Course Syllabus

(NOTE: This is a preliminary draft of the course syllabus. The final version will be provided at the end of the first week of classes)

1. Course Information

AE/ME 7774		Fatigue of Materials and Structures (~ 3hrs/week)	**Fall Term 2024**
Mondays/Tuesdays	**:**	**To be COnfirmed**	
Wednesdays/ Thursdays	**:**	**To be COnfirmed**	

2. Instructor & Grader Information

Instructor & Grader:	Dr. Louis SATYANARAYAN Ph.D.
Email :	Louis.Satyanarayan@georgiatech-metz.fr
Office Room Number:	226
Office Hours (by appointment):	Tuesdays: 11:00AM – 12:00PM
	Thursdays: 11:00 AM – 12:00 PM

I am always available for short questions or concerns just after class.

If required you may also send an email to make an appointment or come directly to my office in the slots given above.

3. General Information

- *Course Outline: Fatigue of Materials and Structures*
  Methods to predict the fatigue life of structural components, characterization of the response of materials to cyclic loading, Mechanical (and microstructural) aspects of nucleation and growth of cracks under cyclic loading conditions, Fatigue resistant design of structures, notch effects, cumulative damage, multiaxial loading and fatigue crack initiation & propagation are studied.
- ***Crosslisted with AE / ME 7774.***
- BRING A CALCULATOR TO THE CLASS REGULARLY
- Classes will be a good mix of lectures, problem solving sessions, real-life examples and interesting discussions on the subject.
- The lectures will try to balance theoretical concepts and practical examples so that the students can appreciate both aspects.
- Many example problems will be presented during the lectures that show how to use effective problem-solving strategies in the analysis of fatigue

4. Pre &/or CoRequisites

Please confirm with the Academics Office (GTA)

Pre-requisites:

- ME 4214 Mechanical Behavior of Materials
- COE-3001: Mechanics of Deformable Bodies
- MATH 2401 Calculus III (C or better), and
- MATH 2403 Differential Equations (C or better)

5. Textbook:

- Julie A. Bannantine, Jess J. Comer, and James L. Handrock, Fundamentals of Metal Fatigue Analysis; First Edition, Pearson Education, 1997. Subra Suresh, Fatigue of Materials; 2nd Edition, Cambridge University Press, 1998.

6. Syllabus/Topics covered

Objective	To provide a working knowledge of state of the art methods and contemporary issues of fatigue life prediction and associated physical processes, with emphasis on metal fatigue.

Course Overview

No.	Chapter Name	Description
1	Physics of Fatigue Processes	• Crack nucleation • Crack propagation ○ metals, polymers, ceramics

2	Stress & Strain Response of Metals	• Monotonic tensile tests
		• Temperature and rate dependence
		• Cyclic response
		  ○ hardening, softening
		  ○ cyclic stress-strain curve
		  ○ with / without residual stresses.

3	Strain Life Relationships: LCF, HCF	• Stress-life and Basquin's Law • Coffin-Manson Law • Cyclic property estimates • Combined strain-life curve
	Quiz 1	
4	Influence of Mean Stress, Surface Finish, Hardness	• Role of mean stresses on small crack nucleation/growth • Models for mean stress effects • Load sequence effects on mean stress

		• Effects of surface finish and hardness on fatigue
5	Fatigue at Notches	• Theoretical stress concentration, size effects and Kf • Neuber's rule and notch root stress-strain analysis • Load sequence effects on notch root behavior
6	Variable Loading	• Cycle counting techniques and history reconstruction • Damage summation - linear and nonlinear approaches • Component calibration curves • Applications to loading spectra
	Quiz 2	

7	Scatter in Fatigue	• Probability distributions for scatter of
		  ○ fatigue strength
		  ○ fatigue life (S-N curves)
		• Size effects and weak link theory
		• Scatter in HCF versus LCF

8	LEFM Concepts and growth laws for physically long cracks	• Stress intensity factor and DK • Cyclic crack tip fields • Paris growth law • Threshold and fracture regimes • Crack closure and DKeff
9	Growth of small/short cracks	• Characteristics of microstructurally small crack growth • Mechanics considerations/ Residual strength analyses. • Kitagawa diagram and HCF thresholds • Small cracks growing from notches • Transition to long crack behavior
	Quiz 3	
10	Multiaxial fatigue	• Historical overview of multiaxial HCF and LCF crack initiation • Critical plane observations for small fatigue cracks • Gamma plane representation
	Final Exam	

7. Course Outcomes:

Outcome 1: To develop a student's understanding of the basic principles of Fatigue of materials & structures.

1.1 The student will demonstrate an ability to recognize the crack initiation & nucleation in materials by understanding the physics of fatigue.

1.2 The student will demonstrate an ability to qualify stress-strain response under cyclic loading, strain rate and temperature dependence.

1.3 The student will demonstrate an ability to qualify material response under low & high cycle loading conditions.

Outcome 2: To develop a student's skills in analyzing stress concentration, fatigue response behavior at notches and surface & hardness effects.

2.1 The student will demonstrate an ability to apply appropriate simplifying assumptions to understand stress concentration, hardness effects and loading patterns on fatigue response.

2.2 The student will demonstrate an ability to analyze variable loading patterns and Damage summation under linear and nonlinear approaches

Outcome 3: To provide the student with some specific knowledge regarding probability distribution & statistical analysis observed under high and low cyclic loads, introduce crack closure concepts

3.1 The student will be able to recognize basic probability distributions for scatter of fatigue strength and fatigue life of structural components

3.2 The student will demonstrate knowledge of important practical cases of load sequence effects and closure/plasticity models and their physical implications

Outcome 4: To provide the student an insight into complex multi-axial fatigue concepts, time and temperature dependent fatigue models

4.1 The student will demonstrate an ability to recognize multi-axial HCF and LCF crack initiation phenomenon

4.2 The student will demonstrate an ability to distinguish between intergranular versus transgranular formation/growth of cracks and understand the combined effects of coupled-field thermomechanical fatigue.

8. Correlation between Course Outcomes and Student Outcomes:

AE / ME7774 Fatigue of Materials and Structures											
	Mechanical Engineering Student Outcomes										
Course Outcomes	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**

Outcome 1.1	x				x						x
Outcome 1.2	x				x						x
Outcome 1.3	x				x						x
Outcome 2.1	x				x						x
Outcome 2.2	x				x						x
Outcome 3.1	x				x						x
Outcome 3.2	x				x						x
Outcome 4.1	x				x						x
Outcome 4.2	x				x						x

9. GWW School of Mechanical Engineering Student Outcomes:

a. an ability to apply knowledge of mathematics, science and engineering
b. an ability to design and conduct experiments, as well as to analyze and interpret data
c. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
d. an ability to function on multidisciplinary 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
h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
i. a recognition of the need for, and an ability to engage in life-long learning
j. a knowledge of contemporary issues
k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

10. GT Academic Honor Code

As usual the GT Academic Honor Code is followed for this class. Please check this link for clear information : http://www.honor.gatech.edu/plugins/content/index.php?id=9

11. Canvas

Your instructor uses CANVAS to send you messages and your results of homeworks and quizzes. You are supposed the check your ME7774 messages and announcements every day to make sure you don't miss anything. It is not guaranteed that the system will email you messages after being posted.

12. GRADING

a. WEIGHT:

- Quiz 1 : 25% (closed book, closed notes, will include Chapters 1-3, more info below)

- Quiz 2 : 25% (closed book, closed notes, will include Chapters 4-6, more info below)
- Quiz 3 : 25% (closed book, closed notes, will include Chapters 7-9, more info below)
- Final Exam: 25% (closed book, closed notes, All chapters from 1-11, more info below)

You are however allowed to bring a calculator, a unit conversion sheet and also a cheat sheet maximum 2 sides of one A4-size sheet of paper, normal size letter type

For each Quiz, you will receive a numerical grade on canvas. These numbers must be

interpreted as :

90%-100% : A
80%-89.99%: B
70%-79.99%: C
60%-69.99%: D
below 60% : F

Should canvas make any calculation for you, ignore it, because it does not count the above-mentioned

weights for each task.

b. About Homeworks, Quizzes

- All tasks will be submitted through CANVAS. The standard procedure is to upload pictures of your HW.
- A HW can be short or extensive, however each HW will have the same weight.
- A QUIZ will be turned in on paper when the exam is done.
- For homeworks you are allowed to work together and discuss with your colleagues, but you must turn in your own homework and not copy that of your colleagues or a solutions manual.

13. Course Expectations & Guidelines

a. BEHAVIOR IN CLASS :

Class participation (being present, paying attention, asking questions if needed, ...) is perfect. What is not OK is “noise”. Noise means that you disturb your teacher and also your colleague students who equally paid their tuition fees and have the right to follow my class. For urgent matters, you are excused to leave class briefly and then to return (bathroom, water fountain, something urgent, ...) – do it quietly please.

b. Academic Integrity

Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. For information on Georgia Tech's Academic Honor Code, please visit

http://www.catalog.gatech.edu/policies/honor-code/ or

http://www.catalog.gatech.edu/rules/18/.

Any student suspected of cheating or plagiarizing on a quiz, exam, or assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for violations.

c. Attendance and/or Participation

Attendance and participation in class is required. If you miss class for any reason, it is your responsibility to obtain the notes for that day from a fellow student. This includes any announcements, concerns, helpful hints, etc. given by the instructor to the class.

d. Collaboration & Group Work

- Discussions between students on homework problems outside of class and during in-class problem solving sessions is encouraged.
- However, quizzes and exams must be written and submitted by each student independently.
- Copying and/or cutting and pasting someone else's work and submitting it as your own is not permitted.

e. Extensions, Late Assignments, & Re-Scheduled/Missed Exams

- No credit will be given for the late submission of any course work.
- It is your responsibility to ensure that your work is submitted to Canvas by the appropriate time.
- Any work missed because of Institute-approved activities (e.g., field trips and athletic events) can be made up.

14. Acknowledgements (for making the core of this syllabus):

Sections 3-8 prepared by: David McDowell (ME), Richard Neu (ME), William Johnson (MSE), George Kardomateas (AE) with changes incorporated by Louis Satyanarayan

Sections 2-3 and 13 prepared by: Marc K. Smith with changes incorporated by Louis Satyanarayan

Sections 9-13 prepared by: N. Declercq with changes incorporated by Louis Satyanarayan