MS Program

in

Materials Science and Engineering

1.1 The Program Objectives

The objectives of the Program are to prepare graduates:

1. to cater the higher demands in terms of comprehensive knowledge in the field of Materials Science and Engineering in the Kingdom and the gulf region.
2. with in-depth proficiency in Material science and engineering fields relevant to local and regional industry in an interdisciplinary approach.
3. with competitive skills in research techniques, interdisciplinary teamwork, and critical analysis of materials science and engineering problems.

1.2 The Unique Opportunities the Program Offers

- The MS Program in Materials Science and Engineering is a new specialization in the Kingdom. No similar program is available at any of the Kingdom's respectable schools. This will offer a unique opportunity for the students to receive a higher education degree in a much needed area of specialization.
- The Program will also offer the local and regional industries an excellent opportunity to conduct specialized research locally instead of outsourcing the same to institutions overseas.

The Programs offers an opportunity for KFUPM to utilize its faculty's versatile experience in an interdisciplinary fashion.

2 DEGREE REQUIREMENTS

Conferment of Master of Science in Materials Science and Engineering degree requires successful completion of 24 credit hours of graduate level courses and a successful defense of a written research thesis. The research described in the thesis will be directed by a faculty advisor. The 24 credit hours represent 8 courses with 3 credit hours each. These must include:

1. Three core courses,
2. Five courses from the elective courses list from any of the program major fields.

2.1 MS in Materials Science and Engineering Degree Plan

FIRST SEMESTER

Course	Title	Lect.-Credits
MSE 501	Materials Structures and Defects	3-0-3
MSE-502	Thermodynamics of Materials	3-0-3
XX-XXX	Elective I	3-0-3
		9-0-9

SECOND SEMESTER

Course	Title	Lect.-Credits
MSE 503	Materials Characterization	3-0-3
XX XXX	Elective II	3-0-3
XX XXX	Elective III	3-0-3
MSE 599	Seminar	1-0-0
		10-0-9

THIRD SEMESTER

Course	Title	Lect.-Credits
XX XXX	Elective IV	3-0-3
XX 5XX	Free Elective	3-0-3
		6-0-6

FOURTH SEMESTER

Course	Title	Lect.-Credits
MSE-610	MS Thesis	0-0-6

Total Credits **30**

The Elective (XX XXX) courses can be chosen from any of the program major fields. Only one 400 level course from the program major fields can be taken from the approved courses in the Materials Science and Engineering Program. The Free Elective course (XX 5XX) can be taken outside the approved courses in the Materials Science and Engineering Program.

3 PROGRAM COURSES

3.1 Core Courses

MSE 501	Materials Structure and Defects
MSE 502	Thermodynamics of Materials
MSE 503	Materials Characterization

3.2 Elective Courses in Corrosion

CE 504	Corrosion in Reinforced Concrete
MSE 511	Corrosion in Oil and and Petrochemical Industries
MSE 512	Fundamentals of Cathodic Protection Design
ME 575	Advanced Corrosion Engineering

3.3 Elective Courses in Failure Analysis

MSE 521	Deformation and Fracture Mechanics of Structural Materials
MSE 522	Failure Analysis in Materials Science
ME 578	Mechanical Behavior of Engineering Polymers
ME 583	Fatigue and Fracture of Engineering Materials
CE 630	Damage Mechanics
ME 675	Phase Transformation in Metals

3.4 Elective Courses in Advanced Materials and Processing

ME 479	Modern Materials
MSE 531	Engineering Nanomaterials
MSE 532	Engineering Ceramics
MSE 533	Coatings and Surface Engineering
MSE 534	Engineering Composite Materials
MSE 535	Biomaterials
MSE 536	Nanotechnology: Synthesis, Structure and Properties
CHE 541	Polymeric Materials and Processing

3.5 General Elective Courses

MSE 541	Electronic, Optical and Magnetic Properties of materials
MSE 542	Advanced Metal Casting
MSE 543	Welding Processes & Metallurgy
MSE 544	Fundamentals of Heat Treatment
MSE 545	Non-Ferrous Extractive Metallurgy
MSE 546	Materials Selection and Design
MSE 547	Finite Element Analysis In Material Science & Engineering
ME 579	Advanced Mechanical Behavior of Materials
ME 585	Advanced Physical Metallurgy
MSE 590	Special Topics in Materials Science and Engineering I

MSE 591	Special Topics in Materials Science and Engineering II
MSE 606	Independent Research

3.6 Courses Descriptions

Following are the description of the courses to be offered for the students in the MS in Materials Science and Engineering Degree program. Complete syllabi are provided in the Appendix A.

ME 479 Modern Materials 3-0-3
Electrical, magnetic, optical, and thermal properties of materials. Advanced ceramics, composites. Advanced engineering plastics. High-temperature materials. Advanced coatings. Advanced materials processing system such as rapid solidification and powder metallurgy. Selection of modern materials.
Prerequisite Graduate standing

CE 504 Corrosion in Reinforced Concrete 3-0-3
Corrosion mechanisms including corrosion cells, electrochemical reactions, polarization and passivity; forms of corrosion, corrosion mechanisms of reinforcing steel in concrete structures; environmental effects; effect of concrete properties; corrosion testing; corrosion protection including cathodic protection, corrosion inhibitors, chloride extraction, re-alkalization, and protective coatings.
Prerequisite Graduate standing

CHE 541 Polymeric Materials and Processing 3-0-3
Classification of polymers; chemical, physical and mechanical properties; molecular structural-property relationships; processing methods; design and selection criteria; environmental effects.
Prerequisite Graduate standing

ME 575 Advanced Corrosion Engineering 3-0-3
Corrosion thermodynamics and kinetics. Effect of environmental factors on major forms of corrosion. Environmental conditioning. Mass transfer and corrosion. Anodic and cathodic protection of metals. Organic and nonmetallic coating. Design for corrosion prevention. Testing, monitoring and inspection. Materials selection for corrosion resistance.
Prerequisite Graduate standing

ME 578 Mechanical Behavior of Engineering Polymers 3-0-3
General introduction to polymers and their applications. Types of mechanical behavior. Hookean and rubber elasticity. Plastic deformation. Fracture. Linear viscoelasticity. Dynamic mechanical behavior and testing. Experimental methods. Mechanical properties of polymeric composites
Prerequisite Graduate standing

ME 579 Advanced Mechanical Behavior of Materials 3-0-3
Description of stress, strain, strain rate and elastic properties of materials. Fundamental aspects of crystal plasticity. Theory and characteristics of dislocations. Strengthening mechanisms at low temperature. Deformation at elevated temperatures and deformation

maps. Emphasizing the relationships between microscopic mechanisms and macroscopic behavior of materials.
Prerequisite Graduate standing

ME 583 Fatigue and Fracture of Engineering Materials 3-0-3
Stress/Strain controlled Fatigue-Life prediction laws. Continuum fracture mechanics. Fracture modes. Fracture mechanics and microscopic plastic deformation/fracture mechanics combined approach. Cleavage, ductile fracture, fatigue, creep-fatigue and environmental cracking phenomena.
Prerequisite Graduate standing

ME 585 Advanced Physical Metallurgy 3-0-3
Review of structure of metals, analytical methods, dislocation and plastic deformations, diffusion, solidification of metals, nucleation and growth kinetics, phase diagrams, thermally activated plastic deformations, fracture and fracture mechanics.
Prerequisite Graduate standing

CE 630 Damage Mechanics 3-0-3
Phenomenological aspects of damage; manifestation of damage and measurement and mechanical representation of damage; thermodynamics and micromechanics of damage; potential dissipation function and strain-damage coupled constitutive equations; damage evolution equations; brittle versus ductile damage; anisotropic damage of concrete; fatigue damage; local and average damage; scale effect and characteristic length; elasto-plastic damage of concrete structures; finite element modeling of damage.
Prerequisite Graduate standing

ME 675 Phase Transformation in Metals 3-0-3
Examines the thermodynamics and fundamentals of rate processes in metals. Phenomenological and atomistic points of view are considered. Kinetics of liquid-solid, solid-solid transformations and transport of matter in solids are discussed.
Prerequisite Graduate standing

MSE 501 Materials Structure and Defects 3-0-3
Provides fundamental understanding of the structure and properties of perfect and defective materials. Topics include: Crystallography and crystal structures, Point defects in crystals, Dislocation theory, Grain boundaries.
Prerequisite Graduate standing

MSE 502 Thermodynamics of Materials 3-0-3
This course is a thorough introduction to the basic principles and practical application of thermodynamics and kinetics appropriate for first year graduate students in materials science and engineering program. The topics covered include: classical and irreversible thermodynamics, phase equilibria, theory of solutions, surface phenomena, thermodynamics and kinetics of chemical reactions, electrochemistry, gas-solid reactions, and brief introduction to diffusion.
Prerequisite Graduate standing

MSE 503 Materials Characterization 3-0-3

Characterization techniques for crystal structure and composition, Characterization methods for phase changes. Nanoindentation. Error analysis and statistical measurements, Crystal structure and grain size, Phase analysis and composition, Microstructure and crystal orientation. The course will include several visits to the materials lab and an experimental term project.

Prerequisite Graduate standing

MSE 511 Corrosion in Oil and Petrochemical Industries 3-0-3

Principles of corrosion; forms of corrosion in oil and gas industries; corrosion in petroleum production and operations; corrosion in petrochemical industry. Corrosion detection and monitoring techniques. Corrosion inhibition fundamentals, quality control, selection and application of oil field water chemistry. Emulsion theory and selection. Control by coating offshore and onshore installations. Economics of corrosion control in oil and gas industry.

Prerequisite Graduate standing

MSE 512 Fundamentals of Cathodic Protection Design 3-0-3

A basic understanding of principles of corrosion, failures by corrosion, principles and methods of corrosion protection. Basic theory and cathodic protection basics. Types of cathodic protection systems. Cathodic protection criteria. Cathodic protection survey and monitoring. Cathodic protection design. Stray current electrolysis.

Prerequisite Graduate standing

MSE 521 Deformation and Fracture Mechanics of Structural Materials 3-0-3

Material microstructure and properties; dislocations and their role in controlling mechanical properties; integration of materials microstructure and solid mechanics principles; mechanical behavior of metallic alloys, engineering polymers and composites. Fracture based on continuum fracture mechanics and microstructural damage mechanisms and relationships between material toughness, design stress, and flaw size. Additional topics include fatigue loading, elevated temperature behavior, material embrittlement, time-dependency, experimental design, and damage-tolerant life prediction.

Prerequisite Graduate standing

MSE 522 Failure Analysis

A review of deformation, ductile and brittle fracture, fracture toughness, failure modes, stress corrosion, hydrogen damage, wear, stress concentration, fracture mechanics, fatigue, techniques and procedures for failure analysis, case studies..

Prerequisite Graduate standing

MSE 531 Engineering Nanomaterials 3-0-3

Synthesis of nano-powders and nanostructured precursors (metals, ceramics, intermetallics, CNT), Manufacturing of bulk nanostructured materials and nanocoatings, Reactivity and handling of nanoparticles, Characterization of nanomaterials, Physical and mechanical properties of nanomaterials.

Prerequisite Graduate standing

MSE 532 Engineering Ceramics 3-0-3

Topics covered include: Bonding in Ceramics, Structure of Ceramics, Processing Technologies, Properties of Ceramics, and Applications of Ceramics.

Prerequisite MSE 501

MSE 533 Coatings and Surface Engineering 3-0-3

Surface science. Surface characterization. Surface modification. Coatings and thin films. Tribology. Surface engineering and control of surface properties.

Prerequisite MSE 502

MSE 534 Engineering Composite Materials

Properties, manufacture, forms of composites; micromechanics; orthotropic lamina properties; laminate analysis; theories; failure analysis; thermal, environmental effects.

Prerequisite Graduate standing

MSE 535 Biomaterials

This course introduces engineering students to materials as they interact with biological systems, primarily in medicine. Topics will include an overview of the theory, practice of biomaterial science and introduce them to new materials used for Medical Applications. The course will include biology and biochemistry background, properties of materials used in medical applications, classes of materials used in medicine, host reactions involved in biomaterials. It will cover also biological testing of biomaterials, degradation of materials in the biological environment, applications of materials in medicine and artificial organs, tissue engineering. Practical aspects of biomaterials including new products and standards will also be covered.

Prerequisite Graduate standing

MSE 536 Nanotechnology: Synthesis, Structure and Properties 3-0-3

Nanotechnology are being globally in the limelight as a new dream material in the 21st century and broadening their applications to almost all the scientific areas, such as aerospace science, bioengineering, environmental energy, materials industry, medical and medicine science, electronic computer, security and safety, and science education. Now they are known to be superior to any other existing material in mechanical, electrical, and hydrogen storage characteristics.

Prerequisite Graduate standing

MSE 541 Electronic, Optical and Magnetic Properties of materials 3-0-3

Quantitative description of electronic, optical, and magnetic structure-property relationships of materials. Strategies for the development of new materials and introduction to applications of these materials.

Prerequisite Graduate standing

MSE 542 Advanced Metal Casting 3-0-3

Melt treatment, solidification aspects; nucleation and growth, working mechanism of chemical refiners, solid solutions and eutectic solidification, thermal analysis of solidification, micro and macro segregation, unconventional refinement mechanism, conventional and advanced casting processes, mold design, heat-treatment of casting, types of defects, quality control.

Prerequisite Graduate standing

MSE 543 Welding Processing and Metallurgy 3-0-3

This course introduces the basic concepts used in welding and joining. It examines the significance of joining, the process options, and process fundamentals, welding metallurgy and weld ability of materials, design, economics, and inspection and quality control of joining. Specific topics covered in the course will be the physical principles of fusion welding; heat flow; thermal cycles; HAZ and physical metallurgy and mechanical properties of welded joints; applications of welding to large structures; testing of welds; nondestructive testing; design, economics and weld specifications. Welding Metallurgy: weldability of mild steel, stainless steel , aluminum alloys, and cast iron. Weld Defects: weld cracking, weld defects, welding codes, contractions and residual stresses. Nondestructive testing; radiographic and ultrasonic testing methods, quality control and assurance

Prerequisite Graduate standing

MSE 544 Fundamentals of Heat Treatment

Steel Phases, phase transformation diagrams, microstructure-mechanical properties relations, steel heat treatment processes, tool steel heat treatments, processes equipment, nonferrous alloys treatments

Prerequisite Graduate standing

MSE 545 Non-Ferrous Extractive Metallurgy 3-0-3

Physical and chemical principles involved in the extraction of non-ferrous metals. Principles of hydro-metallurgical processes; extraction of aluminum, copper, nickel, silver and gold. Refining processes of non-ferrous metals.

Prerequisite MSE 502

MSE 546 Materials Selection and Design 3-0-3

Stage of product development, materials performance in service, economic of materials, material selection process, selection of materials for mechanical strength and other properties, design and selection of materials, failure prevention, case studies in design and selection of materials.

Prerequisite Graduate standing

MSE 547 Finite Element Analysis in Material Science & Engineering 3-0-3

Introduction to Finite Element Analysis; Finite Element Formulation; Linear and Non-linear FEA; Modeling of Materials (Metal and Non-Metals) for Structural, Thermal including phase change, Fluids, and Electromagnetic analysis; Practical applications in component design and materials processing; Future developments.

Prerequisite Graduate standing

MSE 590 Special Topics in Materials Science and Engineering I 3-0-3

Advanced topics are selected from the broad area of Materials Science and Engineering. Contents of the course will be provided in detail one semester before its offering. Approval of the Departmental Graduate Committee and the Graduate Council must be secured before offering this course.

Prerequisite Graduate standing

MSE 591 Special Topics in Materials Science and Engineering II 3-0-3
See the description of MSE 590.
Prerequisite Graduate standing

MSE 599 Seminar 1-0-0
Graduate students working towards M.S. degree, are required to attend the seminars given by faculty, visiting scholars, and fellow graduate students. Additionally each student must present at least one seminar on a timely research topic. Among other things, this course is designed to give the student an overview of research in the department, and a familiarity with the research methodology, journals and professional societies in his discipline. Graded on a Pass or Fail basis.
Prerequisite Graduate standing

MSE 606 Independent Research 3-0-3
Course to be offered on a student-to-faculty basis. For a student to register in such a course with a specific faculty member, a clear Research Plan of the intended research work during the course is required to be approved by the Graduate Committee of the department and reported to the Deanship of Graduate Studies. At the end of the course, the student should submit a report and present his work to the Department Graduate Committee publicly.

MSE 610 MS Thesis 0-0-6
Prerequisite Consent of instructor

ME 479: Modern Materials

Course Description

Electrical, magnetic, optical, and thermal properties of materials. Advanced ceramics, composites. Advanced engineering plastics. High-temperature materials. Advanced coatings. Advanced materials processing system rapid solidification and powder metallurgy. Selection of modern materials.

Textbook(s) and/or other required material

Textbook:

1. William Callister, Materials Science and Engineering: An Introduction, John Wiley & Sons, 2007.
2. William Smith, and Javad Hashemi, Foundation of Materials Science and Engineering, 4th Edition, McGraw-Hill, 2006.
3. Handouts.

Reference Books:

1. M. Barsoum, Fundamentals of Ceramics, McGraw-Hill, 1997.
2. R. A. Flinn, and P. K. Rojan, Engineering Materials and their Applications, 4th Edition, John Wiley, 1995.
3. R. F. Gibson, Principles of Composite Materials Mechanics, McGraw-Hill, 1994.

***Course Objectives*:**

The purpose of this course is to

1. To introduce mechanical engineering students to the physical properties including electrical, thermal, magnetic, and optical, as well as new advanced materials, such as nano-materials. The objective will address high-temperature materials, advanced coatings, and advanced processing.

***Course Learning Outcomes*:**

After taking this course, students will be able to:

1. Understand physical and chemical properties of materials.
2. Understand relationships between structure and properties of different materials.
3. Understand the effect of elevated temperature on mechanical, chemical, and physical properties of materials.
4. Learn the basics of advanced coatings.
5. Learn basics of advanced manufacturing processes.

***Topics Covered*:**

- Introduction to physical properties of materials.
- Properties and structures of composite materials.
- Ceramic materials, some properties of ceramics.
- Processing of ceramics; molding, and chemical bonding.

- Plastics, polymerization, bond strength, bonding position on near-polymerization mechanisms, polymer structures.
- High-temperature materials.
- Advanced coatings: Processes and properties.
- Advanced processing.
- Industrial applications of composites and ceramics.

Class/laboratory schedule (i.e., number of sessions each week and duration of each session):

Three class lecture per week, 50 minutes each.

Contribution of Course to Meeting the Professional Component:

- Students will be introduced to the fundamentals of electrical, thermal, magnetic and optical materials as well as new advanced materials, such as nano-materials. Students will learn the structure and properties of high-temperature materials and advanced coatings as well as new developments in processing technologies.

Course Assessment

State weightage of each type of assessment.

Method	%
Major Exam 1	20
Major Exam 2	25
Project and Presentation	20
Final Exam	35

MSE 501: Materials Structures and Defects

Course Description

Provides fundamental understanding of the structure and properties of perfect and defective materials. Topics include: Crystallography and crystal structures, Point defects in crystals, Dislocation theory, Grain boundaries.

Course Objective

To the student, this course will:

provide basic and quantitative knowledge of perfect crystals,
provide basic and quantitative knowledge of defects in crystals,
prepare them for advanced courses in Materials Science and Engineering,
develop the ability to carry out research and further understanding.

Text

1) Introduction to Dislocations, D. Hull and D. J. Bacon, Butterworth-Heinemann, 2001.
2) Introduction to Crystallography, Revised Edition, C. Hammond, Oxford Science Publications, 1992.

References

3) Thermodynamics in Materials Science, R. T. DeHoff, CRC, 2006.
4) Selected literature (papers by D. Kulhmann-Wilsdorf, H. Mughrabi)
5) Theory of Dislocations, J. P. Hirth and J. Lothe, Krieger Publishing Co., 1982.
6) Handbook of Crystallography, A. G. Jackson, Springer-Verlag, 1991.
7) International Tables for Crystallography, Kluwer Academic Publishers, 1996.

Pre-requisite

Graduate standing or consent of the instructor

Course Outline

1) Crystallography and Crystal Structures **(9 lectures)**
    a) The lattice and its properties
    b) Crystal structure and morphology
    c) Principles of symmetry
    d) The 14 Bravais lattices
    e) Point groups
    f) Space groups
    g) Amorphous and Aperiodic structures
    h) Introduction to experimental techniques for crystal structure determination

Point Defects in Crystals **(5 lectures)**
    a) Classification of point defects
    b) Defects in metals
    c) Defects in stiochiometric compounds

d) Defects in nonstiochiometric compounds

Dislocation Theory **(14 lectures)**

a) Introduction to dislocations
b) Movement of dislocations
c) Elastic properties of dislocations
d) Dislocations in face-centered cubic metals
e) Dislocations in other crystal structures
f) Jogs and intersection of dislocations
g) Dislocation dynamics
h) Origin and multiplication of dislocations
i) Dislocation arrays and grain boundaries

Course Grades

HWs	20%
Midterm Exam	30%
Project	20%
Final Exam	30%

Term Project:

A problem in structure, defects or dislocations; may be related to the research area of the student.

One page proposal	7^{th} week
Final written report	14^{th} week
Oral presentation in class	15^{th} week

Course Outcomes

Students successfully completing the course should:

1) have the fundamental and quantitative understanding of structure of perfect and defective crystals,
2) have the basic understanding of dislocation theory from a materials science and engineering perspective,
3) have the ability to apply the course material in their research and to develop further understanding on their own,
4) be prepared for more advance courses in Materials Science and Engineering.

MSE 502 Thermodynamics in Materials Science

Course Description

This course is a thorough introduction to the basic principles and practical application of thermodynamics and kinetics appropriate for first year graduate students in materials science and engineering program. The topics covered include: classical and irreversible thermodynamics, phase equilibria, theory of solutions, surface phenomena, thermodynamics and kinetics of chemical reactions, electrochemistry, gas-solid reactions, and brief introduction to diffusion.

Course Objectives

1. To provide the students with a clear understanding of the fundamentals and applications of thermodynamic in materials systems.
2. To introduce the concepts of thermodynamics to predict phase stability.
3. To introduce the basics of chemical reactivity of materials systems.
4. To provide the basic concepts in kinetics and diffusion.

Text

1. Thermodynamics and Kinetics in Materials Science, B. Bokstein, M. Mendev, and D. Sorlovitz, Oxford University Press, 2005.
2. Additional lecture notes/handouts will be supplied throughout the course.

References

1. *Introduction to the Thermodynamics of Materials, D. Gaskell, Taylor & Francis, 2003.*
2. *Thermodynamics in Materials Science, R. T. DeHoff, CRC, 2006.*
3. Thermodynamics of Materials, D. Ragone, Wiley, 1995.
4. *Interfaces in materials : atomic structure, thermodynamics and kinetics of solid-vapor, solid-liquid and solid-solid interfaces, J. Howe, Wiley, 1997.*
5. *Topics in Metallurgical Thermodynamics, O. Devereux, Krieger Publishing Company, 1989.*

Pre-requisite

Graduate standing or consent of the instructor

Course Outline

	Topic	*No. classes (75 minute-class)*
1	Laws of thermodynamics	2
2	Gibbs phase rule and Clausius-Clapeyron equation	2
3	Thermodynamic theory of solutions	3
4	Binary and Ternary Phase Diagrams	4
	Fe-C phase diagrams	2

5	Thermodynamics of chemical reactions	2
6	Interfacial phenomena	2
7	Kinetics of homogeneous chemical reactions	3
8	Thermodynamics of irreversible processes	2
9	Diffusion	3
10	Applications: electrochemistry and oxidation	5
		30

Grading

HWs	15%
Midterm Exam	25%
Project	15%
Final Exam	35%

Course Outcomes

1. Interpret and read binary and ternary phase diagrams.
2. Understand and predict phase distributions for a given binary phase diagram.
3. Predict chemical reactivity and equilibrium of multi-phase materials as a function of temperature.
5. Apply thermodynamics principles to predict spontaneous direction of electrochemical and high temperature gas/metal reactions.

Syllabus prepared by Dr. Zuhair Gasem (Nov/2008).

MSE 503: Materials Characterization

Course Description

Characterization techniques for crystal structure and composition, Characterization methods for phase changes. Nanoindentation. Error analysis and statistical measurements, Crystal structure and grain size, Phase analysis and composition, Microstructure and crystal orientation. The course will include several visits to the materials lab and a experimental term project.

Course Objective

To the student, this course will:

provide an understanding of error analysis and statistical measurements,
provide advanced understanding of materials characterization techniques,
develop an understanding in the use of different techniques for characterizing engineering materials,
develop the ability to utilize appropriate characterization techniques in research and further understanding,
provide a foundation for advanced courses in Materials Science and Engineering.

Text

1) Introduction to Diffraction in Materials Science and Engineering, A.D. Krawitz, John Wiley Publications, 2001.
2) *Characterization of Materials, E.N.* Kaufmann, John Wiley Publication, 2003.
3) Selected papers from literature.

References

1) Scanning Electron Microscopy and X-Ray Microanalysis, L. Eric, Kluwer Academic Publication, 2002.
2) *Electron Microscopy of Thin Crystals,* P. Hirsch et al., Robert Krieger Publishing, USA, 1977.
3) *Structural and Chemical Analysis of Materials*, J.P. Eberhart. John Wiley Publication, 1992.

Pre-requisite

Graduate standing or consent of the instructor

Course Outline

1) Introduction to error analysis **(5 lectures)**
2) Statistical measurements **(2 lectures)**
3) ISO standards for laboratories and instruments **(2 lectures).**
4) Introduction to materials characterization techniques **(2 lectures)**
5) Nanoindentation **(2 lectures)**
6) Fundamentals and application of X-ray diffraction technique **(5 lectures)**
    a) Production and Properties of X-Rays
    b) X-Rays Scattering
    c) X-ray Diffraction Law
    d) X-rays Characterization of Engineering Materials

e) Real time X-ray mapping
f) Introduction to experimental techniques for crystal structure determination

Thermal Characterization Techniques **(5 lectures)**

e) Thermoanalytical instrumentation
f) Techniques and methodology
g) The basis of thermal analysis
h) Applications in metals, polymers, composites and ceramics

Scanning Electron Microscopy and Energy Dispersive Spectroscopy **(5 lectures)**

j) SEM instrument and operation
k) Image acquisition and enhancement
l) Specimen preparation, conductive coatings
m) Qualitative energy-dispersive spectroscopy
n) Quantitative energy-dispersive spectroscopy

Transmission Electron Microscopy **(5 lectures)**

o) Basic components and characteristics
p) Image acquisition and contrast
q) Bright field and dark field imaging
r) Selected area diffraction pattern
s) Specimen preparation techniques
t) High voltage electron microscopy

Analysis Techniques **(4 lectures)**

u) Photoelectron spectrometry
v) Auger electron spectrometry
w) Secondary ion mass spectrometry
x) Atomic force microscope

Course Grades

HWs	20%
Midterm Exam	30%
Experimental Project	20%
Final Exam	30%

Course Outcomes

Students successfully completing the course should:

1) have a broad understanding of the techniques used to characterize the properties of solids,
2) have the fundamental understanding of the underlying mechanisms in the context of material science and engineering,
3) have the ability to utilize the appropriate characterization techniques in their specific research,
4) be prepared for more advanced courses in Materials Science and Engineering.

CE 504 Corrosion in Reinforced Concrete

Corrosion mechanisms including corrosion cells, electrochemical reactions, polarization and passivity; forms of corrosion, corrosion mechanisms of reinforcing steel in concrete structures; environmental effects; effect of concrete properties; corrosion testing; corrosion protection including cathodic protection, corrosion inhibitors, chloride extraction, re-alkalization, and protective coatings.

Prerequisite:

Graduate standing or consent of the instructor

<u>Syllabus Split into 30 Lectures by Dr. Shamshad Ahmad, as follows:</u>

Lecture Number	Subject
1 2	Introduction, Corrosion cells, Types of corrosion cell, Mechanism of corrosion of steel in concrete
3 4	Passivity, Pourbaix diagram, Polarization of electrochemical reactions
5 6	States of reinforcement corrosion, Time-dependence of corrosion states, Effect of reinforcement corrosion on structural behavior
7 8	Effects of oxygen, moisture, relative humidity, and temperature on reinforcement corrosion
9 10	Effects of carbonation, chlorides, sulfates, stray current, and bacteria on reinforcement corrosion
11 12	Effects of cement composition, cement content, water/cement ratio, aggregate size and grading, and use of mineral admixtures on reinforcement corrosion
13 14	Effects of corrosion inhibitors and protective coatings on reinforcement corrosion
15 16	Effect of construction practices, cover thickness, and cover cracking on reinforcement corrosion
17 18	Modeling related to reinforcement corrosion
19 20 21 22	Design for durability: • Evaluation of exposure conditions • Formulation of materials specifications and selection of a suitable cover thickness and rebar diameter • Structural design considering durability
23	Assessment of causes and extent of corrosion damage in reinforced concrete

24	structures: • Methods for detection and assessment of corrosion damage • Prediction of residual service life against reinforcement corrosion • Methodology for assessment of corrosion damage • Case studies on the assessment of corrosion damage
25	
26	
27	Repair and rehabilitation of reinforced concrete structures damaged by reinforcement corrosion: • Repair options and basic repair principles • Conventional method of repairing • Electrochemical intervention techniques including cathodic protection, chloride removal, and realkalization
28	
29	
30	

MSE 511 – Corrosion in Oil and Petrochemical Industries

Course Description

Principles of corrosion; forms of corrosion in oil and gas industries; corrosion in petroleum production and operations; corrosion in petrochemical industry. Corrosion detection and monitoring techniques. Corrosion inhibition fundamentals, quality control, selection and application of oil field water chemistry. Emulsion theory and selection. Control by coating by coating offshore and onshore installations. Economics of corrosion control in oil and gas industry.

Course Objectives

1) To provide a basic understanding of corrosion problems encountered in oil and gas production.

To provide a practical understanding of corrosion control and corrosion monitoring technique and field applications.

Textbooks

1) **Corrosion in the Petrochemical Industry**, Ed: Linda Garverick, ASM Int., Materials Park, OH, USA.

Michael Davies, and P. J. B. Scott, **Oilfield Water and Technology**, NACE, 2006

References

1) Metcor, Oilfield Metallurgy and Corrosion, 3rd Ed., NACE, 2004

Protective Coatings and Corrosion Assessments, Corrometrics, NACE, 2004

Materials Protection, NACE, Houston, TX

Prerequisites

Graduate standing or consent of the instructor

Course Outline:

	No. of Lectures
Corrosion principles in oil and gas production	
Electrochemical principles of corrosion:	
● Metallurgically influenced corrosion, mechanically induced corrosion, and environmental induced corrosion ……………………………………	4
● Effect of oxygen, hydrogen sulfide, and carbon dioxide ………………...	2
● Identification of pitting crevices, microbiological, crevice, intergranular, corrosion fatigue and stress corrosion cracking, theories and control methods in oil and gas industry …………………………………………..	4
● Failure identification and occurrence in petroleum production. Corrosion in downhill equipment, such as pumping wells, gas lift wells, flowing wells, and casing. Corrosion on surface equipment, such as flowlines and well heads …………………………………………………	3

- Corrosion testing utilizing chemical, electrochemical, and inspection methods ……………………………………………………………….. 3
- Laboratory tests for inhibitor selection, immersion, wheel, electrical and electrochemical testing …………………………………………………. 2
- Corrosion inhibitor applications. Consideration of important factors for inhibitor progress ……………………………………………………… 2
- Characteristics, dosage, and application problems ………………………. 3
- Water chemistry and water analysis for scale control in oil field water systems ………………………………………………………………... 1
- Desalting, reverse emulsion and desalting in oilfield operations ………... 2
- Corrosion control by coatings, evaluation and selection of coatings ……. 3
- Corrosion control by cathodic protection ………………………………... 3
- Economics of corrosion control in oil and gas industries ……………….. 2

Course Grades:

Homework …………… 15%
Mid-term Exam ……… 30%
Project Work …………. 15%
Final Exam …………… 35%

Term Project:

The term projects would be oriented to field problems in oil and gas industries.

- Proposal to be submitted by the 4th week of the course.
- Final report to be submitted after the 12th week.
- Oral presentation in class during the 14th week.

Course Outcomes:

On successful completion of the course the students would be able to:

► Comprehend the corrosion problems faced by oil and gas industries.

► Understand the basics of treatment of oil and gas for corrosion prevention.

► Designing and monitoring of corrosion control programs.

MSE 512 – Fundamentals of Cathodic Protection Design

Course Description :: A basic understanding of principle of corrosion, failures by corrosion, principles and methods of corrosion protection. Basic theory and cathodic protection basics. Types of cathodic protection systems. Cathodic protection criteria. Cathodic protection survey and monitoring. Cathodic protection design. Stray current electrolysis.

Course Objectives ::
1) To provide a basic knowledge of cathodic protection and its application to prevent failure.
2) To create an understanding of the principles of design of cathodic protection systems.

Textbooks ::
1) A. W. Peabody, **Peabody's Control of Pipeline Corrosion**, NACE, USA.
2) Jerome Edinger, **Peabody's Control of Pipeline Corrosion: Workbook**, NACE, USA.

References :: **ASM Handbook of Corrosion**, Vol. 13, ASM, Metals Park, Ohio, 2006.

Prerequisites :: Graduate standing or consent of the instructor

Course Outline:

	No. of Lectures
Mechanism of corrosion and electrochemical principles …………………………..	3
Basics of Cathodic Protection Theory: ……………………………………………..	5
■ Fundamentals of electricity as applied to cathodic protections.	
■ Formation of corrosion cells by dissimilar metals, dissimilar soils, old pipes-new pipes, mill scale, and differential aeration corrosion.	
Working Principles of Cathodic Protection: ……………………………………..	8
■ Impressed current and galvanic anode systems.	
■ Galvanic anode and impressed current anodes, principles of design, efficiency, specifications, and applications.	
■ Calculations of life-time, potential, and resistance of single and multiple anode	
Criteria of Cathodic Protection: IR Proof, –850 mV criteria, 100 mV criteria, NACE criteria ………………………………………………………………………	2
Measurements in Cathodic Protection: Soil resistivity, pipe-to-soil calculations, structure-to-anode, structure-to-earth, and anode-earth potentials …………………	4
Cathodic Protection Surveys: …………………………………………………….	3

- Soil resistivity survey.
- Pipe-to-soil potential survey.
- Coating resistance and line current measurements.

Groundbed Design: Remote vs. close groundbeds ……………………………….. 4

Stray Current Corrosion: Interference in underground cathodic protection systems and their control ………………………………………………………………. 2

Designing of Simple Cathodic Potential System: Design calculations involving current requirement tests, insulation, soil resistivity, number of anodes, life of anodes, and use of design charts …………………………………………………… 4

Course Grades:

Homework ……………	15%
Mid-term Exam ………	35%
Project Work ………….	20%
Final Exam ……………	30%

Term Project:

- Proposal to be submitted by the 4th week of the course.
- Final report to be submitted after the 12th week.
- Oral presentation in class during the 14th week.

Course Outcomes:

Students after completion of the course would be able to:

- Understand the importance of cathodic protection in prevention of failures of underground structures.
- Understand the underlying theory behind the technology of cathodic protection.
- Understand the design of cathodic protection system.
- Design simple cathodic protection system.

MSE 521: Deformation and Fracture Mechanics of Structural Materials

Course Descriptoin Material microstructure and properties; dislocations and their role in controlling mechanical properties; integration of materials microstructure and solid mechanics principles; mechanical behavior of metallic alloys, engineering polymers and composites. Fracture based on continuum fracture mechanics and microstructural damage mechanisms and relationships between material toughness, design stress, and flaw size. Additional topics include fatigue loading, elevated temperature behavior, material embrittlement, time-dependency, experimental design, and damage-tolerant life prediction.

Course Objectives:

The course aims to provide an understanding of the deformation process at the microscopic level and how this process affects the bulk properties of structures made of metallic and non metallic materials. The course aims also at teaching the students the principals of fracture mechanics in monotonic and cyclic loading conditions using energy and stress intensity approaches**.** It will give the students an insight in microstructural damage and its effects on the life of structures.

Textbook: Deformation and Fracture Mechanics of Engineering Materials, 4th Edition, by Richard W. Hertzberg, 1996, John Wiley

Pre-requisites: Graduate standing or consent of the instructo

Course Outline

Topics	**No of Lect. (50 min)**
I- DEFORMATION	
Elements of dislocation theory	5-6
Slip and Twinning in crystalline solids	1-2
Strengthening mechanisms in metals	3-4
Mechanical behavior of metallic alloys	5-6
High Temperature Deformation of metallic alloys	2-3
Mechanical behavior of metallic engineering polymers and composites.	2-3
II- FRACTURE MECHANICS	
Elements of fracture mechanics	1-2
Energy Methods	1-2
Stress Field Approach	3-4
Transition Temperature approach to Fracture Mechanics	1-2
Fracture Toughness	2-3
Microstructural aspects of fracture toughness	2-3
Environment Assisted Cracking	1-2

Fatigue Damage and Fatigue life Prediction Fatigue Crack Propagation and Life Prediction	2-3 2-3

Projects:

Term projects related to deformation and fracture of real structures will be assigned.

Course Grades

Homework	**15%**
Project	15%
Quizzes	15%
Mid-Term	25%
Final	30%
Total	**100%**

MSE 522: Failure Analysis in Materials Science

Course Description

A review of deformation, ductile and brittle fracture, fracture toughness, failure modes, stress corrosion, hydrogen damage, wear, stress concentration, fracture mechanics, fatigue, techniques and procedures for failure analysis, case studies.

Course Objective

To the student, this course will:

1. provide understanding of basics of failure analysis,
2. provide knowledge of fatigue and fracture mechanics involved,
3. develop the ability to carry out failure analysis.

Textbook

Failure Analysis of Engineering Materials, Charles R. Brooks, Ashok Choudhury, Charlie R. Brooks, McGraw-Hill Professional, 2001.

References

Failure of Materials in Mechanical Design: Analysis, Prediction, Prevention, 2nd Edition, Jack A. Collins, Wiley-Interscience, 1993.
Failure Analysis Case Studies II, D.R.H. Jones, Pergamon, 2001.
Introduction to Dislocations, D. Hull and D. J. Bacon, Butterworth-Heinemann, 2001.

Pre-requisite

Graduate standing or consent of the instructor

Course Outline

Deformation **(4 lectures)**
Engineering stress and strain
True stress and true strain
Elastic and plastic deformation
Slip by dislocation movement
Twinning
Deformation of single and poly-crystalline materials
Fracture **(6 lectures)**
Ductile and Brittle Fracture
Failure modes: overloading (yielding in tension and compression), fatigue, creep, corrosion, impact, wear, stress corrosion
Stress concentration
Metallic materials
Polymeric materials
Ceramics
Composites
Electronic materials
Elements of Fracture Mechanics **(6 lectures)**
Stress intensity factor
Plane strain stress intensity factor testing

Fatigue crack growth (Paris law)
Fatigue life design
Total life method
Damage tolerant design
Failure Analysis **(9 lectures)**
Fractography
Metallography
Techniques for failure analysis
Procedure for failure analysis
Case studies
Engineering Design against Failure **(3 lectures)**
Safety factor
Fracture toughness
Fatigue life prediction

Course Grades

HWs	20%
Midterm Exam	30%
Project	20%
Final Exam	30%

Term Project:
A problem in structure, defects or dislocations; may be related to the research area of the student.

One page proposal	7th week
Final written report	14th week
Oral presentation in class	15th week

Course Outcomes
1. Students successfully completing the course should:
2. have understanding of techniques and procedures of failure analysis,
3. have the fundamental and quantitative understanding of fatigue and fracture mechanics,
4. be able to carry out failure analysis on real failures.

MSE 531: Engineering Nanomaterials

Course Description

Synthesis of nano-powders and nanostructured precursors (metals, ceramics, intermetallics, CNT), Manufacturing of bulk nanostructured materials and nanocoatings, Reactivity and handling of nanoparticles, Characterization of nanomaterials, Physical and mechanical properties of nanomaterials.

Course Objective

To the student, this course will:

1) introduce nanomaterials as a new emerging class of engineering materials,
2) provide basic knowledge and understanding in synthesis, properties and applications of nanomaterials,
3) identify the role of nanomaterials in nanotechnology revolution
4) appreciate the challenges related to handling nanomaterials and health and safety implications,
5) provide a foundation for advanced courses in Materials Science and Engineering.

Text

1) *Nanomaterials: Synthesis, Properties and Application, eds. A.S.* Edelstein, and R.C. Cammarata, Institute of Physics Publishing, London, 2002.
2) Selected papers from literature.

References

1) Nanostructured Materials: Selected Synthesis Methods, Properties and Application, Kluwer Academic Publication, Netherlands, 2002.
2) *Nanotechnology and Materials Science*, S. Mitura, Elsevier Science, 2000.
3) *Nanostructured Materials: Science and Technology*, G.M. Chow, and N.I. Noskova, Kluwer Academic Publication, Netherlands, 1998.
4) *Societal Implications of Nanoscience and Nanotechnology*, M.C. Roco, and W.M. Bainbridge, Kluwer Academic Publication, Netherlands, 2002.
5) *Characterization of Nanophase Materials,* Z.L. Wang, John Wiley & Sons, 2001.
6) *Nanostructured Materials: Science and Technology*, Chow, G.M., and Noskova, N.I., Kluwer Academic Publication, Netherlands, 1998.

Pre-requisite

Graduate standing or consent of the instructor

Course Outline

1) Introduction to nanomaterials **(1 lecture)**

Synthesis of nanoparticles by chemical and physical routes **(6 lectures)**

a) Nucleation and growth from solutions
b) Stabilization of fine particles against agglomeration
c) Metals and intermetallics
d) Ceramics and composites
e) Nanoparticles via organized membranes
f) Carbon nanotubes, nanowires, & nano porous structures

Formation of Nanostructures by Mechanical Attrition **(3 lectures)**

i) High-energy ball milling and mechanical attrition
j) Phenomenology of nanostructure formation
k) Non-equilibrium solid solutions
l) Nanocomposites by mechano-chemistry
m) Mechanism of grain-size reduction
n) Property-microstructure relationships

Processing of Nanostructured Sol-Gel Materials **(3 lectures)**

y) Synthesis of oxides by the sol-gel process
z) Powder-free processing of gel shapes
aa) Consolidated gels, sintering
bb) Prospects for the sol-gel processing of nanostructured materials

Consolidation of Nanocrystalline Materials by Compaction and Sintering **(4 lectures)**

a) Dry compaction of nanocrystalline particles
b) Wet compaction of nanocrystalline particles
c) Grain growth during pressureless sintering
d) Pressure-assisted sintering
e) Microwave sintering and spark plasma sintering

Characterization of Nanostructured Materials **(4 lectures)**

a) Nanostructures of metals and ceramics
b) Structures of nanophase materials
c) Atomic defects and dislocations
d) Grain and grain boundaries
e) Stability and strains
f) Characterization by scattering techniques

Chemical Properties of Nanostructured Materials **(3 lectures)**

a) Nanostructures in chemistry
b) Effect of nanoscale materials on chemical reactivity
c) Effect of chemistry on nanostructures

Mechanical properties of Nanostructured Materials **(3 lectures)**

a) Low temperature properties
b) High temperature properties
c) Superplasticity
d) Future directions

Assessment of Technological and Environmental Impacts **(3 lectures)**

a) Properties of nanomaterials and applications
b) Nanostructures in electronics, memories and electronic devices,
c) Nanostructured materials for magnetic recording
d) Environmental and health implications

Course Grades

HWs	20%
Midterm Exam	30%
Project	20%
Final Exam	30%

Course Outcomes

Students successfully completing the course should:

1) differentiate between nanomaterials and conventional materials,
2) have a broad understanding of the techniques used to synthesize nanomaterials,
3) evaluate the properties of nanomaterials,
4) appreciate the health and safety implications related to nanomaterials,
5) identify the role of nanomaterials in current nanotechnology revolution,
6) be prepared for more advanced courses in Materials Science and Engineering.

MSE 532: Engineering Ceramics

Course Description

Topics covered include: Bonding in Ceramics, Structure of Ceramics, Processing Technologies, Properties of Ceramics, and Applications of Ceramics.

Course Objectives

1) To introduce students to the fundamental chemical and structural nature of ceramic materials.

2) To teach students the relationships between structure, properties, processing and performance of ceramics that are essential for understanding the role of these materials in the design of engineering systems.

Text

1) ***Modern Ceramic Engineering: Properties, Processing, and Use in Design***, D.W. Richerson, Taylor and Francis Group, 2006.
2) ***Engineering Ceramics***, M. Bengisu, Springer Verlag, 2001.

References

1) ***Fundamentals of Ceramics***, Michel W. Barsoum, IOP publishing, 2003.
2) ***Materials Science and Engineering: An Introduction***, William D. Callister, Jr., Wiley 2007.
3) ***Ceramic processing & sintering***, N. RAHMAN Mohamed, Lavoisier, 2003.
4) ***Electroceramics: Materials, Properties, Applications***, A. J. Moulson, J. M. Herbert, Wiley 2003.
5) ***Ceramic Materials for Electronics***, Relva C. Buchanan, Marcel Dekker Inc., 2004.
6) ***Introduction to Ceramics, 2nd Edition,*** W. David Kingery, H. K. Bowen, Donald R. Uhlmann, Wiley 1976.

Pre-requisite

MSE 501

Course Outline

Bonding and structure of Ceramics **(6 lectures)**

a) Ceramic Bonding.
b) Ceramic Crystal Structures.
c) Ceramic Density Computation.
d) Defects in Ceramic Structures.
e) Ceramic Phase Diagrams.

Processing Technologies **(8 lectures)**

cc) Raw Materials
dd) Mixing and Grinding
ee) Calcination
ff) Shaping
gg) High Temperature Processing
hh) Finishing

Properties of Ceramics **(10 lectures)**

f) Electrical properties
g) Thermal Properties
h) Magnetic Properties
i) Optical Properties
j) Mechanical properties

Applications of Ceramics **(4 lectures)**

k) Structural applications.
l) Military applications.
m) Cutting Tools and Abrasives.
n) Automotive and aerospace applications.
o) Refractory applications.
p) Ceramics for Energy Production.
q) Biotechnological applications.
r) Electrical, Electronic, and Magnetic Applications.

Course Grades

HWs	20%
Midterm Exam	30%
Project	20%
Final Exam	30%

Course Outcomes

Students successfully completing the course should:

Describe the use of ceramic materials in different technical and industrial applications including the advantages and disadvantages of the various types of ceramics for specific applications.
Apply the principles of materials science and engineering to ceramic materials selection.
Conduct independent library research on ceramic materials and report the results of their investigation in both oral and written forms.
Enhance their group-working skills through in-class discussions and assignments.
Analyze and interpret data on ceramic materials available in the scientific literature.

MSE 533: COATINGS AND SURFACE ENGINEERING

Course Description

Advanced coatings; metallic, ceramic & and polymeric coatings, high temperature corrosion, basic of chemical thermodynamics, thermodynamic stability And Ellingham diagrams Thin film Technology and Microelectronic

Course Objective

To the student, this course will:

provide basic knowledge of Chemical thermodynamics,
provide basic knowledge of High temperature Corrosion
provide basic knowledge of Ceramic, Metallic, and Polymer coatings .
develop the ability to carry out research and further understanding.

Text

7) Thermodynamics in Materials Science, R. T. DeHoff, CRC, 2006.
8) Metallurgical Thermochemistry , Kubachwesky and
9) Deposition Techniques for Films and Coatings, Rointan Bunshahah et a; (1982 D. Kulhmann-Wilsdorf, H. Mughrabi)

References (change)

10) Theory of Dislocations, J. P. Hirth and J. Lothe, Krieger Publishing Co., 1982.
11) Handbook of Crystallography, A. G. Jackson, Springer-Verlag, 1991.
12) International Tables for Crystallography, Kluwer Academic Publishers, 1996.

Pre-requisite

MSE 502

Course Outline

13) 101-level Chemistry & Chemical thermodynamics & High temperature Corrosion **(13 lectures)**
    a) Thermodynamic functions, Entropy, Gibbs Energy, and Equilibrium.
    a)
    b) b)Basic considerations in Thermodynamic stability and Stability diagrams (3 lectures)
    c) Properties of Oxides, carbides, Nitrides, and Sulfides (2 lecture)
    d) Ellingham Diagrams (1 lecture)
    e) Oxidation (2 lectures)
    f) Carburization (2 lectures)
    g) Sulfidation (1 lecture)
    h) Molten sat attack (1 lecture)
    i) Methods of testing (1 lecture)

Advanced Coatings**(7 lectures)**

o) Classification of Coatings(1 lecture)
p) Evaporation (2 lecture)
q) Chemical Vapor deposition (1lectures)
r) Adhesion & Microstructure (1 lecture)
s) Organic Polymer Coatings (1 lectures)
t) Thin Film Characterization (1 lecture)
ii)

Course Grades

HWs	20%
Midterm Exam	30%
Project	20%
Final Exam	30%

Term Project:

A problem in structure, defects or dislocations; may be related to the research area of the student.

One page proposal	7^{th} week
Final written report	14^{th} week
Oral presentation in class	15^{th} week

Course Outcomes

Students successfully completing the course should:

14) have the fundamental and quantitative understanding of Chemical thermodynamics
15) have the basic understanding of High Temperature Corrosion
16) Basic Knowledge of metallic , Ceramic & AND POLYMER COATINGS
17) have the ability to apply the course material in their research and to develop further understanding on their own,

be prepared for more advance courses in Thin film Technology and Microelectronic

MSE 534 – Engineering Composite Materials

Course Description:
Engineering Composite Materials. 3 Credits. Properties, manufacture, forms of composites; micromechanics; orthotropic lamina properties; laminate analysis; theories; failure analysis; thermal, environmental effects.

Objectives: This course is intended to give engineering students a working knowledge of engineering composite materials and allow him to make rational decisions in the design of composite structures.

Textbook: Agarwal, B. D., and Broutman, L. J., **Analysis and Performance of Fiber Composites**, John Wiley & Sons, New York, 1980 (or latest edition).

References: Tsai, S. W., **Composite Design**, Think Composites, Dayton, OH, 1988.

Halpin, J. C., **Primer on Composite Materials: Analysis**, Technomics, Lancaster, PA, 1904.

Jones, R. M., **Mechanics of Composite Materials**, McGraw-Hill, New York, 1975.
Piggott, M. R. **Load bearing Fiber Composites**, Pergamon Press, Oxford, 1980 (or latest edition).

Harris, B., **Engineering Composite Materials**, The Institute of Metals, London, 1988.

Mallick, P. K., **Fiber-Reinforced Composites: Materials, Manufacturing, and Design**, Marcel Dekker, Inc., New York, 1988.

Ashbee, K., **Fundamental Principles of Fiber Reinforced Composites**, Technomics, Lancaster, PA, 1989.

Prerequisites by Topics:
Graduate standing or consent of the instructor

Topics:

	Topic	*No. of Classes*
1.	Definitions, classification, terminology, and rationale for use ……….	1 Class
2.	Properties, manufacture and forms of constituents …………………..	4 Classes
3.	Theory and techniques of property prediction ………………………..	4 Classes
4.	Mechanical properties of discontinuous composites …………………	2 Classes

5.	Elastic behavior of orthotropic lamina ……………………………….	2 Classes
6.	Strength theories of orthotropic lamina ………………………………	2 Classes
7.	Principles of laminate analysis ……………………………………….	4 Classes
8.	Design of laminate structures ………………………………………...	3 Classes
9.	Failure of laminates, impact, fatigue, and fracture mechanics ……….	3 Classes
10.	Bonding and joint design ……………………………………………..	2 Classes
	Examinations …………………………………………………………	3 Classes

Computer Usage:

1. Homework assignments in Topics 5 through 10 require computer use. Micro-computers and mainframes may be used.
2. The student is required to generate their own code in any of the following programming languages: Fortran 77, Basic, Pascal, or C.

ABET Category Content:

Engineering Science … 2 credits or 67%
Engineering Design … 1 credit or 33%

MSE 535 : Biomaterials

Course Description:

This course introduces engineering students to materials as they interact with biological systems, primarily in medicine. Topics will include an overview of the theory, practice of biomaterial science and introduce them to new materials used for Medical Applications. The course will include biology and biochemistry background, properties of materials used in medical applications, classes of materials used in medicine, host reactions involved in biomaterials. It will cover also biological testing of biomaterials, degradation of materials in the biological environment, applications of materials in medicine and artificial organs, tissue engineering. Practical aspects of biomaterials including new products and standards will also be covered.

Course Objectives:

The purpose of this graduate course is to introduce engineering students to biomaterials and their properties, classes and their use in the medical areas such as tissue engineering, artificial organs and implantable medical devices. Upon completing this course, students should:

1- Understand the basic principles behind human tissue response to artificial surface implantation,
2- Be familiar with the general types of materials and their properties, which are used in soft and hard tissue replacements, drug delivery devices, and extracorporeal devices,
3- Understand host reactions to biomaterials and their evaluation and Biological Testing of Biomaterials.
4- Understand the aspects of degradation of Materials in the Biological Environment and the applications of Materials in Medicine Biology and artificial organs
5- Be familiar with the ethical Issues in the Development of New Biomaterials and legal aspects of biomaterials

Text books:

1- Biomaterial Science- An Introduction to Material in Medicine Second edition by , Buddy Ranter, Allan Hofman. 2004. Elsevier Academic Press.
2- Biomaterials , An Introduction. Third Edition. By Joon Park and R.S.Lakes. 2007. By Springer Publisher.
3- Biomaterials. CRC Press. 2007. Edited By Joyce Wong and Joseph Bronzino.
4- Biomaterials . Alpha Science. 2006 by Sujata Bhat.

Pre-requisites:

Graduate standing or consent of the instructor

Course Outline:

A. Materials Science and Engineering

1-Properties of Materials

- Bulk Properties of Materials
- Finite element analysis
- Surface Properties and surface characterization of Materials
- Role of water in biomaterials

2- Classes of Materials Used in Medicine

- Polymers
- Silicon Biomaterials
- Medical Fibers and Biotextiles
- Hydrogels
- Applications of "smart polymers "as biomaterials
- Bioresorbable and bioerodible materials
- Natural materials
- Metals
- Ceramics, glasses, and glass-Ceramics
- Pyrolytic Carbon for Long-Term Medical Implants
- Composites
- Nonfouling Surface
- Textured and Porous Materials
- Surface-Immobilized biomoloecules

B. Biology, Biochemistry, and Medicine

1- Background Concepts

- Protein structure and properties
- The role of adsorbed protein in tissue response to biomaterials
- Cells and cell injury
- Tissues and Cell-biomaterial interaction
- Mechanical forces on cells

2- Host Reactions to Biomaterials and Their Evaluation

- Inflammation, Wound Healing, and the Foreign Body Response
- Immunology and the Complement System
- Systemic Toxicity and Hypersensitivity
- Blood Coagulation and Blood—Materials Interactions
- Tumorigenesis and Biomaterials
- Biofilms , biomaterials, and device related infections
- Sterilization of Implants

3- Biological Testing of Biomaterials

- Introduction to testing Biomaterials

- *In Vitro* Assessment of tissue compatibility
- *In Vitro* Testing of tissue compatibility
- Microscopy for biomaterial science

4- Degradation of Materials in the Biological environment

- Introduction to Degradation of Materials in the Biological environment
- Chemical and Biochemical Degradation of Polymers
- Derivative Effect of the biological environment on metals and Ceramics
- Pathological Calcification of Biomaterials

5- Applications of Materials in Medicine Biology and artificial organs

- Introduction
- Cardiovascular Medical Devices
- Artificial red blood cell Substitute
- Dental Implantation
- Burn Dressing and skin Substitutes
- Bioelectrodes
- Diagnostic and Biomaterials
- Drug Delivery System
- Medical Application of Silicones

6- Tissue Engineering

- Introduction to Tissue Engineering
- Overview of Tissue Engineering
- Immunoisolation

C- Practical Aspects of Biomaterials

1- Implants, Devices and Biomaterials

- Introduction
- Sterilizations of Implants and Devices
- Implants and Device Failure
- Correlation, surface and Biomaterials Science

2- New Products and Standards

- Introduction
- Development and regulation of Medical Products Using Biomaterials
- Ethical Issues in the Development of New Biomaterials
- Legal Aspects of Biomaterials

Course Outcomes:

1- Students should be able to identify and understand the main terms largely used in biomaterials literature, basic properties of various biomaterials, correctly associate terms with processes/phenomena.

2- The students should gain the ability to apply knowledge of mathematics, science, and engineering to problems in materials engineering.
3- At the end of this course students will be able to presents a balanced perspective on the evolving discipline of Biomaterials.
4- To gain a solid appreciation for the special significance of the word biomaterial as well as the rapid and exciting evolution and expansion of biomaterials science and its applications in medicine.
5- The students should gain the ability to identify, formulate, and solve engineering problems, particularly in the context of materials selection and design.

MSE 536 Nanotechnology: Synthesis, Structure and Properties

Bulletin Description	Nanotechnology are being globally in the limelight as a new dream material in the 21st century and broadening their applications to almost all the scientific areas, such as aerospace science, bioengineering, environmental energy, materials industry, medical and medicine science, electronic computer, security and safety, and science education. Now they are known to be superior to any other existing material in mechanical, electrical, and hydrogen storage characteristics. Nanotechnology has the following applications. • Material for production of 10,000 times more integrated semiconductors Material for 1/3 time's scale-down of existing electronic devices. • Material for elevation of the existing electron emission current from 10 to 100 times level, using a low voltage. • Material for high functional composites which can drastically enhance the strength of structures, such as automobiles or aircraft • This course will cover the design, synthesis, properties, and characterization of nanoparticle.
Pre-requisites (if any)	Graduate standing or consent of the instructor
Co-requisites (if any)	
Teaching Methodology	Lectures and tutorials
Instructor(s)	Dr. Muataz Ali Atieh Email: motazali@kfupm.edu.my Office: 16-208 Tel: 8607513

Course Objectives

- To bring awareness of a variety of nanofabrication techniques (e.g. CVD, PVD, Laser ablation Technique, Arc Discharge, nanolithography, self assembled monolayers,).
- Importance of nanocharacterization
- To provide information on novel nanostructures (e.g. carbon nanotubes, Nanowires, nano porous structures etc).
- To explain in details the Synthesis methods of Nanoparticle.
- Surface modification of nanoparticles

Textbook:

Yury G. Gogotsi (2006) Carbon Nanomaterials CRC Press.

References

1. Contributor Michael J. O Connell (2006) Carbon Nanotubes: Properties and Applications 2006 CRC Press
2. Contributor Mildred S. Dresselhaus, Gene Dresselhaus, Phaedon Avouris (2001) Carbon Nanotubes: Synthesis, Structure, Properties, and Applications 2001 Springer
3. Peter John Frederich Harris, (1999) High Resolution electron Microscopy and Electron DiffractionCarbon Nanotubes and Related Structures: New Materials for the Twenty-first, Cambridge University Press.

COURSE OUTLINES / CONTENTS

1. Introduction
   - 1.1 History of Fullerenes
   - 1.2 Relation of Carbon Nanotubes to other Carbon Materials
   - 1.3 Carbon Nanotube Structure and Defects
   - 1.4 Special Properties of Carbon Nanotubes

2. Nanotube Growth and Characterization
   - 2.1 Introduction
   - 2.2 Growth Mechanism
   - 2.3 Arc Discharge
     - 2.3.1 Synthesis of SWNT
     - 2.3.2 Synthesis of MWNT
   - 2.4 Laser Ablation
     - 2.4.1 SWNT versus MWNT
     - 2.4.2 Large Scale Synthesis of SWNT
     - 2.4.3 Ultra Fast Pulses from a Free Electron Laser (FEL) Method
     - 2.4.4 Continuous Wave Laser-Powder Method
   - 2.5 Chemical Vapor Deposition
     - 2.5.1 General Approaches and Mechanism
     - 2.5.2 Single-Walled Nanotube Growth and Optimization
     - 2.5.3 Growth Mode of single-Walled Nanotubes in CVD
     - 2.5.4 Plasma enhanced chemical vapor deposition
     - 2.5.5 Thermal chemical vapor deposition
     - 2.5.6 Alcohol catalytic chemical vapor deposition
     - 2.5.7 Vapor phase growth
     - 2.5.8 Aero gel-supported chemical vapor deposition
     - 2.5.9 Laser-assisted thermal chemical vapor deposition
     - 2.5.10 CoMoCat process
     - 2.5.11 High pressure CO disproportionation process
   - 2.6 Gas Phase Catalytic Growth
   - 2.7 Controlled Nanotube Growth by Chemical Vapor Deposition
     - 2.7.1 Aligned Multi-Walled Nanotube Structures
     - 2.7.2 Directed Growth of Single-Walled Nanotubes
     - 2.7.3 Growth of Isolated Nanotubes on Specific Surface Sites

Method of Evaluation	Test I	20 %
	Test II	20 %
	Quizzes	10 %
	Homework (Assignments)	05 %
	Attendance and Class Participation	05 %
	• Final Examination	40 %
	TOTAL	100 %

Course Outcome

The fundamental objective of nanotechnology is to model, simulate, design and manufacture nanostructures and nanodevices with extraordinary properties and assemble them economically into a working system with revolutionary functional abilities. Nanotechnology offers a new paradigm of groundbreaking material development by controlling and manipulating the fundamental building blocks of matter at nanoscale, that is, at the atomic/molecular level

- Provide understanding, characterization and measurements of nanostructure properties
- Provide ability for synthesis, processing and manufacturing of nanocomponents and nanosystems
- Provide ability for design, analysis and simulation of nanostructures .
- Prepare students to conduct research and development of economically feasible and innovative applications of Nanotechnology in all spheres of our daily life.

CHE 541: Polymeric Materials and Processing

Course Description

Classification of polymers; chemical, physical and mechanical properties; molecular structural-property relationships; processing methods; design and selection criteria; environmental effects.

Course Objectives

1. To broaden the knowledge of students about polymers, their applications, and their processes.
2. To teach students the chemical and physical structures of polymers.
3. To teach students different polymer processing methods and equipment.
4. To teach students how to select plastics for different applications.

Text

Principles of Polymer Engineering, N. G. McCrum, C.P. Buckley; and C.B. Bucknall, Oxford Science Publications, 2nd Ed., **1999**.

References

1) **Plastics Engineering**. By R.J. Crawford: Butterworth Heinemann, **1998**.
2) **Principles of Polymer Systems**. Ferdinand Rodriguez: Hemisphere Publishing Corporation, **1989**.

Pre-requisite

Graduate standing or consent of the instructor

Co-requisite:

Graduate standing or consent of the instructor

Course Outline

18) Introduction to polymeric materials **(2 lectures)**
Chemical and Physical Structures of Polymers **(7 lectures)**
Mechanical, Chemical, and Physical Properties of Polymers **(7 lectures)**
Fiber-Polymer Composites **(2 lectures)**
Polymer Processing Methods and Equipment **(8 lectures)**

Fluid Flow and Heat Transfer in Melt Processes **(4 lectures)**
Interaction between Processes and Properties **(6 lectures)**
Design and Selection of Plastics for Applications **(5 lectures)**
Environmental Aspects of Plastics **(2 lectures)**
Special topics in polymer processing **(2 lectures)**

Students' Evaluation

Regular Assignments:	10%
Mid-Term Exam:	25%
Project Assignments:	30%
Final Exam:	35%

Course Outcomes

Students successfully completing the course should:

a. have fundamental knowledge of polymeric materials;
b. have good understanding of polymer processes;
c. have developed a comprehensive knowledge about polymeric applications.

MSE 541 Electronic, Optical, and Magnetic Properties of Materials

Course Description

Quantitative description of electronic, optical, and magnetic structure-property relationships of materials. Strategies for the development of new materials and introduction to applications of these materials.

Course objectives

- Introduction to the quantitative description of structure-property relationships for electronic, optical, and magnetic properties of materials
- Understand the role of electronic, magnetic, and optical properties in the development, selection, and application of materials

Textbook(s) and/or other required material

Rolf Hummel, Electronic Properties of Materials, 3rd Ed., Springer (2001, corrected 2005), ISBN 0-387-95144-X.

Livingston, James D. Electronic Properties of Engineering Materials. New York, NY: Wiley, 1999. ISBN: 9780471316275.

Course Prerequisite(s) Prerequisite knowledge and/or skills

Graduate standing or consent of the instructor

Topics covered

1. Consequences of the Drude model, electrical properties of metals
2. Large scale optical properties
3. Electrons in crystals
4. Real and reciprocal lattices, Brillouin zones
5. Electron energy levels in real materials
6. Effective mass, density of states
7. Fermi distribution, Fermi surfaces
8. Electrical properties of metals revisited
9. Band structures of real metals and metallic glasses
10. Other "Electronic" Properties: Specific heat
11. Thermal conductivity
12. Semiconductors: Band structure and doping

13. Conduction by holes in semiconductors and metals
14. PN junctions, Schottky diodes, BJTs and FETs
15. Optical properties: index of refraction, absorption, etc.
16. Optical absorption, spectra of metals and semiconductors
17. Organic "metals" and semiconductors
18. Ionic conductivity, superionic conductors
19. Dielectrics: Electrical Properties of Insulators
20. Ferroelectricity: Origins and Properties
21. Electronic effects in structural phase transitions
22. Magnetism: electron spin, para- and diamagnetism in solids
23. Soft and hard magnetic materials
24. Ionic magnetism and the Heisenberg model
25. Thermodynamic effects in magnetic devices
26. Itinerant magnetism
27. Superconductivity: phenomena
28. Superconducting materials
29. BCS theory of superconductivity
30. Bose Statistics in Optics: Stimulated Emission, Lasers
31. Optical Materials for Photonics

Course outcomes

1. Ability to develop and to apply knowledge of mathematics, physics, and thermodynamics to the electronic, magnetic, and optical properties of materials.
2. Understanding of the design and development of new materials, and an understanding of what fundamental measurements are required in the development of new electronic, magnetic, and optical materials.
3. Formulation and presentation of outstanding problems in electronic, magnetic, and optical materials and the practical needs motivating research and development through an in-class presentation and end-of-semester paper.

MSE 542 : Advanced Metal Casting

Course Description	Melt treatment, solidification aspects; nucleation and growth, working mechanism of chemical refiners, solid solutions and eutectic solidification, thermal analysis of solidification, micro and macro segregation, unconventional refinement mechanism, conventional and advanced casting processes, mold design, heat-treatment of casting, types of defects, quality control.
Objectives	1- Provide understanding of the fundamentals of casting process 2- Identify the solidification process variables influencing casting microstructure and quality. 3- Provide students with engineering methods for testing and quality control
Textbook	1) Stefanescu, D. M., **Science and Engineering of Casting Solidification**, 2nd Ed, 2009 2) Merton C. Flemings, **Solidification Processing**, McGraw-Hill Inc., USA, 1974. 3) W. Kurz, D. J. Fisher, **Fundamentals of Solidification**, Trans Tech Pub, 1986.
Pre/Co-Requisites by Topic	) Graduate standing or consent of the instructor
References	Journal Articles

Course Outline (1.15hr/class)

1)	Properties of liquid metals...	1 Classes
2)	Homogeneous and Heterogeneous Nucleation………………………………	2 Classes
3)	Dendritic growth………………	1 Class
4)	Eutectic growth..	2 Classes
5)	Cell structure...	1 Classes
6)	Heat and Mass Transfer...	2 Classes
7)	Kinetics of Solidification..	4 Classes
8)	Macro/microsegregation and modeling…	3 Classes
9)	Solidification of castings and ingots..	2 Classes
10)	Microstructure control of aluminum alloys………………….	2 Classes
11)	Refinement by processing……………………………………………………...	2 Class
12)	Rapid Solidification…………………………………………………… …………….	1 Class

13)	Die casting	1 Class
14)	Continuous casting, direct chill casting	2 Class
15)	Mold Design……………………………………………………………	2 Classes
16)	Defects and testing	1 class
17)	Heat treatment of ferrous and non ferrous alloys	1 class

Design Activities/Projects

Summaries journal articles on selected subjects on solidification theory, modeling and refinement techniques, and mould design

Computer Usage

Assignments need simple computer programs such as Fortran and the use of spreadsheets, such as excel or Lotus 1-2-3. If ProCast software is available then it will be used.

Course Grades

1) Homework 30%
2) Midterm Test 20%
3) Class Project 20%
4) Final Exam 30%

Student Learning Outcome

1) To be able to identify the methods of high quality melts
2) To be able mathematically describe the dendritic structure
3) To be able to mathematically describe the eutectic structure
4) To be able to determine the effects of heat transfer, temperature on the development of microstructures within a cast
5) To be able to model the effect of microsegregation on solidification microstructure
6) To be able to understand the working mechanism of chemical refiners
7) To be able to identify design aspects of casting molds
8) To be able to produce casting with required properties and quality

learn industrial practices in controlling/refining aluminum alloy microstructure

ABET Category

Engineering Science...... 2.0 Credits

Engineering Design....... 1.0 Credits

MSE 543 Welding Processes & Metallurgy

Course Description

This course introduces the basic concepts used in welding and joining. It examines the significance of joining, the process options, and process fundamentals, welding metallurgy and weld ability of materials, design, economics, and inspection and quality control of joining. Specific topics covered in the course will be the physical principles of fusion welding; heat flow; thermal cycles; HAZ and physical metallurgy and mechanical properties of welded joints; applications of welding to large structures; testing of welds; nondestructive testing; design, economics and weld specifications. Welding Metallurgy: weldability of mild steel, stainless steel , aluminum alloys, and cast iron. Weld Defects: weld cracking, weld defects, welding codes, contractions and residual stresses. Nondestructive testing; radiographic and ultrasonic testing methods, quality control and assurance.

Course Objective

1. Act as a first graduate course in welding by integrating knowledge from many areas of natural science and engineering through the wide range of issues that arise in a discussion of welding science and technology.
2. Survey important concepts related Physics of welding and welding metallurgy associated with welding technology.
3. Provide a comprehensive overview of all common fusion (liquid state) and solid state welding processes, process parameters and automation trends in welding technology.
4. Provide an understanding of Welding process selection, codes, and specifications .
5. Provide an understanding of weld quality characterization and weld integrity and management of welding process by understanding welding defects, and testing techniques to assess the quality of welded joints.

Text

1. Cary, Modern Welding Technology, 4th Ed.
2. Supplementary Lecture Notes –Available on Web

References

1. ASM Handbook Volume 06: Welding, Brazing, and Soldering
2. Lancaster, The Metallurgy of Welding Brazing and Soldering
3. By G.M. Evans and N. Bailey Metallurgy of Basic Weld Metal
4. M. P. Groover, Fundamentals of Modern Manufacturing Materials, Processes, and Systems, John Wiley & Sons, Inc., 1999
5. Lindberg and Braton, Welding and Other Joining Processes, Ally & Bacon, Inc., Boston, 1976.
6. Flinn, Fundamentals of Metal Casting, Addison-Wesley, Reading, 1963.
7. Manufacturing Processes for Engineering Materials- by Serope Kalpakjian, 5th Edition, 2008.

Pre-requisite

Graduate standing or consent of the instructor

Course Outline

Course delivery will include lectures, workshops, case studies, tutorials and multimedia presentations covering the following areas:

1. Introduction Fusion Welding, welding terminology, welding symbols. (2 hours)
2. Common Industrial Welding Processes and Equipment: oxyacetylene welding, shielded metal arc welding, gas tungsten arc welding, flux cored arc welding, gas metal arc welding, submerged arc welding, resistance spot welding. Physics of Welding: the welding arc, electrical machinery and behavior, process control, cost estimation, heat flow and temperature distributions, weld metal phenomena, contractions and residual stresses. (10 hours)
3. Advanced Fusion Welding Processes: Plasma, Laser, EB, (3 hours)
4. Solid State Welding Processes: Ultrasonic, friction, and stir friction welding (2 hours)
5. Soldering and Brazing Processes and Equipment. (2 hours)
6. Automated Welding Systems (2 hours)
7. Metallurgy of welding of steels , cast irons, and nonferrous metals and alloys, to explain the effects of welding processes and conditions (including post-weld heat treating) on microstructure and properties; causes and prevention of defects and deficiencies which can occur in different alloys, including porosity, cracking, and embrittlement ; metallurgy of soldered and brazed joints. (10 hours)
8. Mechanical Properties of Weldments and Design of Welded Structures: static design concepts, fracture mechanics, fracture control concepts, fatigue of welds. (6 hours)
9. Weld Quality in welding fabrication; welding standards; welding procedure qualification; nondestructive examination methods for welds and brazed joints such as radiography, dye penetrant , magnetic particle, ultrasonic, and eddy current techniques. (4 hours)
10. Case Studies and 2 hours Exam (4 hours)

Course Grades

HWs/Take Home Exam	20 %
Midterm Exam	30 %
Project	20 %
Final Exam	30 %

Term Project

An in depth project report on a design or a research problem /topic related to Welding Processes & Metallurgy

One page proposal	4^{th} week
Final written report	14^{th} week
Oral presentation in class	15^{th} week

Course Outcomes

Students successfully completing the course should:
1. Will become familiar with all the common welding process
2. Will become familiar with all the common welding problems associated with welding ferrous

materials and aluminum alloys.
3. Will become aware of factors which control the cost of welding.
4. Will be exposed to industrial welding practices and problems by multimedia presentations showing video clips from welding industry.
5. Students will be exposed to the static and fatigue strength of weldments - through case studies of the failure of some welded structure at the conclusion of the course.
6. Topics such as plasma physics, heat flow, physical metallurgy, nondestructive testing, fracture mechanics, economics, industrial safety, physical chemistry, thermodynamics, and electrical circuits arise in the course will be understood in an integrated fashion in relevance to the course.
7. Will appreciate and become aware of difficulties in making a good weld and why weld defects occur as frequently as they do.

Prepared by:

Anwar Khalil Sheikh, November 2008

MSE 544 : Fundamentals of Heat Treatment

Course Descriptio	Steel Phases, phase transformation diagrams, microstructure-mechanical properties relations, steel heat treatment processes, tool steel heat treatments, processes equipment, nonferrous alloys treatments.
Objectives	1- Provide Fundamental scientific understanding of steels heat treatment 2- Provide basic knowledge of processes used for heat treatment processes 3- Provide students with basics of heat treatment of non ferrous alloys
Textbook	1) Krauss G., **Steel: Heat Treatment and Processing Principles**, Am. Soc. of Metals., 1990 2) Rpbert Wilson; **Metallurgy and Heat Treatment of Tool Steel,** McGraw-Hill, 1975.
References	Journal Articles
Pre/Co-Requisites by Topic	Graduate standing or consent of the instructor

Course Outline (1.15hr/class)

1) Steel Phases and structures .... 2 Classes
2) Pearlitr Ferrite, and Cementite………………………………………… 1 Classes
3) Martensite………………………………………………………………. 2 Class
4) TTT and CCT.. 2 Classes
5) Heat Treatment to produce Ferrite and Pearlite .... 2 Classes
6) Hardness and Hardenability .... 1 Classes
7) Tempering .... 2 Classes
8) Martempering and Austempering…………………………………………... 1 Classes
9) Thermomechanical Treatment .... 1 Classes
10) Surface Hardening and Modification ………………………………. 2 Classes
11) Stainless steel treatment……………………………………………………... 2 Class
12) HT of selected tool steels and applications 3 Class
13) Furnace Equipment and Protective atmosphere……………………………... 1Classes
14) Solution and Age-heat treatment for Al-Alloys …………………………… 2 Class
15) Super alloys heat treatment…... 2 Classes
16) Magnesium and Titanium Heat treatment 1 class
17) Testing ………………………………………………………………….. 1 class

Design Activities/Projects

Summaries journal articles on selected subjects on modern heat treatment processes and microstructure-properties relationship. Project on treatment of bulk or surface modification. A set of 3 labs will be conducted to demonstrate the different heat treatment methods a along with microstructure and mechanical properties testing.

Computer Usage

Assignments need simple computer programs such as excel or Lotus 1-2-3.

Course Description

1) Homework 10%
2) Midterm Test 30%
3) Class Project 25%
4) Final Exam 35%

Student Learning Outcome

1) To be able to identify different microstructure of steels
2) To be able design steel alloys depending on the steel microstructure-properties relationships
3) To be able to select and control the heat treatment process of heat treatment for steels and tool steels
4) To be able to select and control surface heat treatment of steels and tool steels
5) To know the used equipment for heat treatment processes
6) To identify the major processes for treating Non-ferrous alloys, i.e. Al-Alloys
7) learn industrial practices in controlling Metallic alloys microstructure

ABET Category

Engineering Science...... 2.0 Credits

Engineering Design....... 1.0 Credits

MSE 545: Non-Ferrous Extractive Metallurgy

Course Description

Physical and chemical principles involved in the extraction of non-ferrous metals. Principles of hydro-metallurgical processes; extraction of aluminum, copper, nickel, silver and gold. Refining processes of non-ferrous metals. Physical and chemical principles involved in the extraction of non-ferrous metals. Principles of hydro-metallurgical processes; extraction of aluminum, copper, nickel, silver and gold. Refining processes of non-ferrous metals.

Course Objectives

1) Provide a fundamental knowledge of non-extractive metallurgical principles to enable engineers to exploit the non-ferrous materials of the Kingdom.
2) Understand the fundamental principles of the processes in extraction of non-ferrous metals from their ores.

Textbooks

1) T. Rosenqist, Principles of Extractive Metallurgy, McGraw-Hill, 2003.
2) F. Habashi, Principles of Extractive Metallurgy, Vols. I and II, Gordon and Breach, 2001.

Pre-requisite

MSE 502

Course Outline

Importance of extractive metallurgy. A survey of methods used in extraction. The economic importance of non-ferrous extractive metallurgy.

A review of physical and chemical principles involved in the extraction of non-ferrous metals. Law of Mass Action. Factors affecting equilibrium, such as temperature, pressure and concentration. Review of concepts of heat and free energy changes in the extraction of metals.

Relationship between free energy and equilibrium constants, effect of pressure and temperature. Application of free energy-temperature diagrams to metal extraction.

Extraction of metals. Affinity of metals for carbon, oxygen, chloride and nitrogen.

Extraction of metals from sulphides, e.g., copper and tin. Transformation to sulphide or oxides. The process of reduction of oxides.

Extraction of metals from chlorides; reduction of chlorides with carbon and gas. Production of copper, tin, and aluminum from chloride.

Slags: metal-to-oxygen bonding forces, structure and properties of slags.

Smelting processes: types of smelting for copper and nickel; concentrate smelting.

Matte smelting; smelting of mixed molten sulfides. Continuous copper smelting.

Fire, vacuum, and zone refining of metals. Application to aluminum, copper and zinc.

Electrolytic refining; nickel, lead, and aluminum refining.

Leaching of copper and aluminum oxides.

Leaching of silver and gold.

Precipitation processes; extraction of copper, aluminum, silver, and gold.

Environmental considerations in extractive metallurgy, removal of contaminating compounds from gases, heat recovery and water cleaning.

Course Grades

HWs	20%
Midterm Exam	30%
Project	20%
Final Exam	30%

Course Outcomes

Students successfully completing the course should:

1) Identify the fundamental processes involved in extraction of non-ferrous metals from their ores.
2) Understand the thermodynamics principles involved in the extraction of non-ferrous metals from their ores.
3) Understand the principles of refining of metals, such as zone refining, and metal refining.
4) Understand the effect of extraction principles on the environment.

MSE 546: Materials Selection And Design

Course Description
Stage of product development, materials performance in service, economic of materials, material selection process, selection of materials for mechanical strength and other properties, design and selection of materials, failure prevention, case studies in design and selection of materials.

Course Objectives

This course will give students a systematic methodology for selecting materials and processes as the foundation for designing with materials, and provide structured case studies in which this methodology is used.

Pre-requisites

Graduate standing or consent of the instructor

Text
Materials Selection in Mechanical Design, M.F. Ashby, 3rd Ed., Elsevier Butterworth-Heinemann, New York, 2005.

Reference
Materials: Engineering, science, processing and Design, M. F. Ashby, H. Shercliff and D. Cebon, Elsevier Butterworh-Heinemann, New York, 2007.

Other Essential Resources

Cambridge Engineering Selector Software, v. 4.x, and associated databases and materials selection tools
Granta Design, Ltd. website: http://www.grantadesign.com/
CES In Depth, an online book accessible through CES 4.x.

Course Outline

Part 1 (4 lectures)
Materials in design
The evolution of engineering materials
The design process
Types of design
Design tools and materials data
Function, material, shape and process
Case study

Part 2 (13 lectures)
Classes of engineering materials
Definition of materials properties
Displaying material properties using materials selection charts
Deriving property limits and material indicies
Structural indices
Selection of material and shape
Shape factors
Efficiency of standard sections
Material limits for shape factors
Material indices which include shape
The microscopic or microstructural shape factor
Co-selecting material and shape
Materials processing and design processes and their influence on design
Process attributes
Systematic process selection
Process selection diagrams
Process cost
Case studies

Part 3 (8 lectures)
Multiple constraints and compound objectives
Application of property limits and indices
The method of weight factors
Methods employing fuzzy logic
Systematic methods for multiple constraints
Compound objectives, exchange constants and value functions
Case studie

Part 4 (3 lectures)
Forces for change in materials selection and design
Materials and the environment
Natural materials

Course Grades

HWs	10%
Project	30%
Midterm Exam	30%
Final Exam	30%

Term Project

Students are required to work on an independent project related to the course material. A project proposal is due after the first six weeks of the course, and a final report in the form of a short technical paper is due one week before the end of the semester.

Course Outcomes

1- Students will learn the breadth of engineering materials, their properties and means for processing them, and the principles of engineering design.

2- Students will learn a software-based methodology for selecting materials, shapes and processes to meet application needs.

3- Students will examine methodologies for coping with constrains and conflicting objectives in materials selection in design.

4- This course prepares students for graduate research and employment in the area of materials and engineering design.

MSE 547: Finite Element Analysis In Material Science & Engineering

Course Description

Introduction to Finite Element Analysis; Finite Element Formulation; Linear and Non-linear FEA; Modeling of Materials (Metal and Non-Metals) for Structural, Thermal including phase change, Fluids, and Electromagnetic analysis; Practical applications in component design and materials processing; Future developments.

Course Objective

1. To provide students with a fundamental understanding of FEA concepts.
2. To provide students with fundamental understanding of the strengths and limitations of FEA in the context of real materials-related problems.
3. To illustrate how FEM can be used to solve practical problems related to different areas of engineering involving mechanical and thermodynamic properties, phase transformations, microstructure evolution during processing.
4. To introduce some advanced topics and features

Course Learning Outcomes

After the successful completion of the course, the students will be able to
1. Formulate a finite element problem from "real world" materials.
2. Identify the constitutive equations and assumptions that drive the system.
3. Model the systems from various types of materials in a manner amenable to FE solution techniques.
4. Determine appropriate system constraints and boundary conditions.
5. Utilize a commercial finite element package
6. Discuss the validity and accuracy of the results of a FE analysis.

Text & References

1) **Textbook:**
2)

Reference:

- S. Moaveni, Finite Element Analysis. 3rd Edition, Prentice Hall, Upper Saddle River, New Jersey, 2007.
- Logan, Daryl L.: **A First Course in the Finite element Method**, 3rd Edition, Thomas Learning Publishing, 2001.
- R.H. Wagoner, J.-L. Chenot : **Metal Forming Analysis**,
- Cambridge University Press, 2001,
- Bathe, K. **Finite Element Procedures**, Prectice Hall, 1996.
- Belytschko, T., Lu, W.K., Moran, B. **Nonlinear Finite Elements for Continua and Structures**, John Wiley, 2000.
- Instructor's Notes

Pre-requisite

Graduate standing or consent of the instructor

Course Outline

	Topic	**# of Classes (Wks)**
1	**Finite Element Method: Introduction and Theory** *Engineering problems, numerical methods, basic steps in the FEM, direct formulation, minimum total potential energy formulation.*	4 (2)
2	**Linear Structural Analysis using a Commercial FEA Software** *The software environment, graphical user interface (GUI), pre-and post-processors, element types, model and mesh generation.*	3 (1 1/2)
3	**Introduction Nonlinear Finite Element Method**	3 (1 1/2)
4	**Material Models for FE Structural Analysis** *Material model interface for mechanical properties, non-linear elastic materials, orthotropy, hyper elasticity, viscoelasticity, Rate-independent plasticity, Rate-depended plasticity, Gasket material, Shape memory-alloy material.*	6 (3)
5	**Material Models for FE Thermal Analysis** *Material model interface for thermal properties, conductivity, specific heat, enthalpy, emissivity, convection or film coef, heat generation rate.*	4 (2)
6	**Material Models for FE Fluids Analysis** *Material model interface for CFD properties, viscosity, emissivity, density, conductivity, specific heat.*	2 (1)
7	**Material Models for FE Electromagnetic Analysis** *Material model interface for electromagnetic properties, relative permeability and permittivity, resistivity, coercive force.*	2 (1)
8	Material Curve Fitting	1 (1/2)
9	Composite Materials Modeling	3 (1 1/2)
10	Advanced Topics	2 (1)

Course Grades

HWs	20%
Midterm Exam	30%
Project	20%
Final Exam	30%

Term Project:

A problem in structure, defects or dislocations; may be related to the research area of the student.

One page proposal	7th week
Final written report	14th week
Oral presentation in class	15th week

ME 575 –Advanced Corrosion

Course Description

The main objective of this course is to provide students with a strong foundation in electrochemical thermodynamics and electrode kietics governing corrosion processes. The course emphsises basic concepts of electrochemical processes that occur at the metal/electrolyte interface. Various forms of localized corrosion and environment-assisted cracking are discussed for susceptible engineering alloys. Students will be assigned labarotary assignments to emphasis basic corrosion measurements.

Course Objectives

The main objectives of the course are:

1. To provide the basic principles governing corrosion of metals and alloys.
2. To introduce the students to electrochemical thermodynamics to predict corrosion tendency.
3. To introduce the students to electrode kinetics to predict corrosion rates.
4. To introduce various aspects of localized corrosion and environment-assisted cracking of metals and alloys.

Textbook

Corrosion of Metals: physicochemical principles and current problems, H. Kasche, Springer, 2003.

References

1. Principles of corrosion and prevention, D.A. Jones.
2. Corrosion mechanisms, edited by F. Mansfield
3. Corrosion: Metal, environment reactions, by L.L. Shreir

Pre-requisite

Graduate standing or consent of the instructor

Course Outline

Topic	# classes
Thermodynamics of corrosion	4
Electrolytic mechanism of corrosion	4
Kinetics of electrode reactions	4
Corrosion of homogeneous alloys	2
Rusting of Iron and Steels	2
Passivity	2
Galvanic corrosion	2

Pitting corrosion	2
Crevice corrosion	2
Stress corrosion cracking	3
Hydrogen embrittlement	3
Total	30

Grading

HW 15%
Term Project 15%
1st Major Exam 20%
2nd Major Exam 20%
Final 30%

Curse Outcomes

Upon successful completion of this course, students should be able to:

1. Predict corrosion tendency using thermodynamic principles.
2. Apply electrode kinetics for basic corrosion principles.
3. Applying thermodynamics and electrode kinetics to understand basic forms of coercions.

Understand the basic mechanisms in localized corrosion and environment-assisted cracking of engineering alloys.

ME 578: Mechanical Properties of Engineering Polymers

Course Description

The course material will cover the following subjects: 1) general introduction to polymers and their applications; 2) types of mechanical behavior; 3) Hookean and rubber elasticity; 4) plastic deformation; 5) fracture; 6) linear viscoelasticity; 7) dynamic mechanical behavior and testing; 8) loss tangent; 9) experimental methods; 10) mechanical properties of polymeric composites.

Course Objectives

1) To broaden the knowledge of students about polymers, their applications, and their mechanical properties.

To introduce the concept of linear viscolelasticity to students.

To teach students the yield and fracture behavior of polymers.

To teach students the behavior of polymer composites.

Text

An Introduction to the Mechanical Properties of Solid Polymers, by I.M. Ward and D.W. Hadley. John Wiley: New York, 1998.

References

1) *Principles of Polymer Engineering*, N. G. McCrum, C.P. Buckley; and C.B. Bucknall, Oxford Science Publications, 2nd Ed., 1999.

Mechanical Properties of Solid Polymers, by I.M. Ward. John Wiley: New York, 1985.

Pre-requisite

Graduate standing or consent of the instructor

Course Outline

Introduction to polymeric materials: Structure of polymers (4 lectures)
The deformation of an elastic solid (2 lectures)
Rubber-like elasticity (5 lectures)
Principles of linear viscoelasticity (6 lectures)
The measurement of viscoelastic behavior (4 lectures)
Anisotropic mechanical behavior (6 lectures)
Relaxation transitions (4 lectures)
Yield and fracture behavior of polymers (6 lectures)
Polymer Composites: Macro- and Micro-scale (8 lectures)

Course Grades:

Regular Assignments: 10%
Major Exam I: 25%
Major Exam II: 30%
Final Exam: 35%

Course Outcomes

Students successfully completing the course should:

1) have fundamental knowledge of mechanical properties of polymers;

have good understanding of the viscoelastic behavior of polymers;

have developed a comprehensive knowledge about polymeric composites.

ME 579 – Advanced Mechanical Behavior of Materials

Course Description

Description of stress, strain, strain rate and elastic properties of materials. Fundamental aspects of crystal plasticity. Theory and characteristics of dislocations. Strengthening mechanisms at low temperature. Deformation at elevated temperatures and deformation maps. Emphasizing the relationships between microscopic mechanisms and macroscopic behavior of materials.

Course Objectives

The main objective of this course is to examine elastic and plastic deformation, microstructural mechanisms that are responsible for deformation and strengthening mechanisms, and high temperature deformation, fatigue and fracture mechanisms of materials. Special emphasis will be given to the microstructure-mechanical properties relationships.

5. To provide the basic principles governing structure-mechanical property relationships.
6. To introduce the students to the fundamentals of elastic deformation and elastic properties.
7. To introduce the theory of dislocations.
8. To introduce the fundamentals of plastic deformation and strength properties with emphasis on strengthening mechanisms in metallic alloys.
9. To describe the basic concepts in creep, fatigue, and fracture.

TextBook

1. Mechanical Behavior of Materials, M. A. Meyers and K. K. Chawla, Mechanical Behavior of Materials, Prentice-Hall, 1999.

References

4. Mechanical Behavior of Materials, T. H. Courtney, 2nd Ed., McGraw Hill, 2000.
5. Deformation and Fracture Mechanics of Engineering Materials, R. W. Hertzberg, 4th Ed., John Wiley & Sons, Inc., 1996.
6. Mechanical Metallurgy, G.E.Deter, 3rd Ed, McGraw-Hill, 1988.
7. Mechanical Behavior of Materials, W. F. Hosford, Chapman, 2005.
8. Mechanical Behavior of Materials, K. Bowman, Chapman, 2004.
9. The Plastic Deformation of Metals, R.W.K. Honeycombe, 2nd Ed, Arnold,1985.

Pre-requisite

Graduate standing or consent of the instructor

Course Outline

Topic	# classes
Elasticity and Viscoelasticity	3

Plasticity	3
Point and Line defects	4
Interfacial and Volumetric defects	2
Geometry of deformation and Work Hardening	3
Strengthening Mechanisms	4
Creep and Superplasticity	3
Fracture Mechanics	2
Microscopic aspects of fracture	3
Fatigue	3
Total	30

Grading

HW 15%
Term Paper 10%
1st Major Exam 20%
2nd Major Exam 20%
Final 35%

Curse Outcomes

4. Understand elastic and plastic properties of the different classes of materials.
5. Predict strengthening mechanisms in engineering alloys.
6. Realizing the different mechanical modes of failure of materials.
7. Correlate microstructure to deformation behavior of engineering materials.

Syllabus prepared by Dr. Zuhair Gasem (Nov/2008).

ME 583: Fatigue and Fracture of Engineering Materials

Course Description: Stress/Strain controlled Fatigue-Life prediction laws. Continuum fracture mechanics. Fracture modes. Fracture mechanics and microscopic plastic deformation/fracture mechanics combined approach. Cleavage, ductile fracture, fatigue, creep-fatigue and environmental cracking phenomena.

Course Objective:
The course aims to provide a comprehensive understanding of the fatigue process including the tools necessary for quantifying fatigue damage and estimating fatigue life in both safe-life and fail-safe approaches. The course aims also at teaching the students the principals of fracture mechanics in monotonic and cyclic loading conditions using energy and stress intensity approaches. It will help provide an understanding of the fatigue fracture mechanisms to help answer the following questions: why does fatigue occur? How does fatigue damage develop? and how to control fatigue failures?

References:
1. Fatigue of Materials, S. Suresh, Cambridge University Press, 2nd Ed., 1998.
2. Fracture Mechanics: Fundamentals and Applications, T.L. Anderson, CRC Press, 2nd Ed., 1995.
3. Mechanical Behavior of Materials, N. E. Dowling, Prentice Hall, 2nd Edition, 1999.
4. Deformation and Fracture Mechanics of Engineering Materials, R.W. Hertzberg, Wiley, 4th Ed., 1996.
5. Principles of Fracture Mechanics, R. J. Sanford, Pearson Education, Inc., 2003.

Pre-requisites:
Graduate standing or consent of the instructor

Tentative Topics	No of Lectures
1. **Introduction to fatigue and Fracture**	1
2. **Stress Analysis and Elements of Elasticity**	2
3. **Stress-Based Approach to Fatigue**	5-6
a. Fatigue testing	
b. Fatigue failure process	
c. S-N curve for metals and non-metals	
d. Mean stress effect	
e. Notch effects	
f. Multiaxial stresses	
g. Variable amplitude loading	
4. **Strain-Based Approach to Fatigue**	3-4
a. Elastic-Plastic stress-strain response under cyclic loading	
b. Strain-life approach	
c. Mean Stress effect	
d. Stress concentration	
e. Multiaxaial stress effects	
5. **Fracture mechanics**	4-5

    a. Energy approach
    b. Crack tip stress field approach
    c. Plasticity effect
    d. Fracture toughness
6. **Fatigue Crack Growth** 5-6
    a. Crack growth characterization
    b. Mean stress effects
    c. Crack retardation
    d. Life estimation
    e. High temperature FCG
    f. Environment assisted crack growth
7. **Mechanisms** 5-6
    a. Cyclic deformation
    b. Cyclic Hardening and softening
    c. Ductile fracture by void initiation and growth
    d. Cleavage fracture
    e. Intergranular fracture
    f. Microscopic stages of fatigue crack growth
    g. Different regimes of fatigue crack growth
8. **Fatigue failure control** 2-3

Computer Usage:

Students will be introduced to the finite element analysis of cracked bodies using ANSYS Code. ANSYS Program will be used in realizing some of the term projects.

Projects:

Term projects related to fatigue fracture of components and structures.

Course Grades:

Homework	10%
Project	20%
Quizzes	15%
Mid-Term	25%
Final	30%
Total	**100**

ME 585: ADVANCED PHYSICAL METALLURGY

Course Description

Review of structure of metals, analytical methods, dislocation and plastic deformations, diffusion, solidification of metals, nucleation and growth kinetics, phase diagrams, thermally activated plastic deformations, fracture and fracture mechanics.

Course Objectives

To introduce students to advanced crystallography of metallic, polymeric and ceramic materials.
To introduce students to advanced concepts in dislocation theory and plastic deformation and its application in strengthening
To introduce students to advanced topics in diffusion and phase transformation
To introduce advanced students to binary and ternary phase diagrams.
To provide advanced understanding of thermally activated plastic deformation

Text

Reed-Hil and Abbachian, Physical Metallurgy Principles, 3rd edition, 1992, PWS-KENT

References

1. D. A. Porter and K. E. Easterling, *Phase Transformations in Metals and Alloys,* 2nd Edition, Nelson Thornes, 2001

2. Instructors notes/web based search

Pre-requisite

Graduate standing or consent of the instructor

Course Cotents

1. Atomic Structure and Bonding of Atoms.
2. Crystallography and X-ray diffraction,
3. Advanced Treatment of the Thermodynamic properties of Metallurgical Systems
4. Dislocation theory and plastic deformation
5. Binary and Ternary Phase Equilibria.
6. Solidification of metals.
7. Techniques of Optical and Electron metallography, Observations of Dislocations.
8. Deformation Phenomenon, Stress and strain tensors, Yield Behavior in Metals and Alloys.
9. Theories of work hardening in metals.

10. Temperature and strain rate, dependence of flow stress, Fatigue, Creep and Fracture toughness Testing

11. **Course Grades**

HWs	20%
Midterm Exam	30%
Project	20%
Final Exam	30%

Term Project:

A problem in physical metallurgy; may be related to the research area of the student.

One page proposal	5th week
Final written report	14th week
Oral presentation in class	15th week

Course Outcomes

Students successfully completing the course should:

2) have the fundamental understanding of the crystallography
3) have the advanced understanding of interrelationships between dislocation and plastic deformation
4) have the advanced understanding of the binary and ternary phase diagrams.
5) have the advanced understanding of rate processes in solid state transformations

have advanced understanding of thermally activated plastic deformation and farcture

CE 630: Damage Mechanics

Course Description

Phenomenological aspects of damage; manifestation of damage and measurement and mechanical representation of damage; thermodynamics and micromechanics of damage; potential dissipation function and strain-damage coupled constitutive equations; damage evolution equations; brittle versus ductile damage; anisotropic damage of concrete; fatigue damage; local and average damage; scale effect and characteristic length; elasto-plastic damage of concrete structures; finite element modeling of damage.

Course Objectives

Damage mechanics is the study of material damage based on the introduction of damage variables and their evolution under the applied loading conditions.
This course will give students an appreciation of the phenomenology of damage in structures, its measurement, and its proper modeling in constitutive equations. Through the presentation of some case studies, it will also help students learn how to apply powerful techniques to the solution of practical problems in engineering

Textbook

A course on damage mechanics, J. Lemaitre, Springer, Berlin, Germany, 1996.

Reference

Notes/Handouts: provided via internet and hardcopy.

Pre-requisites

Graduate standing or consent of the instructor

Course Outline

Part 1 (5 lectures)

- Phenomenological aspects of damage
- Manifestation of damage
- Measurement of damage
- Mechanical representation of damage

Part 2 (8 lectures)

- Thermodynamics and micromechanics of damage
- Potential dissipation function
- Strain-damage coupled constitutive equations
- Damage evolution equations

Part 3 (15 lectures)

- Brittle versus ductile damage
- Anisotropic damage of concrete

- Fatigue damage
- Local and average damage
- Scale effect and characteristic length
- Elasto-plastic damage of concrete structures
- Methods for predicting crack initiation
- Finite element modeling of damage
- Case studies

Computer Requirements

Students will need access to MatLab or similar, and potentially to a finite element code (if a student decides to use this for the project, but not required).

Course Grades

HWs	10%
Project	30%
Midterm Exam	30%
Final Exam	30%

Term Project

Students are required to work on an independent project related to the course material. A project proposal is due after the first six weeks of the course, and a final report in the form of a short technical paper is due one week before the end of the semester.

6) Course Outcomes

1. Students will learn the basics of material damage as the gradual process of mechanical deterioration that ultimately results in component failure
2. Students will examine methodologies for coping with damage in structural analysis by the introduction of damage variables and their evolution under the applied loading conditions.
3. Students will learn through case studies and a practical project the experimental, theoretical and numerical aspects of damage in materials and structures.
4. This course prepares students for graduate research and employment in the area of mechanics of materials and computational mechanics..

ME 675: PHASE TRANSFORMATION IN METALS

Course Description

Examines the thermodynamics and fundamentals of rate processes in metals. Phenomenological and atomistic points of view are considered. Kinetics of liquid-solid, solid-solid transformations and transport of matter in solids are discussed.

Course Objective

To the student, this course will:

- provide important principles of phase transformation
- provide general laws of phase transformation
- provide understanding of kinetics, mechanisms and microstructure of solid state transformation in metals and alloys
- develop the ability to carry out research involving phase transformation in solids.

Text

D. A. Porter and K. E. Easterling, *Phase Transformations in Metals and Alloys,* 2nd Edition, Nelson Thornes, 2001

References

7) Thermodynamics in Materials Science, R. T. DeHoff, CRC, 2006.
8) Instructors notes/web based search

Pre-requisite

Graduate standing or consent of the instructor

Course Cotents

12. Thermodynamics and kinetics of alloys: binary and ternary systems; kinetics of transformation.
    2. Diffusion: interstitial and substitutional diffusion, the relationship between macroscopic diffusion and atomic mechanisms; mass transfer in porous materials and other transport phenomena.
    3. Interfaces and surfaces: structures and properties of surfaces, grain boundaries and interphase interfaces; the effect of interfaces on transformation.
    4. Solidification and melting: casting; welding technology; continuous casting.
    5. Diffusional transformation: general theory of nucleation and growth; important phase transformations such as precipitate, massive, spinodal, ordering transformation etc; transformation of steels.
    6. Diffusionless transformations: the crystallography and kinetics of nucleation and growth of Martensite transformation; shape memory materials.

Course Grades

HWs 20%

Midterm Exam	30%
Project	20%
Final Exam	30%

Term Project:

A problem in phase transformation in metals; may be related to the research area of the student.

One page proposal	5th week
Final written report	14th week
Oral presentation in class	15th week

Course Outcomes

Students successfully completing the course should:

9) have the fundamental and quantitative understanding of the thermodynamics and kinetics of phase transformation in solids.
10) have the basic understanding of interrelationships between structural imperfections (point, line and surface) and the atomistic transport processes that control the evolution of material microstructure.
11) be prepared to apply basic elements of alloy thermodynamics and reaction kinetics to develop quantitative analyses of phase transformations in materials processing.