# 14:635:314 STRENGTH OF MATERIALS

## Course Outline, Spring 2006

### Miscellaneous Information

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| Class Hours: | Monday, Wednesday 5:00 -6:20pm, SEC-217 |
| Instructor: | M. J. Matthewson |
| Office: | Engineering A133 |
| Telephone: | 732-445-5933 |
| E-mail: | *mjohnm@fracture.rutgers.edu* |
| Web: | *www.rci.rutgers.edu/~mjohnm/classes* |
| Office Hours: | I operate an open door policy - if I am in I will be glad to talk to you. However, I also have formal office hours so that you know when you can find me in:<br>Tuesday, Thursday 4:40 - 5:10pm, Monday, Wednesday 4:15 - 4:45pm, or by appointment. |

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### Textbooks

The textbook for this course is *Mechanical Properties of Ceramics,* Wachtman (Wiley). This book is currently being rewritten for a second edition by Professors Cannon and Matthewson. Some updated chapters will be made available to the students. Other books which provide background information include sections of *Engineering Materials Handbook, Vol. 4, Ceramics and Glasses* (ASM International), *An Introduction to the Mechanical Properties of Ceramics,* Green (CUP), *Fracture of Brittle Solids - Second Edition,* Lawn (CUP), and *Mechanical Behavior of Ceramics,* Davidge (CUP, out of print).

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### Grading

The grade for this course is made up of 5 problem sets (20%), 2 quizzes (40%) and a final exam (40%). Problem sets should be individual efforts but students are encouraged to help each other with hints. The quizzes and final exam are all closed book. Calculators will be provided - if students want to use their own calculator, they must demonstrate clearing the calculator's memory at the start of the exam - please come early if you chose the latter.  Students should bring graph paper and a ruler to all exams.

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## Schedule

Click here to see the schedule.

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## Course Outline

Section numbers correspond to chapter numbers in Wachtman's book.

**1. Stress and Strain**
Stress tensor, rotated coordinate system, principal stress, Mohr's circle, 3D case, stress invariants. Strain, vector displacement field.

**2. Types of Mechanical Behavior**
Overview of different types of behavior. Elasticity and brittle fracture.

**3. Elasticity**
Isotropic bodies, elastic moduli. Tensor notation, reduced notation, stiffness and compliance matrices, orientation dependence.

**4. Strength of Defect-Free Solids**
Theoretical strength in tension and shear.

**5. Linear Elastic Fracture Mechanics**
Stress concentrators, Griffith theory, modes of fracture.  Irwin - stress intensity approach, stress intensity factors for various crack and loading geometries. Irwin - energy release rate approach, relationship of $G$ and $K$, multiaxial stress.

**6. Measurement of Elasticity, Strength and Toughness**
Crack stability, tension, flexure tests, bending of thin beams. Measurement of $K_I$. Indentation tests. Elastic constants.

**7. Statistical Treatment of Strength**
Statistical distributions, Weibull's weakest link theory, calculation of parameters, maximum likelihood techniques, effect of specimen size, effect of test technique, calculation of safety factors.

**8. Subcritical Crack Propagation**
Mechanism, $V$-$K$ behavior, kinetics models, dynamic and static fatigue equations, reliability predictions, strength-probability-time diagrams, proof testing.

**9. R-Curve Behavior**
Stable growth, measurement, indentation.

**10-13. Toughening Mechanisms**
Strength vs toughness, crack deflection, crack bridging, microstructural effects, grain size, second phase particles. Transformation toughening, transformation zone. Fiber composites, elastic behavior, crack deflection.

**14. Cyclic Fatigue**
Mechanisms, cycles to failure.

**15. Thermal Shock**
Thermal stress, residual strength.

**16. Fractography**
Fracture patterns, state of stress, nature of origin, failure stress.

**17-18. Dislocations and Plasticity**
Definition of edge and screw dislocations, force on dislocation, glide, climb, self energy, line tension. Dislocation multiplication, Read and Frank-Read sources, forces between dislocations, velocity, work hardening.

**19-20. Creep & Creep Rupture**
Nabarro-Herring creep, Coble creep, mechanism maps. Categories of microstructures, Monkman-Grant equation, failure mechanism maps.

**Friction, Wear & Lubrication**
Amonton's laws of friction, theoretical justification. Wear, types of wear. Lubrication. (This topic is not covered in Wachtman's book. It will only be covered in class if time permits.)

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## ABET A-O REQUIREMENTS

**A. Apply knowledge of mathematics, science and engineering**
Students use their mathematic and scientific knowledge to understand the mechanical properties of materials in terms of the principals of fracture mechanics.  Mathematical models are developed to describe and explain the mechanical properties of materials including their elasticity, strength, toughness and reliability.
**B. Design and conduct experiments, as well as to analyze and interpret data**
Students learn the experimental techniques that are used to measure mechanical properties like elastic modulus, strength, toughness.  Equations are derived which show how the experimental results may be used to extract the values of key physical parameters.  Students learn at analyze strength data to characterize the stochastic nature of the strength of brittle materials and then use the results to assess reliability.

**C. Design a system, component, or process to meet desired needs**
The principles of fracture mechanics are used to specify design requirements for simple processes. Students learn how to calculate a minimum required strength for survival of a component for long periods under stress.
**L. Use experimental, statistical, and computational methods to analyze the behavior of ceramic systems**
Students learn experimental methods for measuring the mechanical properties of materials. They are then able to analyze data by hand and using the computer to determine strength, toughness, etc. Students learn to use a Weibull graph to understand the statistics of strength and use that understanding to predict failure probabilities under given service conditions. Throughout students are taught to assess data critically and to identify and suggest explanations for any deviations from theory.
**M. Apply advanced science and engineering principles to materials systems**
Students learn how defects and microstructure control the mechanical behavior of materials. They learn what materials properties control the strength and hence how the microstructure or the choice of material can be modified to improve mechanical reliability.
**N. Understanding of the fundamental principles underlying and connecting structure, properties, processing and performance related to the material systems utilized in ceramic engineering**
Fundamental models for fracture are used to develop a mathematical description of mechanical behavior. Students learn that the macroscopic behavior can be related to crack tip processes and the interaction of the crack with external stresses and the microstructure of the material.
**O. Apply and integrate knowledge from each of the above four elements of the field to solve material selection and design problems**
Students learn how to design a component for successful application without failure. They learn how to take into account the statistical variability of strength, fatigue, creep.

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## Student Feedback

I take the comments made by students on the teaching assessment forms very seriously so that I can improve the quality of this course. Below I address issues raised by students the last time I taught this class:

**Do not exceed the scheduled class time:**
I will avoid running over the scheduled 80 minutes for the class. However, it is important that we start on time so I request all students arrive promptly. Note that the first few minutes of class are very important since that is when I discuss up-coming assignments, homework hints, scheduling issues, *etc.*

**Write more neatly:**
I'll do my best!

Please give me feedback on how I am doing with these improvements. Please do not wait until the end of the semester for the teaching assessment forms if you think I can usefully make changes immediately. Any and all constructive criticism will be gratefully received!

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Dr. M. J. Matthewson, 060104.