INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad - 500 043

AERONAUTICAL ENGINEERING

COURSE DESCRIPTION FORM

Course Title	**FLIGHT MECHANICS – II**			
Course Code	**A52111**			
Regulation	**R15-JNTUH**			
Course Structure	**Lectures**	**Tutorials**	**Practical's**	**Credits**
	4	-	-	4
Course Coordinator	Ms. G Swathi, Assistant Professor			
Team of Instructors	Ms. G Swathi, Assistant Professor, Mr. A Rathan Babu, Assistant Professor			

I. COURSE OVERVIEW

Flight mechanics is the science that investigates the control of aircraft and other flying vehicles. From the time of the Wright brothers it was recognized that flight without control is impossible. Since then, several different concepts for controlling aircraft flight have been devised including control surfaces, deformable surfaces, rockets and others. This course introduces some of these concepts and describes their operation, as well as the degree of stability that they can provide. Both aircraft and helicopters are addressed. Modern aircraft control is ensured through automatic control systems. Their role is to increase safety, facilitate the pilot's task and improve flight qualities. The course will introduce modern aircraft control and discuss some of its objectives and applications.

II. PREREQUISITE(S)

Level	Credits	Periods	Prerequisite
UG	4	5	Concepts on Introduction of Aerospace Engineering, Flight Mechanics I

III. MARKS DISTRIBUTION

Sessional Marks	University End Exam Marks	Total Marks
Mid Semester Test There shall be two midterm examinations. Each midterm examination consists of subjective type and objective type tests. The subjective test is for 10 marks of 60 minutes duration. Subjective test of shall contain 4 questions; the student has to answer 2 questions, each carrying 5 marks. The objective type test is for 10 marks of 20 minutes duration. It consists of 10 Multiple choice and 10 objective type questions, the student has to answer all the questions and each carries half mark. 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 marked 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:

I. **Discuss** the concepts of Flight performance.
II. **Understand** the parameters affecting the performance.
III. **Formulate** the equations of motion for an aircraft in atmospheric flight.
IV. **Motivate** the assumptions made to simplify a flight mechanics problem.
V. **Explain** the basic modes of motion and related mechanisms of an aircraft.
VI. **Perform** a simple trajectory calculations using simplifies equations of motion.
VII. **Present** your results in a well written report.

VI. COURSE OUTCOMES

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

1. **Estimate** the aerodynamic derivatives of a given airplane.
2. A**nalyze** the aircraft equations of rigid-body motion.
3. **Evaluate** aircraft flight characteristics using computational techniques.
4. **Understand** the effects of aerodynamic and propulsive controls on equilibrium conditions.
5. **Identify** the significance of flight stability and its impact of aircraft operations and pilot workload.
6. **Explain** the meaning of aerodynamic stability derivatives and their sources.
7. **Relate** the effects of aerodynamic derivatives on flight stability.
8. **Analyze** dynamics and control of flight vehicles.
9. **Describe** the impact of flight stability and trim on all atmospheric flight vehicles.

VII. HOW PROGRAM OUTCOMES ARE ASSESSED

Program outcomes		Level	Proficiency assessed by
PO1	**General knowledge:** An ability to apply the knowledge of mathematics, science and Engineering for solving multifaceted issues of Aeronautical Engineering	H	Assignments, Tutorials
PO2	**Problem Analysis**: An ability to communicate effectively and to prepare formal technical plans leading to solutions and detailed reports for Aeronautical systems	H	Assignments
PO3	**Design/Development of solutions**: To develop Broad theoretical knowledge in Aeronautical Engineering and learn the methods of applying them to identify, formulate and solve practical problems involving Aerodynamics	H	Mini Projects
PO4	**Conduct investigations of complex problems**: An ability to apply the techniques of using appropriate technologies to investigate, analyze, design, simulate and/or fabricate/commission complete systems involving complex aerodynamics flow situations.	H	Projects
PO5	**Modern tool usage**: An ability to model real life problems using different hardware and software platforms, both offline and real-time with the help of various tools along with upgraded versions.	S	Projects
PO6	**The engineer and society**: An Ability to design and fabricate modules, control systems and relevant processes to meet desired performance needs, within realistic constraints for social needs		--

PO7	**Environment and sustainability**: An ability To estimate the feasibility, applicability, optimality and future scope of power networks and apparatus for design of eco-friendly with sustainability		--
PO8	**Ethics**: To Possess an appreciation of professional, societal, environmental and ethical issues and proper use of renewable resources	S	Oral Discussions
PO9	**Individual and team work**: An Ability to design schemes involving signal sensing and processing leading to decision making for real time Aeronautical systems and processes at individual and team levels.		--
PO10	**Communication**: an Ability to work in a team and comprehend his/her scope of work, deliverables, issues and be able to communicate both in verbal, written for effective technical presentation	S	Presentations
PO11	**Project management and finance**: To be familiar with project management problems and basic financial principles for a multi-disciplinary work	H	Development of Prototype, Projects
PO12	**Life-long learning**: An ability to align with and upgrade to higher learning and research activities along with engaging in life-long learning.	S	Seminars, 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	H	Lectures, Assignments
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	S	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	Seminars and 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 – Supportive **H – Highly Related**

IX. SYLLABUS

UNIT – I

AIRCRAFT IN EQUILIBRIUM FLIGHT- ELEVATOR ANGLE AND STICK FORCES TO TRIM- LONGITUDINAL STATIC AND MANEUVER STABILITY:

Need For Controlled Flight. Equilibrium, Stability, Control, Trim- Definitions- Examples. Longitudinal Forces And Moments On Aircraft In Un-Accelerated Flight- Contribution Of Principal Components. Equations Of Equilibrium- Thrust, Angle Of Attack, Elevator Angle Required To Trim. Control Gradient, Airplane Lift Curve Slope And Pitch Stiffness. Tailless Aircraft And Aircraft With Fore Planes. Longitudinal Static Stability- Definition, Relation To Control Gradient, Pitch Stiffness. Stick Fixed Neutral Point- Static Margin. Effect Of Flaps And Flight Speed On Force And Moment Coefficients, Aerodynamic Derivatives, Stability, Trim.

Steady, Symmetric Pull-Up Maneuvers- Equations Of Motion-Pitch Rate, Pitch Damping. Control To Trim, Trim Curves- Elevator Per G- Maneuver Point, Maneuver Margin- Relation To Static Margin. Statutory Limits On Position Of Center Of Gravity. Determination Of Neutral And Maneuver Points By Flight Testing.

UNIT – II

ESTIMATION OF AERODYNAMIC FORCE AND MOMENT DERIVATIVES OF AIRCRAFT:

Significance Of Aerodynamic Derivatives. Derivatives Of Axial, Normal Force Components And Pitching Moment With Respect To The Velocity, Angle Of Attack, Angle Of Attack Rate, Pitch Rate, Elevator Angle-Dependence On Vehicle Geometry, Flight Configuration- Effect Of Flaps, Power, Compressibility And Aero Elasticity.

Lateral-Directional Motions- Coupling- Derivate Of Side Force, Rolling And Yawing Moments With Respect To The Side Slip, Rate Of Side Slip, Roll Rate, Yaw Rate, Aileron, Rudder Deflections- Dependence On Vehicle Geometry, Flight Configuration. Estimation- The Strip Theory Method. Relation Between Dimension-Less And Dimensional Aerodynamic Derivatives.

UNIT – III

STICK FREE LONGITUDINAL STABILITY- CONTROL FORCES TO TRIM, LATERAL-DIRECTIONAL STATIC STABILITY AND TRIM:

Elevator Hinge Moments- Relation To Control Stick Forces. Hinge Moment Derivatives. Stick Force To Trim In Symmetric Un-Accelerated Flight, Maneuvering Flight. Stick Force Gradients- Effect Of Trim Speed- Role Of Trim Tab. Effect Of Freeing Elevator On Tail Effectiveness, Static And Maneuver Stability. Elevator-Free Factor. Stick-Free Neutral And Maneuver Points, Stability Margins- Relation With Stick Force Gradients. Aerodynamic And Mass Balancing Of Control Surfaces. Control Tabs- Types, Function, and Construction.

Lateral-Directional Static Stability, Definition, Requirements. Equilibrium Of Forces And Moments. Aileron, Rudder, Elevator And Thrust Required To Trim Aircraft In Steady Sideslip, Roll, Coordinated Turn, Engine Out Condition. Cross Wind Landings.

UNIT – IV

AIRCRAFT EQUATIONS OF MOTION- PERTURBED MOTION- LINEARISED, DECOUPLED EQUATIONS OFMOTION OF AIRCRAFT:

Description Of Motion Of Flight Vehicle- Systems Of Reference Frames. Euler Angles, Angles Of Attack And Sideslip– Definitions- Earth To Body Axis Transformation, Rotating Axis System- Expressions For Linear And Angular Moment Of Rigid Body, Time Derivatives- Inertia Tensor, Components Of Linear And Angular Velocities, Accelerations. Components Of Aerodynamic, Gravity Forces, Moments Applied On Flight Vehicle. Equations Of Motion- Longitudinal And Lateral-Directional. Relation Between Angular Velocity Components And Euler Angle Rates. Determination Of Velocities Of Airplane In Earth Axis System. Determination Of Vehicle Trajectory- Outline Of Method.

Description Of Motion As Perturbations Over Prescribed Reference Flight Condition. Equation Of Motion In Perturbation Variables. Assumption Of Small Perturbations, First Order Approximations- Linearized Equations Of Motion. Decoupling Into Longitudinal And Lateral-Directional Motions- Conditions For Validity, Role Of Symmetry. Linearized Longitudinal And Lateral-Directional Equations Of Perturbed Motion.

UNIT – V

LONGITUDINAL AND LATERAL-DIRECTIOAL DYNAMIC STABILITY:

Linearized Longitudinal Equations Of Motion Of Aircraft - Three Degree Of Freedom Analysis- Characteristic Equations- Solutions- Principal Modes Of Motion- Characteristics- Time Constant, Undammed Natural Frequency And Damping Ratio- Mode Shapes- Significance. One Degree Of Freedom, Two Degree Of Freedom Approximations- Constant Speed, Constant Angle Of Attack Approximation- Solutions- Comparison With Three Degree of Freedom Solutions- Justification Of Approximations. Lateral Directional Equations- Three Degrees of Freedom Analysis. Principal Modes- Characteristics- Mode Shapes- Significance, Lower Order Analysis- Approximate Solutions.

Determination of Longitudinal And Lateral Stability From Coefficients Of Characteristic Equation- Stability Criteria, Approximate Roots. Special Problems In Aircraft Dynamics- Roll Coupling, High Angle Of Attack Operation. Aircraft Spin- Entry, Balance Of Forces In Steady Spin, Recovery, Pilot Techniques.

TEXT BOOKS:

1. Yechout, T.R. et al., “Introduction to Aircraft Flight Mechanics”, AIAA education Series, 2003, ISBN 1-56347577-4.
2. Nelson, R.C., “Flight Stability and Automatic Control”, 2nd edn, Tata McGraw Hill, 2007, ISBN 0-07- 066110-3.

REFERENCES:

1. Etkin, B. and Reid, L.D., “Dynamics of Fligh”t, 3rdedn, John Wiley, 1998, ISBN 0-47103418-5.
2. Schmidt, L.V., “Introduction to Aircraft Flight Dynamics”, AIAA Education Series, 1998, ISBN A-56347- 226-0.
3. McCormick, B.W., “Aerodynamics, Aeronautics, and Flight Mechanics”, 2ndedn., Wiley India, 1995, ISBN 978- 0471575061

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** Equilibrium, stability, control, trim	**UNIT-I: AIRCRAFT IN EQUILIBRIUM FLIGHT ELEVATOR ANGLE AND STICK FORCES TO TRIM LONGITUDINAL STATIC AND MANEUVER STABILITY** Need for controlled flight Equilibrium, stability, control, trim- definitions- examples.	T1, T2, T3
2-3	**Derive** forces and moments	Longitudinal forces accelerated flight- and moments on aircraft in un-accelerated flight	T1, T2, T3
4-6	**Discuss** principal components	Contribution of principal components.	T1, T2, T3
7	**Derive** equations of equilibrium	Equations of equilibrium- thrust, angle of attack, elevator angle required to trim.	T1, T2, T3
8	**Explain** control gradient, lift curve slope and pitch stiffness	Control gradient, airplane lift curve slope and pitch stiffness.	T1, T2, T3
9	**Discuss** tailless aircraft and **Define** longitudinal static stability	Tailless aircraft and aircraft with fore-planes. Longitudinal static stability- definition, relation to control gradient, pitch stiffness.	T1, T2, T3
10	**Explain** NP and static margin	Stick fixed neutral point- static margin.	T1, T2, T3
11-12	**Explain** effects of flaps and flight speed	Effect of flaps and flight speed on force and moment coefficients, aerodynamic derivatives, stability, trim.	T1, T2, T3
13	**Explain** different maneuvers	Steady, symmetric pull-up maneuvers	T1, T2, T3
14	**Derive** equations of motion	Equations of motion-pitch rate, pitch damping.	T1, T2, T3
15	**Explain** how to control trim	Control to trim, Trim curves- elevator per g- maneuver point, maneuver margin- relation to static margin.	T1, T2, T3
16-17	**Discuss** various limits on cg	Statutory limits on position of center of gravity. Determination of neutral and maneuver points by flight testing.	T1, T2, T3
18	**Discuss** the importance of aerodynamic derivatives	**UNIT-II**:ESTIMATION OF AERODYNAMIC FORCE AND MOMENT DERIVATIVES **OF AIRCRAFT** Significance of aerodynamic derivatives	T1, T2, T3, T4
19-20	**Derive** force components	Derivatives of axial, normal force components and pitching moment with respect to the velocity, angle of attack, angle of attack rate, pitch rate, elevator angle	T1, T2, T3, T4
21-23	**Explain** dependence on vehicle geometry and effects of flap	Dependence on vehicle geometry, flight configuration- effect of flaps, power, compressibility and aero elasticity.	T1, T2, T3, T4
24-26	**Derive** lateral directional motions and its derivatives	Lateral-directional motions- coupling- derivatives of side force, rolling and yawing moments with respect to	T1, T2, T3, T4

		the side slip, rate of side slip, roll rate, yaw rate, aileron, rudder deflections	
27	**Discuss** flight configuration	Dependence on vehicle geometry, flight configuration.	T1, T2, T3, T4
28-29	**Explain** strip theory method	Estimation- the strip theory method.	T1, T2, T3, T4
30	**Discuss** the relation between dimension and dimensionless aerodynamic derivatives	Relation between dimension-less and dimensional aerodynamic derivatives.	T1, T2, T3, T4
31-32	**Explain** elevator hinge moments	**UNIT-III : STICK FREE LONGITUDINAL STABILITY- CONTROL FORCES TO TRIM, LATERAL-DIRECTIONAL STATIC STABILITY AND TRIM** Elevator hinge moments- relation to control stick	T1, T2, T3, T4
33-35	**Explain** elevator hinge moment derivatives	Hinge moment derivatives.	T1, T2, T3, T4
36-37	**Derive** stick forces to trim	Forces Stick force to trim in symmetric un-accelerated flight, maneuvering flight.	T1, T2, T3, T4
38-39	**Derive** stick force gradients	Stick force gradients- effect of trim speed- role of trim tab	T1, T2, T3, T4
40-41	**Explain** the effect of freeing elevator	Effect of freeing elevator on tail effectiveness, static and maneuver stability.	T1, T2, T3, T4
42	**Explain** stick free NP	Elevator-free factor. Stick-free neutral and maneuver points, stability margins- relation with stick force gradients.	T1, T2, T3, T4
43	**Explain** aerodynamic and mass balancing control surfaces	Aerodynamic and mass balancing of control surfaces.	T1, T2, T3, T4
44	**Explain** control tabs	Control tabs- types, function and construction.	T1, T2, T3, T4
45	**Define** lateral directional static stability	Lateral-directional static stability, definition, requirements.	T1, T2, T3, T4
46	**Derive** equilibrium forces and moments	Equilibrium of forces and moments.	T1, T2, T3, T4
47-48	**Explain** control surfaces required to trim	Aileron, rudder, elevator and thrust required to trim aircraft in steady sideslip, roll, coordinated turn, engine out condition. Cross wind landings.	T1, T2, T3, T4
49	**Describe** motion of flight vehicle reference system	UNIT – IV: AIRCRAFT EQUATIONS OF MOTION- PERTURBED MOTION- LINEARISED, DECOUPLED EQUATIONS OF MOTION OF AIRCRAFT Description of motion of flight vehicle systems of reference frames	T1, T2, T3, T4
50-51	**Derive** Euler's angles, aoa, side slip and expressions for linear, angular moments of rigid body	Euler angles, angles of attack and sideslip– definitions- earth to body axis transformation, Rotating axis system- expressions for linear and angular moments of rigid body, time derivatives inertia tensor, components of linear and angular velocities, accelerations.	T1, T2, T3, T4
52	**Derive** components of aerodynamic, gravity forces, moments	Components of aerodynamic, gravity forces, moments applied on flight vehicle.	T1, T2, T3, T4
53	**Derive** Equations of motion	Equations of motion- longitudinal and lateral-directional. Relation between angular velocity components and Euler angle rates.	T1, T2, T3, T4
54-55	**Determine** velocities of airplane in earth axis system	Determination of velocities of airplane in earth axis system. Determination of vehicle trajectory- outline of method.	T1, T2, T3, T4
56	**Describe** motion as perturbations over prescribed reference flight condition.	Description of motion as perturbations over prescribed reference flight condition.	T1, T2, T3, T4

57-58	**Derive** equation of motion in perturbation variables	Equation of motion in perturbation variables. Assumption of small perturbations, first order approximations- linearized equations of motion. Decoupling into longitudinal and lateral-directional motions- conditions for validity, role of symmetry.	T1, T2, T3, T4
59-60	**Derive** linearized longitudinal and lateral- directional equations of perturbed motion.	Linearized longitudinal and lateral-directional equations of perturbed motion.	T1, T2, T3, T4
61-62	**Derive** linearized longitudinal equations of motion of aircraft	UNIT – V: LONGITUDINAL AND LATERAL DIRECTIOAL DYNAMIC STABILITY Linearized longitudinal equations of motion of aircraft - three degree of freedom analysis- characteristic equations- solutions- principal modes of motion- characteristics- time constant, undamped	T1, T2, T3, T4
		natural frequency and damping ratio- mode Shapes- significance.	
63-64	**Explain** one degree of freedom, two degree of freedom approximations	One degree of freedom,two degree of freedom approximations- constant speed, constant angle of attack approximation- solutions- comparison with three degree of freedom solutions- justification of approximations.	T1, T2,T3, T4
65-66	**Derive** lateral directional equations	Lateral directional equations- three degrees of freedom analysis. Principal modes- characteristics- mode shapes- significance, lower order analysis- approximate solutions.	T1, T2,T3, T4
67	**Determine** longitudinal and lateral stability from coefficients of characteristic equation	Determination of longitudinal and lateral stability from coefficients of characteristic equation- stability criteria, approximate roots.	T1, T2,T3, T4
68-69	**Discuss** special problems in aircraft dynamics	Special problems in aircraft dynamics- roll coupling, high angle of attack operation	T1, T2, T3, T4
70-73	**Explain** aircraft spin	Aircraft spin- entry, balance of forces in steady spin, recovery, pilot techniques	T1, T2, T3, T4

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	S				H					H			H			
II	S	H	H	S										H		
III							H								H	
IV		S										H	H			H
V					S											
VI	H						S					S			H	
VII			H	H	S								H			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	H											H	H		
2	S		H													
3				H	H										H	
4													S			
5		H														
6			H													S
7												S				
8				H												
9		H	S												H	

S – Supportive **H - Highly related**

Prepared by: Ms. G Swathi, Assistant Professor,
Mr. A Rathan Babu, Assistant Professor

HOD, AE