1999, ISBN: 1-56347-281-0.
2. Howe, D., Aircraft Conceptual Design Synthesis, Professional Engineering Publishing, London, 2000, ISBN: 1-86058-301-6.
3. Fielding, J.P., Introduction to Aircraft Design, Cambridge University Press, 2005, ISBN: 0-521-657222-9.

**REFERENCES:**


1. AIAA Aerospace Design Engineer's Guide, 5th edn, AIAA Education Series, 2003, ISBN 1-56347-590-1.
2. Jenkinson, L.R. and Marchman III, J. F., Aircraft Design Projects for Engineering Students, Butterworth Heinemann, 2003, ISBN: 0 7506 5772 3.
3. Brandt, S.A. et. al., Introduction to Aeronautics: A Design Perspective, 2nd edn, AIAA Education Series, AIAA, 2004, ISBN: 1-56347-701-7.
4. Anderson, J.D. Jr., Aircraft Performance and Design, McGraw-Hill, 1999, ISBN: 0-07-001971-1.
5. Dole, C.E., Flight Theory and Aerodynamics: A Practical Guide to Operational Safety, Wiley, 1981, ISBN: 0-471-09152-9
6. Taylor, J., Jane's All the World Aircraft, latest edition, Jane's, London.
7. Stinton, The Design of the Airplane, second edition, AIAA, 2001, ISBN: 0-56347-524-6.
8. Kroo I., Applied Aerodynamics: A Digital Textbook, Desktop Aeronautics Inc., http://www.desktopaero.com/appliedaero/preface/welcome.html
9. Keane, A.J. And Nair, P.B., Computational Approaches for Aerospace Design, Wiley, 2005, ISBN: 0-470-85540-1.


## 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 |
|---|---|---|---|
| 1-2 | **Define** various Designs | **UNIT-I**<br>**OVERVIEW OF THE DESIGN PROCESS,SIZING FROM A CONCEPTUAL SKETCH AIRFOIL AND GEOMETRY SELECTION,THRUST TO WEIGHT RATIO,WING LOADING** | T1-2.1 |
| 3-4 | **Explain** the different phases involved in Design | Phases of Design, RFP, Problem Definition, conceptual process Information retrieval, aircraft requirements, configuration options, Integrated product development and aircraft design. | T1-2.2,2.3,2.4 |
| 5-6 | **Sketch** the conceptual design | The initial conceptual sketches, | T1-3.1 |
| 7-8 | **Estimate** L/D and Takeoff weight | L / D estimation. Initial takeoff weight build-up. | T1-3.2 |
| 9-11 | **Estimation** of weight. | Empty weight estimation –historical trends, fuel fraction estimation, mission profiles, mission segment weight fractions | T1-3.3,3.4 |
| 12-14 | **Design** of airfoil | Airfoil selection, airfoil design, design lift coefficient, stall, airfoil thickness ratio and other airfoil considerations. | T1-4.2 |
| 15-17 | **Design** of tail geometry | Wing geometry and wing vertical location, wing tip shapes. Tail geometry and arrangements. | T1-4.3,4.4,4.5 |
| 18-20 | **Estimation** of weight ratio | Thrust to weight ratio-statistical estimation, thrust matching | T1-5.1,5.2 |
| 21-22 | **Selection** of thrust to weight ratio &wing loading | Wing loading – performance constraints. Selection of thrust-to-weight ratio and wing loading. | T1-5.3,5.4 |
| 23 | **Describing** the initial sizing & configuration layout | **UNIT-II**<br>**INITIAL SIZING & CONFIGURATION LAYOUT** | T-6.1 |
| 24-26 | **Comparing** the fixed engine and rubber engine. | Sizing with fixed engine and with rubber engine. Geometry sizing of fuselage, wing, tail, control surfaces. | T1-6.2,6.3,6.4,6.5 |
| 27-28 | **Development** of conceptual design | Development of configuration lay out from conceptual sketch. The inboard profile drawing, wetted area | T1-7.1,7.2,7.3 |

| | | | |
|---|---|---|---|
| 29-30 | **Explanation** of Lofting methods | Volume distribution and fuel volume plots. Lofting-definition significance and methods, flat wrap lofting | T1-7.4,7.5,7.6 |
| 31-33 | **Explanation** of Configuration Layout | Special consideration in configuration lay out. Isobar tailoring, Sears-Haack volume distribution, structural load paths Radar | T1-7.7,7.8,7.9,7.10 |
| 34-36 | **Describing** vulnerability, crashworthiness, producibility, maintainability | Considerations of vulnerability, crashworthiness, producibility, maintainability | T1-8.4,8.5,8.6, 8.8,8.9 |
| 37-39 | **Design** of fuselage | Fuselage design- crew station, passenger compartment, cargo provisions, weapons carriage, gun installation. | T1-9.2,9.3,9.4,9.5,9.6 |
| 40 | **Explain** the systems of Aircraft | **UNIT-III**<br>**PROPULSION & FUEL SYSTEM INTEGRATION, LANDING GEAR & SUBSYSTEMS.** | T1-10.1 |
| 41-43 | **Describe** the propulsion system | Propulsion selection, jet engine integration, engine dimensions, inlet geometry, inlet location, captures area calculation. | T1-10.2,10.3,10.4 |
| 44-45 | **Estimation** of engine size | Boundary layer diverters, nozzle integration, engine cooling provisions, engine size estimation. | T1-10.2,10.3,10.4 |
| 46-47 | **Explain** the Fuel system Design | Fuel system design and integration. Landing gear arrangements, guidelines for lay out. | T1-10.5,11.2 |
| 48-50 | **Explain** the Landing gear system Design | Shock absorbers – types, sizing, stroke determination, gear load factors. Gear retraction geometry. | T1-11.3,11.4,11.6 |
| 51-53 | **Explain** the Aircraft system | Aircraft subsystems, significance to configuration lay out. The baseline design layout and report of initial specifications. | T1-11.8 |
| 54 | **Analyze** different streams of aircraft design | **UNIT-IV**<br>**BASELINE DESIGN ANALYSIS- AERODYNAMICS & PROPULSION, STRUCTURES & WEIGHT AND BALANCE** | T1-12.1 |
| 55-56 | **Estimate** aerodynamic forces | Estimation of lift curve slope, maximum lift coefficient, complete drag build up. | T1-12.2,12.3,12.4 |
| 57-59 | **Methods** involved in the engine design | Installed performance of an engine, installed thrust methodology, net propulsive force, part power operation | T1-13.5 |
| 60-61 | **Discuss** different types of aircraft loads along with categories | Aircraft loads, categories– maneuver, gust, inertial, power plant, landing gear loads | T1-14.2,14.3,14.4,14.6 |
| 62-63 | **Explain** v-n diagrams | Limit loads, the V-n diagram. Air load distribution on lifting surfaces. | T1-14.5 |
| 64 | **Review** of methods of structural analysis. | Review of methods of structural analysis. | T1-14.10 |
| 65-66 | **Selection** of materials | Material selection. Weights and moments statistical group estimation method, centre of gravity excursion control. | T1-14.8,14.9 |
| 67 | **Discuss** the Baseline Design | **UNIT-V**<br>**BASELINE DESIGN–STABILITY & CONTROL, PERFORMANCE AND CONSTRAINT ANALYSIS** | T1-16.1 |
| 68-70 | **Estimation** of static stability, velocity and trim | Estimation of static pitch stability, velocity stability and trim. Estimation of stability and control derivatives. Static lateral-directional stability &trim. Estimation of aircraft dynamical characteristics, handling qualities. Cooper – Harper scale, relation to aircraft dynamic characteristics. | T1-16.3,16.4,16.5,16.6,16.7,16.10 |

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|---|---|---|---|
| 71-73 | **Estimation** of dynamic stability, velocity and trim | Performance analysis and constraint analysis– steady level flight, minimum thrust required for level flight, range and loiter endurance. Steady climbing and descending flight, best angle and rate of climb, time to climb and fuel to climb. Level turning flight, instantaneous turn rate, sustained turn rate. | T1-17.3,17.4 |
| 74-76 | **Analyze** the performance of aircraft | Energy maneuverability methods of optimal climb trajectories and turns. The aircraft operating envelope. Take off analysis, Balanced field length. Landing analysis. Fighter performance measures of merit | T1-17.6,17.7,17.8 |
| 77-79 | **Explaining** the Effects of wind on aircraft performance | Effects of wind on aircraft performance. Initial technical report of baseline design analysis and evaluation. Refined baseline design and report of specifications | T1-17.9,17.10 |

## XI. MAPPING COURSE OBJECTIVES LEADING TO THE ACHIEVEMENT OF 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 | | | H | | | H | | | | S | | | H |
| II | H | H | | H | | | | | | | H | | | H | | |
| III | | H | H | | | H | | | S | | | | | S | H | |
| IV | H | | | | | | S | | | | S | | H | | | H |
| V | H | S | | H | | S | | | | S | | | | | H | |

**S – Supportive** **H - Highly related**

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

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

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | | | | H | | | | | | H | | | S | | | |
| 13 | H | | | | | | H | | S | | | H | | | H | |
| 14 | | | H | | | S | | | | | H | | | | | |
| 15 | H | | | | | | | H | | | | | | H | | |

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**Prepared by:** Ms. M Snigdha, Assistant Professor, Dept of AE
Ms. G Swathi , Assistant Professor, Dept of AE

**HOD, Aeronautical Engineering**