

# CARLETON UNIVERSITY

## Department of Mechanical & Aerospace Engineering

### AERO 3101 LIGHTWEIGHT STRUCTURES

#### INSTRUCTOR

Prof. Mostafa El Sayed, PhD, PEng

**Office:** CB3206 **Tel:** 613-520-2600 ext 4138 **Email:** mostafa.elsayed@carleton.ca

**Office hours:** Lectures are asynchronously posted on CULearn. Scheduled Thursday lectures are used for office Hours. MS Teams platform is used for office hours meetings. Additional office hours can be arranged by appointment.

#### TEACHING ASSISTANT

Mr. Andrew MacMillan

**Email:** [ANDREWMACMILLAN4@cmail.carleton.ca](mailto:ANDREWMACMILLAN4@cmail.carleton.ca)

**PA Session:** Wednesday 8:30 to 10:00 am. MS Teams platform is used for PA session meetings.

**Office Hour:** TBD. MS Teams platform is used for office hours meetings.

#### PREREQUISITES

MAAE 3202 Mechanics of Solids II

#### COURSE OUTLINE

Weight reduction in structural design has been an important and constantly growing aspect of product development in weight critical applications in defence, aerospace, automotive and biomedical industries. The larger the structural stiffness and strength to its weight ratios, the lighter the structure is. This course is designed to introduce students to the fundamental concepts of lightweight structures. The course enables students to solve general engineering problems in stress-strain analysis effectively with particular focus on aerospace structural systems.

##### **1. Introduction**

Basic course assumptions; Definitions of structural systems; Principles of solution in structural analysis; Some basic static failure modes in lightweight structures; Structural static determinacy and indeterminacy analysis; Review of elementary theory of elasticity.

##### **2. Energy Methods for Deflections and Reactions**

Review: External work; Elastic strain energy, Principle of conservation of energy; Potential Energy; Principle of minimum potential energy; Castigliano's theorems; Principle of virtual work.

Unit-load and unit-displacement methods; Rayleigh-Ritz methods; Introduction to the finite element methods (bar and truss systems).

### **3. Flange-Web (Semi-Monocoque) Structures**

Idealisation for thin-walled structures: sheet-stringer construction; shear flow in sheets and direct stresses in stringers. Shear flow in single and multi-cell closed sections. Shear deformation and the shear centre of closed sections. Torsion and beam shear of multi-cell structures.

### **4. Bending of Thin Plates**

The flat plate as a two-dimensional counterpart of a beam: review of beam equations. Assumptions in thin plate theory. Symmetric bending of thin circular plates; stress resultants and the governing equations. Boundary conditions and example solutions. Method of superposition. Rectangular plates; method of solution.

### **5. Buckling Instability**

Primary and secondary buckling. Review of Euler strut buckling theory and its limitations. Empirical formulas for design. Effects of eccentricity, initial curvature, and transverse loads. Energy methods for buckling loads. Buckling of thin plates: uniaxial and biaxial loads.

### **EVALUATION**

Midterm	30%
Final	70%

### **REFERENCES**

1. Ugural AC, Fenster SK. Advanced strength and applied elasticity. 4<sup>th</sup> Ed. New York: Elsevier Science; 1987.
2. T.H.G. Megson, an Introduction to Aircraft Structural Analysis Butterworth-Heinemann Elsevier Publishers (2010).
3. D.W.A. Rees, Mechanics of Optimal Structural Design- Minimum Weight Structures, John Wiley & Sons (2009).
4. D.J. Peery and J.J. Azar, Aircraft Structures, McGraw-Hill (1982).
5. H.D. Curtis, Fundamentals of Aircraft Structural Analysis, McGraw-Hill (1997).
6. D.H. Allen and W.E. Haisler, Introduction to Aerospace Structural Analysis, John Wiley & Sons (1985).
7. B.K. Donaldson, Analysis of Aircraft Structures, an Introduction, McGraw-Hill (1993).
8. E.F. Bruhn, Analysis and Design of Flight Vehicle Structures Jacobs Publishing (1973).
9. M.C.Y. Niu, Airframe Structural Analysis Technical Book Co. (1988).

## **REQUESTS FOR ACADEMIC ACCOMMODATION**

You may need special arrangements to meet your academic obligations during the term. For an accommodation request, the processes are as follows:

### **Pregnancy Obligation**

Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, visit the Equity Services website: [carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf](https://carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf)

### **Religious Obligation**

Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, visit the Equity Services website: [carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf](https://carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf)

### **Academic Accommodations for Students with Disabilities**

If you have a documented disability requiring academic accommodations in this course, please contact the Paul Menton Centre for Students with Disabilities (PMC) at 613-520-6608 or [pmc@carleton.ca](mailto:pmc@carleton.ca) for a formal evaluation or contact your PMC coordinator to send your instructor your Letter of Accommodation at the beginning of the term. You must also contact the PMC no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). After requesting accommodation from PMC, meet with your instructor as soon as possible to ensure accommodation arrangements are made. [carleton.ca/pmc](https://carleton.ca/pmc)

### **Survivors of Sexual Violence**

As a community, Carleton University is committed to maintaining a positive learning, working and living environment where sexual violence will not be tolerated, and its survivors are supported through academic accommodations as per Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit: [carleton.ca/sexual-violence-support](https://carleton.ca/sexual-violence-support)

### **Accommodation for Student Activities**

Carleton University recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation must be provided to students who compete or perform at the national or international level. Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. <https://carleton.ca/senate/wp-content/uploads/Accommodation-for-Student-Activities-1.pdf>

For more information on academic accommodation, please contact the departmental administrator or visit: [students.carleton.ca/course-outline](https://students.carleton.ca/course-outline)