MAE T 201 Introduction to Materials Engineering Technology (3) This course provides an overview of the basic science and technology of materials to two year associate degree students. The objective is to provide students with an understanding of how structure/property/processing relationships are developed and used for different types of materials with an emphasis on ferrous based metal alloys. Knowledge of these basics is needed to provide a foundation for study of the fundamentals and applications of powder metallurgy. The course begins with a general introduction to materials science and materials engineering. Here the student is expected to gain an appreciation for the importance of studying materials. The first major topic covers the fundamental basis of the science of materials - atomic structure and bonding. Basic chemistry is reviewed, including the structure of atoms, chemical bonding, types of bonds, and the relationship of bonding to arrangement in the periodic table. The next topic addresses crystal structure and crystal geometry. Crystal structures for common metals are presented using the hard sphere model. The concepts of space lattice, unit cells, crystallographic directions, crystallographic planes, and polymorphism are discussed. Following crystal structures, the basic science of solidification is introduced and some common processing techniques used for fabricating metal components are presented. This includes direct pour ingot casting, semicontinuous casting, continuous casting, and growth of single crystals. Crystalline imperfections in solids and how these imperfections can influence material properties are discussed. The phenomenon of diffusion in solids is covered so that students may gain a quantitative understanding of the kinetics of rate processes and the effects of temperature on diffusion. A few practical industrial applications of diffusion processes are presented. An important topic covered in this course is interpretation of binary phase diagrams. The student is expected to understand the concepts of phase diagram, Gibb’s phase rule, binary isomorphous alloy systems, lever rule, nonequilibrium solidification, binary eutectic alloy systems, binary peritectic alloy systems, and binary monotectic systems. In addition, invariant reactions and phase diagrams with intermediate phases and compounds are discussed. The last topic covers engineering alloys with emphasis on iron and steel alloys. Steel processing, alloy designation, phases, constituents, and invariant reactions in the iron-iron carbide phase diagram are reviewed. The student is introduced to isothermal transformation diagrams and learns how to predict microstructures formed during common heat treatments. Alloy steels are presented, including classification of alloy steels, effects of alloying elements, and hardenability testing.

**Prerequisite:** CHEM 110, MATH 082

MAE T 202 Materials Testing (3) This course provides an overview of testing of engineering materials to two year associate degree students. The objective is for students to gain familiarity with common methods of testing for the properties of materials. A broad knowledge of materials testing is needed in dealing with the specification and acceptance of materials fabricated using powdered metal (P/M) technology. This course begins with a short introduction on the role of testing in controlling material properties. The first major topic is metrology. This gives the students a review of common gauges used for dimensional measurement. The next topic covers statistics and data analysis. Here it is important for the student to gain an understanding of how to record and present numerical data. The concepts of mean, standard deviation, coefficient of variation, grouped data, frequency polygon, ogive, cumulative percent, and histogram are reviewed. Following statistics, the basic principles of mechanical behavior are presented. The concepts of stress, strain, elasticity, strength, and ductility are introduced. Tensile testing is covered in considerable depth and includes details of the testing apparatus, test specimens, test procedures, and data interpretation. Other common mechanical tests used in engineering work are presented. This includes compression testing, hardness testing, shear testing, bend testing, and impact testing. The student is introduced to standard procedures used in materials testing as described by the American Society for Testing and Materials (ASTM) and by other literature published by the Metal Powder Industries Federation (MPIF). Fatigue testing is introduced to the student using stress vs. cycles to failure curves. This also includes various types of fatigue testing apparatus, test specimens, and test procedures. Nondestructive testing (NDT) techniques are discussed. The emphasis here is on how surface and subsurface structural flaws (i.e., cracks) may be detected in components without physically destroying them. A major shift in topics occurs when scanning electron microscopy (SEM) is presented. The SEM is an important topic because of its use in fractography and failure analysis. Elements of fracture mechanics are covered to give insight into why and how fracture may occur in components at stress levels well below the ultimate tensile strength due to the presence of a critical sized flaw. The final topic in the course is failure analysis. Case histories of actual part failures are discussed, and suggested guidelines in carrying out failure analysis are presented.

**Prerequisite:** MATH 082, PHYS 150

MAE T 203 Introduction to Powder Metallurgy (3) This course is comprehensive study of powdered metal technology including production, characterization, compaction, sintering, and finishing operations. MAE T 203 Introduction to Powder Metallurgy (3) This course is comprehensive study of powdered metal technology for two year associate degree students. The objective is for students to gain familiarity with fundamental concepts associated with powdered metal (P/M) technology. Topics include powder sampling, powder characterization, test methods/techniques, compaction, sintering, finishing operations, and powder fabrication. This course starts with a brief introduction to powder metallurgy that covers the historical development and industrial need for P/M engineered components. The first major topic is powders. Different ways to obtain a representative sample of powder from a large storage container are discussed. Powder characteristics such as average particle size, particle shape, flow ability, and particle size distribution are covered in some detail. Other important properties of loose powder covered include apparent (Hall) density, Arnold density, and tap density. The student is introduced to standard procedures used in powder testing as described by the Metal Powder Industries Federation (MPIF). The next major topic is powder compaction.

**Prerequisite:** CHEM 110, MATH 082
This starts with a short description of the different types of presses used in classical "die press and sintering"; P/M processing. Different types of die press set-ups are reviewed along with compaction tooling requirements. Compressibility of loose powder is discussed with an emphasis on the factors for predicting, both qualitatively and quantitatively, that influence the green density of powder compacts. The effect of lubricants on compressibility is included here. A milestone topic in this course is on sintering theory. Material transport mechanisms that may occur during sintering and their effects of densification are presented from a theoretical viewpoint. Variables that influence densification during sintering are emphasized. Liquid phase sintering and activated sintering are included. Practical examples and microstructures of sintered engineering materials are presented. Sintering furnaces are discussed with the comparative advantages and disadvantages of different types of sintering atmospheres used. The effect of the sintering atmosphere on the composition, microstructure and mechanical properties of powder compacts is discussed. The next topic is finishing operations that are used to modify components after they have been sintered. This includes operations like refinishing, sizing, coining, steam oxidation, tumbling, and machining. The last topic covered in this course is powder fabrication. Four basic methods of producing metal powders are discussed: mechanical fabrication, electrolytic fabrication, chemical fabrication, and atomization. Typical examples of the resulting powders are given along with how fabrication method affects the size, shape, microstructure, chemistry and cost of the powder.

Prerequisite: CHEM 110, MATH 082

MAET 204: Structure Characterization Laboratory

3 Credits

A hands-on course with emphasis on equipment and lab techniques used for microstructural evaluation of metals. MAE T 204W Structure Characterization Laboratory (3) This is a laboratory course for two year associate degree students with emphasis on equipment and techniques used for microstructural evaluation of metals. The objective is to provide students with practical laboratory skills in metallography and optical microscopy needed to observe and interpret microstructures of various metal alloys. Furthermore, the student gains valuable writing experience in preparing concise and effective technical reports. Lectures, videotapes, and demonstrations are used to introduce students to fundamental concepts and special techniques used in metallography and microstructural analysis of metals. The course begins with a brief overview of metallography and a discussion of safety in the laboratory. Elements of good technical report writing are introduced. Metallographic principles are presented using reference brochures and videotapes. This includes sectioning, mounting, coarse grinding, fine grinding, rough polishing, final polishing and microetching. Added topics cover the fundamentals of metallographs and photomicrography. A review of the iron-iron carbide system is given based upon material presented in MAE T 201 taught in the third semester of the materials program. Supplementary material on copper alloys is introduced latter in the course so that the physical metallurgy of brass and bronze can be better grasped by the student. This course has three laboratory experiments: (1) specimen preparation and optical microscopy, (2) characterization of powdered metal (P/Ni) iron and carbon steel alloys, and (3) characterization of wrought brass, wrought bronze, and sintered bronze alloys. Each experiment requires that the students prepare a technical report that is graded for its grammar, spelling, technical accuracy, and completeness. The student gains valuable experience in preparing metallographic specimens and appreciates the importance of achieving a representative structure. Laboratory work requires observing and interpreting microstructures of both wrought and porous P/N4 iron and carbon steel alloys. Quantitative metallography is used by students to estimate the carbon content of a selected P/M carbon steel alloy. Special metallographic techniques are learned for preparing porous P/1/4 alloys to reveal their true pore structure. The student develops experimental skills in measuring the density P/M samples and the surface hardness of polished metallographic samples. Also, experience at identifying microconstituents in non-ferrous based alloys is of particular value to the student. The technical reports require the presentation of Rockwell hardness and Knoop microhardness data in the form of tables and graphs.

Prerequisite: M E 442W

Writing Across the Curriculum

MAET 205: Powder Metallurgy Laboratory

4 Credits

A capstone course emphasizing hands-on laboratory experience in powder metallurgy and semester project; field trips to nearby P/M industries. MAE T 205 Powder Metallurgy Laboratory (4) This is a capstone course emphasizing hands-on laboratory experience in powder metallurgy. Students carry out routine engineering tests on powdered metal materials and document experimental data in a laboratory notebook. Each student is assigned a semester project and prepares a final written report and oral presentation on their findings. Class field trips give students direct exposure to local industries that use P/M technology. The course begins with a brief introduction covering course requirements and lab safety rules. A review of technical writing is presented which addresses elements of effective workplace writing, technical business letters, resumes, cover letters, and use of the Penn State library. A general discussion and demonstration is given for various metal powder testing methods. This is based upon material presented in MAE T 203 taught in the third semester of the materials program. The student is referred to the published procedures described in the standard test methods for metal powders and powder metallurgy products established by the Metal Powder Industries Federation (MPIF). Supplementary material on stainless steel alloys is introduced since this type of powder is used for the in-class demonstrations by the instructor. Students are required to participate in a class exercise in characterizing a selected stainless steel powder. This exercise covers powder sampling, flow ability, apparent density, tap density, sieve analysis, average particle size and powder shape. The exercise also covers powder compaction behavior by requiring the students to fabricate transverse rupture specimens and measure the resulting green density associated with a given loading pressure. Each student learns how to record their data in their own laboratory notebook using a standard format. One unique feature of this course is the scheduled class field trips to nearby P/M industries and the particulate matter laboratory at State College. A major turning point occurs when each student is assigned a semester project and allowed to work independently on their project for the remainder of the semester. This project requires that the student contact a vendor and order metal powder for evaluation. The student performs engineering tests on this powder and prepares a written report on their findings. An outline for the content and depth of discussion for written reports is provided by the instructor. The last scheduled day of class is used for student presentations on their semester project to peers and industry representatives.

Prerequisite: MAE T201, MAE T202, MAE T203, CHEM 111, MATH 083
MAET 297: Special Topics

1-9 Credits/Maximum of 9

Formal courses given infrequently to explore, in depth, a comparatively narrow subject that may be topical or of special interest.