# Appendix A – Course Syllabi

**MET Required Courses**

- MET 220
- MET 220L
- MET 231
- MET 232
- MET 310
- MET 310L
- MET 320
- MET 321/L
- MET 330
- MET 330L
- MET 332
- MET 351
- MET 352
- MET 422
- MET 433
- MET 440
- MET 440L
- MET 464
- MET 465

**MET Electives**

- MET 110
- MET 426
- MET 430/L
- MET 432‡
- MET 443†
- MET 445
- MET 450
- MES 475
- MET 489
- MET 491*

**Other Required Engineering**

- EE 301/L
- EM 214
- ME 216
- EM 321
- IENG 301

**Support Courses**

- CHEM 112
- CHEM 112L
- CHEM 114
- CHEM 114L
- ENGL 101
- ENGL 279
- ENGL 289
- MATH 123
- MATH 125
- MATH 225
- MATH 321
- MATH 373
- PHYS 211
- PHYS 213

† After 2010 MET 443 was replaced by the 2-credit hour Advances in Processing and Nanoengineering of Polymers (MES 475) and the 1-credit hour Composites Manufacturing (MET 489)

* Beginning in 2015-16, MET 491 was renumbered as Security Printing Technology (MET 444/544)

‡ New course Spring 2016

## MET 220 – MINERAL PROCESSING AND RESOURCE RECOVERY: (3-0)/3

### INSTRUCTOR
Dr. J. J. Kellar, MI 112, Ph. (605) 394-2343, jon.kellar@sdsmt.edu

### TEXTBOOK
Mineral Processing and Resource Recovery (online text), Ken Han and Jon Kellar, 2008

### COURSE INFORMATION
**Catalog Description:** An introductory course in mineral processing highlighting unit operations involving comminution, sizing, froth flotation, gravity separation, electrostatic separation, magnetic separation and flocculation. Other topics discussed include remediation of contaminant effluents and the unit operations associated with recycling of post-consumer materials using mineral processing techniques.
**Prerequisites:** MATH 123, CHEM 112
**Co-requisites:** none
**Required Course:** B.S. Metallurgical Engineering ("C" or better), B.S. Mining Engineering
**Selected Elective:** none

### COURSE GOALS
**Specific Outcomes**
- Given system mass flows, grades and recoveries the student will be able to complete a system mass balance.
- The student will be able to calculate a material's specific surface area given particle size and density information.
- Given sieve data the student will be able to construct a Gaudin-Schumann plot and determine size and distribution moduli.
- Given particle size and density the student will be able to determine whether the particle settles according to Stokesian conditions, and the particle settling velocity regardless of particle diameter (Han approach)
- For a given particle type the student will be able to determine the optimal surface treatment and solution conditions to cause desired particle wettability.
- Given particle size and density the student will be able to utilize gravity-based methods to cause particle separation and concentration.
- The student will be able to predict particle separation based upon the magnetic and electrostatic properties for a given particle mixture.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (b), (c), (e), (k)

### TOPICS
Abundance of the elements, and resources (1 class); Mass balances, grade, recovery (3 classes); Particle characterization, particle diameter, specific surface area, density, particle sizing (4 classes); Comminution: crushing, grinding, general crushing and grinding flowsheets, Bond Theory, critical speed, Gaudin-Schuhmann Distribution, Tyler sieve series, circulating load (4 classes); Movement of solids in fluids, Stokesian settling, Newtonian settling, free and hindered settling (5 classes); Classification devices, mechanical classifiers, elutriators, hydrocyclones (4 classes); Froth flotation, contact angle, flowsheets, surface charge, electrical double layer,

hydrophobicity/hydrophilicity, adsorption-physisorption, chemisorption, frothers, oxide, sulfide, coal flotation de-inking of paper (5 classes); Gravity concentration concentration criterion sluice-particle stratification jig-consolidation trickling cones, spirals, shaking table (5 classes); Heavy media separation (2 classes); partition coefficient, Tromp curve; Magnetic separation (2 classes); magnetic susceptibility, MSW separation and recovery-USBM process , Electrostatic separation (2 classes); automobile recycling Thickening (2 classes); flocculants Shultz-Hardy Rule

**PREPARED BY**

J.J. Kellar, March 12, 2016

## MET 220L – MINERAL PROCESSING AND RESOURCE RECOVERY LABORATORY: (0-1)/1

**INSTRUCTOR** Dr. J. J. Kellar, MI 112, Ph. (605) 394-2343, jon.kellar@sdsmt.edu

**TEXTBOOK** Mineral Processing and Resource Recovery (online text), Ken Han and Jon Kellar, 2008

### COURSE INFORMATION

**CATALOG DESCRIPTION**: An introductory laboratory course in mineral processing highlighting relevant unit operations.
**Prerequisite:** none
**Pre-** or **Co-requisites:** MET 220
**Required Elective**: B.S. Metallurgical Engineering
**Selected Elective:** none

### COURSE GOALS

The objective of this course is to provide students with the working knowledge of a variety of mineral processing equipment, formulas and concepts. Students will be able to better understand the chemical and physical processes on particle liberation, separation and concentration. Upon completion of the course the students will be able to apply this knowledge in design and in subsequent upper-level courses.

**Specific Outcomes**

- The student will be able to perform a simple mass balance, and calculate grade and recovery for basic mineral processing unit operations.
- The student will be able to comminute mineral samples and generate sieve data for a Gaudin-Schuhmann size distribution plot. From the Gaudin-Schuhmann diagram the student will be able to determine the size and distribution modulus for the system.
- The student will be able to correctly sample ore samples of various sizes and composition.
- The student will be able to determine particle shape and show how shape effects surface area and mineral processing unit operations.
- The student will be able to compare particle size measurements from a variety of measurement techniques and statistically examine this comparison.
- The student will understand the trade-offs associated with maximizing grade and recovery while minimizing costs.
- The student will be able to perform bench-scale flotation tests and understand the connection between comminution, adsorption, hydrophobic character and flotation response.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (b), (d), (g), (k)

### TOPICS

- History of mineral processing and metallurgy
- Mass balances
- Comminution
- Sampling

- Particle characterization
- Movement of solids in fluids
- Froth flotation
- Gravity concentration
- Magnetic separation
- Basic statistics

**PREPARED BY**

J.J. Kellar, March 12, 2016

## MET 231 - STUCTURE AND PROPERTIES OF MATERIALS LABORATORY: (0-1)/1

### INSTRUCTOR
Dr. Michael West, MI 108, (605) 394-1283, Michael.West@sdsmt.edu

### TEXT BOOK
No textbook required.

### COURSE INFORMATION
**Catalog Description:** A laboratory involving quantitative metallography, heat treating practice, mechanical property measurements and metallurgical design of the thermal mechanical treatment of metals
**Prerequisite:** none
**Pre- or Co-requisite:** MET 232
**Required Elective**: B.S. Metallurgical Engineering, B.S. Mechanical Engineering
**Selected Elective:** none

### COURSE GOALS
The objective of this laboratory program is to relate the properties of engineering materials to the materials microstructure developed during thermal and mechanical processing. Students will become familiar with mechanical testing and metallurgical evaluation of materials according to ASTM standards. Students will gain an understanding of the variability of material properties. Finally, students will also practice writing technical reports that detail experimental findings. The laboratory exercises in MET 231 are timed to follow or coincide with lecture content in MET 232.

**Specific Outcomes**

- Students will be able to use ASTM standard index and look up appropriate standards for materials testing.
- Given a metallographic specimen, students will be able to measure grain size using ASTM methods.
- Students will be able to conduct a Rockwell hardness test on a metal sample using appropriate scales.
- Students will understand the effects of carburizing and decarburizing on the microhardness of steel.
- Students will be able to take tensile test data and generate an appropriate stress-strain curve.
- Students will be able to interpret important mechanical properties from a stress strain curve for a metal.
- Students will be able to conduct a Charpy impact test and use the data to determine the ductile to brittle transition temperature for a metal.
- Given a metallographic specimen of steel, students will be able to estimate the carbon content.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (b), (d), (g), (k)

**TOPICS**

- Statistics
- ASTM Standards
- Hardness Testing
- Microhardness Testing
- Charpy Impact Testing
- Tensile Testing
- Strain Gages
- Optical Metallography
- Scanning Electron Microscopy
- Thermomechanical (Jominy) Testing
- Laboratory report writing

**PREPARED BY**

Michael West, March 27, 2016

## MET 232 - PROPERTIES OF MATERIALS: (3-0)/3

### INSTRUCTOR

Dr. Michael. West, MI 108, Ph. (605) 394-1283, michael.west@sdsmt.edu

**TEXTBOOK:** Materials Science and Engineering: An Introduction, 8th Ed, W. D. Callister, Jr., and D. G. Rethwisch, 2010

### COURSE INFORMATION

**Catalog Description**: A course in engineering materials and their applications. The different technological uses of metals, ceramics, plastics, and composite materials are discussed and explained in terms of their basic atomic structure, and mechanical, thermal, optical, electrical, and magnetic properties. Material selection in engineering design is emphasized.

**Prerequisites:** MATH 123 and CHEM 112

**Co-requisites:** none

**Required Elective**: B.S. Metallurgical Engineering, B.S. Mechanical Engineering

**Selected Elective:** B.S. Chemical Engineering

### COURSE GOALS

**Specific Outcomes**

- Given electronegativity data the student will understand the basics of atomic bonding and the resulting structure of crystalline solids.
- Given a specific type of defect the student will know and be able to identify the role the imperfection imparts in the development of mechanical and physical properties of materials.
- Given systems time, temperature data students will be able to perform using mass transport in solids as it pertains to design of alloys and the carburization of steels.
- Given basic input data such as stress and strain students will be able to determine the mechanical properties of materials, and apply these material properties in the design system components.
- Given an image of a fractured specimen the student will be able to identify ductile, brittle, fatigue and high strain rate fractures.
- Given binary phase information the student will be able to predict equilibrium and non-equilibrium structures.
- Given hardenability data for steel and a specified heat treatment schedule, the student will be able to predict if the material meets minimum strength requirements.

**Student Outcomes Addressed:** Major: (a), (b), (c), (e), (g), (h), (i), (j) (k)

### TOPICS

- Metal Structures
- Imperfections in Solids
- Solid State Diffusion
- Mechanical Behavior of Metals
- Strengthening Mechanisms
- Phase diagrams
- Kinetics of Phase Transformations
- Iron Carbon Alloys
- Properties/Microstructure
- Nonferrous metals Alloys
- Properties/Microstructure

**PREPARED BY**

Michael West, March 27, 2016

## MET 310 – AQUEOUS EXTRACTION, CONCENTRATION AND RECYCLING: (3-0)/3

### INSTRUCTOR
Dr. William M. Cross, MI 110, (605) 394-2485, William.Cross@sdsmt.edu

### TEXT BOOK
Fundamentals of Aqueous Metallurgy, K. N. Han, SME, p. 212, 2002

### COURSE INFORMATION
**Catalog Description:** Scientific and engineering principles involved in the winning of metals from ores and scrap. Areas covered include the unit operations of comminution, sizing, solid/liquid separations, leaching, ion exchange, solvent extraction, and surface phenomena as related to flocculation, froth floatation, and electrostatic separation.

**Prerequisites:** MET 320 or CBE 321, or CHEM 342
**Co-requisites:** none
**Required Course:** B.S. Metallurgical Engineering
**Selected Elective:** B.S. Chemical Engineering

### COURSE GOALS
**Specific Outcomes**

- The student will be able to understand the meaning of surface tension and apply this concept to various practical processes.
- The student will be able to understand how solids obtain the surface charges and understand the significance of the surface potential, potential determining ion, Stern potential and zeta-potential in relation to practical applications.
- The student will be able to estimate the adsorption density from the adsorption isotherm and comprehend the role of the surface charge and other adsorption driving forces on the adsorption density and be able to apply in practices.
- The student will be able to distinguish the major differences between sulfide and oxide froth flotation.
- The student will be able to correctly balance half-cell reactions.
- The student will be able to calculate the equilibrium activities of products for hydrometallurgical systems.
- The student will be able to make and utilize Pourbaix diagrams to understand equilibrium leaching and environmental phenomena.
- The student will be able to formulate and suggest tests to confirm the rate expression for given concentrations of reactants and products as a function of time.
- The student will able to understand and apply the effect of temperature on the rate of reaction.
- The student will be able to understand the solvent extraction/ion exchange mechanisms and the selectivity relationship between the elements to be separated.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (b), (e), (f), (g), (h), (i), (j), (k)

### TOPICS
- Mineral Particle Size, Shape and Size Distributions
- Liberation of Valuable Mineral, Liberation Models, Measuring Liberation

- Hydrometallurgy; Activity Coefficients, Solubility Calculations, Metal Complexation, Effect of Temp and Pressure on Equilibrium, Pourbaix Diagrams, Leachants, Leaching Techniques
- Leaching Kinetics: Kinetic Expression, Data Analysis, Temperature Effect on Leaching Kinetics.
- Removal of Metal Ions from Leach Liquor: Solvent Extraction, Electrowinning, Ion Exchange
- Interfacial Phenomena: Surface Tension, Wetting Phenomena, Spreading, Theoretical Aspects of Adsorption, Gibbs Adsorption Equation.
- Origin of Charges, Electrical Double Layer, Gouy Model, Stern and Grahame Approach, Electrokinetics: Zeta and Streaming Potentials, Electrokinetics, Flotation of Oxides and Sulfides.

**PREPARED BY**
William M. Cross, February 24, 2016

## MET 310L - AQUEOUS EXTRACTION, CONCENTRATION AND RECYCLING LABORATORY (0-1)/1

### INSTRUCTOR
Dr. M.S. Safarzadeh, MI 103, ph. (605) 394-1284, sadegh.safarzadeh@sdsmt.edu

### TEXTBOOK
Hydrometallurgy: Fundamentals and Applications, 1st Ed., Michael Free

### COURSE INFORMATION
**Catalog Description**: Laboratory experiments in design of processing equipment and cost estimation, zeta potential, surface tension, leaching kinetics, electrowinning, and solvent extraction.
**Prerequisite:** none
**Pre- or Co-requisite:** MET 310
**Required Course:** B.S. Metallurgical Engineering
**Selected Elective:** B.S. Chemical Engineering

### COURSE GOALS
**Specific Outcomes**
- The student will be able to apply statistical design and analysis of experiments to optimize a process.
- The student will able to design a set of leaching process experiments which can be analyzed statistically to optimize the process response surface.
- The student will be able to measure surface tension of liquids contact angle of water with and without surfactants to identify a set of experimental parameters to optimize grade, recovery or their combination for a flotation system.
- The student will be able to calculate the Gibbs free energy of adsorption of metal ions on solid surface and examine the effect of charge of solids on the adsorption density of these ions.
- The student will be able to understand important parameters affecting the leaching of metals and calculate the activation energy.
- The student will be able to understand the principles of solvent extraction, cementation, ion exchange and solution precipitation.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (b), (c), (d), (g), (k)

### TOPICS
Experimental Design, Process Design, Leach Kinetics, Leaching Equilibrium, Recovery of Metal Ions from Solution, Adsorption and Precipitation of Metal Ions, Contact Angle Measurements, Surface Tension Measurements, Cementation, STABCAL solution chemistry software, Atomic Absorption Spectroscopy, Electrowinning, Solvent Extraction

### PREPARED BY
M.S. Safarzadeh, March 23, 2016

## MET 320 - METALLURGICAL THERMODYNAMICS: (4-0)/4

### INSTRUCTOR

Dr. M.S. Safarzadeh, MI 103, ph. (605) 394-1284, sadegh.safarzadeh@sdsmt.edu

### TEXTBOOK

Introduction to the Thermodynamics of Materials, 5th Ed., David Gaskell

### COURSE INFORMATION

**Catalog Description**: The principles of chemical thermodynamics and their application to metallurgical engineering processes. Topics covered include the zeroth, first and second laws of thermodynamics, the fundamental equations of state for open and closed systems, criterion of equilibrium, heat capacities, reaction equilibrium constants and their dependence upon temperature and pressure, chemical potential, standard and reference states, stability diagrams, and solution thermodynamics.

**Prerequisites:** PHYS 211, CHEM 112, MATH 125

**Co-requisites:** none

**Required Course:** B.S. Metallurgical Engineering, B.S. Geological Engineering

**Selected Elective:** none

### COURSE GOALS

**Specific Outcomes**

- Given the initial state (i.e. two of the following: T, P, V), the final state (i.e. one of the following: T, P, V), and the path followed (isothermal, isochoric, isobaric, adiabatic, reversible, free expansion) by an ideal gas, the student will be able to calculate ΔU, ΔH, ΔS, q, and w.
- The student will be able to calculate $\Delta S_{total}$ when a body of given mass, heat capacity, and initial temperature equilibrates with a heat sink of specified temperature.
- The student will be able to calculate $\Delta S^{Mixing}$ when two or more pure components at the same temperature, pressure, and state form an ideal solution.
- Given a chemical reaction where the temperatures and amounts of reactants, the final temperature and amounts of the products, and corresponding enthalpies of formation at 298 K and the heat capacities are specified, the student will determine the heat added to or removed from the system.
- The student will be able to integrate the Clausius and the Clausius-Claperyon Equations and given all but one of the variables in the equation solve for the remaining variable using the equation. The student must recognize that melting or boiling point information constitutes a (T, P) set.
- The student will be able to calculate ΔG for a condensed-phase reaction at constant temperature as a function of pressure given the molecular weights and densities of the reactants and products and the ΔG at a specified pressure.
- The student will be able to determine the equilibrium constant for a reaction from ΔG° of formation data for the reaction and to correctly describe the standard state for each component involved in the reaction.

- The student will calculate the equilibrium state (partial pressures, moles) for a reaction involving known initial amounts of gases and pure condensed phases occurring at a given temperature and pressure. The student will be provided either the $\Delta G°$ or $K_{Equil}$ for the reaction.
- The student will determine activities and activity coefficients for component i from the integral molar Gibbs energy of mixing and from the partial molar Gibb's energy of mixing for component i.
- The student will derive the Fundamental equations for an open system, the Maxwell Relations, the "Other" Thermodynamic relationships, the criterion of equilibrium for systems at constant temperature and pressure.
- The student will calculate the cell potential for electrolytic cells involving dissolved components in non-aqueous systems.
- The student will determine using the Ellingham Diagram relative oxide stabilities, equilibrium oxygen pressures, equilibrium $H_2/H_2O$ and $CO/CO_2$ ratios for any reaction on the Ellingham Diagram.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE: (**a), (b), (c), (e), (k)

## TOPICS

First Law of Thermodynamics (9 classes), Forms of Energy, Heat and Work, Joules Experiments, Conservation of Energy, Concept of Maximum Work, Isothermal Expansion, Reversible, Adiabatic Expansion, Constant Pressure Processes, Constant Volume Processes, Enthalpy, Second Law of Thermodynamics (9 classes), 2nd Law Statement, Carnot Cycle, 4 Propositions, Statistical Entropy (2 classes), Physical Meaning of Entropy, Boltzman Equation, Mixing Entropy, Stirling's Approximation, Auxiliary Functions (3 classes), Fundamental Equations of State, Maxwell Relationships, Other Thermodynamic Relations, Chemical Potential, Gibbs-Helmholtz Equation, Criteria of Equilibria, Heat Capacity and Entropy Changes (5 classes), Sensible Heats, Transformation Heats, Reaction Heats, Adiabatic Flame Temperatures, Heat Balances, JANAF Thermochemical Tables, Phase Equilibria in One Component Systems (6 classes), Clausius-Claperyon Equation, Heats of Vaporization From Vapor Pressure Data, Shift in Transformation Temperature with Pressure, The Behavior of Gases (3 classes), Compressibility Factor, Law of Corresponding States, Equations of State, Fugacity, Reactions Equilibria (13 classes), Equilibria in Gaseous Systems, The Equilibrium Constant, Reaction Extent Problems, Equilibria in Systems Containing Condensed Phases, Ellingham Diagram, Activities, Solution Thermodynamics (9 classes), Absolute and Partial and Integral Molar Quantities, Relative and Partial Integral Molar Quantities, Ideal Solutions, Excess Quantities, Gibb's Duhem Equation, Tangent Intercept Method, a=f(T), Change in Reference State, 1 wt % Reference State Interaction Parameters, Phase Equilibria and Electrochemistry (as time permits), Tests (5 classes)

## PREPARED BY

M.S. Safarzadeh, March 23, 2016

## MET 321 - HIGH TEMPERATURE EXTRACTION, CONCENTRATION, AND RECYCLING (3-1)/4

**INSTRUCTOR:** Dr. M.S. Safarzadeh, MI 103, ph. (605) 394-1284, sadegh.safarzadeh@sdsmt.edu

**TEXTBOOK:** Principles of Extractive Metallurgy, 2nd Ed., Terkel Rosenqvist

### COURSE INFORMATION

**CATALOG DESCRIPTION**: Thermodynamic principles involved in the winning of metals. Areas covered include calcination, oxidation, reduction processes, smelting, high - temperature refining, electrorefining, slags, and slag-metal interactions.
**Prerequisites:** MET 320
**Corequsistes:** none
**Required:** B.S. Metallurgical Engineering
**Selected Elective:** none

### COURSE GOALS

**Specific Outcomes**

- Given sufficient but minimal mass flow information on an open process, the student shall calculate all unstated mass flows.
- Given sufficient but minimal heat and mass flow information on an open process, the student shall calculate all unstated heat and mass flows.
- Given isothermal activity data as a function of composition for a standard state, the student will be able to calculate $\Delta G^\circ$ for a new standard state and the corresponding variation of activity coefficients in the new standard with respect to the new composition variable.
- Given liquidus temperature and composition data for a phase diagram in which a pure component A is in equilibrium with the liquid, the student will be able to derive the equation for finding the activity of the liquid component A in the solution relative to the pure, liquid A.
- Given the Fe-O-C phase diagram in which percent $O_2$ vs T is plotted, the student will be provided the underlying equations and cite the required data for calculating any equilibrium line on the diagram.
- The student will be able to calculate the cell potential for required for the reduction of any metal by molten salt electrolysis given $\Delta G^0$ of formation for the salt. This includes combined reactions and reduction from molten salt solutions such as encountered in the Hall Cell.
- The student will be able to describe the fundamental problem of producing Zn from ZnO by carbothermic reduction and recommend at least two methods of effecting the recovery of metallic Zn.
- The student will sketch the silica slag network, show the effect of basic component additions on the network, and describe the effect such additions have on slag viscosity and conductivity. The student must be able to cite at least five basic slag components.
- Given a ternary phase diagram and the rules of interpretation, the student will determine the temperature and order of solidification from the liquid state at any specified bulk

composition and will describe all phases present and their relative amounts at any given temperature.

- Given activity coefficient data for a component in a metal phase, the corresponding data for the component in the oxidized state in a slag in equilibrium with the metal, the standard Gibbs energy for the oxidation, and the chemical potential of the oxidation agent, the student will determine the slag-metal distribution ratio of the component.
- Given an Ellingham diagram, the student will provide the order of oxidation in a specified matte smelting process.
- The student will describe in detail all of the steps to performing a gold assay and the purpose of each step.
- The student will describe the differences in process in a mini steel mill and an integrated steel mill.
- The student will be able to determine the rate of free evaporation of liquid metals alloy components in vacuum using the Langmuir equation. The student will be given the solution composition, activity coefficient data for each component, their molecular weights, and the temperature.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE: (**a), (b), (c), (k)

## TOPICS

Cost, conservation, and concentration of mineral resources (2 classes), Sampling, Process Outline, Library & Internet Resources, Thermo Review (I class), Phase Rule, Ternary Phase Diagrams (4 classes), Roasting (10 classes), Stability Diagrams (M-O-S, M-X-Y), Roaster Diagrams, STABCAL software for the construction of stability diagrams (1 class), Zn Roasting, Sintering and Calcination (1 class), Solution Thermodynamics (7 classes), Temperature Dependence of Activity, Alternative Standard States, Activities From the Phase Diagram, Gibbs-Duhem Integration using the Alpha Function, Derivation and Application of the Gibb's Phase Rule, Processes by elemental group, Oxidation - reduction reactions (8 classes), Smelting and converting reactions (6 classes), Refining processes (3 classes), Refractories and slags (2 classes), Fused salt electrolysis (4 classes), Tests (3 or 4 classes)

## PREPARED BY

M.S. Safarzadeh, March 23, 2016

## MET 330 - PHYSICS OF METALS: (3-0)/3

### INSTRUCTOR

Dr. G.A. Crawford, MI 104, (605) 394-5133, grant.crawford@sdsmt.edu

### TEXTBOOK

Physical Metallurgy Principles, 4th Edition, Reed-Hill & Abbaschian, 2009

### COURSE INFORMATION

**Catalog Description**: The fundamental principles of physical metallurgy with an emphasis on the mathematical description of mechanisms that control the structure of materials. Topics covered are the structure of metals, x-ray diffraction, elemental theory of metals, dislocation theory, slip phenomena, grain boundaries, vacancies, annealing, and solid solutions.

**Prerequisites:** MET 232 with a grade of "C" or better
**Co-requisites:** none
**Required Course:** B.S. Metallurgical Engineering
**Selected Elective:** none

### COURSE GOALS

**Specific Outcomes**

- Given unit cell and crystal structure information, students will be able to determine volumetric, planar and linear density within a crystal lattice.
- Given atomic and structure information for metals, students will be able to predict the degree of solubility of solid solutions.
- Given an x-ray powder diffraction intensity scan, students will be able to determine the crystal structure and lattice parameter for a metal.
- Students will be able to calculate the resolved shear stress to cause slip in a metal.
- Students will understand atomic bonding in materials and how bonding influences physical properties and elastic constants.
- Students will understand how to use a stereographic projection, pole figures, and inverse pole figures for crystallographic analysis and texture analysis of metals.
- Students will understand the fundamentals of dislocation structure, movement, and generation in metal crystal systems and the importance of dislocations in plastic deformation and strengthening of metals.
- Students will understand basic metal characterization methods including electron microscopy, optical microscopy, and bulk and surface chemical analysis methods.
- Given activation energy for vacancy formation, students will be able to calculate the equilibrium number of vacancies for a metal at high temperature.
- Given diffusivity data for solid state diffusion, students will be able to estimate the concentration profile of a diffusing species in a metal using Fick's $2^{nd}$ law.
- Given a distribution coefficient based on the phase diagram, students will be able to estimate the concentration gradient in a directionally solidified ingot.
- Students will understand the nature of the energy barrier associated with homogeneous nucleation. Given degree of subcooling, students will be able to estimate the critical nucleus size for a metal.

- Students will be able to describe the effects of grain size reduction, alloying and dislocation density on strength and recrystallization temperature.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (b), (e), (k)

**TOPICS**

- Crystal Structure
- Structure Determination
- Characterization of metals
- Grain Boundaries
- Dislocations
- Vacancies
- Diffusion
- Solidification
- Nucleation and Growth
- Solid Solutions
- Phase Diagrams
- Recovery and Recrystallization
- Phase Transformations
- Precipitation
- Twinning/Martensitic Transformations

**PREPARED BY**

G.A. Crawford, April 12, 2016

## MET 330L PHYSICS OF METALS: (0-1)/1

### INSTRUCTOR
Dr. G.A. Crawford, MI 104, (605) 394-5133, grant.crawford@sdsmt.edu

### TEXTBOOK
Physical Metallurgy Principles, 4th Edition, Reed-Hill & Abbaschian, 2009

### COURSE INFORMATION
**Catalog Description**: Practical laboratory exercises that involve (1) x-ray diffraction methods, (2) transmission electron microscopy as it applies to dislocations in materials, (3) recovery, recrystallization and grain growth as it applies to annealing of materials, (4) optional and scanning electron microscopy as it applies to the microstructure of materials, and (5) thermomechanical processing of metals with limited regions of solid solubility.
**Prerequisites:** MET 231
**Pre- or Co-requisites:** MET 330
**Required Course:** B.S. Metallurgical Engineering
**Selected Elective:** none

### COURSE GOALS
**Specific Outcomes**

- Students will continue development of technical writing skills through the preparation of engineering reports.
- Students will be able to perform metallographic sample preparation, optical metallography, and microhardness testing.
- Students will develop experimental skills in heat treating of steels, aluminum alloys, and copper alloys.
- Given a tensile testing specimen, students will be able to perform uniaxial tensile testing.
- Students will be able to use phase diagrams, hardenability data, TTT curves, IT curves and other information to develop specific microstructures in steels.
- Students will be able to identify microstructures in various steels alloys, cast irons, aluminum alloys, and copper alloys.
- Students will understand the iron-carbon system, aluminum alloy systems, and copper alloy systems.
- The student will get an understanding of x-ray diffraction laboratory techniques and obtain experience determining the crystal structure, lattice parameter and composition of an unknown pure sample using x-ray diffraction. Students will also perform quantitative phase analysis of known and unknown materials.
- The students will obtain an understanding of point and line defects in crystalline solids and will understand the motion of edge dislocations through construction of a “bubble raft” model.
- Students will gain an understanding of heat treatment steels including austenizing, quenching, and tempering. Students will understand the impact of alloy composition on heat treatment and resulting microstructure and mechanical behavior of the material.
- Students will learn the effect of dislocation pinning by interstitial atmospheres on stress-strain curve in low carbon steels.

- The students will gain a mechanistic understanding of recovery, recrystallization and grain growth. Students will gain hands-on experience with rolling mill operation.
- Students will understand precipitation hardening of metal alloys. Given a phase diagram, students can discuss the possibility of precipitate formation by a three step (1) solution heat treatment, (2) quench and (3) aging process. Students will develop a practical and mechanistic understanding of the relationship between precipitate growth and mechanical behavior in precipitate strengthened alloys.
- Students will gain a practical and theoretical understanding of diffusion of carbon in steel. Students will gain an understanding of the relationship between carbon concentration and microstructure and hardness of steel. Given a steel specimen students will be able to perform carburizing and decarburizing operations, analyze the thickness of the carburized/decarburized layer and compare results to analytic calculations using Fick's $2^{nd}$ law.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (b), (d), (e), (g), (k)

## TOPICS

- Laboratory experiments supporting MET 330 lecture content.
  - Metallography principles
  - Fundamentals of x-ray diffraction
  - Dislocation motion via the "bubble raft" model
  - Sharp yield point and dislocation atmospheres
  - Diffusion in steel
- Laboratory experiments supporting MET 332 lecture content.
  - Tempered martensite in steel and steel alloys
  - Recovery, recrystallization and grain growth in copper alloys
  - Precipitation hardening of aluminum alloys
  - Metallurgy of cast irons

## PREPARED BY

G.A. Crawford, April 12, 2016

## MET 332 THERMOMECHANICAL PROCESSING: (3-0)/3

### INSTRUCTOR
Dr. Michael West, MI 108, (605) 394-1283, Michael.West@sdsmt.edu

### TEXT BOOK
Steels: Processing, Structure, and Performance, George Krauss, ASM International, 2005.

### COURSE INFORMATION
**Catalog Description:** The relationship between the structure and properties of materials. Topics covered are the iron-carbon system, hardenability of iron base alloys, stainless steels, cast irons, aluminum, copper and magnesium, rubber and copper polymers. Concepts of heat treatment, age hardening, dispersion hardening, and hot and cold working correlated with modification of the structure and physical properties of materials.
**Prerequisites:** MET 232 with a grade of "C" or better
**Pre or Corequisites:** MET 330 and MET 320 or ME 211
**Required Course:** B.S. Metallurgical Engineering
**Selected Elective:** none

### COURSE GOALS
The objective of this course is to develop a professional understanding of the relationship between microstructure and mechanical and physical properties of metals and alloys. Students that successfully complete the course requirements will understand and be able to predict the structure of metals based on alloy composition, heat treatment, and mechanical processing. Students will also understand selection of alloys based on the resulting mechanical properties.

**Specific Outcomes**

- Given any binary phase diagram with any invariant reaction, the student can discuss the initial and final microstructure through drawings and words formed during solidification and/or solid-state invariant reactions. In addition students can compute the fraction of phases present at any specified temperature and alloy composition.
- Students will understand the relationship between processing, microstructures, properties and performance of carbon steels, alloy steels, cast irons, aluminum alloys copper alloys, stainless steels, tool steels, titanium alloys, and nickel alloys.
- Students will understand the steel making process, ingot and continuous solidification processes, microstructures, heat treatments, mechanical processing, national and international alloy designations, and surface hardening processes.
- Students will understand basic technical terminology to specific alloy groups such as annealing, stress relief, normalizing, tempering, martempering, austempering, quenching, solution annealing, precipitation hardening, over aging, sensitization, work hardening, cold rolling, carburizing, nitriding, etc.
- Students will understand diffusion topics such as homogenization and carburization. Several solutions to Fick's second law are developed in class and used to solve engineering problems.

- Students will understand alloy steels and the effects of alloy composition on performance. In addition, students will understand how to use TTT curves, IT curves, hardenability data to design specific alloy thermo-mechanical processes.
- Students will understand the aluminum alloy designation system, aluminum refining processes, casting methods, work hardening operations, solution and aging treatments, and the effect of alloying on specific properties and processing.
- Students will know the stainless steel designation systems, types of stainless steels, thermo-mechanical processing methods, corrosion resistance issues, limitations, and processing cautions.
- Students will understand the above topics for cast irons, tool steels, copper alloys, titanium alloys and nickel based alloys.
- Students will be able to design and select alloys for specific engineering applications.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (b), (c), (e), (k)

**TOPICS**

- Phase diagrams
- Ferrous Alloys – Steels, Cast Irons, Stainless Steels
- Non-ferrous Alloys – Aluminum, Copper, Nickel
- Development of superalloys
- Heat treatment
- Precipitation hardening
- Surface treatments
- Metalworking fundamentals
- Alloy selection

**PREPARED BY**

Michael West, March 27, 2016

## MET 351 METALLURGICAL ENGINEERING DESIGN I: (2-0)/2

**INSTRUCTOR** Dr. G.A. Crawford, MI 104, (605) 394-5133, grant.crawford@sdsmt.edu

### TEXTBOOK

Optional: Engineering Design, a Materials and Processing Approach, George E. Dieter, McGraw-Hill Company, Third Edition, 2000.

### COURSE INFORMATION

**Catalog Description**: Introduction to engineering design. Compare the scientific method with the engineering design method. Define the concept of need as it pertains to the design process. Develop skills associated with the use of modern and classic sources of information. In addition, material selection processes, interaction of materials, and materials processing topics are presented. Focus on the design process, and the design method. The development of interdisciplinary teams is a high priority.

**Pre- or Co-requisites:** MET 320

**Co-requisites:** none

**Required Course**: B.S. Metallurgical Engineering

**Selected Elective:** none

### COURSE GOALS

**Specific Outcomes**

The objectives of this course are to provide hands on practical experience on metallurgical engineering design. Students develop their projects by working teams under the direction and supervision of one or more faculty mentors. During the semester students will demonstrate the ability to:

- Define the problem and establish the project requirements and constraints.
- Gather information and establish the state of the art on the design science and technology.
- Conceptualize various concept solutions to the design problem.
- Use decision matrices for the selection of the candidate solution.
- Establish the candidate design and the tasks needed to achieve this design.
- Establish a project schedule.
- Work effectively in a team environment.
- Write progress and final design reports.
- Make effective oral presentations.
- Integrate knowledge, vertically and horizontally, and apply analytical tools from a variety of metallurgical engineering courses.
- Manage the project effectively by using a project schedule and other management tools.
- Develop and implement appropriate and detailed manufacturing plans.
- Write progress and final design reports, incorporating ethical, environmental and societal issues pertinent to the specific design project.
- Test and evaluate prototype performance.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (b), (c), (d), (e), (f), (g), (h), (k)

**TOPICS**

- Interdisciplinary junior capstone design projects.
- Design process
- Project management
- Effective teamwork
- Engineering statistics and the design process
- Trade studies and decision matrices
- Global, societal and environmental context
- Intellectual property and ethical considerations

**PREPARED BY**

G.A. Crawford, April 14, 2016

**MET 352 METALLURGICAL ENGINEERING DESIGN II: (1-0)/1**
**INSTRUCTOR** Dr. G.A. Crawford, MI 104, (605) 394-5133, grant.crawford@sdsmt.edu

**TEXTBOOK**
Optional: Engineering Design, a Materials and Processing Approach, George E. Dieter, McGraw-Hill Company, Third Edition, 2000.

**COURSE INFORMATION**

**Catalog Description**: A continuation of the design sequence.
**Prerequisites:** MET 351
**Co-requisites:** none
**Required Course**: B.S. Metallurgical Engineering
**Selected Elective:** none

**COURSE GOALS**

**Specific Outcomes**

The objectives of this course are to provide hands on practical experience on metallurgical engineering design. Students develop their projects by working teams under the direction and supervision of one or more faculty mentors. During the semester students will demonstrate the ability to:

- Define the problem and establish the project requirements and constraints.
- Gather information and establish the state of the art on the design science and technology.
- Conceptualize various concept solutions to the design problem.
- Use decision matrices for the selection of the candidate solution.
- Establish the candidate design and the tasks needed to achieve this design.
- Establish a project schedule.
- Work effectively in a team environment.
- Write progress and final design reports.
- Make effective oral presentations.
- Integrate knowledge, vertically and horizontally, and apply analytical tools from a variety of metallurgical engineering courses.
- Manage the project effectively by using a project schedule and other management tools.
- Develop and implement appropriate and detailed manufacturing plans.
- Write progress and final design reports, incorporating ethical, environmental and societal issues pertinent to the specific design project.
- Test and evaluate prototype performance.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (b), (c), (d), (e), (f), (g), (h), (k)

**TOPICS**

- Interdisciplinary junior capstone design projects.

**PREPARED BY**

G.A. Crawford, April 14, 2016

## MET 422 - TRANSPORT PHENOMENA: (4-0)/4

### INSTRUCTOR

Dr. M.S. Safarzadeh, MI 103, ph. (605) 394-1284, sadegh.safarzadeh@sdsmt.edu

### TEXTBOOK

Transport Phenomena in Metallurgy, G. H. Geiger and D. R. Poirier

### COURSE INFORMATION

**Catalog Description**: The principles of momentum, heat and mass transfer and their application to metallurgical engineering. Topics covered include thermal conductivity, mass diffusion, mechanisms of transport, Fourier's and Fick's Laws, shell balance, boundary conditions, equations of change, unsteady-state transport, mass and heat distributions in turbulent flow, and interphase transport.
**Prerequisites:** MATH 321
**Pre or Co-requisites:** MET 320
**Required Course:** B.S. Metallurgical Engineering
**Selected Elective:** none

### COURSE GOALS

**Specific Outcomes**

- Students are expected to write Newton's Law, Fourier's Law, and Fick's Law and describe the analogies among them.
- Students will perform shell balances for momentum, heat, and mass transfer and obtain the differential equation describing the velocity, temperature, and concentration gradient.
- Students are expected to understand the difference between Newtonian and non-Newtonian flows.
- Students will be able to reduce the Equations of Continuity and Change for rectangular, cylindrical and spherical coordinates to the terms applicable for a specified condition.
- Students will be able to derive from linear, steady-state flow distributions in laminar flow volumetric and average flow equations.
- Students provided a set of independent variables upon which a dependent variable depends will reduce the set to a dimensionless set using Buckingham Pi Theory.
- Students will be able to design packed and fluidized beds for given system for uniform particles given their density, shape, and size and the fluid's rheological properties.
- Students must determine the modes of heat transfer (conduction, convection, and radiation) and describe the governing equations for each mode.
- Students are expected to calculate the heat transfer rate for convective heat transfer given heat transfer correlation and its pertinent parameters.
- Students will determine heat loss from radiative systems using Kirchhoff Loop electric analog solution method.
- Students will solve 1D USS and 2D SS heat transfer and mass transfer problems using spreadsheets.
- Students will determine the concentration dependency of diffusivity.
- Students will be able to derive differential equations describing diffusion through a stagnant gas film, a moving gas stream, and a falling liquid film.

- Students will describe the mathematical similarities between turbulent convective heat transfer and turbulent diffusion including the correspondence between dimensionless groups.

  **STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (b), (c), (e), (k)

**TOPICS**

Introduction to momentum, energy and mass transfer analogies between Newton's, Fourier's, and Fick's Laws (1), Theoretical and semi-empirical equations for viscosity of gases, liquids, and molten slags (3), Newtonian and non-Newtonian fluids (1), Laminar flow and momentum balances: flow of a falling film; flow through a circular tube (3), Equations of continuity: rectangular volume, arbitrary shape using vectors (3), Substantial time derivative; total and partial time derivatives (2), General equations of momentum transfer: Naiver-Stokes, Euler equations (2), Applications of the general equation of motion: flow through a long vertical cylindrical duct, Couette-Hatschek viscometer, creeping flow around a sphere; flow near the leading edge of a flat plate, Dimensional analysis: Re, Fr numbers (1), Turbulent flow: time-smoothed quantities Interphase transport: friction factor (2), Flow through packed and fluidized beds (4), Theoretical and semi-empirical equations for thermal conductivity of fluid and solids (1), Heat conduction flat plates, cylinders through composite walls with generation (4), Heat transfer with forced and natural convection (4), Transient systems (4), Solidification heat transfer (2), Dimensional analysis: Nu, Gr numbers (1), Molar and mass flux Theoretical and semi empirical equations for diffusivity of gases, liquids and ionic species (3), Diffusion in solids of gas through thin film, concentration dependent diffusivity transient diffusion (3), Mass transfer in fluid systems diffusion through a stagnant gas film, diffusion in a moving gas stream, diffusion into a falling liquid film, forced convection (4), Dimensional analysis: Sh, Sc numbers (1)

**PREPARED BY**

M.S. Safarzadeh, March 16, 2016

## CBE 433/MET 433 - Process Control (3-0)/3

**INSTRUCTOR:** Dr. Timothy M Brenza (Chemical Engineering), MI 210 (temporary), ph. (605) 394-1766, Timothy.Brenza@sdsmt.edu

**TEXTBOOK**

Principles and Practice of Automatic Process Control, by C. A. Smith and A. B. Corripio, 3rd ed., John Wiley & Sons, New York, (2006).

**COURSE INFORMATION**

**Catalog Description**: (3-0) 3 credits. Analysis and design of process control systems for industrial processes, including controller tuning and design of multivariable control schemes. This course is cross-listed with MET 433.
**Prerequisites:** MATH 321 and senior standing
**Co-requisites:** none
**Required Course:** B.S. Metallurgical Engineering, B.S. Chemical Engineering
**Selected Elective:** none

**COURSE GOALS**

**Specific Outcomes**

After completion of this course the average student is expected to be able to:

- Model the dynamic behavior of physical processes and automatic control systems using algebraic and differential equations, and by using block diagrams and transfer functions representing the Laplace transforms of those equations.
- Tune feedback controllers to produce a desired mode of response.
- Identify and sketch graphs illustrating overdamped, critically damped, underdamped, undamped and unstable systems, and predict which response will occur based on the transfer functions describing a system.
- Model complex process behavior using empirical first-order-plus-dead-time models, and tune automatic controllers based on those process models.
- Illustrate control techniques and response modes using simulation software.
- Explain advanced control techniques of feed-forward and cascade control using block diagrams, process and instrumentation diagrams, and time-domain graphs.
- Explain and use basic concepts of statistical process control, including statistics of central tendency and variability, and control charts.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE: (**a), (b), (k)

**TOPICS**

- Feedback control
- Control algorithms
- P & IDs
- Laplace transforms
- 1st order processes
- 2nd order processes
- Block diagrams/transfer functions
- P, PI, PID control

- Tuning controllers
- Dead-time
- Tuning formulas
- Advanced control (feedforward, cascade)
- Statistical process control

**Class Schedule:** Varies
**Contribution to Criterion 5:**
Engineering Science: 3 credits or 100%
Engineering Design: 0 credits of 0%

**PREPARED BY**
Timothy Brenza, May 2, 2016. (Formatted to MET specifications by S. M. Howard May 22, 2016)

## MET 440/540 MECHANICAL METALLURGY: (3-0)/3

### INSTRUCTOR
Dr. G.A. Crawford, MI 104, (605) 394-5133, grant.crawford@sdsmt.edu

### TEXTBOOK
Mechanical Metallurgy, Dieter, G. E., 3rd Ed., McGraw-Hill, Boston, 1986.

### COURSE INFORMATION
**Catalog Description**: A course concerned with responses of metals to loads. Areas covered include elastic and plastic deformation under different force systems, dislocation theory, fracture, internal friction, fatigue, creep, residual stresses, and general fundamentals of metal working.
**Prerequisites:** MET 232 with a grade of "C" or better
**Pre- or Co-requisite**: ME 216 or EM 321
**Required Course:** B.S. Metallurgical Engineering
**Selected Elective:** B.S. Mechanical Engineering

### COURSE GOALS
**Specific Outcomes**

- The objectives of this course are to provide hands on practical experience on metallurgical Graphical and analytical determination of state of stress in mechanical components. Vector and tensor representation in different system of axis. Calculation of elastic stresses from elastic strains and elastic stress/strain relationships.
- Stress distribution and stress concentration in mechanical components.
- Strength theories for design in brittle and ductile materials. Yield surfaces and yield envelops.
- Given the original dimensions of a mechanical component and the original tridimensional state of stress, calculate the final dimensions and the final state of stress in the mechanical component.
- Calculation in engineering materials of the: (a) theoretical cohesive tensile strength, (b) cohesive tensile strength from the stress concentration point of view, establishment of the fracture stress by the Griffith's equations and (d) establishment of the fracture stress by the Griffith-Orowan equations.
- Measurement of the fracture toughness of engineering materials: Plane strain, COD, CTOD, J integral and R curves. Calculation of plasticity corrections.
- Calculation of dimensions, failure stresses and failure envelopes in mechanical components using linear elastic fracture mechanics and fracture theories for design.
- Criteria for the fatigue design of mechanical components including fatigue crack initiation and fatigue crack propagation. Calculation of the dimensions and fatigue life of mechanical components under specific fatigue parameters.
- Establishment of creep mechanisms and plotting of creep data for engineering design. Working knowledge of creep deformations maps.
- Calculation of constants in creep equations, creep stresses and life time, in the creep design of engineering components.
- Introduction to the methodologies for evaluating failure analysis of metallic components.

- Calculation of stress intensity factors, strain energy release rates, fracture toughness, plane strain toughness, testing methods, and toughness of materials.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (e), (k), (i)

## TOPICS

- Introduction to Mechanical Metallurgy and Mechanical Behavior in 1D stress state
- Theory of Elasticity and Mechanical Behavior
- Theory of Plasticity and Mechanical Behavior
- Fracture Theory
- Fracture Mechanics
- Fatigue
- Creep
- Metalworking Techniques

## PREPARED BY

G.A. Crawford, April 22, 2016

## MET 440L/540L – MECHANICAL METALLURGY LAB: (0-1)/1

**INSTRUCTOR** Dr. B.K. Jasthi, MI 101, Ph. (605) 394-2342, bharat.jasthi@sdsmt.edu

**TEXTBOOK** Mechanical Metallurgy, Dieter, G.E, 1996

**COURSE INFORMATION**

**Catalog Description:** A course that provides practical experience in the mechanical behavior of metals focusing on mechanical testing, mechanical processing, and failure analysis.
**Prerequisites:** MET 231
**Pre- or Corequisites:** MET 440/540
**Required Course:** B.S. Metallurgical Engineering
**Selected Elective:** none

**COURSE GOALS**

**Specific Outcomes**

- The objectives of this course are to provide hands on practical experience on metallurgical Students will be able to conduct a Rockwell hardness test on a metal sample using appropriate scales.
- Students will be able to perform a tensile test and generate an appropriate stress-strain curve.
- Students will be able to interpret important mechanical properties from a stress strain curve for a metal.
- Students will be able measure fracture toughness of engineering materials.
- Students will be able to perform Nano indentation of materials and will be able to interpret the mechanical properties.
- Students will develop their fundamental understanding of fatigue failures of metallic materials.
- Students will be able to perform basic statistical analysis and apply statistical process control in a typical industrial setting.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (b), (d), (k)

**TOPICS**

- Statistical Analysis and Gage Repeatability and Reproducibility
- Hardness Testing
- Nano Indentation
- Tensile Testing
- Fatigue Testing
- Statistical process Control
- Fracture Toughness Testing

**PREPARED BY**

B.K. Jasthi

## MET 464 METALLURGICAL ENGINEERING DESIGN III: (0-2)/2

### INSTRUCTOR
Dr. G.A. Crawford, MI 104, (605) 394-5133, grant.crawford@sdsmt.edu

### TEXTBOOK
Optional: Engineering Design, a Materials and Processing Approach, George E. Dieter, McGraw-Hill Company, Third Edition, 2000.

### COURSE INFORMATION
**Catalog Description**: A continuation of the design sequence
**Prerequisites:** MET 352
**Co-requisites:** none
**Required Course**: B.S. Metallurgical Engineering
**Selected Elective:** none

### COURSE GOALS
**Specific Outcomes**

The objectives of this course are to provide hands on practical experience on metallurgical engineering design. Students develop their projects by working teams under the direction and supervision of one or more faculty mentors. During the semester students will demonstrate the ability to:

- Define the problem and establish the project requirements and constraints.
- Gather information and establish the state of the art on the design science and technology.
- Conceptualize various concept solutions to the design problem.
- Use decision matrices for the selection of the candidate solution.
- Establish the candidate design and the tasks needed to achieve this design.
- Establish a project schedule.
- Work effectively in a team environment.
- Write progress and final design reports.
- Make effective oral presentations.
- Integrate knowledge, vertically and horizontally, and apply analytical tools from a variety of metallurgical engineering courses.
- Manage the project effectively by using a project schedule and other management tools.
- Develop and implement appropriate and detailed manufacturing plans.
- Write progress and final design reports, incorporating ethical, environmental and societal issues pertinent to the specific design project.
- Test and evaluate prototype performance.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (b), (c), (d), (e), (f), (g), (h), (k)

### TOPICS
- Interdisciplinary senior capstone design projects.
- Design process
- Project management

- Effective teamwork
- Engineering statistics and the design process
- Trade studies and decision matrices
- Global, societal and environmental context
- Intellectual property and ethical considerations

**PREPARED BY**

G.A. Crawford, April 24, 2016

## MET 465 METALLURGICAL ENGINEERING DESIGN IV: (0-1)/1.

### INSTRUCTOR
Dr. G.A. Crawford, MI 104, (605) 394-5133, grant.crawford@sdsmt.edu

### TEXTBOOK
Optional: Engineering Design, a Materials and Processing Approach, George E. Dieter, McGraw-Hill Company, Third Edition, 2000.

### COURSE INFORMATION
**Catalog Description**: A continuation of the design sequence, which includes a final technical design report and appropriate display material for the School of Mines Design Fair.
**Prerequisites:** MET 464
**Co-requisites:** none
**Required Course**: B.S. Metallurgical Engineering
**Selected Elective:** none

### COURSE GOALS
**Specific Outcomes**

The objectives of this course are to provide hands on practical experience on metallurgical engineering design. Students develop their projects by working teams under the direction and supervision of one or more faculty mentors. During the semester students will demonstrate the ability to:

- Define the problem and establish the project requirements and constraints.
- Gather information and establish the state of the art on the design science and technology.
- Conceptualize various concept solutions to the design problem.
- Use decision matrices for the selection of the candidate solution.
- Establish the candidate design and the tasks needed to achieve this design.
- Establish a project schedule.
- Work effectively in a team environment.
- Write progress and final design reports.
- Make effective oral presentations.
- Integrate knowledge, vertically and horizontally, and apply analytical tools from a variety of metallurgical engineering courses.
- Manage the project effectively by using a project schedule and other management tools.
- Develop and implement appropriate and detailed manufacturing plans.
- Write progress and final design reports, incorporating ethical, environmental and societal issues pertinent to the specific design project.
- Test and evaluate prototype performance.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (b), (c), (d), (e), (f), (g), (h), (k)

### TOPICS
- Interdisciplinary senior capstone design projects.

### PREPARED BY

G.A. Crawford, April 23, 2016

## MET 110 INTRODUCTION TO METALLURGICAL ENGINEERING: (1-0)/1

### INSTRUCTOR
Dr. Michael West, MI 108, (605) 394-1283, Michael.West@sdsmt.edu

### TEXT BOOK
No textbook required.

### COURSE INFORMATION
**Catalog Description:** An introductory course for incoming freshmen in metallurgical engineering covering the history of, career opportunities in, and engineering practices of metallurgical engineering. This course will include group projects and presentations, problem solving, engineering ethics, technical reports and field trips.
**Prerequisites:** none
**Co-requisites:** none
**Required Course:** none
**Selected Elective:** B.S. Metallurgical Engineering

### COURSE GOALS
The objectives of this course are to provide hands on practical initial experience in Metallurgical Engineering Design. Students develop their projects by working in interdisciplinary teams under the direction and supervision of one or more Faculty mentors. During the development of the course the students will demonstrate acquire skills to

- Gather information
- Conceptualize various solutions
- Evaluation of design concepts and select a candidate design
- Work in a team environment
- Communicate effectively by written reports and oral presentations

**Specific Outcomes**

- Understand metallurgical engineering curriculum
- Discuss potential career paths in metallurgical engineering
- Develop a working vocabulary of metallurgical engineering concepts
- Work effectively in a team environment
- Produce written reports
- Make effective oral presentations

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (c), (d), (e), (f), (g), (h), (j), (k)

**TOPICS**
Orientation for Metallurgical Engineering, Field Trips, Research Projects on Topics in Metallurgical Engineering, Presentation and Discussion of the Design Program, Literature Search, Brainstorming, Design of Experiments

**PREPARED BY**
Michael West, March 27, 2016

## MET 426/526 - STEELMAKING: (3-0)/3

### INSTRUCTOR
Dr. B.K. Jasthi, MI 101, Ph. (605) 394-2342, bharat.jasthi@sdsmt.edu

### TEXTBOOK
The Making, Shaping and Treating of Steel, Vol. 2: Steelmaking and Refining Volume 11th Edition, Iron & Steel Institute, Richard J. Fruehan, 1998

### COURSE INFORMATION
**Catalog Description**: Chemical reactions and heat and mass transport phenomena associated with the production of steel. Unit operations studied include the blast furnace, the basic oxygen furnace, the electric arc furnace, and selected direct reduction processes.
**Prerequisites:** MET 320 or graduate standing
**Co-requisites**: none
**Required Course:** None
**Selected Elective:** B.S. Metallurgical Engineering

### COURSE GOALS
**Specific Outcomes**
- Students will be able to understand chemical reactions involved in various iron and steel making processes.
- Students will be familiar with blast furnace iron making and would be able to perform burden calculations.
- Students will be able to predict whether a carbothermic reduction of a particular metal oxide is feasible or not, at a specific temperature using an Ellingham diagram.
- Given the hot metal and raw material compositions, the students will be able to calculate the weight of ore used and weight of slag made in an iron making blast furnace.
- Given the Ellingham diagram of oxides, the students will be able to predict the sequence of oxidation reactions of various elements in a basic oxygen furnace.
- Students will be familiar with secondary steel making processes along with the physiochemical fundamentals of steel making process.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (e)

### TOPICS
- History of Iron making; Principles of Iron making – Reduction, Smelting, Direct Reduction, and Raw materials for Iron making.
- Preparation of Iron ores; Coke Making, Agglomeration of Iron ore fines, Sintering and Pelletizing principles.
- General Physiochemical Fundamentals
- Blast Furnace iron making, general construction features, refractory lining, physical chemistry of Blast Furnace reactions and modern developments.
- Classification of steel making process, and Physical Chemistry of Primary Steel Making: Decarburization, desiliconization. Dephosphorization and desulphurization.
- Secondary Steel Making, Ladle Metallurgy and vacuum treatment of steels.

- Ingot and Continuous Casting.
- Specialty Steels;  Stainless Steels and  manufacturing of alloy steels (Electro Slag Refining, Vacuum Arc Remelting, Vacuum Induction Melting)

**PREPARED BY**

B.K. Jasthi, April 12, 2016

## MET 430/430L – WELDING METALLURGY AND ENGINEERING: (2-1)/3

### INSTRUCTOR

Dr. B.K. Jasthi, MI 101, Ph. (605) 394-2342,bharat.jasthi@sdsmt.edu

### TEXTBOOK

The Procedure Handbook of Arc Welding, 14th ed., James F. Lincoln Arc Welding Foundation, 1994

### COURSE INFORMATION

**Catalog Description**: Introduces the state-of-art in welding processes and technology. Discusses fundamentals of the fabrication welded structures by introducing basics of solidification in welds, metallurgy of welds, fatigue and fracture in welds, joint design and weld defects and inspection. Laboratory exercises will focus on advanced welding processes, characterization, and materials testing methods.
**Prerequisites:** MET 232
**Corequisites:** MET 430L
**Required Course:** None
**Selected Elective:** B.S. Metallurgical Engineering, B.S. Mechanical Engineering

### COURSE GOALS

**Specific Outcomes**

- Given a fusion welding process for aluminum alloys, students will be able to select an alloy to avoid hot cracking in welds.
- Given geometry and type of steel alloy, students will be able to determine welding parameters to avoid cold cracking.
- Given the thermal history for a fusion weld or solid state weld, students will be able to predict the microstructure in weld and heat-affected zones in steel and aluminum alloys.
- Students will understand the nature of segregation in fusion welds.
- Students will be able to appropriately size butt and fillet welds for required loading on a welded structure.
- Students will be able to choose an appropriate non-destructive evaluation method to detect defects in a welded structure.
- Students will be able to locate appropriate standards which govern welding processes.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (b), (k)

### TOPICS

- Overview and classification of welding processes
- Fusion and non-fusion welding
- Flow of heat in welds
- Solidification theory basics
- Nature of residual stresses, shrinkage and distortion
- Review of metallurgy of steel, aluminum
- Review of microstructure development as a function of temperature
- Microstructure of the heat affected zone
- Nature of welding discontinuities/defects

- Weldability issues
- Welded joint design
- Introduction to fracture and fatigue in welded joints
- Corrosion in welds
- Inspection of welds

Lab Topics
In the laboratory section, students are instructed in proper welding safety. The laboratory section is designed to introduce students to welding processes through a number of hands-on activities. Written reports are required. Laboratory topics include:

- Gas Welding/Cutting
- GMA Welding
- GTA Welding
- Laser Welding
- Ultrasonic Welding
- Friction Stir Welding

**PREPARED BY**
B.K. Jasthi, April 13, 2016

## MET 432/532 – ADVANCED MATERIALS AND PROCESSES: (3-0)/3

### INSTRUCTOR

Dr. B.K. Jasthi, MI 101, Ph. (605) 394-2342, bharat.jasthi@sdsmt.edu

### TEXTBOOK

There is no single text book that covers all the topics for this course. However, the following books are listed as reference materials.

- Superalloys-II "Principles and Prevention of Corrosion", C.T. Sims, N.S. Stoloff, and W.C. Hagel, 1987
- Superalloys – A technical Guide (2nd Edition) 2002-
- The superalloys: Fundamentals and Applications - Roger C. Reed (2006) .
- Superalloys - Alloying and Performance, Geddes, Blaine; Leon, Hugo; Huang, Xiao (2010).
- Manufacturing Engineering & Technology, Serope Kalpakjian, Steven Schmid, 7th Edition, 2013.

### COURSE INFORMATION

**Catalog Description:** The physical metallurgy, structure, advanced processing methods, and applications of various advanced metallic materials will be covered in this course. Topics will include laser processing, advanced forging, powder metallurgy and other emerging techniques for materials such as superalloys, metal matrix composites, nanocrystalline materials, advanced steels, titanium alloys, shape memory alloys, amorphous materials and mechanical alloyed materials.

**Prerequisites:** MET 232 or graduate standing

**Co-requisites**: none

**Required Course:** None

**Selected Elective:** B.S. Metallurgical Engineering, B.S. Mechanical Engineering

### COURSE GOALS

**Specific Outcomes**

- Given a specific high temperature application, students will be able to select a material that can survive a particular temperature and environment.
- Students will be able to perform Thermo-Calc simulations and calculate the thermal stability of various phases in superalloys.
- Students will be able to comprehend the microstructure and mechanical properties relationship for various advanced materials.
- Students will be able to choose an appropriate post weld heat treatment to achieve specific mechanical properties for materials.
- Given a powder material and particle size, students will be able to perform sintering time and temperature calculations needed for densification.
- Students will be able to select a specific surface engineering technique and coating that can give the optimum combination of microstructure and tribological properties.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (c), (e)

**TOPICS**

- Introduction to superalloys, guide to selection of superalloys for high temperature applications
- Physical metallurgy of superalloys; Structure properties relationship; and Heat treatment
- Forming and fabrication of superalloys (melting, casting, refining and joining)
- Friction stir processing, and Additive Manufacturing
- Powder metallurgy of high temperature materials (ODS materials, CIP & HIP processes).
- Surface Engineering (Laser, PVD, PEO, Cold Spray and Thermal Spray Processes)
- Amorphous Materials (Physical and mechanical properties, Formation and joining)
- Nanocrystalline materials, Shape Memory Alloys
- Physical metallurgy of Titanium and its alloys
- Review of High Entropy Alloys
- Review of  Metal Matrix Composites

**PREPARED BY**

B.K. Jasthi, April 17, 2016

## MET 443 COMPOSITE MATERIALS: (3-0)/3

### INSTRUCTORS:

Dr. Jon J. Kellar, Office Hours: 2-3 pm M, Tu, W, Th
Dr. Lidvin Kjerengtroen, Office Hours, 2-3 pm M, Tu, W, Th

### TEXTBOOK:

Engineering Mechanics of Composite Materials, 2nd Edition, Daniel and Ishai, Oxford 2006

### COURSE INFORMATION

**Catalog Description:** The course will cover heterogeneous material systems; basic design concepts and preparation; types of composite materials; advances in filaments, fibers and matrices; physical and mechanical properties; failure modes; thermal and dynamic effects; and applications to construction, transportation and communication. This course is cross-listed with ME 443.
**Prerequisites:** ME 316 or concurrent enrollment in MET 440
**Corequisites:** none
**Required Course:** None
**Selected Elective:** B.S. Metallurgical Engineering, B.S. Mechanical Engineering

### COURSE GOALS

Students will be able to determine the effects of mechanics and materials chemistry on composite performance

**Specific Outcomes**

- Given a particular matrix/reinforcement combination students will be able to identify a manufacturing process to produce a desired composite part.
- Given one of the major fibrous reinforcements the students will be able to describe the design, manufacturing and properties of advanced fibers.
- For a given matrix/reinforcement systems students will be able to determine the role of interfaces and interface phases and their properties in the design, manufacture and properties of PMCs, MMCs and CMCs.
- For a given matrix/reinforcement system student will be able to predict the microstructural properties (stiffness, strength, fracture toughness and fatigue).
- For a given composite system the student will be able to describe the fundamental properties/parameters such as anisotropic, orthotropic, and non-homogenous material behavior.
- For a given composite system the student will be able to carry out two dimensional transformations of stress, strain, and directional elastic parameters.
- For a given set of constituent properties the student will be able to estimate laminate material properties including laminate properties and strength estimates using common failure criteria**.**
- Given a laminate system the student will have basic understanding of the assumptions of laminate behavior and the significance of laminate stacking order.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (c)

**TOPICS**

- Fibers
- Fibers and Whiskers and Nanocomposites
- Reinforcement/Matrix Interface
- Interfaces-Wettability
- Interfaces-Bonding
- The Interphase Methods for Measuring Bond Strength
- Polymer Matrices
- Polymer Matrix Composite Processing
- Polymer Matrix Composite Interfaces/Interphases
- Structure, Properties and Applications of PMCs
- Elastic behavior of composite lamina-Micromechanics
  - Basic concepts including RVE
  - Stiffness
  - Thermal and moisture expansion
  - Lamina Strength
- Ply Mechanics
  - Coordinate systems
  - Stress, strain, and constitutive relationships
  - Off-axis Stiffness and properties
- Macro Mechanics
  - Basic assumptions of laminates
  - Computation of stress
  - Common laminate types: symmetric, balanced, and quasi-isotropic, and specially orthotropic
  - Carpet plots
- Failure and Strength
  - Tsai-Hill
  - Tsai-Wu
  - Maximum Strain Criterion

**PERSON BY**

Jon Kellar and Lidvin Kjerengtroen, May 6, 2010

## MET/CBE 445/545 - OXIDATION AND CORROSION OF METALS: (3-0)/3

### INSTRUCTOR

Dr. B.K. Jasthi, MI 101, Ph. (605) 394-2342, bharat.jasthi@sdsmt.edu

### TEXTBOOK

Principles and Prevention of Corrosion, Denny Jones, Second Edition, Prentice Hall, 1996

### COURSE INFORMATION

**Catalog Description**: Initially the thermodynamics of electrochemical processes are covered; use of the Nernst Equation and Pourbaix diagram is presented in this material. Fundamentals of electrode kinetics are then discussed with special emphasis on the derivation of the Butler-Volmer equation and application of the Evan's diagram. Following presentation of these fundamental concepts, phenomena observed in corrosion and oxidation such as uniform attack, pitting, stress corrosion cracking, and corrosion fatigue are discussed. Finally, selection of materials for site specific applications is covered.

**Prerequisites:** MET 320 or CHE 222 or ME 311 or graduate standing
**Co-requisites**: none
**Required Course:** None
**Selected Elective:** B.S. Metallurgical Engineering, B.S. Chemical Engineering, B.S. Mechanical Engineering

### COURSE GOALS

**Specific Outcomes**

- Students will be able to understand what oxidation, reduction, anodic and cathodic reactions are in relation to corrosion of metals and alloys.
- Students will be able to obtain the EMF values from the free energy information and vice versa.
- Students will be able to understand the effect of ionic activity on EMF and obtain the activity coefficient for ionic species if concentration is given.
- Students will be able to understand origin of galvanic corrosion and its practical implication.
- Students will be able to understand what passivation is and how this property is used in practice to prevent or minimize corrosion of various metals and alloys.
- Students will be familiar with how complexing agents affect the corrosion behavior.
- Students will be able to understand how to construct and use the Pourbaix diagram for simple systems and how it is used in relation to metal corrosion.
- Students will be able to apply the role of various ingredients in alloy systems in corrosion prevention.
- Students will be able to apply various corrosion mechanisms and their preventive measures to practical systems.
- Students will be familiar with basic corrosion testing procedures for typical systems.
- Students will be familiar with various materials used in corrosion related areas and to know how to select right materials for various corrosive media.
- Students will be able to select various metals, alloys and other materials used in corrosion applications.

- Students will be able to understand the major differences between wet and dry corrosion situations and know important variables affecting dry corrosion.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (e), (k)

## TOPICS

- Introduction
- Electrochemical aspects of corrosion cell potentials; Electromotive force; Ionic activity; Steps involved in corrosion; Cell polarization
- Stability of ions, metals and alloys; Pourbaix Eh-pH diagrams;
- Stability of ions in solutions
- Different forms of corrosion; Galvanic, Erosion, Crevice, Pitting, Selective leaching, Intergranular corrosion, Stress corrosion
- Corrosion testing; Classification, Purposes; Surface preparation; Duration
- Material selection; Metals, Alloys; Thermoplastics; Coatings
- Effect of mineral acids; Sulfuric acid, Nitric acid; Hydrochloric acid
- High temperature corrosion; Mechanisms and kinetics
- High temperature materials

## PREPARED BY

B.K. Jasthi, April 14, 2016

## MET 450/550 - FORENSIC ENGINEERING: (3-0)/3

### INSTRUCTOR

Dr. G.A. Crawford, MI 104, (605) 394-5133, grant.crawford@sdsmt.edu

### TEXTBOOK

Analysis of Engineering Materials, Brooks, C.R. and Chaudhury, A., *Failure,* McGraw-Hill, New York, 2002.

### COURSE INFORMATION

**Catalog Description**: The principles of physical metallurgy, mechanical metallurgy, manufacturing processes, and service environments will be used to determine the cause(s) for failure of metallic, composite, and polymer engineering components. Analytical techniques and procedures to characterize fractographic features and microstructures will also be reviewed, such as optical metallography, macrophotography, and scanning electron microscopy. Actual failed engineering components from a variety of industrial applications will be used as examples and be evaluated in the course. Fundamental engineering concepts, legal procedures of forensic engineering, failure mechanisms, technical report writing, and remedial recommendations will also be discussed.
**Prerequisites:** MET 231, MET 232, and ME 216 or EM 321, or permission of instructor
**Co-requisite:** none
**Required Course:** None
**Selected Elective:** B.S. Metallurgical Engineering

### COURSE GOALS

**Specific Outcomes**

- The objectives of this course are to provide hands on practical experience on metallurgical Understand and implement the approach (methodology) of failure analysis to fractured materials.
- Understand the application of optical microscopy, stereomicroscopy, scanning electron microscopy, energy dispersive spectroscopy and other related techniques in the analysis of failed components.
- Be able to prepare and preserve fractured samples, clean samples for proper evaluation, and document samples for future evaluation.
- Apply the mechanical aspects and macroscopic fracture surface orientation to failed components. This includes tensile testing, principle stresses, stress concentrations, plane stress, plan strain, strain rate, temperature, crack propagation, and fracture mechanics.
- Be able to identify fracture modes including ductile, brittle, and fatigue failures. This includes understanding the macroscopic features and characteristics.
- Be able to identify and explain the microscopic features and characteristics of fracture surfaces such as cleavage, river patterns, fan patterns, microvoid coalescence, quisicleavage, intergranular, striations.
- Understand the application of governmental and industrial standards to failures and how to apply them to failure analysis.
- Review a variety of case studies in a forensic engineering analysis.

- Understand the importance, purpose and legal issues associated with warnings and safety systems in mechanical devices.
- Be able to write a comprehensive forensic engineering report on an actual failed component including testing data and analysis.

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (e), (f), (k)

**TOPICS**

- Failure Analysis: An introduction
- Approach to failure analysis
- Mechanical aspects of failure
- Macroscopic aspects of failure
- Failure Modes
- Overload failure
- Fatigue failure
- Wear failures
- Corrosion failures
- Elevated temperature failures
- Failure Analysis Report Writing: content, style, terminology, etc.
- Legal Issues: liability, terminology, lawyers, requirements, etc.
- Microelectronic failure analysis
- Medical device failure analysis
- Case Studies: numerous case studies will be reviewed throughout the semester

**PREPARED BY**

G.A. Crawford, April 22, 2016

## MES 475/575 – ADVANCES IN PROCESSING AND NANOENGINEERING OF POLYMERS: (2-0)/2

### INSTRUCTOR

Dr. David. R. Salem, CAPE106, Ph. (605) 394-5279, david.salem@sdsmt.edu

### TEXTBOOK

Selected peer-reviewed articles from the scientific literature and handouts are used

### COURSE INFORMATION

**Catalog Description**: The course will begin with an overview of the basic principles of polymer rheology and structure formation. It will then review recent examples from the scientific literature in which concepts and theories of rheological behavior and structure formation at multiple length scales have been further developed and/or applied to the processing of polymers and composites with advanced functional and multifunctional properties. Special attention will be paid to research related to processing challenges in the formation of polymer nanocomposites, nanofibers and hierarchical composite structures. As part of this course, students will be expected to develop skills in reviewing and critically assessing the scientific literature, and in developing research strategies based on current state of knowledge. This course is cross-listed with CBE 475575 and NANO 475/575.
**Prerequisites:** CHEM 114 /CHEM 114L, or MES 604, or permission of instructor
**Co-requisites**: none
**Required Course:** None
**Selected Elective:** B.S. Metallurgical Engineering, B.S. Chemical Engineering

### COURSE GOALS

**Specific Outcomes**

- The student will be able to understand the primary concepts of structure formation in polymers at scales of nanometers to micrometers, and how structure formation is influenced and controlled by processing conditions
- The student will be able to relate polymer structure to observed properties
- The student will be able to comprehend how nanotechnology is being applied to increase control over the structure and properties of polymer-based materials, and understand some of the central challenges involved.
- The student will be able to critically analyze and compare different approaches to the processing and creation of polymer nanocomposites with advanced properties
- The student will be able to develop an ability to review and condense complex scientific articles into clear, well organized summaries, especially in the form of scientific presentations

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (e), (g), (j), (k)

### TOPICS

- Polymers and Polymer Processing (1 class)
- Polymer Structure, Morphology and Properties: Structure-Property Relationships, Crystallization, and Melting (1 class)

- Polymer Structure, Morphology and Properties: Strain Induced Orientation and Crystallization (1 class)
- Principles of Composites (1 class)
- Nanotechnology in Polymer Engineering: Concepts of Nanomaterial Synthesis (1 class)
- Articles for review, presentation and discussion are selected from leading peer reviewed journals covering processing and properties of advanced, multifunctional composites and nanocomposites. Journals used include: Materials Science and Engineering; Carbon; Nature Materials; Advanced Functional Materials; Composites, Part A; Composites Science and Technology; Journal of Polymer Science; ACS Nano; Proceedings of the National Academy of Sciences, and others. The articles are selected for both strengths and flaws, in order to develop skills in critical assessment. In addition to reviewing and debating the state of current technology, suggestions and strategies for advancing the state-of-the-art are discussed.

**PREPARED BY**

David Salem, April 23, 2016

**MET 489/589 – COMPOSITES MANUFACTURING:** (1-0)/1
**INSTRUCTOR** Dr. David. R. Salem, CAPE106, Ph. (605) 394-5279, david.salem@sdsmt.edu

**TEXTBOOK**
Selected peer-reviewed articles from the scientific literature and handouts are used

**COURSE INFORMATION**

**Catalog Description**: A background in the concepts of polymers and polymerization as well as an overview of composites concepts, constituent materials, and manufacturing processes provide the groundwork in the first half of the course. A more detailed study of the Vacuum Assisted Resin Transfer molding (VARTM) processing builds upon this groundwork, including topics such as process materials and parameters, mold design and manufacture, and product design considerations. The course concludes with post-processing topics. In conjunction with the concepts lecture, students spend time in the lab constructing and using a simple mold which will illustrate some of the challenges of molding and finishing a composite product. This course is cross-listed with CBE 489/589.
**Prerequisites:** none
**Co-requisites**: none
**Required Course:** None
**Selected Elective:** B.S. Metallurgical Engineering, B.S. Chemical Engineering

**COURSE GOALS**

**Specific Outcomes**

- The student will be able to comprehend basics concepts for polymers, polymerization and polymer processing; especially influence of process variables on physical structure of the polymer (molecular orientation, crystallinity etc.)
- The student will become familiar with the principles of composites and composite processing with emphasis on the VARTM method, including post-processing
- The student will demonstrate the ability to measure and interpret key rheological and thermal properties of a thermosetting matrix resin.
- The student will demonstrate the ability to measure and interpret key mechanical properties of a composite
- The student will demonstrate ability to run a VARTM molding process; apply post-processing; and identify and understand source of defects

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (b), (d), (e), (k)

**TOPICS**

- Polymer Processing, Structure and Properties (2 classes)
- Principles of composites (1 class)
- Vacuum Assisted Resin Transfer Molding (VARTM) (1 class)
- Designing for VARTM processing (1 class)
- Post-processing (1 class)
- Rheology and glass transition measurements (1 lab)
- Impact resistance, anisotropy and tensile failure (1 lab)
- VARTM demonstration (1 lab)
- VARTM processing practice (2 labs)

- Post-processing practice (1 lab)

**PREPARED BY**

David Salem, April 23, 2016

## MET 491 – Security Printing Technology: (3-0)/3

**INSTRUCTOR**
Dr. William M. Cross, MI 110, (605) 394-2485, William.Cross@sdsmt.edu

**TEXT BOOK**
Selected papers and handouts

**COURSE INFORMATION**

**Catalog Description*:** The security and anti-counterfeiting technology field will be covered with an emphasis on printing of security end products.
**Prerequisites:** none
**Co-requisites**: none
**Required Course:** None
**Selected Elective:** B.S. Metallurgical Engineering

**COURSE GOALS**

**Specific Outcomes**
The student will be able to describe the

- Importance and purpose of the security industry
- Principles involved in the
  - Manufacture and use of security inks
  - Use of substrates in security printing
  - Design and use secure documents and authentication tools

**STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (f), (h), (j), (k)

**TOPICS**

- What is Security Printing and Security Printing Technology
- The Need for Security
- Investigating and Identifying Inauthentic Items
- Secure Document Requirements
- Security Inks: Manufacture and Use
- Printing Methods for Document Security
- Substrates for Printing in Security Applications
- Other Security Markings: Holograms, OVDs
- Secure Document Design
- Secure Document Authentication

**PREPARED BY**
William M. Cross, February 24, 2016

* This provisional, new course will be renumbered to MET 444/544 Security Printing Technology for Fall 2017.

## EE 301/301L: Introductory Circuits, Machines, and Systems: (3-1)/4

**Department:** Electrical Engineering

**Designation:** Required
**Catalog Data:** (3-1) 4 credits. Introduces the essential concepts of electrical engineering concerning circuits, machines, electronics, and systems
**Prerequisites:** Math 125 completed with a "C-" or better, and Math321 completed or concurrent. Not for majors in Electrical or Computer Engineering.
**Textbook:** Principles and Applications of Electrical Engineering, (6th ed.). Rizzoni, 2015

### Course Learning Outcomes

- Apply the fundamentals of electric circuits including Ohm's Law, Kirchhoff's Current and Voltage Laws, and voltage and current division to analyze and build circuits.
- Use DC circuit analysis techniques such as node analysis, mesh analysis, and Norton and Thevenin equivalent circuits to solve for circuit parameters.
- Extend DC analysis techniques to AC networks using phasor notation and conversion of time domain sinusoidal voltages and currents.
- Identify the characteristics of first and second order transients.
- Have an awareness of the advantages of using the frequency domain by way of Bode plot, Fourier series and filtering.
- Use the basic operation and applications of operational amplifiers including inverting, non-inverting, summing, differential amplifiers using ideal analysis and the limitations of real op-amps.
- Be familiar with the basic operation and applications of semiconductor devices such as diodes, LED's, and BJT transistors.
- Be familiar with the basic operation of digital logic gates and their application and link to other technologies (PLC, microcontrollers).
- Have an awareness of electric machines and AC power and their uses.
- Use basic laboratory measurement equipment including the power supplies, digital multimeters, function generators, and oscilloscopes to conduct experiments.

### Topics

- Introduction to EE Lab: Equipment Familiarization/Matlab Introduction
- Ohm's Law: Series Circuit/Parallel Circuit
- Voltage and Current Division: Series Circuit/Parallel Circuit
- Voltage and Current Division Applications: Variable Resistors as Input Devices (potentiometer, thermistor)/Wheatstone Bridge
- Nodal Analysis
- Mesh Analysis
- Thevenin and Norton Circuits
- Use of the Signal Generator and Oscilloscope - Study of AC Signal Properties
- Transient Response of a Circuit: First Order System/Second Order System
- Low and High Pass Filtering: First Order Filter/Second Order Filter
- Fourier Series and FFT

- Diodes, Transistors and Op-Amps: Half-wave Rectifier/Full-wave Rectifier/Common-emitter BJT/Common-emitter BJT with Motor and Snubber Diode/Inverting Amplifier
- Digital Logic: AND, OR, NOT, NAND, NOR circuits with switches and LED's/Cascaded circuit
- Laboratory Practical Exam (individual): Build Circuit/Measuring Critical Parameters/Equipment Identification and Knowledge of Uses

**Class Schedule:** Varies

**PRIMARY STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (k)

**EM 214 Statics: (3-0)/3**

**Department:** Civil Engineering

**Designation:** Required
**Catalog Data:** (3-0) 3 credits. The study of the effects of external forces acting on stationary rigid bodies in equilibrium. Vector algebra is used to study two and three dimensional systems of forces. Trusses, frames and machines, shear and moment in beams, friction, centroids, moments of inertia, and mass moments of inertia are discussed.
**Prerequisites:** MATH 123 with a minimum grade of "C".
**Textbooks:** Vector Mechanics for Engineers, Statics, 10$^{th}$ Ed., Beer and Johnston

**Course Learning Outcomes:**

- Determine the components of a force in rectangular coordinates.
- Draw complete and correct free-body diagrams and write the appropriate equilibrium equations from the free-body diagram.
- Evaluate forces acting on static bodies including determining resultants and 3D components.
- Calculate moments in 2D and 3D about a point and an axis utilizing cross products and dot products.
- Determine the support reactions on a structure.
- Determine the connection forces in trusses and in general frame structures.
- Given standard shapes and corresponding centroids and/or moments of inertia, be able to compute centroids and/or moments of inertia for composite bodies.
- Determine how to identify and solve problems involving dry friction.
- Determine the internal reactions in a beam; draw shear force and bending moment diagrams.

**Topics**

- Fundamental Concepts and Laws
- Statics of Particles
- Equivalent Systems of Forces on Rigid Bodies
- Equilibrium of Rigid Bodies
- Distributed Forces: Centroids & Centers of Gravity & Moments of Inertia
- Analysis of Structures: Trusses, Frames & Machines
- Internal Forces
- Shear & Moment Diagrams of Beams
- Friction

**Class Schedule:** Varies

**PRIMARY STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (e)

## ME 216 - Introduction to Solid Mechanics: (3-0)/3

**Department:** Mechanical Engineering

**Designation:** Required

**Catalog Data:** (3-0) 3 Credits. This course covers the fundamental concepts of solid mechanics including the definition of stress, transformations and states of stress; plane stress, plane strain, octahedral stresses, three dimensional stresses, and principal stresses in two and three dimensions. Additional topics include strain analysis, strain measurements and rosette analysis, generalized Hooke's law, and orthotropic materials. Specific applications are an introduction to composite materials, analysis of thin and thick cylinders, statically indeterminate members, torsional loading of shafts, power transmission and the shaft analysis, torsional loads in non-circular components and thin tubes, stress concentrations, and combined loads.
**Prerequisites:** MATH 125, ME 210 with a minimum grade of "C", or permission of instructor.
**Textbook:** Mechanics of Materials; R. C. Hibbeler, $9^{th}$ ed., Pearson Prentice Hall, 2014.

**Course Learning Outcomes**

- Understand basic definitions and sign conventions for normal and shearing stresses and strains.
- Use the stress transformation equations for the case of plane stress.
- Find principal stresses, maximum in-plane shearing stress, and absolute maximum shearing stress for the case of plane stress.
- Use the strain transformation equations for the case of plane strain.
- Find principal strains and maximum in-plane shearing strain for the case of plane strain.
- Understand the difference between plane stress and plane strain.
- Use the measurements from a strain rosette to determine the strain components at a point on the surface of a body.
- Understand the role of the stress-strain diagram in characterizing the mechanical behavior of a material.
- Identify the mechanical properties used to characterize the behavior of linear elastic isotropic materials.
- Use the generalized Hooke's law to relate the components of stress and strain.
- Quantify the strains induced by a change in temperature.
- Solve problems involving axially loaded members.
- Apply static stress concentration factors to determine the maximum stress in axially loaded members with stress raisers.
- Solve simple problems involving circular shafts subjected to torsion.

**Topics:**

- Analysis of Stress - Definition of stress, average normal stress in an axially loaded bar, average shear stress, allowable stress, plane stress, stress transformation equations for a state of plane stress, principal stresses and maximum in-plane shear stress for the case of plane stress, Mohr's circle for the case of plane stress, absolute maximum shear stress.

- Analysis of Strain - Deformation, definition of strain, plane strain, strain transformation equations for a state of plane strain, principal strains and maximum in-plane shearing strain for the case of plane strain, strain rosettes.
- Material Properties and Stress-Strain Relationships -The tension and compression test, the stress–strain diagram, stress–strain behavior of ductile and brittle materials, Hooke's law, strain energy, Poisson's ratio, the shear stress–strain diagram, Generalized Hooke's law, thermal strain.
- Axial Loading - Saint-Venant's principle, elastic deformation of an axially loaded member, principle of superposition, statically indeterminate axially loaded member, thermal stress, stress concentration.
- Torsion - Torsional deformation of a circular shaft, the torsion formula, power transmission, angle of twist.

**Class Schedule:** Varies

**PRIMARY STUDENT OUTCOMES ADDRESSED BY THIS COURSE: (a), (e), (k)**

## EM 321 Mechanics of Materials: (3-0)/3

**Department:** Civil Engineering

**Designation:** Required
**Catalog Data:** (3-0) 3 credits. Basic concepts of stress and strain that result from axial, transverse, and torsional loads on bodies loaded within the elastic range. Shear and moment equations and diagrams; combined stresses; Mohr's circle; beam deflections; and column action and equations.
**Prerequisites:** EM 214 with a minimum grade of "C".
**Textbooks:** Mechanics of Materials, Beer/Johnston, 6th Ed

### Course Learning Outcomes

- Calculate a state of stress for a point on a loaded object
- Calculate section properties
- Calculate stress and strains
- Apply major concepts of equilibrium and compatibility
- Calculate principal stresses and strains
- Design members or systems to withstand prescribed loadings based on a maximum allowable stress
- Draw shear and bending moment diagrams

### Topics

- Basic concepts of stress and strains.
- Deformation analysis due to torsion, axial flexural and combined loads.
- Design of simple structures to prevent failure.

**Class Schedule:** Varies

**PRIMARY STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (e)

**IENG 301 Basic Engineering Economics**: **(2-0)/2**

**Department:** Industrial Engineering

**Designation:** Required
**Catalog Data:** (2-0) 2 credits**.** Introduces the concepts of economic evaluation regarding capital investments, including the time value of money and income tax effects
**Prerequisite:** Junior or higher standing preferred
**Textbooks:** Engineering Economy, 7th Ed. Blank, Leland; Tarquin, Anthony, ISBN: 978-0-07-337630-1

**Course Learning Outcomes:**

- Move various cash flows across time while accounting for discrete or continuous compound interest, e.g., single payment factors, uniform-series factors, and arithmetic and geometric gradient factors.
- Apply the concept of minimum attractive rate of return in economic decision-making.
- Identify the most appropriate engineering economy tool for evaluating alternatives.
- Evaluate asset alternatives using present worth analysis, annual worth analysis, rate of return analysis, and benefit / cost analysis.
- Utilize computer spreadsheets and their functions to solve engineering economy problems.
- Apply straight-line, declining balance, sum of years digits, units of production, and MACRS depreciation models to reduce the value of the capital investment in an asset.
- Calculate before-tax and after-tax cash flows.
- Determine break-even points on projects utilizing time value money.

**Topics**

- Time Value of Money
- Cash Flow Patterns
- Effective Interest Rates
- Complex Cash Flows
- Net Present Worth and Lifetime Issues
- Annual Worth Analysis
- Perpetuity (Capitalized Costs)
- Bonds
- Internal Rate of Return / Incremental Analysis
- Benefit/Cost Analysis
- Incremental Benefit/Cost Analysis
- Depreciation
- After Tax Cash Flow Analysis
- Break-Even and Sensitivity Analysis

**Class Schedule:** Varies

**PRIMARY STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (c), (h), (k)

## CHEM 112 General Chemistry I: (3-0)/3

**Department:** Chemistry

**Designation:** Required for most majors
**Catalog Data:** (3-0) 3 credits. An introduction to the basic principles of chemistry for students needing an extensive background in chemistry (including chemistry majors, science majors, and pre-professional students). Completion of a high school course in chemistry is recommended
**Prerequisites:** MATH 102
**Textbook:** Chemistry: The Molecular Nature of Matter, 7th Edition, Jespersen, N.D.; Hyslop, A.: Brady, J.E., January 2014, © 2015

### Course Learning Outcomes

- Understand, and use correctly, the symbolic representations, chemical notation, formulas, and systematic rules of nomenclature that characterize the language of chemistry.
- Understand and apply the mole concept in a variety of chemical calculations, including calculating the number of particles in a given mass of substance (and vice versa), and the quantitative relationships between reactants and products in a chemical reaction.
- Recognize the different types of chemical transformations: acid-base, precipitation, combination, decomposition, single-replacement, oxidation-reduction, double replacement, and combustion.
- Understand the basic principles of energy transfer involving chemical systems, including the transfer of heat and work between system and surroundings, the qualitative and quantitative interpretation of thermochemical equations, and the application of Hess's Law.
- Understand the various models of atomic structure, the basic principles of quantum theory, and the experiments that led to those principles.
- Write ground-state electron configurations for atoms and ions of any representative element and the 3d transition series elements.
- Understand the fundamental aspects of chemical bonding, including writing Lewis structures, describing the bonding in molecules by simple valence-bond theory, and using Valence Shell Electron Pair Repulsion Theory to predict the geometries of molecules and ions.
- Use modern atomic theory to understand and predict the properties of different elements.
- Understand the properties of the different states of matter.
- Qualitatively and quantitatively describe the properties of the gaseous state and the fundamental laws governing the behavior of gases.
- Understand, qualitatively and quantitatively, the behavior of solutions and their colligative properties.
- Understand how fundamental intermolecular interactions among particles determine the physical and chemical properties of a system.
- Understand the fundamental postulates of kinetic-molecular theory and use them to explain the physical behavior of the three states of matter.

**TOPICS**

- Atoms and isotopes
- Scientific measurements
- Elements, Compounds, and the Periodic Table
- The Mole and Stoichiometry
- Molecular View of Reactions in Aqueous Solutions
- Oxidation-Reduction Reactions
- Energy and Chemical Change
- The Quantum Mechanical Atom
- The Basics of Chemical Bonding
- Theories of Bonding and Structure
- Properties of Gases
- Intermolecular Attractions and the Properties of Liquids and Solids
- Mixtures at the Molecular Level: Properties of Solutions

**Class Schedule:** Varies

**PRIMARY STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a)

## CHEM 112L General Chemistry I Laboratory: (0-1)/1

**Department:** Chemistry

**Designation:** Required
**Catalog Data:** (0-1) 1 credits. Laboratory designed to accompany CHEM 112
**Pre or Corequisites:** CHEM 112
**Textbook:** CHEM 112L General Chemistry I Manual

**Course Learning Outcomes**

- Understand and follow common laboratory safety practices
- Behave appropriately in the chemistry lab setting
- Understand the basic concepts of chemical experiments
- Study the properties and behavior of matter
- Identify and use common chemical glassware, such as flasks, pipettes, beakers, and graduated cylinders, and know what type to use for measurements
- Use common chemical lab equipment, such as balances, centrifuges, and Bunsen burners safely and properly
- Make accurate and precise quantitative measurements, and know why this is important
- Understand the importance of recording data properly and honestly by keeping true and complete
- Experimental records
- Make complete qualitative observations
- Meet deadlines for submission of work
- Understand the importance of preparation and the consequences for not being prepared
- Identify sources of error in an experiment AND understand **specifically** how those errors affect
- The result of the experiment and be able to predict these effects
- Differentiate qualitative and quantitative experiments
- Understand accuracy and precision and the difference between them
- Follow units and significant figures through calculations and be able to arrive at the correct units and significant figures for the final answer
- Interpret experimental results and draw reasonable conclusions from the results obtained
- Graph data in Excel and be able to use the graph produced to answer scientific questions about
- The experiment and its result
- Interpret data in graphical form and figure out the units on a linear trend line from the graph.

**Topics**

- Stoichiometry and moles
- Balancing chemical reactions
- Limiting reagents and calculations based on these
- Significant figures
- Density and factors that affect it

- Physical changes, and the temperature profile during a physical change
- Concentrations, molarity, and calculations based on these
- Constant pressure calorimetry
- Solubility rules for ionic materials in water
- Net ionic equations for metathesis reactions
- Lewis Structures and molecular geometry including VSEPR theory,
- Resonance and formal charges in Lewis structures
- Polarity in molecules
- How temperature affects vapor pressure of a liquid
- Naming compounds and writing formulae that are correct, and identifying common errors in names and formulae

**Class Schedule:** Varies

**PRIMARY STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (b)

## CHEM 114: General Chemistry II: (3-0)/3

**Department:** Chemistry

**Designation:** Required
**Catalog Data:** (3-0) 3 credits. A continuation of CHEM 112 . An introduction to the basic principles of chemistry for students needing an extensive background in chemistry
**Prerequisites:** CHEM 112 and MATH 102
**Textbook:** Chemistry: Matter and Its Changes, 7th ed., Jespersen, Hyslop

**Course Learning Outcomes**

- Understand rates of reaction and conditions affecting rates.
- Derive the rate equation, rate constant, and reaction order from experimental data.
- Use integrated rate laws.
- Understand the collision theory of reaction rates and the role of activation energy.
- Understand basic reaction mechanisms and identify intermediates and catalyst.
- Understand the nature and characteristics of chemical equilibria.
- Understand the significance of the equilibrium constant, K.
- Understand how to use the equilibrium constant in quantitative studies of chemical equilibria.
- Understand and use Le Châtelier’s Principle in predicting the effects of stresses on equilibrium systems.
- Use the Brønsted-Lowry and Lewis concepts of acids and bases.
- Understand the difference between strong and weak acids in aqueous solutions.
- Be able to relate pH to hydronium and hydroxide ion concentrations.
- Apply the principles of chemical equilibrium to acids and bases in aqueous solution.
- Understand the control of pH in aqueous solutions with buffers.
- Evaluate the pH in the course of acid-base titrations.
- Apply chemical equilibrium concepts to the solubility of ionic compounds.
- Understand the formation and properties of complex ions.
- Understand the concept of entropy and how it relates to spontaneity.
- Use tables of data in thermodynamic calculations.
- Define and use free energy in predicting the spontaneity of chemical processes.
- Be able to apply free energy to equilibrium concepts.
- Balance net ionic equations for oxidation-reduction reactions.
- Understand the principles of voltaic and electrolytic cells.
- Understand how to use electrochemical potentials.
- Be able to apply electrochemical potentials to free energy and equilibrium concepts.
- Be able to calculate energies for nuclear reactions.
- Be able to balance nuclear equations.
- Be able to predict methods of nuclear decay.
- Understand complex ions

**TOPICS** An introduction to the basic principles of chemistry for students needing an extensive background in chemistry

**Class Schedule:** Varies

**PRIMARY STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a)

## CHEM 114L General Chemistry II Laboratory: (0-1)/1

**Department:** Chemistry

**Designation:** Required
**Catalog Data:** (0-1) 1 credits. Laboratory designed to accompany CHEM 114.
**Prerequisites:** CHEM 112L
**Pre or Corequisites:** CHEM 114
**Textbook:** Lab Manual CHEM 114L: General Chemistry Lab II.

**Course Learning Outcomes:**

- Perform procedures for the analytical separation and qualitative determination of selected cations in an aqueous solution.
- Understand the fundamental and operational principles upon which common methods of separation and purification of chemical substances are based.
- Identify sources of error in chemical experiments.
- Interpret experimental results and draw reasonable conclusions.
- Practice laboratory safety procedures.
- Anticipate, recognize, and respond to hazards of chemical materials and manipulations.
- Learn the importance of following correct laboratory procedures.
- Keep legible and complete experimental records.
- Collaborate with peers in obtaining and interpreting data.

**Topics**

- Laboratory Techniques in class.
- Calorimetric Analysis of Food
- Iodine Clock
- Introducing Chemical Equilibrium
- Polymers
- Qualitative Cation Analysis
- Acid Base Titration
- Electrochemical Cells
- Polymers

**Class Schedule:** Varies

**PRIMARY STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (b)

## ENGL 101 Composition I: (3-0)/3

**Department:** Humanities and Social Sciences

**Designation:** Required
**Catalog Data:** (3-0) 3 credits.
Practice in the skills, research, and documentation needed for the effective academic writing. Analysis of a variety of academic and non-academic texts, rhetorical structures, critical thinking, and audience will be included.
**Prerequisites:** Appropriate student placement based on entry level assessment or completion of ENGL 033.
**Textbook:** Varies by section. Examples include Axelrod, Rise. B, St. Martin's Guide to Writing; Raimes, Ann, Pocket Keys to Writing; Eds. Lunsford, Ruskiewica, and Walters, Everything's an Argument

**Course Learning Outcomes**

- Write using standard American English, including correct punctuation, grammar, and sentence structure.
    - Recognize and repair common errors in grammar, punctuation, and usage in papers.
    - Apply standard English grammar, punctuation, and other mechanical aspects to all written assignments.
    - Compose clear, effective sentences and combine them into focused, coherent paragraphs that match the assigned writing purpose.
    - Improve their mastery of punctuation, grammar, and sentence structure through class discussions/exercises, quizzes, instructor feedback, and the draft and revision process.
- Write logically.
    - Recognize and repair common focus and organization errors in their papers.
    - Apply common organizational strategies to all written assignments.
    - Write clear, effective paragraphs and combine them into a logical sequence and focal pattern that matches the assigned writing purpose.
    - Improve their mastery of organization and logical writing through class discussions, written exercises, instructor feedback, and the draft and revision process.
- Write persuasively, with a variety of rhetorical strategies (e.g. expository, argumentative, descriptive).
    - Identify and repair common rhetorical and reasoning errors in their papers.
    - Apply common rhetorical and reasoning strategies to all written assignments.
    - Design and produce writing using appropriate rhetorical strategies that match audience needs and assigned writing purpose.
    - Improve their mastery of persuasion and rhetorical strategies through class discussions, written exercises, instructor feedback, and the draft and revision process.
- Incorporate formal research and documentation into their writing, including research obtained through modern, technology-based research tools.
    - Identify and repair common documentation errors in their papers.
    - Apply common research strategies to all written assignments that require it.

  - Design and produce writing using appropriate research tools that match audience needs, proper documentation requirements, professional ethical standards, and assigned writing purpose.
  - Improve their mastery of research and documentation methods through class discussion, written exercises, quizzes, instructor feedback, and the draft and revision process.

**Topics**

- Writing with emphasis on the essay format
- Research and documentation
- Grammar, punctuation, and mechanics review
- Improve and build confidence in writing ability

**Class Schedule:** Varies

**PRIMARY STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (g)

## English 279 Technical Communications I: (3-0)/3

**Department:** Humanities and Social Sciences

**Designation:** Required
**Catalog Data:** (3-0) 3 credits. Introductory written and oral technical communications with emphasis on research and explanations of scientific and engineering topics.
ENGL 101 or equivalent and sophomore standing.
**Textbook:** Strategies for Technical Communication in the Workplace. 3rd ed. Gurak, Laura and John M. Lannon, Boston: Longman, 2016

**Course Learning Outcomes**

- Write using standard American English, including correct punctuation, grammar, and sentence structure.
    - Recognize and repair common errors in grammar, punctuation, and usage in their written assignments.
    - Apply standard American English and correct grammar, punctuation, and mechanics in written assignments.
    - Compose clear and effective sentences and paragraphs that match the assigned writing purpose.
    - Improve their mastery of punctuation, grammar, and sentence structure through quizzes, instructor feedback, peer review, and the planning/drafting/revising process used to complete their technical writing assignments.
- Write logically.
    - Produce a variety of well-organized and effectively designed short, basic documents.
    - Use the process of planning, drafting, and revision to take a document from initial conception to final product.
    - Improve their mastery of organization and logical writing through class discussions, instructor feedback, peer review, and the planning/drafting/revising process used to complete their technical writing assignments.
- Write persuasively, with a variety of rhetorical strategies (e.g. expository, argumentative, and descriptive).
    - Produce individual and collaborative documents for a variety of technical, professional, and general audiences
    - Recognize and use appropriate conventional formats and visuals applicable to a variety of short, basic technical documents
    - Improve their mastery of persuasion and rhetorical strategies through class discussions, instructor feedback, peer review, and the planning/drafting/revising process used to complete their technical writing assignments.
    - Incorporate formal research and documentation into their writing, including research obtained through modern, technology-based research tools.
- Use the basic research skills and documentation techniques necessary to produce effective written technical communications.
- Exhibit awareness of ethical standards by accurately using sources and formulating text in their papers.

- Improve their mastery of research and documentation methods through class discussions, instructor feedback, peer review, and the planning/drafting/revising process used to complete their technical writing assignments.
- Prepare and deliver speeches for a variety of audiences and settings.
  - Analyze the relevant characteristics of their intended audience.
  - Prepare and deliver speeches of differing lengths, topics, and purposes for a variety of technical, professional, and general audiences.
  - Improve their mastery of audience and setting analysis through class discussion and exercises, peer review, instructor feedback, practice and final speeches.
- Demonstrate listening competencies including choice and use of topic, supporting materials, organizational pattern, language usage, presentational aids, and delivery.
  - Recognize the different speech goals and organizational patterns used for informational, demonstration, and/or persuasion speeches.
  - Demonstrate in individual and/or collaborative speeches their competency in selecting and using appropriate supporting materials and presentational aids for the intended type of speech and audience.
  - Demonstrate in individual and/or collaborative speeches their competency in using appropriate language for the intended type of speech and audience
  - Incorporate effective delivery techniques, both vocal and nonverbal, for the intended speech and audience in individual and/or collaborative speeches
  - Improve their mastery of choosing and using appropriate topics and organizational plans, supporting materials, language, presentation aids, and delivery techniques through class discussion and exercises, peer review, instructor feedback, practice and final speeches.
- Demonstrate listening competencies by summarizing, analyzing, and paraphrasing ideas, perspectives, and emotional content
  - Demonstrate listening competencies through peer review exercises.
  - Improve their mastery of listening skills through class discussions and exercises, instructor and student feedback, practice and final speeches.

**Topics**

- Basic short technical documents
- research and documentation
- Oral presentations.

**Class Schedule:** Varies

**PRIMARY STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (g)

## English 289 Technical Communications I: (3-0)/3

**Department:** Humanities and Social Sciences

**Designation:** Required
**Catalog Data:** (3-0) 3 credits. Advanced written and oral technical communications with emphasis on the research, preparation, and delivery of complex technical documents
**Prerequisites:** ENGL 279 or equivalent and sophomore standing.
**Textbook:** Varies by section. Examples include Axelrod, Rise. B, St. Martin's Guide to Writing; Raimes, Ann, Pocket Keys to Writing; Eds. Lunsford, Ruskiewica, and Walters, Everything's an Argument

**Course Learning Outcomes**

- Write using standard American English, including correct punctuation, grammar, and sentence structure.
  - Recognize and repair common errors in grammar, punctuation, and usage in their written assignments.
  - Apply standard American English and correct grammar, punctuation, and mechanics in written assignments.
  - Compose clear and effective sentences and paragraphs that match the assigned writing purpose.
  - Improve their mastery of punctuation, grammar, and sentence structure through quizzes, instructor feedback, peer review, and the planning/drafting/revising process used to complete their technical writing assignments.
- Write logically.
  - Produce a variety of well-organized and effectively designed short, basic documents.
  - Use the process of planning, drafting, and revision to take a document from initial conception to final product.
  - Improve their mastery of organization and logical writing through class discussions, instructor feedback, peer review, and the planning/drafting/revising process used to complete their technical writing assignments.
- Write persuasively, with a variety of rhetorical strategies (e.g. expository, argumentative, and descriptive).
  - Produce individual and collaborative documents for a variety of technical, professional, and general audiences;
  - Recognize and use appropriate conventional formats and visuals applicable to a variety of short, basic technical documents;
  - Improve their mastery of persuasion and rhetorical strategies through class discussions, instructor feedback, peer review, and the planning/drafting/revising process used to complete their technical writing assignments.
- Incorporate formal research and documentation into their writing, including research obtained through modern, technology-based research tools.
  - Use the basic research skills and documentation techniques necessary to produce effective written technical communications.
  - Exhibit awareness of ethical standards by accurately using sources and formulating text in their papers.

  - Improve their mastery of research and documentation methods through class discussions, instructor feedback, peer review, and the planning/drafting/revising process used to complete their technical writing assignments.
- Prepare and deliver speeches for a variety of audiences and settings.
  - Analyze the relevant characteristics of their intended audience.
  - Prepare and deliver speeches of differing lengths, topics, and purposes for a variety of technical, professional, and general audiences.
  - Improve their mastery of audience and setting analysis through class discussion and exercises, peer review, instructor feedback, practice and final speeches.
- Demonstrate listening competencies including choice and use of topic, supporting materials, organizational pattern, language usage, presentational aids, and delivery.
  - Recognize the different speech goals and organizational patterns used for informational, demonstration, and/or persuasion speeches.
  - Demonstrate in individual and/or collaborative speeches their competency in selecting and using appropriate supporting materials and presentational aids for the intended type of speech and audience.
  - Demonstrate in individual and/or collaborative speeches their competency in using appropriate language for the intended type of speech and audience
  - Incorporate effective delivery techniques, both vocal and nonverbal, for the intended speech and audience in individual and/or collaborative speeches
  - Improve their mastery of choosing and using appropriate topics and organizational plans, supporting materials, language, presentation aids, and delivery techniques through class discussion and exercises, peer review, instructor feedback, practice and final speeches.
- Demonstrate listening competencies by summarizing, analyzing, and paraphrasing ideas, perspectives, and emotional content
  - Demonstrate listening competencies through peer review exercises.
  - Improve their mastery of listening skills through class discussions and exercises, instructor and student feedback, practice and final speeches.

**Topics**

- Complex technical documents, and
- Visuals and graphic design
- Research and documentation
- Oral presentations.

**Class Schedule:** Varies

**PRIMARY STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (g)

## Math 123 Calculus I: (4-0)/4

**Department:** Mathematics

**Designation:** Required
**Catalog Data:** (4-0) 4 credits. The study of limits, continuity, derivatives, applications of the derivative, antiderivatives, the definite and indefinite integral, and the fundamental theorem of calculus.
**Prerequisites:** MATH 115 with a grade of C or appropriate mathematics placement or permission of instructor.
**Textbooks:** Calculus by Thomas plus MyMathLab, 13th ed

### Course Learning Outcomes

- Take derivatives of trigonometric and algebraic functions using the power rule, chain rule, product rule, and quotient rule.
- Use the derivative in applications such as velocity and acceleration, related rates, optimization, and curve sketching.
- Integrate algebraic and trigonometric functions using the power rule and substitution.
- Demonstrate the use of the integral in an application. Examples may include area, volume, moments, work, arc length, and surface area.
- Use a computer algebra system to implement the solution techniques that are covered in Calculus 1

### Topics

- Intro to Calculus & Trigonometry review
- Rates of Change, Limit Laws, One-Sided Limits
- Continuity, Limits of Infinity
- Derivative at Point, Derivative Functions
- Differential Rules, Trig Differentials, Chain Rule, Implicit Differentials
- Extreme Values, Concavity, Optimization, Anti-Derivatives
- Sums, Limit of Sums, Indefinite Integrals
- Area Bounded, Washers & Disks, Shells, Arc Length, Surface Revs

**Class Schedule:** Varies

**PRIMARY STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a)

## Math 125 Calculus II: (4-0)/4

**Department:** Mathematics

**Designation:** Required
**Catalog Data:** (4-0) 4 credits. A continuation of the study of calculus, including the study of sequences, series, polar coordinates, parametric equations, techniques of integration, applications of integration, indeterminate forms, and improper integrals.
**Prerequisites:** MATH 115 or MATH 120 with a minimum grade of "C" or appropriate score on departmental Trigonometry Placement Examination and MATH 123 with a minimum grade of C
**Textbooks:** Calculus by Thomas plus MyMathLab, 13th ed

### Course Learning Outcomes

- Solve linear systems of equations and matrix equations.
- Evaluate integrals with advanced techniques, such as: substitution, Trigonometric substitution, integration by parts, and partial fractions.
- Produce the Taylor series expansions for functions, including many transcendental functions.
- Use a computer algebra system to implement the solution techniques that are covered in Calculus 2.

### Topics

- Calculus with exponentials, logs,
- Inverse trig functions and hyperbolics
- Integration techniques
- Matrices and vectors
- Infinite series

**Class Schedule:** Varies

**PRIMARY STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a)

## Math 225 Calculus III: (4-0)/4

**Department:** Mathematics

**Designation:** Required

**Catalog Data:** (4-0) 4 credits. A continuation of the study of calculus, including an introduction to vectors, vector calculus, partial derivatives, and multiple integrals
**Prerequisite:** MATH 125 with a minimum grade of "C".
**Textbooks:** Calculus by Thomas plus MyMathLab, 13th ed

### Course Learning Outcomes

- Analyze position, velocity, and acceleration in two or three dimensions using the calculus of vector valued functions.
- Use partial derivatives to calculate rates of change of multivariate functions.
- Use multiple integrals to compute the volume, mass, center of mass, and related quantities for multivariate functions.
- Compute line integrals, including those representing work done by a variable force in a vector field

### Topics

- Parametric equations, equations of lines & planes
- Vector-valued functions, functions of several variables
- Polar coordinates, spherical coordinates, cylindrical coordinates, multiple integrals & applications
- Vector calculus & Green's Theorem

**Class Schedule:** Varies

**PRIMARY STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a)

## Math 321 Differential Equations: (3-0)/3

**Department:** Mathematics

**Designation:** Required
**Catalog Data:** **(3-0) 3** credits. Selected topics from ordinary differential equations including development and applications of first order, higher order linear and systems of linear equations, general solutions and solutions to initial-value problems using matrices. Additional topics may include Laplace transforms and power series solutions. In addition to analytical methods this course will also provide an introduction to numerical solution techniques.
**Prerequisites:** MATH 125 with a minimum grade of "C".
**Textbooks:** A First Course in Differential Equations with Modeling Applications, Tenth Edition by Dennis G. Zill.

### Course Learning Outcomes

- Identify an appropriate method to solve first order ordinary differential equation
- Solve homogeneous & non-homogeneous higher order ordinary differential equations
- Implement the use of Laplace Transforms to solve an ordinary differential equation
- Analyze and solve applications involving ordinary differential equations. Some examples of applications include: circuits, vibrating systems, chemical mixing, and population modeling.
- Apply the techniques for solving linear systems of ordinary differential equations
- Implement the use of a software package to aid in solving differential equations numerically and analytically

### Topics

- Development & applications of $1^{st}$ order
- Higher order linear & systems of linear equations
- General solutions & solutions to initial-value problems using matrices
- Laplace transforms & power series solutions
- Introduction to numerical solution

**Class Schedule:** Varies

**PRIMARY STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a)

## MATH 373 Introduction to Numerical Analysis: (3-0)/3

**Department:** Mathematics

**Designation:** Required
**Catalog Data:** (3-0) 3 credits. This course is an introduction to numerical methods. Topics include elementary discussion of errors, polynomial interpolation, quadrature, non-linear equations, and systems of linear equations. The algorithmic approach and efficient use of the computer will be emphasized. Additional topics may include: calculation of eigenvalues and eigenvectors, numerical differentiation and integration, numerical solution of differential equations.
**Prerequisites:** MATH 321 and CSC 150/150L or permission of instructor
**Textbooks:** Applied Numerical Methods with Matlab for Engineers and Scientists by Chapra

### Course Learning Outcomes

- Write finite approximations of the first and second derivative
- Identify the different types of error in numerical methods
- Implement the use of numerical approximation for integration
- Implement the use of Runge-Kutta to solve initial value problems
- Apply numerical methods to solve systems of differential equations
- Apply numerical methods to solve nonlinear equations
- Apply numerical methods to sovle linear systems
- Use some type of software to solve simple forms of partial differential equations

### Topics

- Elementary discussion of errors
- Polynomial interpolation
- Quadrature, non-linear equations & systems of linear equations
- Algorithmic approach
- Calculation of eigenvalues & eigenvectors
- Numerical differentiation & integration
- Numerical solution of differential equations

**Class Schedule:** Varies

**PRIMARY STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a)

## PHYS 211 University Physics I: (3-0)/3

**Department:** Physics

**Designation:** Required
**Catalog Data:** (3-0) 3 credits. This is the first course in a two semester calculus-level sequence, covering fundamental concepts of physics. This is the preferred sequence for students majoring in physical science or engineering. Topics include classical mechanics and thermodynamics. The School of Mines course covers classical mechanics only.
**Prerequisites:** MATH 123 or permission of instructor.
**Textbook:** Fundamentals of Physics, $10^{th}$ Edition, Part 1, Halliday/ Resnick/ Walker

### Course Learning Outcomes

- Demonstrate the scientific method in a laboratory experience. This outcome will be achieved and assessed in Phys 213L course.
- Gather and critically evaluate data using scientific method. Assessment: Students will be able to critically evaluate data (given or obtained) with proper accuracy using appropriate laws and formulas of classical mechanics for scientifically sound presentation of laboratory reports, homework assignments, and of solutions on quizzes and exams.
- Identify and explain the basic concepts, terminology and theories of selected natural sciences. Assessment: Students will be able to identify and apply basic concepts and appropriate laws of classical mechanics in order to solve assigned problems in homework, quizzes, exams, and in oral presentation.
- Apply selected natural science concepts and theories to contemporary issues. Assessment: Students will be able to explain how physics concepts, laws, and phenomena relate to contemporary engineering and science in classroom discussions and written assignments.

### Topics

Classical mechanics

**Class/Laboratory Schedule:** Varies

**PRIMARY STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (c), (e), (f), (i), (k)

## PHYS 213 UNIVERSITY PHYSICS II: (3-0)/3

**Department:** Physics

**Designation:** Required
**Catalog Data:** (3-0) 3 credits. This course is the second course in a two semester calculus-level sequence, covering fundamental concepts of physics. This is the preferred sequence for students majoring in physical science or engineering. Topics include electricity and magnetism, sound, light, and optics. The School of Mines course covers electricity and magnetism only.
**Prerequisites:** PHYS 211
**Textbook:** Fundamentals of Physics, 10th Edition, Part 1, Halliday/ Resnick/ Walker

**Course Learning Outcomes**

- Demonstrate the scientific method in a laboratory experience. This outcome will be achieved and assessed in Phys 213L course
- Gather and critically evaluate data using scientific method. Students will be able to critically evaluate data (given or obtained) with proper accuracy using appropriate laws and formulas of classical mechanics for scientifically sound presentation of laboratory reports, homework assignments, and of solutions on quizzes and exams.
- Identify and explain the basic concepts, terminology and theories of selected natural sciences. Students will be able to identify and apply basic concepts and appropriate laws of classical mechanics in order to solve assigned problems in homework, quizzes, exams, and in oral presentation.
- Apply selected natural science concepts and theories to contemporary issues. Students will be able to explain how physics concepts, laws, and phenomena relate to contemporary engineering and science in classroom discussions and written assignments.

**Topics**

- Electric Charge, charge, conductors and insulators, Coulomb's Law
- Applications of Coulomb's Law
- Applications of Coulomb's Law
- Electric Fields, electric field lines, electric field due to a point charge
- Electric field due to a dipole, continuous charge distributions
- Electric fields due to continuous charge distributions
- Electric fields due to continuous charge distributions
- Point charge and dipole in a electric field
- Gauss' Law, flux of an electric field, Gauss' Law
- Electric Potential , electric potential energy, electric potential, potential from the field
- Potential due to a point charge
- Potential due to continuous charge distributions
- Field from potential
- Capacitance, calculating the capacitance
- Capacitors in parallel and in series
- Energy stored in an electric field
- Capacitor with a dielectric

- Current and Resistance, current and current density
- Resistance and resistivity

**Class/Laboratory Schedule:** Varies

**PRIMARY STUDENT OUTCOMES ADDRESSED BY THIS COURSE:** (a), (c), (e), (f), (i), (k)

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