1. Core Course Requirements

Basic Field Theory: complete one course in each of the following categories

Fluid Mechanics:

AERSP 508*	Foundations of Fluid Mechanics
AERSP 504	Aerodynamics of V/STOL Aircraft
AERSP 511	Aerodynamically Induced Noise
AERSP 524	Turbulence and Applications to CFD: DNS & LES
AERSP 525	Turbulence and Applications to CFD: RANS
AERSP 583	Wind turbine aerodynamics

Dynamics and control:

EMCH 520*	Advanced Dynamics
AERSP 506	Rotorcraft Dynamics
AERSP 518	Dynamics and Control of Aerospace Vehicles
AERSP 550	Astrodynamics
AERSP 597	Autonomy

Solid Mechanics:

AERSP 470*	Advanced Aerospace Structures
AERSP 571	Foundations of Structural Dynamics & Vibrations
AERSP 597	Multifunctional Structures
AERSP 597*	Advanced Composites

Applied Mathematics: complete one course

EMch 524 *	Mathematical Methods in Engineering
MATH 515	Classical mechanics and variational methods
STAT 500	Applied statistics

Note: Classes with * are designated foundational classes in each core area. Students are recommended to take these classes if they have not covered the material being covered in these courses in their prior degree program.

2. Courses that will be offered in 2024/2025

2.1. Fall semester

Course	***Credits***	***Title***
504	3	Aerodynamics of V/STOL Aircraft
508	3	Foundations of Fluid Mechanics
514	3	Stability of Laminar Flows
524	3	Turbulence and Applications to CFD: DNS and LES
571	3	Foundations of Structural Dynamics and Vibration
575	3	Aerospace Materials
590	1	Colloquium
596	1-9	Individual Studies
597-1	1	Aerospace Practicum
597-2	1-3	Advanced Air Mobility
597-3	3	Aerospace Autonomy
597-4	3	Advanced Aerospace Structures
597-5		TBA
597-6		TBA
597-7		TBA
597-8		TBA
597-9		TBA
600	1-15	Thesis Research
601	0	Ph D Dissertation Full-Time
610	1-15	Thesis Research Off Campus
611	0	Ph D Dissertation Part-Time

2.2. Spring semester

Course	***Credits***	***Title***
505	3	Aero and Hydroelasticity
509	3	Dynamics of Ideal Fluids
511	3	Aerodynamically Induced Noise
518	3	Dynamics and Control of Aerospace Vehicles
525	3	Turbulence and Applications to CFD: RANS
550	3	Astrodynamics
565	3	System Identification
575	3	Aerospace Materials
583	3	Wind Turbine Aerodynamics
590	1	Colloquium
596	1-9	Individual Studies
597-1	1	Doctoral Career Prep
597-2		TBA
597-3		TBA
597-4		TBA
597-5	3	Nonlinear Dyn: Theory & App
597-6		TBA
597-7		TBA
597-8	3	Signal Proc-Computer Vision
597-9		TBA
600	1-15	Thesis Research
601	1-15	Ph D Dissertation Full-Time
610	1-15	Thesis Research Off Campus
611	1-15	Ph D Dissertation Part-Time

3. Qualifying Exam

Purpose: The Ph.D. qualifying examination is intended to provide an additional measure (beyond what can be determined from the admissions documents) of a student's preparation for doctoral work. This is particularly useful for a student whose earlier degrees were obtained in non-aerospace engineering programs and/or from other institutions. To be successful in a Ph.D. program, students must understand a range of subjects beyond the particular topic of their dissertation research; hence, the qualifying exam should assess breadth of knowledge, posing questions from the primary fields that constitute our discipline: dynamics, fluids, mathematics, and structures. The exam does not require mastery of all four fields, but instead allows the student some choice in demonstrating a sufficient level of understanding in several areas.

Any graduate student seeking to qualify into the doctoral program is required to take the qualifying examination no later than the third semester of entering the Ph.D. program or the fifth semester of entering our graduate program; any student electing a second attempt at the qualifying exam must take it the next semester after the first attempt. The qualifying exam can be taken by students currently enrolled in the M.S. program; indeed, this is recommended so that M.S. students who are considering the Ph.D. program can learn whether they qualify in time to plan to stay for the Ph.D. – or make alternate arrangements – without a delay after completing their M.S.

Format: Faculty will prepare three questions in each of the four subject areas, following the respective syllabus. Each problem is to be appropriate for a senior-level undergraduate or introductory-level graduate treatment of the subject. The exam is closed book, except for formulas provided with the examination questions and students may bring two sheets of notes (standard US Letter paper, both sides). You may obtain this formula book to familiarize yourself with what is provided from the Graduate Staff Assistant prior to the exam.

A student taking the exam must attempt any eight of the 12 problems; the time limit for the exam is six hours.

Administration: The Director of Graduate Studies will form four committees, one in each field, giving each the responsibility to: (1) generate three problems, with solutions; (2) carefully check the problems for clarity and appropriate level of difficulty; (3) grade student answers.

Following the exam, the department faculty will then meet to review the grades and determine the outcomes. A student who fails the exam on the first attempt is allowed to take the subsequent exam (typically offered near the beginning of each semester). In the event of a second failure, a student is then removed from the Ph.D. program. A student who fails the exam twice may petition the Graduate Academic Committee in writing for an oral qualifying examination. If the petition is granted, the Director of Graduate Studies will form a committee of three faculty to administer the oral exam and request that they make a recommendation of “pass” or “fail;” the Graduate Committee will then make the final decision.

3.1. Fluids

Material is based on AERSP 306, 311, and 312. The recommended graduate level course is AERSP 508.

Control volume analysis

- Continuity, momentum and energy equations, applications

Differential analysis of fluid motion

- Kinematics
- Rotation, vorticity, circulation
- Continuity equation
- Navier-Stokes equations

Incompressible inviscid flow

- Euler equations
- Bernoulli equation
- Velocity potential and stream function
- Elementary flows
- Forces and moments acting on a body
- Thin airfoil theory
- Lifting-line theory
- Slender-body theory

Dimensional analysis and similitude

- Application to problems in aerodynamics, hydrodynamics, rotating machinery, etc.

Incompressible laminar and turbulent flows

- Exact solutions of the Navier-Stokes equations
- Laminar and turbulent pipe flow
- Blasius boundary layer solution
- Integral methods for laminar and turbulent boundary layers
- Similarity analysis of laminar and turbulent boundary layers
- Laminar jets and wakes
- Eddy viscosity and mixing length concepts
- Reynolds averaged equations

Compressible flows

- Thermodynamics
- One-dimensional compressible flow
- Speed of sound and Mach number

- Alternative forms of the one-dimensional energy equation
- Stagnation, static and critical quantities
- Normal and oblique shock relations, shock polar
- Hugoniot equation
- One-dimensional flow with heat addition
- One-dimensional flow with friction
- Supersonic flow over wedges
- Prandtl-Meyer expansions
- Prandtl-Glauert equation
- Linearized theory for thin airfoils
- Full potential equation

Example references:

- White, F.W., *Fluid Mechanics*, 2nd edition, McGraw-Hill, 1989.
- Anderson, J.D., *Modern Compressible Flows, with Historical Perspective*, 2nd ed., Wiley, 1994.
- Anderson, J.D., *Fundamentals of Aerodynamics*, 2nd ed., McGraw-Hill, 1991.
- Munson, B.R., Young, D.F., Okiishi, T.H., *Fundamentals of Fluid Dynamics*, 2nd ed., Wiley, 1994.
- Cengal and Cimbala, Fluid Mechanics, 4th Edition, 2018

(Note: given some duplication of material in these references, students need not review them all; students are also encouraged to consult sources in addition to those listed here.)

3.2. Structures

Material is based on AERSP 301, AERSP 304, and EMCH 315. A course that can count towards graduate course requirements is AERSP 470.

Stress and strain

- Definitions; tensor vs. engineering notations
- Differential equations of stress equilibrium
- Linear strain-displacement relation; compatibility equations
- Stress (/strain) transformation under coordinate change, principal stresses (/strains), and maximum shear stresses (/strains)

Material behavior

- Linearly elastic constitutive relations: isotropic, transversely isotropic, and orthotropic
- Design based on yield and failure criteria (von Mises, Tresca, and max stress/strain) and factor/margin of safety

Static analysis of simple structural members (rods, beams, and shafts)

- Differential equations of equilibrium: boundary conditions, compatibility, St. Venant's principle
- Cross-section properties: solid, thin-walled and thick walled, open and closed, multi-cell, monocoque/semi-monocoque
- Neutral axis, centroid, second moment of inertia, modulus-weighted centroid
- Shear center, center of twist Rigidity, displacements, strains, and stresses of
- Rod extension
- Euler–Bernoulli beam bending, shear flow
- Torsion
- Plate extension and bending
- Structural idealization
- Classical laminated plate theory: stress/moment resultants, A/B/D matrices

Energy methods of simple structures (rods, beams, trusses, and plates)

- Work and potential; strain energy; kinetic energy
- Principle of virtual work; principle of stationary total potential energy Ritz method
- Finite element method

Elastic stability of columns and plates

- Column buckling; effects of initial imperfections or load eccentricity
- Rectangular plate buckling under in-plane loads

Structural vibration of continuum structures

- Analysis of continuum system vibration in bending
- Energy methods of continuum system vibration in extension and bending: Ritz method and FEM

Example references

- Megson, T.H.G., Aircraft Structures for Engineering Students, John Wiley & Sons.
- Donaldson, B.K., Analysis of Aircraft Structures, An Introduction, McGraw-Hill.
- Reddy, J. N., Mechanics of Laminates Composite Plates and Shells: Theory and Analysis, CRC Press.

(Note: given some duplication of material in these references, students need not review them all; students are also encouraged to consult sources in addition to those listed here.)

3.3. *Dynamics and Control*

Material is based on AERSP 304 and AERSP 309. Courses that can count towards graduate course requirements are AERSP 470 and EMCH 520.

Kinematics

- Orthogonal coordinate systems and transformations
- Cartesian, cylindrical, spherical systems
- Motion in inertial and accelerating reference frames
- Rectilinear/curvilinear velocities and accelerations; Coriolis acceleration

Momentum and impulse

- Momentum and impulse – linear and angular
- Newton's laws and D'Alembert's principle

Work and energy principles

- Hamilton's principle
- Lagrange's equations

Rigid body dynamics

- Inertia tensor
- Euler's equations
- Torque-free motion
- Gyroscopic devices

Vibration and structural dynamics

- Lump-parameter systems
- Single and multiple DOF discrete systems
- Algebraic eigenvalue problem; natural frequencies and mode shapes
- Forced response of damped systems

Systems Analysis (AERSP 304)

- Linear systems (linear algebra, least squares, state transition matrix, controllability, observability, similarity transformations)
- Linearization/Taylor series approximations (Equilibrium and stability of equilibria)
- Frequency domain system analysis (via Laplace transform for continuous time systems)
- Control System Analysis and Design (AERSP 304)
- Stability of the closed loop system (frequency domain: poles/zeros, Routh Hurwitz criterion)
- Controller characteristics and compensator design (PD/PID, pole placement)
- Robustness analysis and performance measures (Bode/Root locus, stability margins)

Example references:

- Greenwood, D.T., *Principles of Dynamics*, 2nd ed., Prentice-Hall, 1988.
- Marion, J.B. and Thornton, S.T., *Classical Dynamics of Particles and Systems*, 4th ed., Saunders College Pub.,1995.
- Thornson, W.T., Vibration Theory and Applications, 4th ed., Prentice-hall, 1993
- F. Golnaraghi and B. C. Kuo, *Automatic Control Systems*, McGraw-Hill, 2017.
- K. Ogata, *Modern Control Engineering*, Pearson, 2009.
- R. C. Dorf and R. H. Bishop, *Modern Control Systems*, Pearson, 2016.
- G. F. Franklin, J. D. Powell, A. Emami-Naeini, *Feedback Control of Dynamical Systems*, Pearson, 2015.
- Thornson, W.T., *Vibration Theory and Applications*, 4th ed., Prentice-hall, 1993

(Note: given some duplication of material in these references, students need not review them all; students are also encouraged to consult sources in addition to those listed here.)

3.4. Mathematics

Material in this section is based on AERSP 313 and its prerequisites. Relevant courses that can be used to satisfy graduate requirements are EMCH 524 and MATH 441.

Ordinary differential equations

- First- and second-order equations
- Homogeneous and inhomogeneous equations
- Systems of ordinary differential equations
- Elementary Laplace transforms
- Series solutions
- Sturm-Liouville equation

Partial differential equations

- Classification of equations
- Separable solutions
- Boundary and initial value problems
- Green functions
- Bessel functions
- Similarity solutions
- Characteristics

Vector calculus

- Scalars and Vectors
- Dot and cross products
- Conformal mapping
- Evaluation of line integrals
- Method of residues
- Evaluation of real integrals

Fourier series

Fourier and Laplace transforms, inverse Laplace transforms

Linear algebra

- Matrix operations
- Systems of equations
- Eigenvalues and eigenvectors
- Gaussian elimination
- LU factorization

Numerical analysis

- Interpolation and root finding
- Numerical integration
- Finite difference approximations
- Solution of ordinary differential equations Solution of partial differential equations

Probability

- Averages
- Probability: Probability distributions, conditional probability
- Correlations and spectra

Example references:

- Kreysig, E. *Advanced Engineering Mathematics*, 10th Edition, John Wiley & Sons, 2011
- Arfken, G. B. *Mathematical methods for physicists*, 7th Edition, Academic Press, 2013
- Wylie, C. R. and Barrett, L. C., *Advanced Engineering Mathematics*, 6th Edition, McGraw Hill, 1995

(Note: given some duplication of material in these references, students need not review them all; students are also encouraged to consult sources in addition to those listed here.)