

# **SOLID MECHANICS IN THE ME-EM DEPARTMENT**

***Michigan Tech***

Department of Mechanical Engineering- Engineering Mechanics  
Houghton, MI 49931, U.S.A.

# Solid Mechanics

- a.** Analysis of the stresses and deformations within a body subject to a prescribed system of forces.
- b.** Determination by theoretical (analytical/ numerical) analysis or by experiment of the limiting values of load which a structural element can sustain without suffering damage, failure, or compromise of function.
- c.** Determination of the body shape and selection of those materials which are most efficient for resisting a prescribed system of forces under specified conditions of operation such as temperature, humidity, vibration, and ambient pressure (*design function*).

# Why Take Solid Mechanics Courses?

- To equip yourself with methods of analysis, experimental techniques and computational tools for
  - DESIGN
  - MANUFACTURING
  - BIOMECHANICS
  - HEALTH MONITORING OF STRUCTURES
  - FAILURE PREDICTION OF STRUCTURES
  - DESIGN OF MATERIAL SYSTEMS

# Solid Mechanics Courses

- MEEM 4150 Intermediate Mechanics of Materials
- MEEM 4160 Fundamentals of Experimental Stress Analysis
- MEEM 4170 Failure of Materials in Mechanics
- MEEM 4180 Engineering Biomechanics
- MEEM 5110 Fundamentals of Mechanics/Elasticity
- MEEM 5130 Nanoscale Science and Technology
- MEEM 5150 Advanced Mechanics of Materials
- MEEM 5160 Experimental Stress Analysis
- MEEM 5170 Finite Element & Variational Methods in Engineering
- MEEM 5180 Mechanics of Composite Materials

# MEEM 4150

## Intermediate Mechanics of Materials

- **Course content and applications:**
  - **3-D Stress/Strain transformation & Failure theories**

Today numerical methods such as Finite Element Method provide stress and strain results in three dimension making the understanding of concepts of 3-D transformation more critical than in the past.
  - **Composite rods, shafts and beams**

Reinforced concrete, laminated beams (wood reinforced with metal strips), laminated shafts (titanium coated aluminum shafts), myriad applications of polymer and metal matrix composites have all increased the need to understand 1-D composite structural members.
  - **Non-linear material behavior in rods, shafts and beams**

Biological tissues, plastics, rubber, metals in plastic regions all have non-linear stress-strain relationship that has to be accounted for in developing the theories of 1-D structural elements.
  - **Unsymmetric bending**

The restriction of the cross-section having a plane of symmetry and loading lie in that plane is too restrictive for many applications. A wing of a plane, a tall building, cross-section of human bones are some examples where beam analysis require theory of unsymmetric bending.
  - **Energy methods**

Greatly simplifies calculation of reaction forces in indeterminate structures and the calculation of displacement at a point. Energy methods also form the underpinning of many approximate methods such as Finite Element Method.
  - **Other topics**
    - (i) Discontinuity Functions: reduce tremendous amount of algebra for statically indeterminate structures and when load varies over structural elements.
    - (ii) Stress intensity factor and stress concentration factor are important concepts in design.
- **Pre-requisite:** MEEM 2150

# MEEM 4160 / 5160

## Experimental Stress Analysis

- **Learning Objectives:**

Transmits basic understanding of purposes and uses of experimental stress analysis and makes students familiar with methods used in the field to give experience in either design or analysis of strain- gaged transducer.

- **Major topics:**

Review of Stress and Strain

Electrical Resistance Strain Gage

Strain Gage Circuits and Recording Instruments

Transducer Applications/ Strain Analysis Methods

Elastic Wave Propagation/ Dynamic Stress-Strain Response

Optical Methods of Stress Analysis

- **Prerequisites:** MEEM 2150 and MEEM 3000

# MEEM 4170

## Failure of Materials in Mechanics

- **Learning Objectives:**

Recognition of the potential for failure and identification of the modes of mechanical failure are essential to prediction and prevention of mechanical failure. This course will identify the modes of failure and discuss the more important failure modes in detail. The topic of fatigue failure will be treated extensively with attention to both high-cycle and low-cycle range of fatigue failure.

- **Major Topics:**

- Modes of Failure
- Strength and Deformation of Engineering Materials (Elastic and Plastic)
- Elastic and Plastic Stress-Strain Relationships
- Combined Stress Theories of Failure Their Use in Design
- High-Cycle and Low-Cycle Fatigue
- Cumulative Damage, Life Prediction and Fracture Control
- Fatigue Testing Procedures and Statistical Interpretation of Data
- Creep, Stress Rupture and Fatigue
- Shock and Impact

- **Pre-requisite:** Product Realization I

# MEEM 4180

## Engineering Biomechanics

- **Course Description**

The course provides an overview of musculoskeletal anatomy, the mechanical properties and structural behavior of biological tissues, and biodynamics. Specific course topics will include structure and function relationships in cells, tissues and organs; application of stress and strain analysis to biological cells and tissues; analysis of forces in human function and movement; introduction to viscoelasticity of cells and tissues, and sport biomechanics: concepts of mechanics as they apply to human movement, particularly those pertaining to exercise, sport, and physical activity. The student should gain an understanding of the mechanical and anatomical principles that govern human motion and develop the ability to link the structure of the human body with its function from a mechanical perspective.

- **Course Rationale**

Basic Biomechanics is a junior/senior elective in Mechanical Engineering. The course is meant to provide basic background in biomechanics for engineering students considering medical school, industrial positions in the biomedical and biotechnology fields, and for those planning to attend graduate school in biomedical engineering. For those interested in industrial positions, this course provides a foundation for careers as design engineers in medical device companies and exercise equipment companies, as laboratory/testing technician in research facilities, and as a clinical engineer in the hospital environment. While these positions are available with a Bachelor's degree, most companies (or positions) will require continued training to improve skills in specific areas. This course is appropriate for people on any of these career paths.

# MEEM 4405

## Introduction to the Finite Element Method

- Introduces the use of the finite element method in stress analysis and heat transfer. Emphasizes the modeling assumptions associated with different elements and uses the computer to solve many different types of stress analysis problems, including thermal stress analysis and introductory nonlinear analysis. 2D, 3D, multi-body contact, quasi static and dynamic problems are introduced. The strengths and weaknesses of the finite element method are explored. Class room theory is combined with learning and applying finite element software during lab times. A final project allows the students to get experience defining, setting up, implementing and analyzing a finite element model of a topic of their interest. This includes validating and verifying the model with analytical and experimental estimates from references. A final project report concludes the finite element analysis technical documentation.
- **Credits:** 3.0
- **Lec-Rec-Lab:** (0-2-2)
- **Semesters Offered:** Fall, Spring, Summer
- **Pre-Requisite(s):** MEEM 3502 and (MA 2320 or MA 2321 or MA 2330) and (MA 3520 or MA 3521 or MA 3530 or MA 3560)

# MEEM 5110

## Fundamentals of Mechanics/Elasticity

In this course we will learn the laws of mechanics and thermodynamics that come from common physical principals, and we will learn how to express these laws in a common mathematical framework. We will also learn about constitutive modeling of solids and fluids.

- **Course content:**

- **Tensor analysis:** An advanced mathematical language is needed to describe the laws of mechanics and thermodynamics within a single consistent framework. We will develop a thorough understanding of vectors and tensors and will learn how to prove simple mathematical statements
- **Kinematics:** The same laws of motion and deformation apply to solids, fluids, and multi-body systems. We will learn how to easily describe the motion of a continuum medium mathematically
- **Thermodynamic principles:** The behaviors of solids and fluids are dictated by the conservation of mass, linear momentum, angular momentum, and energy. We will learn how to use these laws to describe the mechanical behavior of a continuous medium and develop constitutive equations
- **Stress:** Although you are familiar with the concept of stress from Mechanics of Materials, the full meaning of stress will be gained through the advanced mathematical language of tensor analysis
- **Elasticity:** We will determine the basic laws of elasticity and learn how to solve simple structural mechanics problems.

# **MEEEM 5130**

## **Nanoscale Science and Technology**

- This course will give an advanced survey to different aspects of active research in nanotechnology, covering the broad area of science and mechanics in nanoscale materials. Fundamental properties of nanomaterials such as, mechanical, electronic, magnetic, optical and bio-chemical properties will be covered. The course will focus on major classes of nanomaterials, including carbon nanotubes, nanostructured materials, nanowires, nanoparticles, nanocomposites, and other nanomaterials. A review on synthesis methods, imaging and spectroscopy techniques, and instruments for property measurements will be given. Applications in renewable energy including photovoltaic cells, hydrogen storage, fuel cells, and nanoelectronic devices will be discussed. The “nanotechnology insight and terminology” gained in this course will enable the students to follow and analyze emerging technologies, breakthroughs, and research problems in nanotechnology."

# MEEM 5150

## Advanced Mechanics of Materials

- **3-D Stress/Strain transformation & Failure theories**

Today numerical methods such as Finite Element Method provide stress and strain results in three dimension making the understanding of concepts of 3-D transformation more critical than in the past.

- **Beams on Elastic Foundations**

Railroad tracks rest on elastic support made of cross ties and earth, long steel pipes rest on earth or a series of periodic supports, load bearing walls in buildings have beams supported periodically by studs that rest on foundation beams, are some of the examples of beams on elastic foundations.

- **Elasticity and MoM**

For number of applications the stress and deformation formulas cannot be obtained from the usual mechanics of material approach and require the use of elasticity equations. Formulas for thick cylinders, thin discs and non-circular shafts are obtained from elasticity equations. Applications of these formulas range from disc brakes to gun barrels to twisting of a wings of an airplane.

- **Thin Plate Theory**

Plates are an important structural element. Floors, ceiling, truck beds, ship deck, are among the countless applications of plates.

- **Non-linear stress and strain (if time permits)**

Cauchy's stress and strain is good for linear theories. The non-linear stress and strain definitions play important roles when materials are subjected to large deformations. In the course we introduce the basic ideas behind the non-linear stress and strain definitions.

# MEEM 5170

## Finite Element and Variational Methods in Engineering

### Learning Objectives:

- To learn weighted-residual methods for finding approximate solution to differential equations.
- To understand the application of finite element method (FEM) for solving linear problems in engineering.
- To learn variational principles in formulating boundary value problems and the application of these principles to approximate methods.

### Major Topics

- Approximation of a function by trial functions
- Weighted residual approximation to the solution of differential equations
- Weak form of a weighted residual statement and natural boundary conditions
- Piecewise defined trial functions
- Approximate solution to 1-D differential equations using FEM
- Continuity requirements for trial functions
- Mapping to natural coordinate system
- Approximate solution to 2-D differential equations using FEM
- Numerical integration
- Combined finite-element (in space), finite difference (in time) approximate solution to 1-D time-dependent problems
- Variational method for symmetric operators
- Rayleigh-Ritz method

# **MEEM 5180**

## **Mechanics of Composite Materials**

### **Course Objectives:**

- To develop a strong understanding of the role of constituents in overall response of composite lamina (micromechanics)
- To develop a strong understanding of the response of a laminate composed of laminae with different orientations (macromechanics) to mechanical and hygrothermal loads.
- To be able to analyze and design fiber-reinforced composites for engineering applications

### **Topics Covered:**

- Elastic behavior of unidirectional lamina
- Strength of unidirectional lamina
- Elastic behavior of multidirectional laminate
- Strength of multidirectional laminate
- Hygrothermal effects
- Stress and failure analysis of multidirectional laminates.

## Solid Mechanics - Faculty Expertise

Students seeking detailed advice on technical electives, graduate school or career opportunities in specific disciplines are encouraged to talk to appropriate faculty listed below.

Faculty	Technical Electives Taught	Expertise
G. Jayaraman Rm. 805, 487-2519 gjayar@mtu.edu	MEEM 4150, MEEM 4170, MEEM 4180, MEEM 5110, MEEM 5130, MEEM 5150	Biomechanics, solid mechanics
I. Miskioglu Rm. 1009, 487-2752 imiski@mtu.edu	MEEM 4150, MEEM 4160/5160, MEEM 4170, MEEM 5150, MEEM 5180	Experimental mechanics, photomechanics, composite materials, nanomechanics
G.M. Odegard Rm. 930, 487-2329 gmodegar@mtu.edu	MEEM 4150, MEEM 4160, MEEM 4170, MEEM 4405, MEEM 5110, MEEM 5150, MEEM 5160, MEEM 5170, MEEM 5180	Computational and experimental mechanics, materials science, nanomechanics
W.W. Predebon Rm. 808, 487-2551 wwpredeb@mtu.edu	MEEM 5110, MEEM 5701	Ceramics, stress wave propagation with microstructural effects, impact phenomena
R. Shahbazian Yassar Rm. 923, 487-3581 reza@mtu.edu	MEEM4170, MEEM 5130, MEEM 5150, MEEM5180	Nanotechnology for Energy Harvesting and Conversion, Mechanics of Nanomaterials
Shokuhfar, Tolou Rm. 503, 487-3104 tshokuhf@mtu.edu	MEEM 4180	Nanotechnology for Medicine, Biomechanics, Bio-inspired Design
M. Vable Rm. 907, 487-2747 mavable@mtu.edu	MEEM 4150, MEEM 4405, MEEM 5150, MEEM 5170	Computational mechanics, finite elements
P. van Susante Rm. 828, 487-3253 pjvansus@mtu.edu	MEEM 4403, MEEM 4405	Finite element analysis, structures, design, mechanics of materials
C. R. Vilmann Rm. 925, 487-2377 crvil@mtu.edu	MEEM 4150, MEEM 4170, MEEM 5170	Fracture mechanics, finite elements, project engineering



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