Doctor of Philosophy in Aerospace Engineering

(By Thesis and Courses)

General Requirements

To obtain the PhD degree in Aerospace Engineering, the student should complete, at least, 41 credit units including the PhD thesis as follows:

- 4 credit units of compulsory courses (2 courses)
- 12 credit units of elective courses (4 courses)
- 25 credit units for the PhD thesis.

A. Compulsory Courses (2 course 4 units)

Course Title		Code/ No.	Units			C.H.
			Th.	Pr.	Tr.	
1	Advanced Mathematical and Numerical Methods in Engineering	AE 711	3	2	0	3
2	Research Seminar in Aerospace Engineering	AE 795	1	1	0	1

B. Elective Courses (4 course 12 units)

Course Title		Code/ No.	Units			C.H.
			Th.	Pr.	Tr.	
3	Continuum Mechanics	AE 722	3	2	0	3
4	Advanced Dynamics	AE 724	3	2	0	3
5	Physical Gas Dynamics	AE 727	3	2	0	3
6	Experimental Methods	AE 729	2	2	0	3
7	Advanced Compressible Flow	AE 732	3	2	0	3
8	Advanced Viscous Flow	AE 733	3	2	0	3
9	Hypersonic Flow	AE 734	3	2	0	3
10	Aerodynamic Configurations	AE 737	3	2	0	3
11	Rotorcraft Aerodynamics	AE 738	3	2	0	3
12	Cascade Aerodynamics	AE 739	3	2	0	3
13	Computational Fluid Dynamics I	AE 741	3	2	0	3
14	Computational Fluid Dynamics II	AE 742	3	2	0	3
15	Industrial CFD	AE 744	3	2	0	3
16	Unstructured CFD Methods	AE 746	3	2	0	3
17	High-Order CFD Methods	AE 748	3	2	0	3
18	Turbulent Flow Modeling	AE 749	3	2	0	3

	Course Title	Code/ No.	Th.	Pr.	Tr.	C.H.
19	Computational Structural Analysis	AE 751	3	2	0	3
20	Aerospace Structural Dynamics	AE 752	3	2	0	3
21	Numerical Methods in Structural Dynamics	AE 753	2	2	2	3
22	Theory of Elasticity	AE 754	3	2	0	3
23	Aeroelasticity of Aircraft Structures	AE 755	3	2	0	3
24	Rotorcraft Structural Dynamics and Aeroelasticity	AE 756	3	2	0	3
25	Aircraft Structural Analysis and Design	AE 757	2	2	0	3
26	Fracture Mechanics of Aerospace Structures	AE 758	3	2	0	3
27	Mechanics and Design of Fiber-Reinforced Composite Structures	AE 759	3	3	0	3
28	Aircraft Design I	AE 760	3	2	0	3
29	Aircraft Design II	AE 761	2	2	0	3
30	Aerospace Robust Control	AE 762	3	2	0	3
31	Random Processes and Kalman Filtering	AE 763	3	2	0	3
32	Aerospace Guidance and Navigation	AE 764	3	2	0	3
33	Aerospace Vehicle Dynamics and Simulation	AE 765	3	2	0	3
34	Advanced Aircraft Reliability	AE 766	3	2	0	3
35	Advanced Aircraft Maintenance Systems	AE 767	3	2	0	3
36	Quality Management in Aerospace Industry	AE 768	3	2	0	3
37	Nonlinear Systems and Control	AE 771	3	2	0	3
38	Optimal Guidance and Control	AE 773	3	2	0	3
39	Spacecraft Dynamics and Control	AE 775	3	2	0	3
40	Rotorcraft Stability and Control	AE 778	3	2	0	3
41	Advanced Propulsion	AE 781	3	2	0	3
42	Rocket Propulsion	AE 784	3	2	0	3
43	Combustion Theory	AE 788	3	2	0	3
44	Special Topics in Aerospace Engineering 1	AE 496	3	2	0	3
45	Special Topics in Aerospace Engineering 2	AE 497	3	2	0	3
46	**	MATH 7**	*	*	0	3
47	**	MATH 7**	*	*	0	3

C.   PhD Thesis (25 units)

Course Title	Code/ No.	Units			C.H.
		Th.	Pr.	Tr.	
48 Doctoral Thesis	AE 799	0	0	0	25

D.   Course Description

Course Code	Course Title	Credits
AE 711	Advanced Mathematical and Numerical Methods in Engineering	(3:2،0)
Mathematical modeling and engineering problem solving, scientific computing, numerical modeling and software programming, validation of numerical solution; conditioning and stability of numerical solution, direct methods for linear and nonlinear systems of equations, iterative methods for under-determined and over-determined systems, polynomial interpolation, curve fitting and shape approximation; formulation of initial and boundary value problems, numerical integration of initial value problems, numerical solution of partial differential equations; fundamental concepts of numerical optimization, constrained and unconstrained optimization algorithms, inverse problems formulation and numerical solution; stochastic modeling and probability.			

Course Code	Course Title	Credits
AE 722	Continuum Mechanics	(3:2،0)
Notations and tensor calculus، stress and strain tensors، rate of deformation tensor، Eulerian and Lagrangian descriptions، conservation principles، constitutive formulations for elastic solids and viscous fluids، formulations of fluid mechanics and solid mechanics problems.			

Course Code	Course Title	Credits
AE 724	Advanced Dynamics	(3:2،0)
Kinematics of particles and rigid bodies، angular velocity، inertia properties، holonomic and nonholonomic constraints، generalized forces، equations of motion، Newtonian frames، linearization، energy and momentum integrals، collisions، mathematical representation of finite rotation.			

Course Code	Course Title	Credits
AE 727	Physical Gas Dynamics	(3:2،0)
Principles of kinetic theory of gases، statistical mechanics as applied to gases، application to gases at high temperatures، very low pressures، etc.			

Course Code	Course Title	Credits
AE 729	Experimental Methods	(3:2،0)

Procedure of experiment design and implementation، measurement methods، transducer fundamentals، instrumentation، optical systems، signal processing، noise theory، analog and digital electronic fundamentals، data acquisition and processing systems، experiments in solid، fluid mechanics and mechatronics، with emphasis on current research methods.

Course Code	Course Title	Credits
AE 732	Advanced Compressible Flow	(3:2،0)

Classification of PDE's governing subsonic، supersonic and transonic flows، full potential equation، transonic small disturbance theory، supersonic and transonic airfoil design، slender bodies of revolution flows، conical flows، wing flows.

Course Code	Course Title	Credits
AE 733	Advanced Viscous Flow	(3:2،0)

Review of governing equations، exact solutions of the Navier-Stokes equations، boundary layer theory، wakes and jets، Three-dimensional boundary layer، statistical theories of turbulence.

Course Code	Course Title	Credits
AE 734	Hypersonic Flow	(3:2،0)

High Mach number flows، Newtonian theory، small disturbance theory، thin shock layers، blunt body problems، hypersonic boundary layers and viscous interactions، thermally and calorically imperfect gases، statistical thermodynamics، kinetic theory of gases، equilibrium and non-equilibrium hypersonic flows، viscous high-temperature flows.

Course Code	Course Title	Credits
AE 737	Aerodynamic Configurations	(3:2‹0)

Aerodynamic design; aircraft aerodynamics: configuration design options‹ delta wings‹ leading edge extensions‹ canard aircraft‹ tailless aircraft‹ aerodynamics of high lift devices‹high angle of attack aerodynamics; missile aerodynamics: subsonic and supersonic slender-body theory‹ wing-body interference‹ downwash‹ sidewash‹ wake vortices‹ wing-tail interference‹ drag prediction‹ aerodynamic controls‹ stability derivatives.

Course Code	Course Title	Credits
AE 738	Rotorcraft Aerodynamics	(3:2‹0)

Vortex wake modeling‹ analytical inflow theories‹ modern computational methods for rotary wing aerodynamic analysis‹ aerodynamic noise.

Course Code	Course Title	Credits
AE 739	Cascade Aerodynamics	(3:2‹0)

Cascade model‹ cascade testing‹ incompressible and compressible flow theories‹ viscous flow‹ numerical predictions techniques‹ design application of cascade data.

Course Code	Course Title	Credits
AE 741	Computational Fluid Dynamics I	(3:2‹0)

Introduction to computational fluid dynamics‹ classification of PDE's‹ finite difference method‹ finite volume method‹ finite element method‹ basic concepts of discretization: spatial and temporal discretization‹ stability analysis‹ convergence‹ consistency and efficiency‹ explicit‹ implicit‹ and iterative techniques; solutions of model equations of hyperbolic‹ parabolic and elliptic types.

Course Code	Course Title	Credits
AE 742	Computational Fluid Dynamics II	(3:2‹0)

Advanced numerical methods for solving Navier-Stokes and Euler equations: pressure-based techniques‹ flux vector splitting‹ flux difference splitting‹ flux limited‹ initial and boundary conditions‹ curvilinear coordinate systems‹ grid generation.

Course Code	Course Title	Credits
AE 744	Industrial CFD	(3:2،0)

Geometry modeling، grid generation، solution strategy، post-processing، parametric studies; industrial applications involving: turbulence، multiphase flow، heat transfer، and combustion.

Course Code	Course Title	Credits
AE 746	Unstructured CFD Methods	(3:2،0)

Unstructured Grids، data structures and algorithms، spatial discretisation: cell-centered schemes، median-dual cell-vertex schemes، temporal discretisation: explicit multistep schemes، implicit schemes، boundary conditions، convergence acceleration techniques.

Course Code	Course Title	Credits
AE 748	High-Order CFD Methods	(3:2،0)

High-order finite difference methods: central explicit، central compact، upwind WENO،spectral methods، spectral volume methods، discontinuous Galerkin method.

Course Code	Course Title	Credits
AE 749	Turbulent Flow Modeling	(3:2،0)

Levels of turbulence modeling، Reynolds Averaged Navier Stokes (RANS) approach : algebraic models، first order closure، second order closure، Large Eddy Simulation (LES) approach، Detached Eddy Simulation (DES) approach، Direct Numerical Simulation (DNS) approach.

Course Code	Course Title	Credits
AE 751	Computational Structural Analysis	(3:2،0)

Finite element methods for linear static structural analysis، basic tools of the finite element method for spring systems، rods، truss، and frames، formulation and solutions of various structural elements.

Course Code	Course Title	Credits
AE 752	Aerospace Structural Dynamics	(3:2‹0)

Dynamic response of single-degree-of-freedom systems‹ Lagrange's equations‹ modal decoupling‹ multi-degrees-of-freedom systems‹ vibration of beams‹ membranes and plates‹ modal analysis of aerospace structures‹ system identification methods‹ experimental methods.

Course Code	Course Title	Credits
AE 753	Numerical Methods in Structural Dynamics	(3:2‹0)

Rayleigh quotient‹ Rayleigh-Ritz and Galerkin methods‹ extraction of eigenvalues and eigenvectors‹ analysis of forced harmonic response‹ direct time integration of large-scale systems‹ nonlinear vibration methods.

Course Code	Course Title	Credits
AE 754	Theory of Elasticity	(3:2‹0)

Governing equations of linear elasticity‹ plane elasticity‹ boundary value problems‹ airy stress function and complex variable methods‹ simple three-dimensional solutions‹ stresses and deformations in continuum media‹ equilibrium equations and energy principles‹ linear and nonlinear elasticity of beams‹ plates and shells.

Course Code	Course Title	Credits
AE 755	Aeroelasticity of Aircraft Structures	(3:2‹0)

Analysis of aeroelastic phenomena in fixed-wing aircraft‹ static aeroelasticity‹ dynamic aeroelasticity‹ dynamic response and transient stresses in aircraft structures.

Course Code	Course Title	Credits
AE 756	Rotorcraft Structural Dynamics and Aeroelasticity	(3:2‹0)

Elementary blade dynamics‹ flap-lag dynamics‹ ground resonance‹ structural dynamics of rotating beams‹ linear and nonlinear elastic blade analysis‹ harmonic balance and trim‹ Floquet theory.

Course Code	Course Title	Credits
AE 757	Aircraft Structural Analysis and Design	(3:2،0)

Stress and strength analysis of wing، fuselage، empennage، fin، and landing gear. Structural analysis of ribs، frames، stiffeners، webs، and skins، diagonal semi-tension field beam. Design، building and testing exercise of a principle component of a small aircraft.

Course Code	Course Title	Credits
AE 758	Fracture Mechanics of Aerospace Structures	(3:2،0)

Fatigue load spectra، structural safety، reliability and life prediction، crack initiation and growth، crack arrest and closure، inspection of structures by non-destructive testing، repairs of structures.

Course Code	Course Title	Credits
AE 759	Mechanics and Design of Fiber-Reinforced Composite Structures	(3:2،0)

Composite material systems، anisotropic plate and shell theory، shear deformation، hydrothermal and interlaminar stresses، finite element modeling، damage، failure، durability of composite materials، design case studies including thin-walled composite structures.

Course Code	Course Title	Credits
AE 760	Aircraft Design I	(3:2،0)

Characteristics of aerospace vehicles، disciplines within aerospace vehicle design، design features، initial sizing، preliminary configuration design، design optimization، performance analysis.

Course Code	Course Title	Credits
AE 761	Aircraft Design II	(3:2،0)

Layout design of wing، fuselage and empennage. Aircraft cost estimation: design، development، manufacturing and operation.

Course Code	Course Title	Credits
AE 762	Aerospace Robust Control	(3:2‹0)

State space representation of linear systems‹ stability‹ controllability and observability‹ linear feedback control‹ observers‹ introduction to Kalman filtering‹ robustness issues in controller analysis and design‹ LQ analysis‹ H2 norm‹ LQR‹ LQG‹ uncertainty modeling‹ small gain theorem‹ H-infinity performance‹ mixed-norm H2/H-infinity problem.

Course Code	Course Title	Credits
AE 763	Random Processes and Kalman Filtering	(3:2‹0)

Probability and random variables and processes‹ correlation‹ shaping filters‹ simulation of sensor errors‹ Wiener filter‹ random vectors‹ covariance propagation‹ recursive least squares‹ linear Kalman filter‹ extended Kalman filter.

Course Code	Course Title	Credits
AE 764	Aerospace Guidance and Navigation	(3:2‹0)

Earth's shape and gravity‹ inertial navigation‹ GPS aiding‹ error analysis‹ guidance systems‹ analysis of the guidance loop‹ estimation of guidance variables‹ adjoint analysis‹ radar detection‹ waveforms‹ ambiguity function‹ radar operation and design‹ Satellite modeling‹ identification‹ and real-time control‹ rules & regulations of satellite telecommunications.

Course Code	Course Title	Credits
AE 765	Aerospace Vehicle Dynamics and Simulation	(3:2‹0)

Reference frames and transformations‹ general equations of unsteady motion‹ perturbation equations‹ application to fixed-wing‹ rotary-wing‹ missiles and space vehicles‹ stability characteristics‹ flight in turbulent atmosphere‹ models for subsystems of propulsion‹ autopilot‹ actuator‹ navigation‹ guidance and seeker.

Course Code	Course Title	Credits
AE 766	Advanced Aircraft Reliability	(3:2‹0)

Reliability testing‹ censoring‹ MTTF estimates‹ confidence intervals‹ Bayesian analysis‹ renewal theory‹ Monte Carlo simulation‹ loads and capacity‹ safety factors‹ extreme value distributions‹ repetitive loading‹ time dependent failure raters‹ failure interactions‹ Markov analysis.

Course Code	Course Title	Credits
AE 767	Advanced Aircraft Maintenance Systems	(3:2،0)

Reliability centered maintenance (RCM)، failure detection، maintenance tasks، developing initial maintenance program، evolution of RCM program، RCM analysis of A/C systems، power plant and structures، the use of operating information، auditing of RCM program.

Course Code	Course Title	Credits
AE 768	Quality Management in Aerospace Industry	(3:2،0)

Total quality management، Deming approach، design for quality، reliability، production for quality، quality planning، quality control، quality assurance، Kaizen approach to quality improvement.

Course Code	Course Title	Credits
AE 771	Nonlinear Systems and Control	(3:2،0)

Classical analysis techniques for nonlinear systems، Lyapanov stability، absolute stability، dissipativity، control Lyapanov functions، feedback linearization، backstepping control، adaptive control.

Course Code	Course Title	Credits
AE 773	Optimal Guidance and Control	(3:2،0)

Constrained optimization، Euler-Lagrange formulation، Pontryagin's minimum principle، systems with quadratic performance index، Hamilton-Jacobi-Bellman approach، second variation and neighboring extremals، singular solutions، numerical solution techniques.

Course Code	Course Title	Credits
AE 775	Spacecraft Dynamics and Control	(3:2،0)

Review of particle dynamics، Newton's laws، the two body problem، Kepler's equation، rigid body dynamics، Euler's equations، Spacecraft attitude dynamics and determination، Gyroscopic instruments، attitude control، underactuated spacecraft dynamics and control.

Course Code	Course Title	Credits
AE 778	Rotorcraft Stability and Control	(3:2‹0))

Rotorcraft general equations of motion‹ rotor forces and moments‹ helicopter stability and control characteristics‹ handling qualities‹ flight control system design.

Course Code	Course Title	Credits
AE 781	Advanced Propulsion	(3:2‹0)

Airbreathing propulsion systems‹ airbreathing engines performance analysis‹ compression‹ combustion and expansion system components‹ special hypersonic airbreathing propulsion topics.

Course Code	Course Title	Credits
AE 784	Rocket Propulsion	(3:2‹0)

Definitions and classifications‹ nozzle theory‹ liquid propellant rocket fundamentals‹ solid propellant rocket fundamentals‹ advanced propulsion systems‹ rocket testing.

Course Code	Course Title	Credits
AE 788	Combustion Theory	(3:2‹0)

Fuels‹ thermochemistry of combustion‹ chemical kinetics and equilibrium‹ laminar premixed combustion‹ turbulent premixed and diffusion combustion‹ combustion modeling‹ numerical predictions methods.

Course Code	Course Title	Credits
AE 795	Research Seminar in Aerospace Engineering	(3:2‹0)

The student will deliver at least one seminar to demonstrate his/her confidence on the selected area research.

Course Code	Course Title	Credits
AE 796	Special Topics in Aerospace Engineering 1	(3:2‹0)

The student studies a course relevant to his field of specialization and the topic of his thesis as advised by his thesis supervisor.

Course Code	Course Title	Credits
AE 797	Special Topics in Aerospace Engineering 1	(3:2‹0)
The student studies a course relevant to his field of specialization and the topic of his thesis as advised by his thesis supervisor.		

Course Code	Course Title	Credits
AE 799	Doctoral Thesis	(25:0‹0)
Original research work conducted by individual PhD candidate in one of the areas of Aerospace Engineering. The work should contribute new knowledge to the field of specialization and demonstrates proficiency and creative thinking.		