# MAE 446 - CRN: 81301 - Mechanics of Composite Materials – Fall 2014

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**Instructor:** Dr. E. J. Barbero—Rm. 511 ESB
**Schedule:** **Tu-Th. 11:00—12:15**, ESB G78
**Office hours:** Tu-Th. 2:00—3:00, ESB 511

Textbook: E. J. Barbero, Introduction to Composite Materials Design--Second Edition, Taylor & Francis (2010), ISBN 1420079158

**SOFTWARE THAT MUST BE INSTALLED IN G78:** MATLAB and Chrome or Firefox

Prerequisites: MAE 243, MATH 251.

Course Objective: For students to learn concurrent material/structural design of products made with fiber-reinforced composite materials such as fiberglass, carbon-epoxy, and so on. The course introduces ways to model the material behavior as it relates to the constituents (fiber, matrix) and the manufacturing processes used to fabricate the material. The course also covers failure prediction and design. The course is organized to have at least one-hour design content and to complement basic strength of materials and mechanical/structural design courses which are part of the curriculum of Mechanical, Aerospace, and Civil Engineering. Use of computer modeling for the analysis of practical examples is encouraged.

Outcomes: The course supports to some extent the following outcomes, with emphasis on those listed in the table below.

A. An ability to apply knowledge of mathematics, science, and engineering.
C. An ability to design a system, component, or process to meet desired needs.
D. An ability to function on multi-disciplinary teams.
E. An ability to identify, formulate and solve engineering problems.
F. An understanding of professional and ethical responsibility.
G. An ability to communicate effectively.
I. Recognition of the need for, and an ability to engage in life-long learning.
K. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

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|---|---|
| Ability to model material and structural behavior using available material data | A,F |
| Ability to apply modern computer tools for analysis | I,K |
| Ability to apply modern composite analysis methods for analysis | A,K |
| Ability to analyze simple structures made of laminated composite materials. | A |
| Ability to design simple structures made of laminated composite materials. | C,D,E,G |

**Bibliography**:


1. CADEC, en.cadec-online.com
2. Reddy, J. N., Mechanics of Laminated Composite Plates-Theory and Analysis, 2nd ed., CRC Press, Boca Raton, FL, 2003, ISBN=0849315921,

Outline (subject to change):

| Week | Date | Topic | Chapter/Section | Notes |
|---|---|---|---|---|
| 1 | 8/19 | Basic concepts, Design process, Design methods | 1 | Project assigned |
| 1 | 8/21 | Materials | 2 | Assigned reading |
| | | Processing | 3 | Assigned reading |
| 2 | 8/26 | Micromechanics, Vf, Wf, density | 4 | |
| | 8/28 | Stiffness, E1, nu12 | 4 | |
| 3 | 9/2 | E2, G12 | 4 | |
| | 9/4 | Hygrothermal | 4 | |
| 4 | 9/9 | Strength F1t | 4 | |
| | 9/11 | Strength F1c | 4 | |
| 5 | 9/16 | Strength | | |
| | 9/18 | Strength | | |
| 6 | 9/23 | Strength | | |
| | 9/25 | Strength | | |
| 7 | 9/30 | Strength F2t | 4 | |
| | 10/2 | F2c, F4, GIc, GIIc | 4 | |
| 8 | 10/7 | Midterm #1 | 5 | DATE FIXED |
| | 10/9 | Ply mechanics | 1—4 | Mid semester |
| 9 | 10/14 | WVU break | 5 | Break |
| | 10/16 | No lecture | 5 | Break |
| 10 | 10/21 | Macromechanics | 6 | |
| | 10/23 | Macromechanics | 6 | |
| 11 | 10/28 | Macromechanics | 6 | |
| | 10/30 | Macromechanics | 6 | |
| 12 | 11/4 | Strength ratio, Max stress | 7 | |
| | 11/6 | FPF, Max. strain | 7 | |
| 13 | 11/11 | Midterm #2 | | DATE FIXED |
| | 11/13 | FPF, Interacting | 7 | |
| 14 | 11/18 | LPF | 7 | |
| | 11/20 | LPF | 7 | |
| 15 | | Thanksgiving | | Break |
| | | Thanksgiving | | Break |
| 16 | | LPF | 7 | |
| | | LPF | 7 | |
| 17 | 12/9 | In-situ | 7 | LAST DAY |
| 18 | 12/17; 8:00-10:00 | FINAL | | DATE FIXED |

Grading:

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|---|---|
| Homework | 20% |
| Project (s) | 20% |
| Midterm (s) | 20% each |
| Final: comprehensive | 20% + % from absent midterm (if any) |
| A | >90/100 |
| B | >80/100 |
| C | >70/100 |
| D | >60/100 |
| F | Otherwise |
| Grade curving | None. |

**Homework**: Assigned weekly. Due in 7 days, on the instructor desk before the class starts. Homework accepted up to immediately following lecture, with 50% penalty.

**Midterm**: No make ups under any circumstances. If absent, the % will be added to the final. Max. one absence. Second one gets a zero. Absence STRONGLY discouraged.

**Teamwork:** Teams of 2 students will be formed. Teams, not individuals, will submit term papers/projects. Although help and discussions are encouraged among the class at large, various teams are forbidden to work together and/or present essentially similar work. Similarities in their work will be penalized. Innovative content and presentation quality will be rewarded.

**Computer usage:** CADEC (Computer Aided Design Environment for Composites) is a specialized application package. MATLAB is used for the project and to perform matrix computations related to class material. CADEC is available at en.cadec-online.com

**Academic Honesty**: Cheating in any way or form is unacceptable at WVU and may result in an F grade and disciplinary action, regardless of overall performance. For definition of "Academic Dishonesty" and code of conduct, refer to the WVU Student Handbook or "Mountie Publication" (http://www.arc.wvu.edu/admissions/integrity.html) and the WVU Undergraduate Catalog.

**Equal Opportunity**: WVU is committed to social justice. WVU does not discriminate on the basis of race, sex, age, disability, veteran status, religion, sexual orientation, color or national origin. Any suggestions as to how to foster an open environment in this class will be appreciated and given serious consideration.

**NO AUDIT STUDENTS ALLOWED, WITHOUT EXCEPTION.**

**Project:** "Evaluation of NASA LaRC failure criterion"
Failure criteria are used to predict failure of composites when subjected to multi-axial states of stress. The criteria are based on uniaxial strength data because only strength data for single lamina under uniaxial stress is available. The quality of a failure criterion depends on how well it predicts the few experimental data points available for multiaxial state of stress. Your job is to (a) find uniaxial and multiaxial data for one or more materials, preferably carbon/epoxy. The uniaxial data must be as complete as possible, including all the uniaxial strength values listed below. (b) to compare the multiaxial strength predicted by the LaRC failure criterion with the multiaxial experimental data.

Here is the set of uniaxial strength data required (notation explained in chapter 4 of the textbook):
F1t, F1c, F2t, F2c, F6, ply thickness,

Composites critical stresses are sigma_1 (longitudinal=fiber direction), sigma_2 (transverse direction), and tau_12 (in-plane shear). When testing laminates, these become sigma_x, sigma_y, and tau_xy.

Triaxial testing is very rare, but if you find some, please report it. Most of the testing is done in biaxial mode, where 2 stress components are applied. There are 8 regions of biaxial state of stress:
I- tension-tension
II-transverse tension-longitudinal compression
III- compression-compression
IV- transverse compression-longitudinal tension
V- longitudinal tension-shear
VI- longitudinal compression-shear
VII- transverse tension-shear
VIII- transverse compression-shear

Groups of 2 students will be formed. Each group will work and report on one of the 8 biaxial modes. A lottery will be used to assign the topics.

Minimum sections that must be included in your report:
1- Description of the experiment(s) performed in the literature
2- Lamina data
3- Laminate data
4- Comparison LaRC vs. experimental
4.1- Comparison of lamina data
4.2- Comparison of laminate data
5- Conclusions

Milestones:
A- Literature search. A list of papers containing the data needed for your group submitted by the deadline. For each item on the list, indicate what mode (I to VIII) is reported in the paper, and what tables or figures contain the data you think is relevant.
The list has to be in IEEE citation format: http://library.queensu.ca/book/export/html/5846 typed in MSWord. The file name should be the Last Name of a team member followed by -X-A,

where X is the topic number (I to VIII) and A means milestone A. Submit a ZIP file with the MSWord.doc file and PDF copies of all papers cited.

B- Draft report containing sections 1, 2, and 3.
C- Incorporate corrections on sections 1--3, and program LaRC in MATLAB, add section 4.
D- Final incorporating all corrections requested.