VILLANOVA UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT

ME 8140 — Fall 2019
Thermoelasticity and Thermal Structures — Dr. B.J. Sullivan

COURSE OBJECTIVE

The primary objective of this course is to provide the fundamental concepts of the theory of thermoelasticity as applied to structural and mechanical systems. Concepts of heat transfer necessary to derive temperature distributions in structures will also be presented. The course will also deal with isotropic (e.g., metallic) and anisotropic (e.g., composite materials) thermal structures.

TENTATIVE COURSE OUTLINE

Lecture	Date	Topic	Supplementary Readings
1	26 Aug	Introduction; Thermal stress problem in high speed flight structures; Heat transfer in structures: conduction theory	Incropera & DeWitt, Chapters 4 and 5; Noda Chapter 3
	2 Sep	*Labor Day – No Class*	
2	9 Sep	Heat transfer in structures: radiation heat transfer - Part 1	Incropera & DeWitt, Chapter 12
3	16 Sep	Heat transfer in structures: radiation heat transfer - Part 2	Incropera & DeWitt, Chapter 13
4	23 Sep	Heat transfer in structures: convection heat transfer	Incropera & DeWitt, Chapters 6 and 7
5	30 Sep	Mechanical and Thermodynamics Foundations of Thermoelasticity	Noda Chapter 4, pp 137-152; Chapter 10
6	7 Oct	Formulation of the Thermoelastic Problem	Noda Ch 4, pp 138-178
	14 Oct	Semester Recess	
7	21 Oct	Thermal Stresses in One-Dimensional Structures: rods and beams	Noda, Chapters 1 and 2
		MID-TERM EXAM electronic distribution	
8	28 Oct	Plane Thermoelastic Problems	Noda, Chapter 5
		Mid-Term Exam solutions are due in class at 6:00 pm	
9	4 Nov	Thermal Stresses in Cylinders	Noda, Chapter 6
10	11 Nov	Thermal Stresses in Spherical Bodies; Thermal Stresses in Plates - Part 1	Noda, Chapter 7
11	18 Nov	Thermal Stresses in Plates - Part 2	Noda, Chapter 8
12	25 Nov	Thermally Induced Instability	Noda, Chapter 9
13	2 Dec	Thermally Induced Vibrations	To be distributed
14	9 Dec	***Student presentations of course projects***	
		FINAL EXAM electronic distribution	
15	16 Dec	**FINAL EXAM solutions are due in class at 6:00 pm**	

COURSE CONDUCT

Course Materials

Before and after each class, electronic versions of course materials will be available to the students by accessing the website http://vucoe.drbriansullivan.com/me-8140/.

Homework Assignments

Homeworks will be assigned but not collected or graded. Homework solutions will be made available to the students for self-assessment purposes. To assist the students in keeping up with the homework and supplementary readings, weekly quizzes will be conducted.

Quizzes

Each week a quiz will be posted to the course website. The weekly quiz will be a question similar to but different from the homework assignment, or based on the lecture notes or supplementary readings. The weekly quiz will be open notes, open book format. Quizzes are due by 6 p.m. on the Monday evening meeting of the following week. For example, electronic (for either Section 001 or DL1) or hand written solutions (for Section 001) for Quiz 1 are due on the evening of Lecture 2. Similarly solutions for Quiz 2 are due on the evening of Lecture 3, and so on.

Examinations

All exams are take-home, open book and open notes examinations.

The Mid-Term and Final examination will be provided to the students electronically no later than one week before the student solutions are due. All students are encouraged but not required to submit their exam solutions both electronically and in hard copy format. At a minimum, student solutions must be hard copy format only for students in Section 001 and electronic format for students in Section DL1.

Course Text

There is no single text book which treats each of the above topics in exactly the same way as they will be covered in this course, or which places the exact same emphasis on the topics as will be placed on them in this course. Consequently, class notes developed by the students from the lectures, supplemented by regularly assigned homework problems, will form the primary source of information. The text book which will be referred to (along with many other texts – see the list below) in the class, and from which most of the homework problems will be assigned, is:

N. Noda, R.B. Hetnarski and Y. Tanigawa, Thermal Stresses, 2nd Edition, ISBN 1-56032-971-8, Taylor & Francis, New York, NY, 2003.

Other books, from which lecture materials have been derived, include the following supplementary texts:

Frank P. Incropera, David P. DeWitt, Theodore L. Bergmann and Adrienne S. Lavine, Fundamentals of Heat and Mass Transfer, 6th Edition (or an earlier edition), ISBN-10 0-471-45728-0, John Wiley & Sons, 2007.

Earl A. Thornton, Thermal Structures for Aerospace Applications, ISBN 1-56347-190-6, AIAA Education Series, Reston, VA, 1996.

B.A. Boley and J.H. Weiner, Theory of Thermal Stresses, ISBN 0-486-69579-4, Dover Publications, Mineola, NY, 1960.

B.E. Gatewood, Thermal Stresses, LCCN 57-6380, McGraw-Hill Book Company, New York, NY, 1957.

S.P. Timoshenko and J.N. Goodier, Theory of Elasticity, McGraw-Hill Book Co., 3rd Edition, 1970.

S.P. Timoshenko and S. Woinowsky-Kreiger, Theory of Plates and Shells, McGraw-Hill Book Company, 2nd Edition, 1959.

J.M. Whitney, Structural Analysis of Laminated Anisotropic Plates, Technomic Publishing Co., 1987.

R.M. Jones, Mechanics of Composite Materials, Taylor & Francis Publishing Group, 2nd Edition, 1998

R. Siegel and John Howell, Thermal Radiation Heat Transfer, 4th Edition, Taylor & Francis, 2002.

Other appropriate texts from the engineering literature will be referenced as required. On occasion, selected papers from the literature of Thermoelasticity and Thermal Structures and Heat Transfer will be referenced and distributed.

Students must do a Course Project, which will involve either further study of a concept introduced in the class, or an investigation of a topic which is not reviewed in class due to lack of sufficient time. The final course grade will be determined on the following basis:

Weekly Quizzes	10%
Course Project	30%
Mid-Term Examination	30%
Final Examination	30%

The scale used to assign letter grades is:

Letter Grade	**Numerical Grade**
A	94 to 100
A-	90 to 93
B+	86 to 89
B	83 to 85
B-	80 to 82
C+	76 to 79
C	73 to 75
F	below 73

INSTRUCTOR AVAILABILITY

The best way to contact me is via email. My e-mail address is brian.sullivan@villanova.edu. I will respond as promptly as possible.

COURSE PROJECT

The course project consists of a research paper on a selected topic in Thermoelasticity and Thermal Structures, not covered within the course material. The research paper should include a limited literature search on the selected topic, citing each publication and summarizing the most important aspects of the publications. The algorithm(s) associated with the selected topic on mechanics of composite materials, which will be provided and described within the publications found in the literature search, should be clearly explained and then used to compute specific composite material properties. The code used to exercise the algorithm should be written by the student in their preferred software, e.g. Mathcad, Matlab, Excel, etc. A copy of the code, results generated by the code, and an explanation of the results, including some basis of verification, should all be included within the student's research paper. Research papers may be written on any of the following topics:

- Closed form solutions from the theory of coupled heat transfer and thermoelasticity
- Detailed stress analysis of orthotropic cylinders due to spatially varying pressure and heat flux
- Thermal stresses in orthotropic conical shells
- Thermally induced plastic deformation in isotropic beams
- Thermally induced plastic deformation in isotropic plates
- Thermally induced plastic deformation in isotropic cylinders
- Thermal buckling of orthotropic cylinders
- Dynamic response of orthotropic cylinders due to rapid heating
- Effects of material non-linearity on thermoelastic response of orthotropic bodies

Research papers on other topics not listed above, and treating material not covered within the course, may also be suggested by the students, subject to instructor approval.

The table below provides the timeline of due dates for the preparation of the research papers:

Research paper item	Description	Due Date	% of Course Project Grade	File Format	Nature of Submission
Research paper topic	Selection of topic for student's Course Project	21 Oct	5%	MS Word	Electronic (Sections 001 and DL1)
Research paper outline	Detailed outline to be used by student in writing the research paper	4 Nov	20%	MS Word	Electronic (Sections 001 and DL1)
Research paper initial draft	Draft version of student's research paper, containing preliminary results	25 Nov	20%	MS Word	Electronic (Sections 001 and DL1)
Final form of research paper	Final version of student's research paper containing final results	9 Dec	40%	MS Word	Electronic (Sections 001 and DL1)
Research paper presentation	Presentation file summarizing research topic & findings	9 Dec	15%	MS Powerpoint	Electronic (Sections 001 and DL1)

In the preparation of the research papers, the format to be used by the students is the following:

- A cover page providing the title of the report and the name of the student.
- A brief introductory section providing some background on the nature of the topic.
- A short section describing the objective of the course project.
- A section describing the technical approach used by the student, including key equations. This section should also describe where the equations were obtained and how they were used in the study.
- A section describing results obtained by the students. The use of graphs and tables, sequentially numbered and containing appropriately descriptive captions, should be freely used in this section.
- A section summarizing the principal conclusions of the research project.
- References used in the performance of the course project can be placed at the end of the report, or can be cited as footnotes and appear at the bottom of selected, specific pages.

As shown in the table above, a Microsoft PowerPoint version of the research paper must also be prepared and used by the students in the presentation of their work to the class. All student presentations, both Section 001 and Section DL1, will occur in class on December 9, 2019, the same day as the due date for the written research papers. Section

DL1 students not able to come to class due to geographical issues will be accommodated via webex and telephone conferencing. All DL1 students who wish to participate in this fashion must notify the instructor no later than November 11, 2019 of their desire to do so, so that proper arrangements can be made.