

AML7870 : TOPOLOGY AND SHAPE OPTIMIZATION (3-0-0, A-SLOT)

Department of Applied Mechanics, 2025-2026, Semester-II

Instructor:	Prof. Prateek Gupta	Time:	MTh 8:00-9:30 AM
Contact:	prgupta@iitd.ac.in , Block IV 342B	Place:	Block III 336

Course Page: <https://web.iitd.ac.in/~prgupta/teaching/TSO.html>

Office Hours: Tuesday 5 pm - 6 pm. Flexible hours by appointment only (based on availability)

References: Course content may be covered in several texts with emphasis on different topics.

1. Christensen and Klarbring, An Introduction to Strutural Optimization
2. Sigmund and Bendosøe, Topology Optimization: Theory, methods, and applications
3. Mohammadi and Pironneau, Applied Shape Optimization for Fluids

Other texts that maybe useful for some specific topics (an incomplete list)

1. Huang and Xie, Evolutionary Topology Optimization of Continuum Structures
2. Haslinger and Mäkinen, Introduction to Shape Optimization: Theory, Approximation, and Computation

Objectives: This is an introductory course in topology and shape optimization, which are subsets of the broader topic on structural optimization. The course aims to introduce formulating optimization problems in engineering design with both solid mechanical and fluid mechanical applications in mind. Primary take-aways of this course are numerical techniques to solve convex optimization problems, approximation of non-convex optimization problems, formulating shape and topology optimization problems, adjoint methods, SIMP, Dynamic optimization

Prerequisites: An undergraduate-level understanding of continuum mechanics, i.e. conservation laws, stress-strain relationship in linear elasticity, stress tensors in fluid mechanics, energy formulation. As per experience, all the knowledge could be replaced by a certain mathematical maturity [1].

Course content as per courses of study: Overview and historical context, design problems in structural optimization: sizing, shape, and topology, linear elasticity review: stress, strain, constitutive laws, Finite element method (FEM) basics for structural analysis, computational fluid dynamics (CFD) basics for flow analysis, general problem statement, design domain, objective functions, constraints: volume, stress, hydrodynamic performance, compliance, manufacturing, SIMP method (solid isotropic material with penalization), gradient-based optimization: MMA, OC method, filtering and regularization techniques, level set methods for topology optimization, phase-field and other implicit methods, topology optimization beyond linear elasticity, parametric and non-parametric shape optimization.

Course Outline (42 hours):

Module 1 - Review of design optimization	3 hours
■ Size, shape, and topology optimization, continuous vs discrete problems, examples of structural, aerodynamics, and mesh optimization	
Module 2 - Optimization and convex programming	3 hours
■ Convex problems, Lagrangian formulation, KKT conditions, Lagrangian Duality	
Module 3 - Sequential explicit convex approximations	3 hours
■ SLP, SQP, CONLIN, MMA	
Module 4 - Discrete optimization problems	6 hours
■ Compliance minimization of a truss, truss sizing and topology optimization, non-smooth optimization using dual problem, ϵ steepest descent algorithm, Golden-Section search, sensitivity analysis of discrete problems	
Module 5 - Review of continuum mechanics	6 hours
■ Index notation, Continuum Kinematics, Reynolds Transport theorem, governing equations for linear elastic solids and Newtonian fluids, energy formulation	
Module 6 - Sensitivity analysis and shape optimization	9 hours
■ 2D/3D isoparametric Galerkin FEM, shape representation using B-splines, Bezier Curves, NURBS, Mesh generation, 2D/3D FDM and FVM for fluids, Aerodynamic optimization, Adjoint formulation	
Module 7 - Topology optimization using SIMP	9 hours
■ Minimum compliance design, design parameterization, solution methods, mesh-refinement and checkerboard effect, regularization, multiple loads, application to dynamics	
Module 8 - Alternative methods	3 hours
■ Evolutionary methods, ESO and BESO, Bubble methods	

Assessment:

- Mid-term exam (30%)
- Major exam (30 %)
- Term project (30 %)
- Assignments (10 %).

There will be one make-up mid-term exam (in the final 1-2 weeks of the semester). Term project topics must be decided in the first month of the course after thorough review of the suggested texts. A list of potential topics will be shared in the first week (after add-drop) of the course.

Course Policy:

- Please register for AML7080, only then you will receive regular updates and announcements via moodle and emails.
- Tentative audit-pass criterion - 30%

Class Policy:

- 75% attendance in lectures is mandatory as per institute norms. Grade penalty will be awarded for short-attendance.

Academic Honesty: Lack of knowledge of the academic honesty policy is not a reasonable explanation for its violation. Each student must go through the honour code of IIT-Delhi and adhere to it.