Learning Goals for MSE courses

Students respond to these goals as **Supplemental Questions**
on the Student Instructional Ratings System at the end of the class
(updated 29 March 2016)

For Fall semester, pages 2-10 need to be printed out and used with the SIRS forms

For Spring semester, pages 12-22 need to be printed out and used with the SIRS forms

(This is page 1)

Some Supplemental Questions are used to obtain student assessment of ABET [a-k] program outcomes as indicated in the following pages with the appropriate letter in [square brackets]. Faculty members also quantitatively assess a sample of student work that exemplifies one or more of the [a-k] quantitatively, using the MSE Rubrics, and they report this assessment (mean, std) on course evaluation forms which are reviewed at the end of each semester by the whole MSE faculty.

Modifications to these goals/questions need to be proposed to the MSE program coordinator, and they are discussed and approved by the MSE faculty.

[a] an ability to apply knowledge of mathematics, science, and engineering
[b] an ability to design and conduct experiments, as well as to analyze and interpret data
[c] an ability to design a system or process to produce a material or component
[d] an ability to function on teams, including multi-disciplinary teams
[e] an ability to identify, formulate, and solve engineering problems
[f] an understanding of professional and ethical responsibility
[g] an ability to communicate effectively
[h] the broad education necessary to understand the impact of engineering solutions in a global and societal context
[i] a recognition of the need for, and an ability to engage in life-long learning
[j] a knowledge of contemporary issues
[k] an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

MSE 200 Materials and Society

Supplemental Questions for SIRS Survey:

Please fill in the appropriate bubble starting with question A:

Strongly Agree O O O O O Strongly Disagree
Neutral

I am able to:

A. Explain the reasons for materials failure in recent significant events,

B. Explain why the materials were chosen for a particular part or system,

C. Describe the advantages and disadvantages of metals, ceramics, polymers, and composite materials for a particular application,

D. Explain how designs constrain material choices,

E. Propose reasons for alternative material or design choices.

MSE 250: Introduction to Materials Science and Engineering (lecture)

(updated 5/27/10)

Supplemental Questions for SIRS Survey:

Please fill in the appropriate bubble:

Strongly Agree O O O O O Strongly Disagree
Neutral

Supplemental Questions for SIRS Survey:

Please fill in the appropriate bubble starting with question A:

Strongly Agree O O O O O Strongly Disagree
Neutral

A. CEM 141 or CEM 151 or LBS 171 prepared me effectively to learn the content of this class

I am able to:

B. describe the basic concepts of atomic bonding, interatomic potentials and atomic coordination in solids as they relate to metals, polymers, and ceramics.

C. explain how atomic diffusion happens, and calculate diffusivities and diffusion distances at an arbitrary temperature.

D. explain how to obtain elastic modulus, yield strength, ultimate strength, toughness and strain-to-fracture, from experimental load-displacement curves.

E. identify and explain time-dependent deformation of materials.

F. understand effects of flaw size on fracture of materials.

G. Predict fatigue lifetime based upon S-N data.

H. determine equilibrium phases, their quantity, and composition as a function of temperature and composition from a binary phase diagram.

I. explain how thermal treatments affect the distribution of equilibrium and non-equilibrium phases in steel.

J. identify the most common environmental factors that degrade structural materials, and methods to minimize/mitigate them.

MSE 250 - Lab: Introduction to Materials Science and Engineering

A. CEM 141 or CEM 151 or LBS 171 prepared me effectively to learn the content of this class

I am able to:

B. Describe the basic concepts of crystallography including Miller Indices of planes and directions, relating density to crystallographic parameters, and stacking sequence of closed-packed crystal structures.

C. Experimentally identify elastic modulus, yield strength, ultimate strength, toughness and strain-to-fracture, from load-displacement curves.

D. Identify correlations between materials hardness with other mechanical properties.

E. Identify ductile-to brittle transition using Charpy impact testing and fracture surface observations

F. Identify mechanisms and approaches commonly used to strengthen different engineering materials.

G. Characterize microstructures of single and multi-phase engineering materials.

H. Characterize changes in properties of steel due to thermal treatments and relate to changes to microstructure.

I. effectively describe experimental findings in oral presentations.

J. write laboratory reports that describe experimental work accurately and objectively.

K. contribute to a team that conducts experiments, analysis, writing, and proof reading to generate an effective laboratory report [d].

L. Describe a contemporary issue that depends on materials composition, selection, and/or performance.

Letters in brackets refer to ABET engineering outcomes a-k

MSE 310: Phase Equilibria in Materials

Supplemental Questions for SIRS Survey:

Please fill in the appropriate bubble starting with question A:

Strongly Agree O O O O O Strongly Disagree
Neutral

A. MSE 250 prepared me effectively to learn the content of this class

B. MTH 234 or MTH 254H or LBS 220 prepared me effectively to learn the content of this class.

I am able to:

C. Explain and determine thermodynamics parameters such as enthalpy, entropy, and free energy of a system at a giving condition.

D. Determine how much energy is absorbed or released in a system due to changes in temperature, phase, pressure, or chemical bonding state.

E. Predict changes in phase transition temperatures due to pressure changes.

F. Determine changes in free energy associated with mixing, and how they are related to phase diagrams, activity, and the equilibrium constant [a].

G. Determine the changes in free energy, enthalpy, entropy, temperature and pressure for equilibrium chemical reaction.

H. Determine the relative stability of a mixture of several compounds in contact with each other, as influenced by temperature, partial pressures, compositions, pH, etc.

I. Read, interpret, and extract quantitative information from ternary phase diagram [k].

J. Qualitatively explain the statistical nature of thermodynamic quantities.

Letters in brackets refer to ABET engineering outcomes a-k

MSE 320 Mechanical Behavior of Materials

Supplemental Questions for SIRS Survey:

Please fill in the appropriate bubble starting with question A:

Strongly Agree O O O O O Strongly Disagree
Neutral

A. Prerequisite MSE 250 prepared me effectively to learn the content of this class

B. Prerequisite ME 222 prepared me effectively to learn the content of this class

I am able to:

C. understand the basic nature and role of dislocations and other crystal defects in plastic deformation.

D. identify microstructural features of brittle and ductile fracture as well as microstructure-property relationships that affect ductility, toughness, fracture, fatigue, and creep of materials [k].

E. understand brittle fracture and predict the fracture strength of brittle solids containing flaws of known size using Griffith Criteria.

F. design an experiment to acquire data needed to characterize elastic constants, yield strength, ultimate strength, strain-to-failure, and work hardening of metals, ceramics, and polymers [a].

G. identify different testing methods associated with tension, compression, fatigue, fatigue crack growth, and creep of metals, ceramics, and polymers.

H. understand conditions which lead to ductile-brittle transitions in metals and predict the fracture strength of ductile materials using simple fracture mechanics concepts, and design tests to determine plane-strain fracture toughness.

I. explain methods for toughening metals, ceramics, and composite materials and apply appropriate rules of mixtures to predict properties.

J. predict fatigue life given load history, information on cracks, cyclic stress intensity and Paris law parameters [e].

K. identify different regions of fatigue crack growth based on ε, ΔK and da/dN.

L. estimate total creep strains given times, temperatures, stresses and an Ashby deformation mechanism map; understand fundamentals of viscoelasticity; understand how to predict time-to-failure given creep temperature and load using the Larsen-Miller Parameter.

M. calculate creep stress exponents and activation energies and identify the different regimes of creep strain-time periods as well understand creep deformation mechanisms.

Letters in brackets refer to ABET engineering outcomes a-k

MSE 331: Materials Characterization Methods I

(updated 5/27/10)

Supplemental Questions for SIRS Survey:

Please fill in the appropriate bubble starting with question A:

Strongly Agree O O O O O Strongly Disagree
Neutral

A. MSE 310 and MSE 320 integrated well with material in this class.

I am able to:

B. quantify microstructures with advanced optical microscopy techniques

C. conduct, analyze, and interpret lab experiments using analytical thermal and mechanical testing analyses to obtain information useful for developing phase diagrams [b,k]

D. use indentation techniques to quantify mechanical properties

E. use optical microscopy to characterize slip phenomena in single crystals

F. conduct experiments that examine time-dependent deformation

G. use thermal analysis techniques to quantify heat of transition, dimensional stability, and chemical stability of materials

H. identify and characterize corrosion and corrosion damage

I. effectively communicate the above experimental work in objective written laboratory reports [g].

Letters in brackets refer to ABET engineering outcomes a-k

MSE 410 Materials Foundations for Energy Applications

Supplemental Questions for SIRS Survey:

Please fill in the appropriate bubble starting with question A:

Strongly Agree O O O O O Strongly Disagree
Neutral

I am able to:

A. Describe the relationships between climate, energy availability and utilization, the development of technology, and the impact of these on societal development

B. Understand the advantages, disadvantages, and limitations of fossil fuels as energy resources

C. Describe the benefits and limitations of carbon neutral energy sources such as solar, wind, nuclear, hydrogen, and bio-based materials

D. Use fundamental principles of physics, chemistry, and materials science to design materials for solar cells, thermoelectric devices, light-emitting diodes, batteries, nuclear energy, and other materials relevant to alternative energy sources

E. Explain how processing affects the performance and cost of materials used in photovoltaic devices, thermoelectric devices, batteries, light-emitting diodes, and other alternative energy devices

MSE 474 Ceramic and Refractory Materials

Updated 2/22/12

Supplemental Questions for SIRS Survey:

Please fill in the appropriate bubble starting with question A:

Strongly Agree   O   O   O   O   O   Strongly Disagree
Neutral

A. MSE 260 prepared me effectively to learn the content of this class

I am able to:

B. Conceptualize that binding energy curve is related to theoretical fracture strength, elastic moduli, thermal expansion

C. Discuss the crystal structures of silicates, clays, and other common ceramic materials in relation to properties

D. Explain the connection between properties and processing techniques of glasses and glass ceramics.

E. Explain the microstructure/mechanical property relationships in ceramics, including the impact of grain size and porosity on fracture and creep [a]

F. Calculate the effective thermal and/or electrical conductivity of a porous or composite ceramic based on the conductivities of each phase, and discuss the assumptions involved in calculation

G. Identify an ethical difficulty, conflicts of interest, and ethical problem solving strategies

H. Explain the operating principles of dielectric, ferro-electrics, paramagnetic, diamagnetic, ferri-magnetic, and anti-ferromagnetic ceramics

I. Explain how defects affect the electrical, mechanical, and processing of ceramic materials.

Letters in brackets refer to ABET engineering outcomes a-k

MSE 476: Physical Metallurgy of Ferrous and Aluminum Alloys

Supplemental Questions for SIRS Survey:

Please fill in the appropriate bubble starting with question A:

Strongly Agree O O O O O Strongly Disagree
Neutral

A. MSE 250 prepared me effectively to learn the content of this class

I am able to:

B. describe why and predict how composition gradients develop during non-equilibrium solidification in ferrous and aluminum alloys,

C. explain how solidification occurs in ingot, welding, and continuous casting of ferrous and aluminum alloys,

D. explain how microstructure and composition can be controlled with microalloying additions to a melt prior to pouring, and with subsequent cooling rates,

E. use empirical models based upon composition and microstructure parameters to predict mechanical properties in steels and aluminum alloys,

F. explain the meaning of terminology relevant to heat treating, and the classes of steel and aluminum alloys,

G. make economically motivated choices to identify a heat treating strategy that will minimize alloy and processing cost to obtain sufficient steel or aluminum alloy material performance for an application [c, e],

H. research literature to explain in oral and written form why heat treating and/or alloy modifications are able to provide particular economic and/or performance benefits.

Letters in brackets refer to ABET engineering outcomes a-k

MSE 477 Mechanical Processing of Materials

Supplemental Questions for SIRS Survey:

Please fill in the appropriate bubble starting with question A:

Strongly Agree   O   O   O   O   O   Strongly Disagree
Neutral

A. (ME 222 and MSE 250) prepared me effectively to learn the content of this class

I am able to:

B. specify the experiments needed to determine the yield (flow) surface of a material for plane-strain deformation conditions.

C. identify the fundamental experimental work needed to determine plastic flow constants and formability limits needed in models for plastic deformation.

D. apply analytical solutions for plastic deformation by bi-axial sheet forming, drawing, extrusion, forging, pressing, and rolling, to predict limits of formability that precludes damage or fracture and the cost of doing these processes on ceramic, glassy, metal and polymer materials, based upon known material deformation data.

E. identify a process and process parameters needed to produce a composite material based upon particulate, fiber or lamellar reinforcement geometries for components made from polymers, metals, and ceramics, determine methods to evaluate the quality of the composite, and to estimate the cost of producing the material.

F. identify the plastic strain, strain rate, heat generation, and wear characteristics of a machining process, and the impact of material properties of tool and workpiece on the economics of the process.

G. identify an appropriate process, process parameters, and cost required to produce a composite material based upon particulate, fiber or lamellar reinforcement geometries for conventional product forms made from polymers, metals, and ceramics.

H. demonstrate the ability to prescribe a process and cost analysis for making a particular part out of a particular material, and present it to the class as if it were a preliminary design review.

MSE 250: Introduction to Materials Science and Engineering (lecture)

(updated 5/27/10)

Supplemental Questions for SIRS Survey:

Please fill in the appropriate bubble starting with question A:

Strongly Agree O O O O O Strongly Disagree
Neutral

A. CEM 141 or CEM 151 or LBS 171 prepared me effectively to learn the content of this class

I am able to:

B. describe the basic concepts of atomic bonding, interatomic potentials and atomic coordination in solids as they relate to metals, polymers, and ceramics.

C. explain how atomic diffusion happens, and calculate diffusivities and diffusion distances at an arbitrary temperature.

D. explain how to obtain elastic modulus, yield strength, ultimate strength, toughness and strain-to-fracture, from experimental load-displacement curves.

E. identify and explain time-dependent deformation of materials.

F. understand effects of flaw size on fracture of materials.

G. Predict fatigue lifetime based upon S-N data.

H. determine equilibrium phases, their quantity, and composition as a function of temperature and composition from a binary phase diagram.

I. explain how thermal treatments affect the distribution of equilibrium and non-equilibrium phases in steel.

J. identify the most common environmental factors that degrade structural materials, and methods to minimize/mitigate them.

MSE 250 - Lab: Introduction to Materials Science and Engineering

(updated 5/27/10)

A. CEM 141 or CEM 151 or LBS 171 prepared me effectively to learn the content of this class

I am able to:

B. Describe the basic concepts of crystallography including Miller Indices of planes and directions, relating density to crystallographic parameters, and stacking sequence of closed-packed crystal structures.

C. Experimentally identify elastic modulus, yield strength, ultimate strength, toughness and strain-to-fracture, from load-displacement curves.

D. Identify correlations between materials hardness with other mechanical properties.

E. Identify ductile-to brittle transition using Charpy impact testing and fracture surface observations

F. Identify mechanisms and approaches commonly used to strengthen different engineering materials.

G. Characterize microstructures of single and multi-phase engineering materials.

H. Characterize changes in properties of steel due to thermal treatments and relate to changes to microstructure.

I. effectively describe experimental findings in oral presentations.

J. write laboratory reports that describe experimental work accurately and objectively.

K. contribute to a team that conducts experiments, analysis, writing, and proof reading to generate an effective laboratory report [d].

L. Describe a contemporary issue that depends on materials composition, selection, and/or performance.

Letters in brackets refer to ABET engineering outcomes a-k

MSE 260 Electronic Structure and Properties of Materials

Revised 5/10/12

Supplemental Questions for SIRS Survey:

Please fill in the appropriate bubble starting with question A:

Strongly Agree O O O O O Strongly Disagree
Neutral

A. (Prerequisites): (PHY 184 or concurrently) and (CEM 141 or CEM 151 or LBS 171) prepared me effectively to learn the content of this class

I am able to:

B. predict basic electrical, thermal, magnetic or superconductive (ETMSC) materials properties of an element or binary compound from its position in the periodic table. This includes an understanding of the relationship between different types of atomic bonding and ETMSC materials properties.

C. describe the basic crystal structures of metals, semiconductors and insulators, as well as crystal structure notation and to be able to calculate bond lengths, atomic density, etc from mass density and crystal structure.

D. comprehend the basic relevance of the Schrödinger wave equation to quantum mechanics.

E. solve problems relating to basic quantum phenomena, including the photoelectric effect, de Broglie wavelength.

F. draw a schematic energy diagram of the electronic structure of metals, semiconductors and insulators, and explain its relationship to electrical and optical properties.

G. explain what ETMO properties are most relevant to particular materials applications such as analog electronic devices, capacitors, optoelectronics, and magnetic recording.

H. describe how metals, semiconductors, ceramics and polymers (materials) may be applied as sensor, electronic devices and products to serve societal needs and well-being [h, j].

Letters in brackets refer to ABET engineering outcomes a-k

MSE 360: Fundamentals of Microstructural Design

Supplemental Questions for SIRS Survey:

Please fill in the appropriate bubble starting with question A:

Strongly Agree O O O O O Strongly Disagree
Neutral

A. MSE 310 and (MSE 260 or concurrently) prepared me effectively to learn the content of this class.

I am able to:

B. Use $\sqrt{Dt}$ properly to make estimates of diffusion phenomena,

C. Use solutions to Fick's 2nd law based upon the thin film, erf, and a series solutions to predict composition gradients and apply these models to simple thermal and mass flow problems [a]

D. Use Arrhenius plots to determine parameters needed for theoretical models of diffusivity to modify material properties at the atomic scale for metal, ceramic polymer, and electronic systems

E. Use understanding of non-equilibrium solidification phenomena to make beneficial changes in microstructures using stored energy in metals, ceramics and polymers.

F. Use understanding of non-equilibrium stored energy from plastic deformation processing and/or phase changes to design microstructures that improve properties in metals, ceramics and polymers.

G. Predict times and temperatures needed to obtain desirable microstructural changes in a heat treating process.

H. Solve problems with mixed units that require unit conversions.

I. Explain how a particular process or technique used in materials processing depends on diffusion, solidification, heat treatment, deformation, in an oral presentation [g, i].

J. Explain how managing atomic behavior enables materials innovations that impact society [h].

Letters in brackets refer to ABET engineering outcomes a-k

MSE 370: Physical Processing of Materials

Updated 2/22/12

Supplemental Questions for SIRS Survey:

Please fill in the appropriate bubble starting with question A:

Strongly Agree O O O O O Strongly Disagree
Neutral

A. MSE 250, 310 and (MSE 260 or concurrently) prepared me effectively to learn the content of this class.

I am able to:

B. discuss the characterization of powders for powder technology in terms of particle size and shape.

C. identify basic methods of of powder synthesis and fabrication.

D. calculate shrinkage and volume fraction porosity of powder compacts given mass density and dimensional data.

E. design simple risers for metals casting and predict solidification temperatures.

F. identify a preferred method of fabrication for a component, given a specified geometry, production rate, and cost constraints [c].

G. explain how time, temperature and particle size affect the densification of powders.

H. describe the various strategies to tailor polymer chemistry for optimum processing, chemical and physical properties [e].

I. discuss the powder preparation for slip casting, including the use of binders, deflocculants, and densification aids.

J. discuss the important parameters involved in surface treatment processes such as thin film microdevice technology, carburization, and thick film coating techniques.

K. identify an ethical difficulty and suggest a potential solution consistent with a particular section of the NSPE code [f].

L. describe methods for characterizing and suppressing corrosion in metals.

Letters in brackets refer to ABET engineering outcomes a-k

MSE 381 Materials Characterization Methods II

(updated 5/27/10)

Supplemental Questions for SIRS Survey:

Please fill in the appropriate bubble starting with question A:

Strongly Agree O O O O O Strongly Disagree
Neutral

A. (MSE 360 or concurrently) and (MSE 370 or concurrently) integrated well with material in this class

I am able to::

B. understand how X Rays are generated, convert from wavelength to frequency or photon energy, and calculate X Ray energies on the basis of the one electron atom model

C. analyze X Ray powder diffraction spectra to identify simple unknown phases/structures

D. use scanning electron microscopy and energy dispersive spectroscopy for analysis and phase identification on the surface of a heterogeneous material.

E. Use scanning electron microscopy to characterize fracture surfaces

F. Characterize electrical properties and relate them to material structure

G. describe how processing can affect the structure of a polymer, using time dependent and vibrational spectroscopy

H. analyze X-Ray photoelectron spectroscopy spectra to determine the constituents of an unknown

I. apply materials characterization techniques to design/select/diagnose material-related relationships between materials properties and materials processing [k]

J. Communicate experimental findings using complex instrumentation and interpret results effectively for readers with a general knowledge in MSE [g]

Letters in brackets refer to ABET engineering outcomes a-k

MSE 425 Biomaterials and Biocompatibility

Supplemental Questions for SIRS Survey:

Please fill in the appropriate bubble starting with question A:

Strongly Agree   O   O   O   O   O   Strongly Disagree
Neutral

A. (MSE 250) prepared me effectively to learn the content of this class.

B. (PSL 250) prepared me effectively to learn the content of this class.

I am able to:

C. understand the dependence of material properties on the materials structure and processing history and how these influence biocompatability.
D. understand the effect of surface morphology on function and biocompatibility.
E. apply the basic concepts of diffusion to solve biomaterials-related problems..
F. understand the relationships between biological tissue properties and the material selection for an implant.
G. apply a basic understanding of statistics to experimental design in biomaterials testing.
H. appreciate the corrosivity of the environment in which biomaterials must function and how this influences design of implant materials.
I. use my understanding of science and engineering to compose a thorough written critique of any contemporary journal publication in the biomaterials literature [j].
J. effectively contribute understanding of biomaterials engineering from the perspective of my core engineering discipline in a project conducted by a multidisciplinary team [d].

Letters in brackets refer to ABET engineering outcomes a-k

MSE 460 Electronic Structure and Bonding in Materials and Devices

Supplemental Questions for SIRS Survey:

Please fill in the appropriate bubble starting with question A:

Strongly Agree O O O O O Strongly Disagree
Neutral

A. (MSE 260) prepared me effectively to learn the content of this class

I am able to:

B. Explain the basic concepts of quantum mechanics and use the Schrödinger equation to solve problems relating to basic quantum phenomena.

C. Calculate bond lengths and atomic density from mass density and crystal structure of metals, semiconductors and insulators.

D. Use the free electron model of metals to predict their electrical and thermal properties [e]

E. Use the band theory of metals to draw energy diagrams of the electronic structure of metals, semiconductors and insulators, and explain its relationship to electrical and optical properties [c].

F. Describe mechanisms of polarization, magnetism and superconductivity

G. Explain the relationship between different types of atomic bonding and the properties of electronic, thermal, magnetic or superconductive properties based upon the position of its elements in the periodic table.

Letters in brackets refer to ABET engineering outcomes a-k

MSE 465 Design and Application of Engineering Materials

Supplemental Questions for SIRS Survey:

Please fill in the appropriate bubble starting with question A:

Strongly Agree O O O O O Strongly Disagree
Neutral

A. (MSE 331 and MSE 381) prepared me effectively to learn the content of this class

I am able to:

B. Integrate the knowledge gained from the courses in materials science curriculum.

C. Analyze and arrive at solutions to material-related issues in professional life [c].

D. Make recommendations based on socio-economic considerations for materials issues.

E. Provide written reports based on literature survey [g].

F. Orally present reports to technical audience and answer questions.

G. Think critically.

Letters in brackets refer to ABET engineering outcomes a-k

MSE 466 Design and Failure Analysis

Supplemental Questions for SIRS Survey:

Please fill in the appropriate bubble starting with question A:

Strongly Agree O O O O O Strongly Disagree
Neutral

A. (MSE 250) prepared me effectively to learn the content of this class

I am able to:

B. apply basic mechanical behavior materials concepts to failure in metallic, polymer, and ceramic materials [e].

C. identify complex stress states arising from simple loading and boundary conditions, and apply modern fracture mechanics concepts to crack-problems.

D. identify the technical cause of failure by i) procuring failed parts, ii) collecting background information, iii) conducting laboratory experiments, iv) analyze and interpret experimental results, v) recommend design revisions [b].

E. function on team with multi-disciplinary strengths that makes effective use of subtasking [d].

F. use nondestructive testing techniques and microscopy to identify the failure modes and origins of failure.

G. recognize and assess the societal costs and potential impacts of engineering failures [h].

H. communicate findings in oral and written reports.

I. recognize and act on ethical issues in engineering problems [f].

Letters in brackets refer to ABET engineering outcomes a-k

MSE 481 Microscopic and Diffraction Analysis of Materials

Supplemental Questions for SIRS Survey:

Please fill in the appropriate bubble starting with question A:

Strongly Agree   O   O   O   O   O   Strongly Disagree
Neutral

A. (PHY 184 or concurrently or PHY 184B or concurrently) prepared me effectively to learn the content of this class.

I am able to:

B. Explain the relationships between atomic structure, x-ray and Auger electron production.

C. Carry out crystal structure analysis of known and unknown materials based on Bragg's law and structure factor determination.

D. Relate changes in diffraction information in reciprocal space to materials changes due to composition, temperature, pressure, and defect content.

E. Design experiments to determine material composition, structure, and defect content [b].

F. Describe complex crystal structures in terms of symmetry and relate materials properties to these symmetry components.

Letters in brackets refer to ABET engineering outcomes a-k