Materials Science and Engineering (MSEN)

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Materials Science and Engineering Website (https://materials-science-engineering.uark.edu/)

Degrees Conferred:
M.S. in Materials Engineering (MATE)
M.S. in Materials Science (MATS)
Ph.D. in Materials Science and Engineering (MSEN)

Program Description: This multidisciplinary program prepares students for careers in the development and manufacturing of micro- to nanoscale materials, processing, and devices in such industries as biosensing, photonics, telecommunications, microelectronics, and MEMs. Typical students in this program will be full-time students residing on campus, but provisions may be made to support remotely located part-time students already engaged in professional careers.

Philosophy of Graduate Education: All entering graduate students from June 1 through May 31 of the following year are formed into a cohort. Cohort members form a natural work group during their first 24 months of graduate school, and the cohort members receive training in how to effectively apply their academic knowledge in professional group environments such as research- or teaching-based academic departments, large governmental research labs, or industrial settings. The cohort training also fosters a supportive graduate community atmosphere that enhances the likelihood of academic success of all the program's graduate students.The techniques used for this training have been developed at the University of Arkansas under the financial sponsorship of the NSF Integrative Graduate Education and Research Training program, and the Department of Education's Fund for Improvement of Post Secondary Education program. Through these methods, our graduate students exit our degree programs with the equivalent of one and a half years of on-the-job training in management techniques useful in a technology-based professional career setting.

Requirements for M.S. in Materials Engineering with Biological Materials and Devices Concentration

Prerequisites to Degree Program: Applicants to the program must satisfy the requirements of the Graduate School as described in this catalog and have the approval of the Graduate Studies Committee of the Materials Science and Engineering program.

Candidates have completed an ABET-accredited or equivalent Bachelor of Science degree in engineering (Washington Accord) and candidates' academic backgrounds will be evaluated by the Graduate Studies Committee for suitability to the graduate program. To be admitted to graduate study in Materials Engineering without deficiency, candidates are required to have completed a math course sequence through differential equations and an introduction to quantum mechanics through courses such as PHYS 3603 Introduction to Modern Physics, PHYS 3613 Modern Physics, or CHEM 3504 Physical Chemistry I. Other undergraduate deficiencies may be identified during the evaluation process, and degree completion will be contingent on successful completion of these identified deficiencies.

Prospective students from foreign countries in which English is not the native language must submit nationally recognized standardized testing results on written English proficiency for consideration by the Graduate School during the admission process. Students may be given conditional admittance pending demonstration of English language skills in appropriate courses at the University of Arkansas. Students wishing to apply for graduate assistantships that require direct contact with students in a teaching or tutorial role must meet the Graduate School's English Language proficiency test requirements for such GA positions.

Requirements for the Master of Science in Materials Engineering Degree: Students choosing this degree program will be assigned an initial adviser upon acceptance to the program. Students will work with the MSEN Program Director to define their M.S. path to best support their career goals after graduation, with three curricula paths available to Materials Engineering students:

- Academic path: Students who plan to complete an academic campus-based research thesis will take this path, although the research topic may include funding and collaboration with outside technical organizations. Students who complete all requirements for M.S. graduation, including an independent research project and thesis acceptable to their thesis committee, will be eligible without Graduate Studies Committee review for admission to the Ph.D. program in Materials Science and Engineering.
- Professional path: Students who plan to enter the technical marketplace after M.S. completion will find this path most beneficial as it requires independent graduate-level research in collaboration with an external technical organization. The research may be in the form of a traditional M.S. six-hour research topic and thesis, or may instead be in the form of two three-hour independent research efforts resulting in written reports with the clarity, style, analysis, and conclusions expected of a journal paper submission. Both the thesis and the written reports will be orally defended before the appropriate student committee. Students in this path will also be required to complete at least one internship of at least six weeks duration to experience a non-academic technical environment. Students completing this path may be considered by the Graduate Studies Committee for admission to the Ph.D. program in Materials Science and Engineering based on the strength of their academic course grades, their independent research depth, and the quality of the written research document.
- Non-thesis path: Students who are funded by personal resources or by graduate assistantships not associated with research or educational grants may complete an M.S. degree with additional course work in place of independent research. While there may be specific narrow career options where this is an appropriate path, the Materials Science and Engineering program strongly recommends the Professional or Academic paths as providing a much better overall career preparation for working in a technical position. Students completing this path cannot be accepted into the Ph.D. program in Materials Science and Engineering.

Students will form either a thesis committee or an advisory committee after they have chosen their M.S. path, defined any independent research areas, and have been accepted into a research group if appropriate. A thesis committee will be made up of at least three faculty members,

with at least one faculty member each from the Fulbright College of Arts and Sciences and the College of Engineering (the student's research professor will chair the thesis committee). The advisory committee will include at least one member of the Graduate Studies Committee, the supervising faculty member for a research experience, and one additional faculty member. If the student is in the Professional path, then either committee must also include at least one technical professional from the partner external organization as an adjunct faculty member or an ex officio committee member.

Students in this degree program can choose an Academic path, a Professional path, or a Non-thesis path. The course hours to meet the minimum requirements for each path are as follows:

Subject Area	Academic Path/ Hours	Professional Path/Hours	Non-Thesis Path/Hours
MSEN 5733L Fabrication at the Nanoscale OR ELEG 5243L Microelectronic Fabrication Techniques and Procedures OR ELEG 5293L Integrated Circuits Fabrication Laboratory OR MEEG 5633 Additive Manufacturing	3	3	3
MSEN 5322 Materials Characterization (Core)	2	2	2
MSEN 5313 Fundamentals of Materials Science (Core)	3	3	3
MSEN 5383 Research Commercialization and Product Development (Core)	3	3	3
MSEN 5811 / MSEN 5911 / MSEN 6811 / MSEN 6911 Operations Management Seminar Series (Core)	4	4	4
MSEN 6323 Materials Engineering Design (Core)	3	3	3
Technical Electives from Concentration List	9	9	9
MSEN 600V Research Thesis	6	(Option) 6	0
MSEN 5513 Applied Research in External Technical Organizations	Not Available	(Or Option) 3 + 3	Not Available
MSEN 5523 Applied On-Campus Collaborative Research with External Technical Organizations	Not Available	(Or Option) 3 + 3	Not Available
MSEN 555V Internship in External Technical Organization or GNEG 5811 Alternating Cooperative Education	Optional (hours do not apply to degree requirement)	>/= 1	Optional (hours do not apply to degree requirement)
MSEN 5821 Ethics for Scientists and Engineers	1 (Applied in Ph.D. curriculum)	1	1
Additional Technical Elective	0	0	>/=2
MSEN 5253 Emerging Technologies in Industry	Recommended in PhD studies	Recommended in PhD studies	3
MSEN 5393 Product Development Process	N/A	N/A	3

If a University of Arkansas undergraduate student is pursuing a Bachelor of Science degree in a department that has implemented an accelerated B.S./M.S. program (typically allowing six hours of graduate-level course work to be shared between the two degrees), the student may implement the same acceleration for a B.S. departmental degree/M.S. Materials Engineering degree set. Both the undergraduate department and the MSEN Program Director must approve the shared courses prior to enrollment.

As part of each student's curriculum, nine hours of coursework must be taken through one of the following concentrations. Courses not listed in the concentration list, but clearly pertaining to the concentration area, may be substituted with the approval of the student's research adviser and the MSEN Program Director. Students who have acquired the knowledge contained in any of the required courses through prior education may

petition the MSEN Program Director for permission to substitute other classes for these required courses.

Additional core courses to develop operations management skills also have been defined for MSEN students. During year one of their graduate studies at the University of Arkansas, students are required to take

MSEN 5811 1st Year Operations Seminar - Infrastructure Management and MSEN 5911 1st Year Operations Seminar - Personnel Management in the fall and spring semesters and MSEN 5821 Ethics for Scientists and Engineers in their first summer. During year two, students are required to take MSEN 6811 2nd Year Operations Seminar - Management and Leadership and MSEN 6911 2nd Year Operations Seminar - Advanced Management and Leadership in the fall and spring semesters, respectively. Students who begin their graduate studies at the University of Arkansas during the spring semester will be required to take MSEN 5811 in the fall semester following their completion of MSEN 6911 or to take MSEN 5811 concurrently with MSEN 6811.

Students are required to attend monthly MSEN Research Communication Seminars during the first three semesters of their M.S. degree program, and will enroll in MSEN 5611 Research Communication Seminar of MS Students in their third semester. Students working more than 20 hours per week in a non-local technology-based professional position approved by the MSEN Director will not be required to be enrolled in this class or attend the monthly seminars as a condition for graduation.

Research thesis hours will be chosen from the student's research adviser's section (MSEN 600V) and will require a written thesis successfully defended in a comprehensive oral exam given by the thesis committee.

A research thesis is required for Academic path students, and is optional for Professional path students. Professional path thesis research must include direct collaboration with an external technical organization.

A student in the Professional path may substitute two Applied Research efforts for a thesis under MSEN 5513 (External location) or MSEN 5523 (Internal on-campus location), provided each semester's research is of graduate-level quality and is reported at the end of the semester through a written paper and in an oral presentation to the advisory committee (note that the written paper must match the clarity, style, analysis, and conclusions expected of a journal paper submission). Regardless of where the research is performed, it must include direct collaboration with an external technical organization.

If a student is taking either a special problems independent study course (such as MSEN 588V) or a special topics course (such as MSEN 587V) to meet partial requirements for their M.S. degree, the instructor must supply the MSEN program office with a syllabus of that class to be included in their program records. The syllabus must include at least the course title, semester, instructor name, a list of specific course objectives, a list of student learning outcomes, sources of content knowledge, and method by which the student's mastery of the learning objectives is demonstrated.

Each student is required to enroll in at least one hour of course work each fall and spring semester until the M.S. degree is issued. If all required course work has been completed, the student may enroll in one hour of master's thesis, or in one hour of a special problems course for credit only.

Students should also be aware of Graduate School requirements with regard to master's degrees (http://catalog.uark.edu/graduatecatalog/degreerequirements/#mastersdegreestext).

Concentration in Biological Materials and Devices

Choose nine hours of the following:		9
BENG 4123	Biosensors & Bioinstrumentation	
BENG 5103	Advanced Instrumentation in Biological Engineering	
BMEG 5213	Tissue Mechanics	
BMEG 5313	Advanced Biomaterials and Biocompatibility	
ELEG 5773	Electronic Response of Biological Tissues	
MEEG 5253	Bio-Mems	
MEEG 5343	Computational Material Science	
MSEN 6323	Materials Engineering Design	
PHYS 5613	Introduction to Biophysics and Biophysical Techniques	

Requirements for M.S. in Materials Engineering with Energy Materials and Devices Concentration

Prerequisites to Degree Program: Applicants to the program must satisfy the requirements of the Graduate School as described in this catalog and have the approval of the Graduate Studies Committee of the Materials Science and Engineering program.

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organizations. Students who complete all requirements for M.S. graduation, including an independent research project and thesis acceptable to their thesis committee, will be eligible without Graduate Studies Committee review for admission to the Ph.D. program in Materials Science and Engineering.

- Professional path: Students who plan to enter the technical marketplace after M.S. completion will find this path most beneficial as it requires independent graduate-level research in collaboration with an external technical organization. The research may be in the form of a traditional M.S. six-hour research topic and thesis, or may instead be in the form of two three-hour independent research efforts resulting in written reports with the clarity, style, analysis, and conclusions expected of a journal paper submission. Both the thesis and the written reports will be orally defended before the appropriate student committee. Students in this path will also be required to complete at least one internship of at least six weeks duration to experience a non-academic technical environment. Students completing this path may be considered by the Graduate Studies Committee for admission to the Ph.D. program in Materials Science and Engineering based on the strength of their academic course grades, their independent research depth, and the quality of the written research document.
- Non-thesis path: Students who are funded by personal resources or by graduate assistantships not associated with research or educational grants may complete an M.S. degree with additional course work in place of independent research. While there may be specific narrow career options where this is an appropriate path, the Materials Science and Engineering program strongly recommends the Professional or Academic paths as providing a much better overall career preparation for working in a technical position. Students completing this path cannot be accepted into the Ph.D. program in Materials Science and Engineering.

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MSEN 600V Research Thesis	6	(Option) 6	0
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MSEN 555V Internship in External Technical Organization or GNEG 5811 Alternating Cooperative Education	Optional (hours do not apply to degree requirement)	>/= 1	Optional (hours do not apply to degree requirement)
MSEN 5821 Ethics for Scientists and Engineers	1 (Applied in Ph.D. curriculum)	1	1
Additional Technical Elective	0	0	>/=2
MSEN 5253 Emerging Technologies in Industry	Recommended in PhD studies	Recommended in PhD studies	3
MSEN 5393 Product Development Process	N/A	N/A	3

If a University of Arkansas undergraduate student is pursuing a Bachelor of Science degree in a department that has implemented an accelerated B.S./M.S. program (typically allowing six hours of graduate-level course work to be shared between the two degrees), the student may implement the same acceleration for a B.S. departmental degree/M.S. Materials Engineering degree set. Both the undergraduate department and the MSEN Program Director must approve the shared courses prior to enrollment.

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Concentration in Energy Materials and Devices

Choose nine hours from the following:		9
CHEM 5283	Energy Conversion and Storage	
ELEG 5223	Design and Fabrication of Solar Cells	
MEEG 5343	Computational Material Science	
MEEG 5353	Lithium-ion Batteries and Beyond: Materials, Characterization, and Performance	
MSEN 5713	Advanced Nanomaterials Chemistry	

MSEN 5733L	Fabrication at the Nanoscale
MSEN 6323	Materials Engineering Design

Requirements for M.S. in Materials Engineering with Mechanical and Structural Materials Concentration

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Students should also be aware of Graduate School requirements with regard to master's degrees (http://catalog.uark.edu/graduatecatalog/degreerequirements/#mastersdegreestext).

Concentration in Mechanical and Structural Materials

Choose nine hours of the following:		9
MEEG 5033	Advanced Mechanics of Materials I	
MEEG 5163	Advanced Product Design	
MEEG 5343	Computational Material Science	
MEEG 5953	Fundamentals of Fracture and Fatigue in Structures	
MEEG 5963	Advanced Fracture Mechanics and Structural Integrity	
MSEN 6323	Materials Engineering Design	
PHYS 5713	Condensed Matter Physics I	
PHYS 6713	Condensed Matter Physics II	

Requirements for M.S. in Materials Engineering with Microelectronic-Photonic Materials and Devices Concentration

Prerequisites to Degree Program: Applicants to the program must satisfy the requirements of the Graduate School as described in this catalog and have the approval of the Graduate Studies Committee of the Materials Science and Engineering program.

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Requirements for the Master of Science in Materials Engineering Degree: Students choosing this degree program will be assigned an initial adviser upon acceptance to the program. Students will work with the MSEN Program Director to define their M.S. path to best support their career goals after graduation, with three curricula paths available to Materials Engineering students:

- Academic path: Students who plan to complete an academic campus-based research thesis will take this path, although the research topic may include funding and collaboration with outside technical organizations. Students who complete all requirements for M.S. graduation, including an independent research project and thesis acceptable to their thesis committee, will be eligible without Graduate Studies Committee review for admission to the Ph.D. program in Materials Science and Engineering.
- Professional path: Students who plan to enter the technical marketplace after M.S. completion will find this path most beneficial as it requires independent graduate-level research in collaboration with an external technical organization. The research may be in the form of a traditional M.S. six-hour research topic and thesis, or may instead be in the form of two three-hour independent research efforts resulting in written reports with the clarity, style, analysis, and conclusions expected of a journal paper submission. Both the thesis and the written reports will be orally defended before the appropriate student committee. Students in this path will also be required to complete at least one internship of at least six weeks duration to experience a non-academic technical environment. Students completing this path may be considered by the Graduate Studies Committee for admission to the Ph.D. program in Materials Science and Engineering based on the strength of their academic course grades, their independent research depth, and the quality of the written research document.
- Non-thesis path: Students who are funded by personal resources or by graduate assistantships not associated with research or educational grants may complete an M.S. degree with additional course work in place of independent research. While there may be specific narrow career options where this is an appropriate path, the Materials Science and Engineering program strongly recommends the Professional or Academic paths as providing a much better overall career preparation for working in a technical position. Students completing this path cannot be accepted into the Ph.D. program in Materials Science and Engineering.

Students will form either a thesis committee or an advisory committee after they have chosen their M.S. path, defined any independent research areas, and have been accepted into a research group if appropriate. A thesis committee will be made up of at least three faculty members, with at least one faculty member each from the Fulbright College of Arts and Sciences and the College of Engineering (the student's research professor will chair the thesis committee). The advisory committee will include at least one member of the Graduate Studies Committee, the supervising faculty member for a research experience, and one additional faculty member. If the student is in the Professional path, then either committee must also include at least one technical professional from the

partner external organization as an adjunct faculty member or an ex officio committee member.

Students in this degree program can choose an Academic path, a Professional path, or a Non-thesis path. The course hours to meet the minimum requirements for each path are as follows:

Subject Area	Academic Path/ Hours	Professional Path/Hours	Non-Thesis Path/Hours
MSEN 5733L Fabrication at the Nanoscale OR ELEG 5243L Microelectronic Fabrication Techniques and Procedures OR ELEG 5293L Integrated Circuits Fabrication Laboratory OR MEEG 5633 Additive Manufacturing	3	3	3
MSEN 5322 Materials Characterization (Core)	2	2	2
MSEN 5313 Fundamentals of Materials Science (Core)	3	3	3
MSEN 5383 Research Commercialization and Product Development (Core)	3	3	3
MSEN 5811 / MSEN 5911 / MSEN 6811 / MSEN 6911 Operations Management Seminar Series (Core)	4	4	4
MSEN 6323 Materials Engineering Design (Core)	3	3	3
Technical Electives from Concentration List	9	9	9
MSEN 600V Research Thesis	6	(Option) 6	0
MSEN 5513 Applied Research in External Technical Organizations	Not Available	(Or Option) 3 + 3	Not Available
MSEN 5523 Applied On-Campus Collaborative Research with External Technical Organizations	Not Available	(Or Option) 3 + 3	Not Available
MSEN 555V Internship in External Technical Organization or GNEG 5811 Alternating Cooperative Education	Optional (hours do not apply to degree requirement)	>/= 1	Optional (hours do not apply to degree requirement)
MSEN 5821 Ethics for Scientists and Engineers	1 (Applied in Ph.D. curriculum)	1	1
Additional Technical Elective	0	0	>/=2
MSEN 5253 Emerging Technologies in Industry	Recommended in PhD studies	Recommended in PhD studies	3
MSEN 5393 Product Development Process	N/A	N/A	3

If a University of Arkansas undergraduate student is pursuing a Bachelor of Science degree in a department that has implemented an accelerated B.S./M.S. program (typically allowing six hours of graduate-level course work to be shared between the two degrees), the student may implement the same acceleration for a B.S. departmental degree/M.S. Materials Engineering degree set. Both the undergraduate department and the MSEN Program Director must approve the shared courses prior to enrollment.

As part of each student's curriculum, nine hours of coursework must be taken through one of the following concentrations. Courses not listed in the concentration list, but clearly pertaining to the concentration area, may be substituted with the approval of the student's research adviser and the MSEN Program Director. Students who have acquired the knowledge contained in any of the required courses through prior education may petition the MSEN Program Director for permission to substitute other classes for these required courses.

Additional core courses to develop operations management skills also have been defined for MSEN students. During year one of their graduate studies at the University of Arkansas, students are required to take

MSEN 5811 1st Year Operations Seminar - Infrastructure Management and MSEN 5911 1st Year Operations Seminar - Personnel

Management in the fall and spring semesters and MSEN 5821 Ethics for Scientists and Engineers in their first summer. During year two, students are required to take MSEN 6811 2nd Year Operations Seminar - Management and Leadership and MSEN 6911 2nd Year Operations Seminar - Advanced Management and Leadership in the fall and spring semesters, respectively. Students who begin their graduate studies at the University of Arkansas during the spring semester will be required to take MSEN 5811 in the fall semester following their completion of MSEN 6911 or to take MSEN 5811 concurrently with MSEN 6811.

Students are required to attend monthly MSEN Research Communication Seminars during the first three semesters of their M.S. degree program, and will enroll in MSEN 5611 Research Communication Seminar of MS Students in their third semester. Students working more than 20 hours per week in a non-local technology-based professional position approved by the MSEN Director will not be required to be enrolled in this class or attend the monthly seminars as a condition for graduation.

Research thesis hours will be chosen from the student's research adviser's section (MSEN 600V) and will require a written thesis successfully defended in a comprehensive oral exam given by the thesis committee.

A research thesis is required for Academic path students, and is optional for Professional path students. Professional path thesis research must include direct collaboration with an external technical organization.

A student in the Professional path may substitute two Applied Research efforts for a thesis under MSEN 5513 (External location) or MSEN 5523 (Internal on-campus location), provided each semester's research is of graduate-level quality and is reported at the end of the semester through a written paper and in an oral presentation to the advisory committee (note that the written paper must match the clarity, style, analysis, and conclusions expected of a journal paper submission). Regardless of where the research is performed, it must include direct collaboration with an external technical organization.

If a student is taking either a special problems independent study course (such as MSEN 588V) or a special topics course (such as MSEN 587V) to meet partial requirements for their M.S. degree, the instructor must supply the MSEN program office with a syllabus of that class to be included in their program records. The syllabus must include at least the course title, semester, instructor name, a list of specific course objectives, a list of student learning outcomes, sources of content knowledge, and method by which the student's mastery of the learning objectives is demonstrated.

Each student is required to enroll in at least one hour of course work each fall and spring semester until the M.S. degree is issued. If all required course work has been completed, the student may enroll in one hour of master's thesis, or in one hour of a special problems course for credit only.

Students should also be aware of Graduate School requirements with regard to master's degrees (http://catalog.uark.edu/graduatecatalog/degreerequirements/#mastersdegreestext).

Concentration in Microelectronic-Photonic Materials and Devices

ELEG 5203	Semiconductor Devices	3
Choose six hours from the following:		6
ELEG 5213	Integrated Circuit Fabrication Technology	
ELEG 5223	Design and Fabrication of Solar Cells	
ELEG 5273	Electronic Packaging	
ELEG 5293L	Integrated Circuits Fabrication Laboratory	
ELEG 5313	Power Semiconductor Devices	
ELEG 5323	Semiconductor Nanostructures I	
ELEG 5353	Semiconductor Optoelectronic Devices	
ELEG 5363	Semiconductor Material and Device Characterization	
ELEG 5383	Introduction of Integrated Photonics	
ELEG 5393	Electronic Materials	
ELEG 5543	Introduction to Power Electronics	
MEEG 5263	Introduction to Micro Electro Mechanical Systems	
MEEG 5343	Computational Material Science	
MSEN 6323	Materials Engineering Design	
PHYS 5713	Condensed Matter Physics I	
PHYS 5734	Laser Physics	
PHYS 5753	Applied Nonlinear Optics	
PHYS 5773	Introduction to Optical Properties of Materials	
PHYS 6713	Condensed Matter Physics II	

Requirements for M.S. in Materials Engineering with Nanoscale Materials and Devices Concentration

Prerequisites to Degree Program: Applicants to the program must satisfy the requirements of the Graduate School as described in this catalog and have the approval of the Graduate Studies Committee of the Materials Science and Engineering program.

Candidates have completed an ABET-accredited or equivalent Bachelor of Science degree in engineering (Washington Accord) and candidates' academic backgrounds will be evaluated by the Graduate Studies Committee for suitability to the graduate program. To be admitted to graduate study in Materials Engineering without deficiency, candidates are required to have completed a math course sequence through differential equations and an introduction to quantum mechanics through courses such as PHYS 3603 Introduction to Modern Physics, PHYS 3613 Modern Physics, or CHEM 3504 Physical Chemistry I. Other undergraduate deficiencies may be identified during the evaluation process, and degree completion will be contingent on successful completion of these identified deficiencies.

Prospective students from foreign countries in which English is not the native language must submit nationally recognized standardized testing results on written English proficiency for consideration by the Graduate School during the admission process. Students may be given conditional admittance pending demonstration of English language skills in appropriate courses at the University of Arkansas. Students wishing to apply for graduate assistantships that require direct contact with students in a teaching or tutorial role must meet the Graduate School's English Language proficiency test requirements for such GA positions.

Requirements for the Master of Science in Materials Engineering Degree: Students choosing this degree program will be assigned an initial adviser upon acceptance to the program. Students will work with the MSEN Program Director to define their M.S. path to best support their career goals after graduation, with three curricula paths available to Materials Engineering students:

- Academic path: Students who plan to complete an academic campus-based research thesis will take this path, although the research

topic may include funding and collaboration with outside technical organizations. Students who complete all requirements for M.S. graduation, including an independent research project and thesis acceptable to their thesis committee, will be eligible without Graduate Studies Committee review for admission to the Ph.D. program in Materials Science and Engineering.

- Professional path: Students who plan to enter the technical marketplace after M.S. completion will find this path most beneficial as it requires independent graduate-level research in collaboration with an external technical organization. The research may be in the form of a traditional M.S. six-hour research topic and thesis, or may instead be in the form of two three-hour independent research efforts resulting in written reports with the clarity, style, analysis, and conclusions expected of a journal paper submission. Both the thesis and the written reports will be orally defended before the appropriate student committee. Students in this path will also be required to complete at least one internship of at least six weeks duration to experience a non-academic technical environment. Students completing this path may be considered by the Graduate Studies Committee for admission to the Ph.D. program in Materials Science and Engineering based on the strength of their academic course grades, their independent research depth, and the quality of the written research document.
- Non-thesis path: Students who are funded by personal resources or by graduate assistantships not associated with research or educational grants may complete an M.S. degree with additional course work in place of independent research. While there may be specific narrow career options where this is an appropriate path, the Materials Science and Engineering program strongly recommends the Professional or Academic paths as providing a much better overall career preparation for working in a technical position. Students completing this path cannot be accepted into the Ph.D. program in Materials Science and Engineering.

Students will form either a thesis committee or an advisory committee after they have chosen their M.S. path, defined any independent research areas, and have been accepted into a research group if appropriate. A thesis committee will be made up of at least three faculty members, with at least one faculty member each from the Fulbright College of Arts and Sciences and the College of Engineering (the student's research professor will chair the thesis committee). The advisory committee will include at least one member of the Graduate Studies Committee, the supervising faculty member for a research experience, and one additional faculty member. If the student is in the Professional path, then either committee must also include at least one technical professional from the partner external organization as an adjunct faculty member or an ex officio committee member.

Students in this degree program can choose an Academic path, a Professional path, or a Non-thesis path. The course hours to meet the minimum requirements for each path are as follows:

Subject Area	Academic Path/ Hours	Professional Path/Hours	Non-Thesis Path/Hours
MSEN 5733L Fabrication at the Nanoscale OR ELEG 5243L Microelectronic Fabrication Techniques and Procedures OR ELEG 5293L Integrated Circuits Fabrication Laboratory OR MEEG 5633 Additive Manufacturing	3	3	3
MSEN 5322 Materials Characterization (Core)	2	2	2
MSEN 5313 Fundamentals of Materials Science (Core)	3	3	3
MSEN 5383 Research Commercialization and Product Development (Core)	3	3	3
MSEN 5811 / MSEN 5911 / MSEN 6811 / MSEN 6911 Operations Management Seminar Series (Core)	4	4	4
MSEN 6323 Materials Engineering Design (Core)	3	3	3
Technical Electives from Concentration List	9	9	9
MSEN 600V Research Thesis	6	(Option) 6	0
MSEN 5513 Applied Research in External Technical Organizations	Not Available	(Or Option) 3 + 3	Not Available

MSEN 5523 Applied On-Campus Collaborative Research with External Technical Organizations	Not Available	(Or Option) 3 + 3	Not Available
MSEN 555V Internship in External Technical Organization or GNEG 5811 Alternating Cooperative Education	Optional (hours do not apply to degree requirement)	>/= 1	Optional (hours do not apply to degree requirement)
MSEN 5821 Ethics for Scientists and Engineers	1 (Applied in Ph.D. curriculum)	1	1
Additional Technical Elective	0	0	>/=2
MSEN 5253 Emerging Technologies in Industry	Recommended in PhD studies	Recommended in PhD studies	3
MSEN 5393 Product Development Process	N/A	N/A	3

If a University of Arkansas undergraduate student is pursuing a Bachelor of Science degree in a department that has implemented an accelerated B.S./M.S. program (typically allowing six hours of graduate-level course work to be shared between the two degrees), the student may implement the same acceleration for a B.S. departmental degree/M.S. Materials Engineering degree set. Both the undergraduate department and the MSEN Program Director must approve the shared courses prior to enrollment.

As part of each student's curriculum, nine hours of coursework must be taken through one of the following concentrations. Courses not listed in the concentration list, but clearly pertaining to the concentration area, may be substituted with the approval of the student's research adviser and the MSEN Program Director. Students who have acquired the knowledge contained in any of the required courses through prior education may petition the MSEN Program Director for permission to substitute other classes for these required courses.

Additional core courses to develop operations management skills also have been defined for MSEN students. During year one of their graduate studies at the University of Arkansas, students are required to take

MSEN 5811 1st Year Operations Seminar - Infrastructure Management and MSEN 5911 1st Year Operations Seminar - Personnel Management in the fall and spring semesters and MSEN 5821 Ethics for Scientists and Engineers in their first summer. During year two, students are required to take MSEN 6811 2nd Year Operations Seminar - Management and Leadership and MSEN 6911 2nd Year Operations Seminar - Advanced Management and Leadership in the fall and spring semesters, respectively. Students who begin their graduate studies at the University of Arkansas during the spring semester will be required to take MSEN 5811 in the fall semester following their completion of MSEN 6911 or to take MSEN 5811 concurrently with MSEN 6811.

Students are required to attend monthly MSEN Research Communication Seminars during the first three semesters of their M.S. degree program, and will enroll in MSEN 5611 Research Communication Seminar of MS Students in their third semester. Students working more than 20 hours per week in a non-local technology-based professional position approved by the MSEN Director will not be required to be enrolled in this class or attend the monthly seminars as a condition for graduation.

Research thesis hours will be chosen from the student's research adviser's section (MSEN 600V) and will require a written thesis successfully defended in a comprehensive oral exam given by the thesis committee.

A research thesis is required for Academic path students, and is optional for Professional path students. Professional path thesis research must include direct collaboration with an external technical organization.

A student in the Professional path may substitute two Applied Research efforts for a thesis under MSEN 5513 (External location) or MSEN 5523 (Internal on-campus location), provided each semester's research is of graduate-level quality and is reported at the end of the semester through a written paper and in an oral presentation to the advisory committee (note that the written paper must match the clarity, style, analysis, and conclusions expected of a journal paper submission). Regardless of where the research is performed, it must include direct collaboration with an external technical organization.

If a student is taking either a special problems independent study course (such as MSEN 588V) or a special topics course (such as MSEN 587V) to meet partial requirements for their M.S. degree, the instructor must supply the MSEN program office with a syllabus of that class to be included in their program records. The syllabus must include at least the course title, semester, instructor name, a list of specific course objectives, a list of student learning outcomes, sources of content knowledge, and method by which the student's mastery of the learning objectives is demonstrated.

Each student is required to enroll in at least one hour of course work each fall and spring semester until the M.S. degree is issued. If all required course work has been completed, the student may enroll in one hour of master's thesis, or in one hour of a special problems course for credit only.

Students should also be aware of Graduate School requirements with regard to master's degrees (http://catalog.uark.edu/graduatecatalog/degreerequirements/#mastersdegreestext).

Concentration in Nanoscale Materials and Devices

Choose nine hours of the following:		9
CHEM 5443	Physical Chemistry of Materials	
ELEG 5303	Introduction to Nanomaterials and Devices (Introduction to Nanomaterials and Devices)	
MEEG 5263	Introduction to Micro Electro Mechanical Systems	
MEEG 5333	Introduction to Tribology	
MEEG 5343	Computational Material Science	
MSEN 5713	Advanced Nanomaterials Chemistry	
MSEN 5733L	Fabrication at the Nanoscale	

MSEN 6323	Materials Engineering Design
PHYS 5713	Condensed Matter Physics I
PHYS 5723	Physics at the Nanoscale
PHYS 5783	Physics of 2D Materials
PHYS 6713	Condensed Matter Physics II

Requirements for M.S. in Materials Engineering with Materials Modeling Concentration

Prerequisites to Degree Program: Applicants to the program must satisfy the requirements of the Graduate School as described in this catalog and have the approval of the Graduate Studies Committee of the Materials Science and Engineering program.

Candidates have completed an ABET-accredited or equivalent Bachelor of Science degree in engineering (Washington Accord) and candidates' academic backgrounds will be evaluated by the Graduate Studies Committee for suitability to the graduate program. To be admitted to graduate study in Materials Engineering without deficiency, candidates are required to have completed a math course sequence through differential equations and an introduction to quantum mechanics through courses such as PHYS 3603 Introduction to Modern Physics, PHYS 3613 Modern Physics, or CHEM 3504 Physical Chemistry I. Other undergraduate deficiencies may be identified during the evaluation process, and degree completion will be contingent on successful completion of these identified deficiencies.

Prospective students from foreign countries in which English is not the native language must submit nationally recognized standardized testing results on written English proficiency for consideration by the Graduate School during the admission process. Students may be given conditional admittance pending demonstration of English language skills in appropriate courses at the University of Arkansas. Students wishing to apply for graduate assistantships that require direct contact with students in a teaching or tutorial role must meet the Graduate School's English Language proficiency test requirements for such GA positions.

Requirements for the Master of Science in Materials Engineering Degree: Students choosing this degree program will be assigned an initial adviser upon acceptance to the program. Students will work with the MSEN Program Director to define their M.S. path to best support their career goals after graduation, with three curricula paths available to Materials Engineering students:

- Academic path: Students who plan to complete an academic campus-based research thesis will take this path, although the research topic may include funding and collaboration with outside technical organizations. Students who complete all requirements for M.S. graduation, including an independent research project and thesis acceptable to their thesis committee, will be eligible without Graduate Studies Committee review for admission to the Ph.D. program in Materials Science and Engineering.
- Professional path: Students who plan to enter the technical marketplace after M.S. completion will find this path most beneficial as it requires independent graduate-level research in collaboration with an external technical organization. The research may be in the form of a traditional M.S. six-hour research topic and thesis, or may instead be in the form of two three-hour independent research efforts resulting in written reports with the clarity, style, analysis, and conclusions expected of a journal paper submission. Both the thesis and the written reports will be orally defended before the appropriate student committee. Students in this path will also be required to complete at least one internship of at least six weeks duration to experience a non-academic technical environment. Students completing this path may be considered by the Graduate Studies Committee for admission to the Ph.D. program in Materials Science and Engineering based on the strength of their academic course grades, their independent research depth, and the quality of the written research document.
- Non-thesis path: Students who are funded by personal resources or by graduate assistantships not associated with research or educational grants may complete an M.S. degree with additional course work in place of independent research. While there may be specific narrow career options where this is an appropriate path, the Materials Science and Engineering program strongly recommends the Professional or Academic paths as providing a much better overall career preparation for working in a technical position. Students completing this path cannot be accepted into the Ph.D. program in Materials Science and Engineering.

Students will form either a thesis committee or an advisory committee after they have chosen their M.S. path, defined any independent research areas, and have been accepted into a research group if appropriate. A thesis committee will be made up of at least three faculty members, with at least one faculty member each from the Fulbright College of Arts and Sciences and the College of Engineering (the student's research professor will chair the thesis committee). The advisory committee will include at least one member of the Graduate Studies Committee, the supervising faculty member for a research experience, and one additional faculty member. If the student is in the Professional path, then either committee must also include at least one technical professional from the partner external organization as an adjunct faculty member or an ex officio committee member.

Students in this degree program can choose an Academic path, a Professional path, or a Non-thesis path. The course hours to meet the minimum requirements for each path are as follows:

Subject Area	Academic Path/ Hours	Professional Path/Hours	Non-Thesis Path/Hours
MSEN 5733L Fabrication at the Nanoscale OR ELEG 5243L Microelectronic Fabrication Techniques and Procedures OR ELEG 5293L Integrated Circuits Fabrication Laboratory OR MEEG 5633 Additive Manufacturing	3	3	3
MSEN 5322 Materials Characterization (Core)	2	2	2
MSEN 5313 Fundamentals of Materials Science (Core)	3	3	3

MSEN 5383 Research Commercialization and Product Development (Core)	3	3	3
MSEN 5811 / MSEN 5911 / MSEN 6811 / MSEN 6911 Operations Management Seminar Series (Core)	4	4	4
MSEN 6323 Materials Engineering Design (Core)	3	3	3
Technical Electives from Concentration List	9	9	9
MSEN 600V Research Thesis	6	(Option) 6	0
MSEN 5513 Applied Research in External Technical Organizations	Not Available	(Or Option) 3 + 3	Not Available
MSEN 5523 Applied On-Campus Collaborative Research with External Technical Organizations	Not Available	(Or Option) 3 + 3	Not Available
MSEN 555V Internship in External Technical Organization or GNEG 5811 Alternating Cooperative Education	Optional (hours do not apply to degree requirement)	>/= 1	Optional (hours do not apply to degree requirement)
MSEN 5821 Ethics for Scientists and Engineers	1 (Applied in Ph.D. curriculum)	1	1
Additional Technical Elective	0	0	>/=2
MSEN 5253 Emerging Technologies in Industry	Recommended in PhD studies	Recommended in PhD studies	3
MSEN 5393 Product Development Process	N/A	N/A	3

If a University of Arkansas undergraduate student is pursuing a Bachelor of Science degree in a department that has implemented an accelerated B.S./M.S. program (typically allowing six hours of graduate-level course work to be shared between the two degrees), the student may implement the same acceleration for a B.S. departmental degree/M.S. Materials Engineering degree set. Both the undergraduate department and the MSEN Program Director must approve the shared courses prior to enrollment.

As part of each student's curriculum, nine hours of coursework must be taken through one of the following concentrations. Courses not listed in the concentration list, but clearly pertaining to the concentration area, may be substituted with the approval of the student's research adviser and the MSEN Program Director. Students who have acquired the knowledge contained in any of the required courses through prior education may petition the MSEN Program Director for permission to substitute other classes for these required courses.

Additional core courses to develop operations management skills also have been defined for MSEN students. During year one of their graduate studies at the University of Arkansas, students are required to take

MSEN 5811 1st Year Operations Seminar - Infrastructure Management and MSEN 5911 1st Year Operations Seminar - Personnel Management in the fall and spring semesters and MSEN 5821 Ethics for Scientists and Engineers in their first summer. During year two, students are required to take MSEN 6811 2nd Year Operations Seminar - Management and Leadership and MSEN 6911 2nd Year Operations Seminar - Advanced Management and Leadership in the fall and spring semesters, respectively. Students who begin their graduate studies at the University of Arkansas during the spring semester will be required to take MSEN 5811 in the fall semester following their completion of MSEN 6911 or to take MSEN 5811 concurrently with MSEN 6811.

Students are required to attend monthly MSEN Research Communication Seminars during the first three semesters of their M.S. degree program, and will enroll in MSEN 5611 Research Communication Seminar of MS Students in their third semester. Students working more than 20 hours per week in a non-local technology-based professional position approved by the MSEN Director will not be required to be enrolled in this class or attend the monthly seminars as a condition for graduation.

Research thesis hours will be chosen from the student's research adviser's section (MSEN 600V) and will require a written thesis successfully defended in a comprehensive oral exam given by the thesis committee.

A research thesis is required for Academic path students, and is optional for Professional path students. Professional path thesis research must include direct collaboration with an external technical organization.

A student in the Professional path may substitute two Applied Research efforts for a thesis under MSEN 5513 (External location) or MSEN 5523 (Internal on-campus location), provided each semester's research is of graduate-level quality and is reported at the end of the semester through a written paper and in an oral presentation to the advisory committee (note that the written paper must match the clarity, style, analysis, and conclusions expected of a journal paper submission).

Regardless of where the research is performed, it must include direct collaboration with an external technical organization.

If a student is taking either a special problems independent study course (such as MSEN 588V) or a special topics course (such as MSEN 587V) to meet partial requirements for their M.S. degree, the instructor must supply the MSEN program office with a syllabus of that class to be included in their program records. The syllabus must include at least the course title, semester, instructor name, a list of specific course objectives, a list of student learning outcomes, sources of content knowledge, and method by which the student's mastery of the learning objectives is demonstrated.

Each student is required to enroll in at least one hour of course work each fall and spring semester until the M.S. degree is issued. If all required course work has been completed, the student may enroll in one hour of master's thesis, or in one hour of a special problems course for credit only.

Students should also be aware of Graduate School requirements with regard to master's degrees (http://catalog.uark.edu/graduatecatalog/degreerequirements/#mastersdegreestext).

Concentration in Materials Modeling

Choose nine hours of the following:		9
CVEG 5383	Finite Element Methods in Civil Engineering	
MEEG 5343	Computational Material Science	
MEEG 5733	Advanced Numerical Methods	
MSEN 6323	Materials Engineering Design	
PHYS 5093	Applications of Group Theory to Physics	
PHYS 5363	Scientific Computation and Numerical Methods	
PHYS 5713	Condensed Matter Physics I	
PHYS 6713	Condensed Matter Physics II	

Requirements for M.S. in Materials Science with Biological Materials and Devices Concentration

Prerequisites to Degree Program: Applicants to the program must satisfy the requirements of the Graduate School as described in this catalog and have the approval of the Graduate Studies Committee of the Materials Science and Engineering program.

Candidates typically have completed a Bachelor of Science degree in the physical or natural sciences and candidates' academic backgrounds will be evaluated by the Graduate Studies Committee for suitability to the graduate program. To be admitted to graduate study in Materials Science without deficiency, candidates are required to have completed a math course sequence through differential equations and an introduction to quantum mechanics through courses such as PHYS 3603 Introduction to Modern Physics, PHYS 3613 Modern Physics, or CHEM 3504 Physical Chemistry I. Other undergraduate deficiencies may be identified during the evaluation process, and degree completion will be contingent on successful completion of these identified deficiencies.

Prospective students from foreign countries in which English is not the native language must submit nationally recognized standardized testing results on written English proficiency for consideration by the Graduate School during the admission process. Students may be given conditional admittance pending demonstration of English language skills in appropriate courses at the University of Arkansas. Students wishing to apply for graduate assistantships that require direct contact with students in a teaching or tutorial role must meet the Graduate School's English Language proficiency test requirements for such GA positions.

Requirements for the Master of Science in Materials Science Degree: Students choosing this degree program will be assigned an initial adviser upon acceptance to the program. Students will work with the MSEN Program Director to define their M.S. path to best support their career goals after graduation, with three curricula paths available to Materials Science students:

- Academic path: Students who plan to complete an academic campus-based research thesis will take this path, although the research topic may include funding and collaboration with outside technical organizations. Students who complete all requirements for M.S. graduation, including an independent research project and thesis acceptable to their thesis committee, will be eligible without the Graduate Studies Committee review for admission to the Ph.D. program in Materials Science and Engineering.
- Professional path: Students who plan to enter the technical marketplace after M.S. completion will find this path most beneficial as it requires independent graduate-level research in collaboration with an external technical organization. The research may be in the form of a traditional M.S. six-hour research topic and thesis, or may instead be in the form of two three-hour independent research efforts resulting in written reports with the clarity, style, analysis, and conclusions expected of a journal paper submission. Both the thesis and the written reports will be orally defended before the appropriate student committee. Students in this path will also be required to complete at least one internship of at least six weeks duration to experience a non-academic technical environment. Students completing this path may be considered by the Graduate Studies Committee for admission to the Ph.D. program in Materials Science and Engineering based on the strength of their academic course grades, their independent research depth, and the quality of the written research document.
- Non-thesis path: Students who are funded by personal resources or by graduate assistantships not associated with research or educational grants may complete an M.S. degree with additional course work in place of independent research. While there may be specific narrow career options where this is an appropriate path, the Materials Science and Engineering program strongly recommends the Professional or Academic paths as providing a much better overall career preparation for working in a technical position. Students completing this path cannot be accepted into the Ph.D. program in Materials Science and Engineering.

Students will form either a thesis committee or an advisory committee after they have chosen their M.S. path, defined any independent research areas, and have been accepted into a research group if appropriate. A thesis committee will be made up of at least three faculty members, with at least one faculty member each from the Fulbright College of Arts and Sciences and the College of Engineering (the student's research professor will chair the thesis committee). The advisory committee will include at least one member from the Graduate Studies Committee, the supervising faculty member for a research experience, and one additional faculty member. If the student is in the Professional path, then either committee must also include at least one technical professional from the partner external organization as an adjunct faculty member or an ex officio committee member.

Students in this degree program can choose an Academic path, a Professional path, or a Non-thesis path. The course hours to meet the minimum requirements for each paths are as follows:

Subject Area	Academic Path/ Hours	Professional Path/Hours	Non-Thesis Path/Hours
MSEN 5733L Fabrication at the Nanoscale OR ELEG 5243L Microelectronic Fabrication Techniques and Procedures OR ELEG 5293L Integrated Circuits Fabrication Laboratory OR MEEG 5633 Additive Manufacturing	3	3	3
MEEG 5343 Computational Materials Science	3	3	3
MSEN 5322 Materials Characterization (Core)	2	2	2
MSEN 5313 Fundamentals of Materials Science (Core)	3	3	3
MSEN 5383 Research Commercialization and Product Development	3	3	3
MSEN 5811 / MSEN 5911 / MSEN 6811 / MSEN 6911 Operations Management Seminar Series (Core)	4	4	4
Technical Electives from Concentration List	9	9	9
MSEN 600V Research Thesis	6	(Option) 6	0
MSEN 5513 Applied Research in External Technical Organizations	Not Available	(Or Option) 3 + 3	Not Available
MSEN 5323 Applied On-Campus Collaborative Research with External Organizations	Not Available	(Or Option) 3 + 3	Not Available
MSEN 555V Internship in External Technical Organization or GNEG 5811 Alternating Cooperative Education	Optional (hours do not apply to degree requirement)	>/= 1	Optional (hours do not apply to degree requirement)
MSEN 5821 Ethics for Scientists and Engineers	Applied in Ph.D. Curriculum	1	1
Additional Technical Elective	0	0	>/=2
MSEN 5253 Emerging Technologies in Industry	Recommended in PhD studies	Recommended in PhD studies	3
MSEN 5393 Product Development Process	Not Available	Not Available	3

If a University of Arkansas undergraduate student is pursuing a Bachelor of Science degree in a department that has implemented an accelerated B.S./M.S. program (typically allowing six hours of graduate-level course work to be shared between the two degrees), the student may implement the same acceleration for a B.S. departmental degree/M.S. Materials Science degree set. Both the undergraduate department and the MSEN program Director must approve the shared courses prior to enrollment.

As part of each student's curriculum, nine hours of coursework must be taken through one of the following concentrations. Courses not listed in the concentration list, but clearly pertaining to the concentration area, may be substituted with the approval of the student's research adviser and the MSEN program Director. Students who have acquired the knowledge contained in any of the required courses through prior education may petition the MSEN program Director for permission to substitute other classes for these required courses.

Additional core courses to develop operations management skills also have been defined for MSEN students. During year one of their graduate studies at the University of Arkansas, students are required to take MSEN 5811 1st Year Operations Seminar - Infrastructure Management and MSEN 5911 1st Year Operations Seminar - Personnel Management in the fall and spring semesters and MSEN 5821 Ethics for Scientists and Engineers in their first summer. During year two, students are required to take MSEN 6811 2nd Year Operations Seminar - Management and Leadership and MSEN 6911 2nd Year Operations Seminar - Advanced Management and Leadership in the fall and spring semesters, respectively. Students who begin their graduate studies at the University of Arkansas during the spring semester will be required to take MSEN 5811 in the fall semester following their completion of MSEN 6911 or to take MSEN 5811 concurrently with MSEN 6811.

Students are required to attend monthly MSEN Research Communication Seminars during the first three semesters of their M.S. degree program, and will enroll in MSEN 5611 Research Communication Seminar of MS Students in their third semester. Students working more than 20 hours per week in a non-local technology-based professional position approved

by the MSEN Director will not be required to be enrolled in this class or attend the monthly seminars as a condition for graduation.

Research thesis hours will be chosen from the student's research adviser's section (MSEN 600V) and will require a written thesis successfully defended in a comprehensive oral exam given by the thesis committee.

A research thesis is required for Academic path students, and is optional for Professional path students. Professional path thesis research must include direct collaboration with an external technical organization.

A student in the Professional path may substitute two Applied Research efforts for a thesis under MSEN 5513 (External location) or MSEN 5523 (Internal on-campus location), provided each semester's research is of graduate-level quality and is reported at the end of the semester through a written paper and in an oral presentation to the advisory committee (note that the written paper must match the clarity, style, analysis, and conclusions expected of a journal paper submission). Regardless of where the research is performed, it must include direct collaboration with an external technical organization.

If a student is taking either a special problems independent study course (such as MSEN 588V) or a special topics course (such as MSEN 587V) to meet partial requirements for their M.S. degree, the instructor must supply the MSEN program office with a syllabus of that class to be included in their program records. The syllabus must include at least the course title, semester, instructor name, a list of specific course objectives, a list of student learning outcomes, sources of content knowledge, and method by which the student's mastery of the learning objectives is demonstrated.

Each student is required to enroll in at least one hour of course work each fall and spring semester until the M.S. degree is issued. If all required course work has been completed, the student may enroll in one hour of master's thesis, or in one hour of a special problems course for credit only.

Students should also be aware of Graduate School requirements with regard to master's degrees (http://catalog.uark.edu/graduatecatalog/degreerequirements/#mastersdegreestext).

Concentration in Biological Materials and Devices

Choose nine hours of the following:		9
BENG 4123	Biosensors & Bioinstrumentation	
BENG 5103	Advanced Instrumentation in Biological Engineering	
BMEG 5213	Tissue Mechanics	
BMEG 5313	Advanced Biomaterials and Biocompatibility	
ELEG 5773	Electronic Response of Biological Tissues	
MEEG 5253	Bio-Mems	
MEEG 5343	Computational Material Science	
MSEN 6323	Materials Engineering Design	
PHYS 5613	Introduction to Biophysics and Biophysical Techniques	

Requirements for M.S. in Materials Science with Energy Materials and Devices Concentration

Prerequisites to Degree Program: Applicants to the program must satisfy the requirements of the Graduate School as described in this catalog and have the approval of the Graduate Studies Committee of the Materials Science and Engineering program.

Candidates typically have completed a Bachelor of Science degree in the physical or natural sciences and candidates' academic backgrounds will be evaluated by the Graduate Studies Committee for suitability to the graduate program. To be admitted to graduate study in Materials Science without deficiency, candidates are required to have completed a math course sequence through differential equations and an introduction to quantum mechanics through courses such as PHYS 3603 Introduction to Modern Physics, PHYS 3613 Modern Physics, or CHEM 3504 Physical Chemistry I. Other undergraduate deficiencies may be identified during the evaluation process, and degree completion will be contingent on successful completion of these identified deficiencies.

Prospective students from foreign countries in which English is not the native language must submit nationally recognized standardized testing results on written English proficiency for consideration by the Graduate School during the admission process. Students may be given conditional admittance pending demonstration of English language skills in appropriate courses at the University of Arkansas. Students wishing to apply for graduate assistantships that require direct contact with students in a teaching or tutorial role must meet the Graduate School's English Language proficiency test requirements for such GA positions.

Requirements for the Master of Science in Materials Science Degree: Students choosing this degree program will be assigned an initial adviser upon acceptance to the program. Students will work with the MSEN Program Director to define their M.S. path to best support their career goals after graduation, with three curricula paths available to Materials Science students:

- Academic path: Students who plan to complete an academic campus-based research thesis will take this path, although the research topic may include funding and collaboration with outside technical organizations. Students who complete all requirements for M.S. graduation, including an independent research project and thesis acceptable to their thesis committee, will be eligible without the Graduate Studies Committee review for admission to the Ph.D. program in Materials Science and Engineering.
- Professional path: Students who plan to enter the technical marketplace after M.S. completion will find this path most beneficial as it requires independent graduate-level research in collaboration with an external technical organization. The research may be in the form of a traditional M.S. six-hour research topic and thesis, or may instead be in the form of two three-hour independent research efforts resulting in written reports with the clarity, style, analysis, and conclusions expected of a journal paper submission. Both the thesis and the written reports will be orally defended before the appropriate student committee. Students in this path will also be required to complete at least one internship of at least six weeks duration to experience a non-academic technical environment. Students completing this path may be considered by the Graduate Studies Committee for admission to the Ph.D. program in Materials Science and Engineering based on the strength of their academic course grades, their independent research depth, and the quality of the written research document.
- Non-thesis path: Students who are funded by personal resources or by graduate assistantships not associated with research or educational grants may complete an M.S. degree with additional course work in place of independent research. While there may be specific narrow career options where this is an appropriate path, the Materials Science and Engineering program strongly recommends

the Professional or Academic paths as providing a much better overall career preparation for working in a technical position. Students completing this path cannot be accepted into the Ph.D. program in Materials Science and Engineering.

Students will form either a thesis committee or an advisory committee after they have chosen their M.S. path, defined any independent research areas, and have been accepted into a research group if appropriate. A thesis committee will be made up of at least three faculty members, with at least one faculty member each from the Fulbright College of Arts and Sciences and the College of Engineering (the student's research professor will chair the thesis committee). The advisory committee will include at least one member from the Graduate Studies Committee, the supervising faculty member for a research experience, and one additional faculty member. If the student is in the Professional path, then either committee must also include at least one technical professional from the partner external organization as an adjunct faculty member or an ex officio committee member.

Students in this degree program can choose an Academic path, a Professional path, or a Non-thesis path. The course hours to meet the minimum requirements for each paths are as follows:

Subject Area	Academic Path/ Hours	Professional Path/Hours	Non-Thesis Path/Hours
MSEN 5733L Fabrication at the Nanoscale OR ELEG 5243L Microelectronic Fabrication Techniques and Procedures OR ELEG 5293L Integrated Circuits Fabrication Laboratory OR MEEG 5633 Additive Manufacturing	3	3	3
MEEG 5343 Computational Materials Science	3	3	3
MSEN 5322 Materials Characterization (Core)	2	2	2
MSEN 5313 Fundamentals of Materials Science (Core)	3	3	3
MSEN 5383 Research Commercialization and Product Development	3	3	3
MSEN 5811 / MSEN 5911 / MSEN 6811 / MSEN 6911 Operations Management Seminar Series (Core)	4	4	4
Technical Electives from Concentration List	9	9	9
MSEN 600V Research Thesis	6	(Option) 6	0
MSEN 5513 Applied Research in External Technical Organizations	Not Available	(Or Option) 3 + 3	Not Available
MSEN 5323 Applied On-Campus Collaborative Research with External Organizations	Not Available	(Or Option) 3 + 3	Not Available
MSEN 555V Internship in External Technical Organization or GNEG 5811 Alternating Cooperative Education	Optional (hours do not apply to degree requirement)	>/= 1	Optional (hours do not apply to degree requirement)
MSEN 5821 Ethics for Scientists and Engineers	Applied in Ph.D. Curriculum	1	1
Additional Technical Elective	0	0	>/=2
MSEN 5253 Emerging Technologies in Industry	Recommended in PhD studies	Recommended in PhD studies	3
MSEN 5393 Product Development Process	Not Available	Not Available	3

If a University of Arkansas undergraduate student is pursuing a Bachelor of Science degree in a department that has implemented an accelerated B.S./M.S. program (typically allowing six hours of graduate-level course work to be shared between the two degrees), the student may implement the same acceleration for a B.S. departmental degree/M.S. Materials Science degree set. Both the undergraduate department and the MSEN program Director must approve the shared courses prior to enrollment.

As part of each student's curriculum, nine hours of coursework must be taken through one of the following concentrations. Courses not listed in the concentration list, but clearly pertaining to the concentration area, may be substituted with the approval of the student's research adviser and the MSEN program Director. Students who have acquired the knowledge contained in any of the required courses through prior education may petition the MSEN program Director for permission to substitute other classes for these required courses.

Additional core courses to develop operations management skills also have been defined for MSEN students. During year one of their graduate studies at the University of Arkansas, students are required to take MSEN 5811 1st Year Operations Seminar - Infrastructure Management and MSEN 5911 1st Year Operations Seminar - Personnel Management in the fall and spring semesters and MSEN 5821 Ethics for Scientists and Engineers in their first summer. During year two, students are required to take MSEN 6811 2nd Year Operations Seminar - Management and Leadership and MSEN 6911 2nd Year Operations Seminar - Advanced Management and Leadership in the fall and spring semesters, respectively. Students who begin their graduate studies at the University of Arkansas during the spring semester will be required to take MSEN 5811 in the fall semester following their completion of MSEN 6911 or to take MSEN 5811 concurrently with MSEN 6811.

Students are required to attend monthly MSEN Research Communication Seminars during the first three semesters of their M.S. degree program, and will enroll in MSEN 5611 Research Communication Seminar of MS Students in their third semester. Students working more than 20 hours per week in a non-local technology-based professional position approved by the MSEN Director will not be required to be enrolled in this class or attend the monthly seminars as a condition for graduation.

Research thesis hours will be chosen from the student's research adviser's section (MSEN 600V) and will require a written thesis successfully defended in a comprehensive oral exam given by the thesis committee.

A research thesis is required for Academic path students, and is optional for Professional path students. Professional path thesis research must include direct collaboration with an external technical organization.

A student in the Professional path may substitute two Applied Research efforts for a thesis under MSEN 5513 (External location) or MSEN 5523 (Internal on-campus location), provided each semester's research is of graduate-level quality and is reported at the end of the semester through a written paper and in an oral presentation to the advisory committee (note that the written paper must match the clarity, style, analysis, and conclusions expected of a journal paper submission). Regardless of where the research is performed, it must include direct collaboration with an external technical organization.

If a student is taking either a special problems independent study course (such as MSEN 588V) or a special topics course (such as MSEN 587V) to meet partial requirements for their M.S. degree, the instructor must supply the MSEN program office with a syllabus of that class to be included in their program records. The syllabus must include at least the course title, semester, instructor name, a list of specific course objectives, a list of student learning outcomes, sources of content knowledge, and method by which the student's mastery of the learning objectives is demonstrated.

Each student is required to enroll in at least one hour of course work each fall and spring semester until the M.S. degree is issued. If all required course work has been completed, the student may enroll in one hour of master's thesis, or in one hour of a special problems course for credit only.

Students should also be aware of Graduate School requirements with regard to master's degrees (http://catalog.uark.edu/graduatecatalog/degreerequirements/#mastersdegreestext).

Concentration in Energy Materials and Devices

Choose nine hours from the following:		9
CHEM 5283	Energy Conversion and Storage	
ELEG 5223	Design and Fabrication of Solar Cells	
MEEG 5343	Computational Material Science	
MEEG 5353	Lithium-ion Batteries and Beyond: Materials, Characterization, and Performance	
MSEN 5713	Advanced Nanomaterials Chemistry	
MSEN 5733L	Fabrication at the Nanoscale	
MSEN 6323	Materials Engineering Design	

Requirements for M.S. in Materials Science with Mechanical and Structural Materials Concentration

Prerequisites to Degree Program: Applicants to the program must satisfy the requirements of the Graduate School as described in this catalog and have the approval of the Graduate Studies Committee of the Materials Science and Engineering program.

Candidates typically have completed a Bachelor of Science degree in the physical or natural sciences and candidates' academic backgrounds will be evaluated by the Graduate Studies Committee for suitability to the graduate program. To be admitted to graduate study in Materials Science without deficiency, candidates are required to have completed a math course sequence through differential equations and an introduction to quantum mechanics through courses such as PHYS 3603 Introduction to Modern Physics, PHYS 3613 Modern Physics, or CHEM 3504 Physical Chemistry I. Other undergraduate deficiencies may be identified during the evaluation process, and degree completion will be contingent on successful completion of these identified deficiencies.

Prospective students from foreign countries in which English is not the native language must submit nationally recognized standardized testing results on written English proficiency for consideration by the Graduate School during the admission process. Students may be given conditional admittance pending demonstration of English language skills in appropriate courses at the University of Arkansas. Students wishing to apply for graduate assistantships that require direct contact with students in a teaching or tutorial role must meet the Graduate School's English Language proficiency test requirements for such GA positions.

Requirements for the Master of Science in Materials Science Degree: Students choosing this degree program will be assigned an initial adviser upon acceptance to the program. Students will work with the MSEN Program Director to define their M.S. path to best support their career goals after graduation, with three curricula paths available to Materials Science students:

- Academic path: Students who plan to complete an academic campus-based research thesis will take this path, although the research topic may include funding and collaboration with outside technical organizations. Students who complete all requirements

for M.S. graduation, including an independent research project and thesis acceptable to their thesis committee, will be eligible without the Graduate Studies Committee review for admission to the Ph.D. program in Materials Science and Engineering.

- Professional path: Students who plan to enter the technical marketplace after M.S. completion will find this path most beneficial as it requires independent graduate-level research in collaboration with an external technical organization. The research may be in the form of a traditional M.S. six-hour research topic and thesis, or may instead be in the form of two three-hour independent research efforts resulting in written reports with the clarity, style, analysis, and conclusions expected of a journal paper submission. Both the thesis and the written reports will be orally defended before the appropriate student committee. Students in this path will also be required to complete at least one internship of at least six weeks duration to experience a non-academic technical environment. Students completing this path may be considered by the Graduate Studies Committee for admission to the Ph.D. program in Materials Science and Engineering based on the strength of their academic course grades, their independent research depth, and the quality of the written research document.
- Non-thesis path: Students who are funded by personal resources or by graduate assistantships not associated with research or educational grants may complete an M.S. degree with additional course work in place of independent research. While there may be specific narrow career options where this is an appropriate path, the Materials Science and Engineering program strongly recommends the Professional or Academic paths as providing a much better overall career preparation for working in a technical position. Students completing this path cannot be accepted into the Ph.D. program in Materials Science and Engineering.

Students will form either a thesis committee or an advisory committee after they have chosen their M.S. path, defined any independent research areas, and have been accepted into a research group if appropriate. A thesis committee will be made up of at least three faculty members, with at least one faculty member each from the Fulbright College of Arts and Sciences and the College of Engineering (the student's research professor will chair the thesis committee). The advisory committee will include at least one member from the Graduate Studies Committee, the supervising faculty member for a research experience, and one additional faculty member. If the student is in the Professional path, then either committee must also include at least one technical professional from the partner external organization as an adjunct faculty member or an ex officio committee member.

Students in this degree program can choose an Academic path, a Professional path, or a Non-thesis path. The course hours to meet the minimum requirements for each paths are as follows:

Subject Area	Academic Path/ Hours	Professional Path/Hours	Non-Thesis Path/Hours
MSEN 5733L Fabrication at the Nanoscale OR ELEG 5243L Microelectronic Fabrication Techniques and Procedures OR ELEG 5293L Integrated Circuits Fabrication Laboratory OR MEEG 5633 Additive Manufacturing	3	3	3
MEEG 5343 Computational Materials Science	3	3	3
MSEN 5322 Materials Characterization (Core)	2	2	2
MSEN 5313 Fundamentals of Materials Science (Core)	3	3	3
MSEN 5383 Research Commercialization and Product Development	3	3	3
MSEN 5811 / MSEN 5911 / MSEN 6811 / MSEN 6911 Operations Management Seminar Series (Core)	4	4	4
Technical Electives from Concentration List	9	9	9
MSEN 600V Research Thesis	6	(Option) 6	0
MSEN 5513 Applied Research in External Technical Organizations	Not Available	(Or Option) 3 + 3	Not Available
MSEN 5323 Applied On-Campus Collaborative Research with External Organizations	Not Available	(Or Option) 3 + 3	Not Available

MSEN 555V Internship in External Technical Organization or GNEG 5811 Alternating Cooperative Education	Optional (hours do not apply to degree requirement)	>/= 1	Optional (hours do not apply to degree requirement)
MSEN 5821 Ethics for Scientists and Engineers	Applied in Ph.D. Curriculum	1	1
Additional Technical Elective	0	0	>/=2
MSEN 5253 Emerging Technologies in Industry	Recommended in PhD studies	Recommended in PhD studies	3
MSEN 5393 Product Development Process	Not Available	Not Available	3

If a University of Arkansas undergraduate student is pursuing a Bachelor of Science degree in a department that has implemented an accelerated B.S./M.S. program (typically allowing six hours of graduate-level course work to be shared between the two degrees), the student may implement the same acceleration for a B.S. departmental degree/M.S. Materials Science degree set. Both the undergraduate department and the MSEN program Director must approve the shared courses prior to enrollment.

As part of each student's curriculum, nine hours of coursework must be taken through one of the following concentrations. Courses not listed in the concentration list, but clearly pertaining to the concentration area, may be substituted with the approval of the student's research adviser and the MSEN program Director. Students who have acquired the knowledge contained in any of the required courses through prior education may petition the MSEN program Director for permission to substitute other classes for these required courses.

Additional core courses to develop operations management skills also have been defined for MSEN students. During year one of their graduate studies at the University of Arkansas, students are required to take MSEN 5811 1st Year Operations Seminar - Infrastructure Management and MSEN 5911 1st Year Operations Seminar - Personnel Management in the fall and spring semesters and MSEN 5821 Ethics for Scientists and Engineers in their first summer. During year two, students are required to take MSEN 6811 2nd Year Operations Seminar - Management and Leadership and MSEN 6911 2nd Year Operations Seminar - Advanced Management and Leadership in the fall and spring semesters, respectively. Students who begin their graduate studies at the University of Arkansas during the spring semester will be required to take MSEN 5811 in the fall semester following their completion of MSEN 6911 or to take MSEN 5811 concurrently with MSEN 6811.

Students are required to attend monthly MSEN Research Communication Seminars during the first three semesters of their M.S. degree program, and will enroll in MSEN 5611 Research Communication Seminar of MS Students in their third semester. Students working more than 20 hours per week in a non-local technology-based professional position approved by the MSEN Director will not be required to be enrolled in this class or attend the monthly seminars as a condition for graduation.

Research thesis hours will be chosen from the student's research adviser's section (MSEN 600V) and will require a written thesis successfully defended in a comprehensive oral exam given by the thesis committee.

A research thesis is required for Academic path students, and is optional for Professional path students. Professional path thesis research must include direct collaboration with an external technical organization.

A student in the Professional path may substitute two Applied Research efforts for a thesis under MSEN 5513 (External location) or MSEN 5523 (Internal on-campus location), provided each semester's research is of graduate-level quality and is reported at the end of the semester through a written paper and in an oral presentation to the advisory committee (note that the written paper must match the clarity, style, analysis, and conclusions expected of a journal paper submission). Regardless of where the research is performed, it must include direct collaboration with an external technical organization.

If a student is taking either a special problems independent study course (such as MSEN 588V) or a special topics course (such as MSEN 587V) to meet partial requirements for their M.S. degree, the instructor must supply the MSEN program office with a syllabus of that class to be included in their program records. The syllabus must include at least the course title, semester, instructor name, a list of specific course objectives, a list of student learning outcomes, sources of content knowledge, and method by which the student's mastery of the learning objectives is demonstrated.

Each student is required to enroll in at least one hour of course work each fall and spring semester until the M.S. degree is issued. If all required course work has been completed, the student may enroll in one hour of master's thesis, or in one hour of a special problems course for credit only.

Students should also be aware of Graduate School requirements with regard to master's degrees (http://catalog.uark.edu/graduatecatalog/degreerequirements/#mastersdegreestext).

Concentration in Mechanical and Structural Materials

Choose nine hours of the following:		9
MEEG 5033	Advanced Mechanics of Materials I	
MEEG 5163	Advanced Product Design	
MEEG 5343	Computational Material Science	
MEEG 5953	Fundamentals of Fracture and Fatigue in Structures	
MEEG 5963	Advanced Fracture Mechanics and Structural Integrity	
MSEN 6323	Materials Engineering Design	
PHYS 5713	Condensed Matter Physics I	
PHYS 6713	Condensed Matter Physics II	

Requirements for M.S. in Materials Science with Microelectronic-Photonic Materials and Devices Concentration

Prerequisites to Degree Program: Applicants to the program must satisfy the requirements of the Graduate School as described in this

catalog and have the approval of the Graduate Studies Committee of the Materials Science and Engineering program.

Candidates typically have completed a Bachelor of Science degree in the physical or natural sciences and candidates' academic backgrounds will be evaluated by the Graduate Studies Committee for suitability to the graduate program. To be admitted to graduate study in Materials Science without deficiency, candidates are required to have completed a math course sequence through differential equations and an introduction to quantum mechanics through courses such as PHYS 3603 Introduction to Modern Physics, PHYS 3613 Modern Physics, or CHEM 3504 Physical Chemistry I. Other undergraduate deficiencies may be identified during the evaluation process, and degree completion will be contingent on successful completion of these identified deficiencies.

Prospective students from foreign countries in which English is not the native language must submit nationally recognized standardized testing results on written English proficiency for consideration by the Graduate School during the admission process. Students may be given conditional admittance pending demonstration of English language skills in appropriate courses at the University of Arkansas. Students wishing to apply for graduate assistantships that require direct contact with students in a teaching or tutorial role must meet the Graduate School's English Language proficiency test requirements for such GA positions.

Requirements for the Master of Science in Materials Science Degree: Students choosing this degree program will be assigned an initial adviser upon acceptance to the program. Students will work with the MSEN Program Director to define their M.S. path to best support their career goals after graduation, with three curricula paths available to Materials Science students:

- Academic path: Students who plan to complete an academic campus-based research thesis will take this path, although the research topic may include funding and collaboration with outside technical organizations. Students who complete all requirements for M.S. graduation, including an independent research project and thesis acceptable to their thesis committee, will be eligible without the Graduate Studies Committee review for admission to the Ph.D. program in Materials Science and Engineering.
- Professional path: Students who plan to enter the technical marketplace after M.S. completion will find this path most beneficial as it requires independent graduate-level research in collaboration with an external technical organization. The research may be in the form of a traditional M.S. six-hour research topic and thesis, or may instead be in the form of two three-hour independent research efforts resulting in written reports with the clarity, style, analysis, and conclusions expected of a journal paper submission. Both the thesis and the written reports will be orally defended before the appropriate student committee. Students in this path will also be required to complete at least one internship of at least six weeks duration to experience a non-academic technical environment. Students completing this path may be considered by the Graduate Studies Committee for admission to the Ph.D. program in Materials Science and Engineering based on the strength of their academic course grades, their independent research depth, and the quality of the written research document.
- Non-thesis path: Students who are funded by personal resources or by graduate assistantships not associated with research or educational grants may complete an M.S. degree with additional course work in place of independent research. While there may be specific narrow career options where this is an appropriate path, the Materials Science and Engineering program strongly recommends the Professional or Academic paths as providing a much better overall career preparation for working in a technical position. Students completing this path cannot be accepted into the Ph.D. program in Materials Science and Engineering.

Students will form either a thesis committee or an advisory committee after they have chosen their M.S. path, defined any independent research areas, and have been accepted into a research group if appropriate. A thesis committee will be made up of at least three faculty members, with at least one faculty member each from the Fulbright College of Arts and Sciences and the College of Engineering (the student's research professor will chair the thesis committee). The advisory committee will include at least one member from the Graduate Studies Committee, the supervising faculty member for a research experience, and one additional faculty member. If the student is in the Professional path, then either committee must also include at least one technical professional from the partner external organization as an adjunct faculty member or an ex officio committee member.

Students in this degree program can choose an Academic path, a Professional path, or a Non-thesis path. The course hours to meet the minimum requirements for each paths are as follows:

Subject Area	Academic Path/ Hours	Professional Path/Hours	Non-Thesis Path/Hours
MSEN 5733L Fabrication at the Nanoscale OR ELEG 5243L Microelectronic Fabrication Techniques and Procedures OR ELEG 5293L Integrated Circuits Fabrication Laboratory OR MEEG 5633 Additive Manufacturing	3	3	3
MEEG 5343 Computational Materials Science	3	3	3
MSEN 5322 Materials Characterization (Core)	2	2	2
MSEN 5313 Fundamentals of Materials Science (Core)	3	3	3
MSEN 5383 Research Commercialization and Product Development	3	3	3

MSEN 5811 / MSEN 5911 / MSEN 6811 / MSEN 6911 Operations Management Seminar Series (Core)	4	4	4
Technical Electives from Concentration List	9	9	9
MSEN 600V Research Thesis	6	(Option) 6	0
MSEN 5513 Applied Research in External Technical Organizations	Not Available	(Or Option) 3 + 3	Not Available
MSEN 5323 Applied On-Campus Collaborative Research with External Organizations	Not Available	(Or Option) 3 + 3	Not Available
MSEN 555V Internship in External Technical Organization or GNEG 5811 Alternating Cooperative Education	Optional (hours do not apply to degree requirement)	>/= 1	Optional (hours do not apply to degree requirement)
MSEN 5821 Ethics for Scientists and Engineers	Applied in Ph.D. Curriculum	1	1
Additional Technical Elective	0	0	>/=2
MSEN 5253 Emerging Technologies in Industry	Recommended in PhD studies	Recommended in PhD studies	3
MSEN 5393 Product Development Process	Not Available	Not Available	3

If a University of Arkansas undergraduate student is pursuing a Bachelor of Science degree in a department that has implemented an accelerated B.S./M.S. program (typically allowing six hours of graduate-level course work to be shared between the two degrees), the student may implement the same acceleration for a B.S. departmental degree/M.S. Materials Science degree set. Both the undergraduate department and the MSEN program Director must approve the shared courses prior to enrollment.

As part of each student's curriculum, nine hours of coursework must be taken through one of the following concentrations. Courses not listed in the concentration list, but clearly pertaining to the concentration area, may be substituted with the approval of the student's research adviser and the MSEN program Director. Students who have acquired the knowledge contained in any of the required courses through prior education may petition the MSEN program Director for permission to substitute other classes for these required courses.

Additional core courses to develop operations management skills also have been defined for MSEN students. During year one of their graduate studies at the University of Arkansas, students are required to take MSEN 5811 1st Year Operations Seminar - Infrastructure Management and MSEN 5911 1st Year Operations Seminar - Personnel Management in the fall and spring semesters and MSEN 5821 Ethics for Scientists and Engineers in their first summer. During year two, students are required to take MSEN 6811 2nd Year Operations Seminar - Management and Leadership and MSEN 6911 2nd Year Operations Seminar - Advanced Management and Leadership in the fall and spring semesters, respectively. Students who begin their graduate studies at the University of Arkansas during the spring semester will be required to take MSEN 5811 in the fall semester following their completion of MSEN 6911 or to take MSEN 5811 concurrently with MSEN 6811.

Students are required to attend monthly MSEN Research Communication Seminars during the first three semesters of their M.S. degree program, and will enroll in MSEN 5611 Research Communication Seminar of MS Students in their third semester. Students working more than 20 hours per week in a non-local technology-based professional position approved by the MSEN Director will not be required to be enrolled in this class or attend the monthly seminars as a condition for graduation.

Research thesis hours will be chosen from the student's research adviser's section (MSEN 600V) and will require a written thesis successfully defended in a comprehensive oral exam given by the thesis committee.

A research thesis is required for Academic path students, and is optional for Professional path students. Professional path thesis research must include direct collaboration with an external technical organization.

A student in the Professional path may substitute two Applied Research efforts for a thesis under MSEN 5513 (External location) or MSEN 5523 (Internal on-campus location), provided each semester's research is of graduate-level quality and is reported at the end of the semester through a written paper and in an oral presentation to the advisory committee (note that the written paper must match the clarity, style, analysis, and conclusions expected of a journal paper submission). Regardless of where the research is performed, it must include direct collaboration with an external technical organization.

If a student is taking either a special problems independent study course (such as MSEN 588V) or a special topics course (such as MSEN 587V) to meet partial requirements for their M.S. degree, the instructor must supply the MSEN program office with a syllabus of that class to be included in their program records. The syllabus must include at least the course title, semester, instructor name, a list of specific course objectives, a list of student learning outcomes, sources of content knowledge, and method by which the student's mastery of the learning objectives is demonstrated.

Each student is required to enroll in at least one hour of course work each fall and spring semester until the M.S. degree is issued. If all required course work has been completed, the student may enroll in one hour of

master's thesis, or in one hour of a special problems course for credit only.

Students should also be aware of Graduate School requirements with regard to master's degrees (http://catalog.uark.edu/graduatecatalog/degreerequirements/#mastersdegreestext).

Concentration in Microelectronic-Photonic Materials and Devices

ELEG 5203	Semiconductor Devices	3
Choose six hours from the following:		6
ELEG 5213	Integrated Circuit Fabrication Technology	
ELEG 5223	Design and Fabrication of Solar Cells	
ELEG 5273	Electronic Packaging	
ELEG 5293L	Integrated Circuits Fabrication Laboratory	
ELEG 5313	Power Semiconductor Devices	
ELEG 5323	Semiconductor Nanostructures I	
ELEG 5353	Semiconductor Optoelectronic Devices	
ELEG 5363	Semiconductor Material and Device Characterization	
ELEG 5383	Introduction of Integrated Photonics	
ELEG 5393	Electronic Materials	
ELEG 5543	Introduction to Power Electronics	
MEEG 5263	Introduction to Micro Electro Mechanical Systems	
MEEG 5343	Computational Material Science	
MSEN 6323	Materials Engineering Design	
PHYS 5713	Condensed Matter Physics I	
PHYS 5734	Laser Physics	
PHYS 5753	Applied Nonlinear Optics	
PHYS 5773	Introduction to Optical Properties of Materials	
PHYS 6713	Condensed Matter Physics II	

Requirements for M.S. in Materials Science with Nanoscale Materials and Devices Concentration

Prerequisites to Degree Program: Applicants to the program must satisfy the requirements of the Graduate School as described in this catalog and have the approval of the Graduate Studies Committee of the Materials Science and Engineering program.

Candidates typically have completed a Bachelor of Science degree in the physical or natural sciences and candidates' academic backgrounds will be evaluated by the Graduate Studies Committee for suitability to the graduate program. To be admitted to graduate study in Materials Science without deficiency, candidates are required to have completed a math course sequence through differential equations and an introduction to quantum mechanics through courses such as PHYS 3603 Introduction to Modern Physics, PHYS 3613 Modern Physics, or CHEM 3504 Physical Chemistry I. Other undergraduate deficiencies may be identified during the evaluation process, and degree completion will be contingent on successful completion of these identified deficiencies.

Prospective students from foreign countries in which English is not the native language must submit nationally recognized standardized testing results on written English proficiency for consideration by the Graduate School during the admission process. Students may be given conditional admittance pending demonstration of English language skills in appropriate courses at the University of Arkansas. Students wishing to apply for graduate assistantships that require direct contact with students in a teaching or tutorial role must meet the Graduate School's English Language proficiency test requirements for such GA positions.

Requirements for the Master of Science in Materials Science Degree: Students choosing this degree program will be assigned an initial adviser upon acceptance to the program. Students will work with the MSEN Program Director to define their M.S. path to best support their career goals after graduation, with three curricula paths available to Materials Science students:

- Academic path: Students who plan to complete an academic campus-based research thesis will take this path, although the research topic may include funding and collaboration with outside technical organizations. Students who complete all requirements for M.S. graduation, including an independent research project and thesis acceptable to their thesis committee, will be eligible without the Graduate Studies Committee review for admission to the Ph.D. program in Materials Science and Engineering.
- Professional path: Students who plan to enter the technical marketplace after M.S. completion will find this path most beneficial as it requires independent graduate-level research in collaboration with an external technical organization. The research may be in the form of a traditional M.S. six-hour research topic and thesis, or may instead be in the form of two three-hour independent research efforts resulting in written reports with the clarity, style, analysis, and conclusions expected of a journal paper submission. Both the thesis and the written reports will be orally defended before the appropriate student committee. Students in this path will also be required to complete at least one internship of at least six weeks duration to experience a non-academic technical environment. Students completing this path may be considered by the Graduate Studies Committee for admission to the Ph.D. program in Materials Science and Engineering based on the strength of their academic course grades, their independent research depth, and the quality of the written research document.
- Non-thesis path: Students who are funded by personal resources or by graduate assistantships not associated with research or educational grants may complete an M.S. degree with additional course work in place of independent research. While there may be specific narrow career options where this is an appropriate path, the Materials Science and Engineering program strongly recommends the Professional or Academic paths as providing a much better overall career preparation for working in a technical position. Students completing this path cannot be accepted into the Ph.D. program in Materials Science and Engineering.

Students will form either a thesis committee or an advisory committee after they have chosen their M.S. path, defined any independent research areas, and have been accepted into a research group if appropriate. A thesis committee will be made up of at least three faculty members, with at least one faculty member each from the Fulbright College of Arts and Sciences and the College of Engineering (the student's research professor will chair the thesis committee). The advisory committee will include at least one member from the Graduate Studies Committee, the supervising faculty member for a research experience, and one additional faculty member. If the student is in the Professional path, then either committee must also include at least one technical professional from the partner external organization as an adjunct faculty member or an ex officio committee member.

Students in this degree program can choose an Academic path, a Professional path, or a Non-thesis path. The course hours to meet the minimum requirements for each paths are as follows:

Subject Area	Academic Path/ Hours	Professional Path/Hours	Non-Thesis Path/Hours
MSEN 5733L Fabrication at the Nanoscale OR ELEG 5243L Microelectronic Fabrication Techniques and Procedures OR ELEG 5293L Integrated Circuits Fabrication Laboratory OR MEEG 5633 Additive Manufacturing	3	3	3
MEEG 5343 Computational Materials Science	3	3	3
MSEN 5322 Materials Characterization (Core)	2	2	2
MSEN 5313 Fundamentals of Materials Science (Core)	3	3	3
MSEN 5383 Research Commercialization and Product Development	3	3	3
MSEN 5811 / MSEN 5911 / MSEN 6811 / MSEN 6911 Operations Management Seminar Series (Core)	4	4	4
Technical Electives from Concentration List	9	9	9
MSEN 600V Research Thesis	6	(Option) 6	0
MSEN 5513 Applied Research in External Technical Organizations	Not Available	(Or Option) 3 + 3	Not Available
MSEN 5323 Applied On-Campus Collaborative Research with External Organizations	Not Available	(Or Option) 3 + 3	Not Available
MSEN 555V Internship in External Technical Organization or GNEG 5811 Alternating Cooperative Education	Optional (hours do not apply to degree requirement)	>/= 1	Optional (hours do not apply to degree requirement)
MSEN 5821 Ethics for Scientists and Engineers	Applied in Ph.D. Curriculum	1	1
Additional Technical Elective	0	0	>/=2
MSEN 5253 Emerging Technologies in Industry	Recommended in PhD studies	Recommended in PhD studies	3
MSEN 5393 Product Development Process	Not Available	Not Available	3

If a University of Arkansas undergraduate student is pursuing a Bachelor of Science degree in a department that has implemented an accelerated B.S./M.S. program (typically allowing six hours of graduate-level course work to be shared between the two degrees), the student may implement the same acceleration for a B.S. departmental degree/M.S. Materials Science degree set. Both the undergraduate department and the MSEN program Director must approve the shared courses prior to enrollment.

As part of each student's curriculum, nine hours of coursework must be taken through one of the following concentrations. Courses not listed in the concentration list, but clearly pertaining to the concentration area, may be substituted with the approval of the student's research adviser and the MSEN program Director. Students who have acquired the knowledge contained in any of the required courses through prior education may petition the MSEN program Director for permission to substitute other classes for these required courses.

Additional core courses to develop operations management skills also have been defined for MSEN students. During year one of their graduate studies at the University of Arkansas, students are required to take MSEN 5811 1st Year Operations Seminar - Infrastructure Management and MSEN 5911 1st Year Operations Seminar - Personnel Management in the fall and spring semesters and MSEN 5821 Ethics for Scientists and Engineers in their first summer. During year two, students are required to take MSEN 6811 2nd Year Operations Seminar - Management and Leadership and MSEN 6911 2nd Year Operations Seminar - Advanced Management and Leadership in the fall and spring semesters, respectively. Students who begin their graduate studies at the University of Arkansas during the spring semester will be required

to take MSEN 5811 in the fall semester following their completion of MSEN 6911 or to take MSEN 5811 concurrently with MSEN 6811.

Students are required to attend monthly MSEN Research Communication Seminars during the first three semesters of their M.S. degree program, and will enroll in MSEN 5611 Research Communication Seminar of MS Students in their third semester. Students working more than 20 hours per week in a non-local technology-based professional position approved by the MSEN Director will not be required to be enrolled in this class or attend the monthly seminars as a condition for graduation.

Research thesis hours will be chosen from the student's research adviser's section (MSEN 600V) and will require a written thesis successfully defended in a comprehensive oral exam given by the thesis committee.

A research thesis is required for Academic path students, and is optional for Professional path students. Professional path thesis research must include direct collaboration with an external technical organization.

A student in the Professional path may substitute two Applied Research efforts for a thesis under MSEN 5513 (External location) or MSEN 5523 (Internal on-campus location), provided each semester's research is of graduate-level quality and is reported at the end of the semester through a written paper and in an oral presentation to the advisory committee (note that the written paper must match the clarity, style, analysis, and conclusions expected of a journal paper submission). Regardless of where the research is performed, it must include direct collaboration with an external technical organization.

If a student is taking either a special problems independent study course (such as MSEN 588V) or a special topics course (such as MSEN 587V) to meet partial requirements for their M.S. degree, the instructor must supply the MSEN program office with a syllabus of that class to be included in their program records. The syllabus must include at least the course title, semester, instructor name, a list of specific course objectives, a list of student learning outcomes, sources of content knowledge, and method by which the student's mastery of the learning objectives is demonstrated.

Each student is required to enroll in at least one hour of course work each fall and spring semester until the M.S. degree is issued. If all required course work has been completed, the student may enroll in one hour of master's thesis, or in one hour of a special problems course for credit only.

Students should also be aware of Graduate School requirements with regard to master's degrees (http://catalog.uark.edu/graduatecatalog/degreerequirements/#mastersdegreestext).

Concentration in Nanoscale Materials and Devices

Choose nine hours of the following: 9

CHEM 5443	Physical Chemistry of Materials
ELEG 5303	Introduction to Nanomaterials and Devices (Introduction to Nanomaterials and Devices)
MEEG 5263	Introduction to Micro Electro Mechanical Systems
MEEG 5333	Introduction to Tribology
MEEG 5343	Computational Material Science
MSEN 5713	Advanced Nanomaterials Chemistry
MSEN 5733L	Fabrication at the Nanoscale
MSEN 6323	Materials Engineering Design
PHYS 5713	Condensed Matter Physics I
PHYS 5723	Physics at the Nanoscale
PHYS 5783	Physics of 2D Materials
PHYS 6713	Condensed Matter Physics II

Requirements for M.S. in Materials Science with Materials Modeling Concentration

Prerequisites to Degree Program: Applicants to the program must satisfy the requirements of the Graduate School as described in this catalog and have the approval of the Graduate Studies Committee of the Materials Science and Engineering program.

Candidates typically have completed a Bachelor of Science degree in the physical or natural sciences and candidates' academic backgrounds will be evaluated by the Graduate Studies Committee for suitability to the graduate program. To be admitted to graduate study in Materials Science without deficiency, candidates are required to have completed a math course sequence through differential equations and an introduction to quantum mechanics through courses such as PHYS 3603 Introduction to Modern Physics, PHYS 3613 Modern Physics, or CHEM 3504 Physical Chemistry I. Other undergraduate deficiencies may be identified during the evaluation process, and degree completion will be contingent on successful completion of these identified deficiencies.

Prospective students from foreign countries in which English is not the native language must submit nationally recognized standardized testing results on written English proficiency for consideration by the Graduate School during the admission process. Students may be given conditional admittance pending demonstration of English language skills in appropriate courses at the University of Arkansas. Students wishing to apply for graduate assistantships that require direct contact with students in a teaching or tutorial role must meet the Graduate School's English Language proficiency test requirements for such GA positions.

Requirements for the Master of Science in Materials Science Degree: Students choosing this degree program will be assigned an initial adviser upon acceptance to the program. Students will work with the MSEN Program Director to define their M.S. path to best support their career goals after graduation, with three curricula paths available to Materials Science students:

- Academic path: Students who plan to complete an academic campus-based research thesis will take this path, although the research topic may include funding and collaboration with outside technical organizations. Students who complete all requirements for M.S. graduation, including an independent research project and thesis acceptable to their thesis committee, will be eligible without the Graduate Studies Committee review for admission to the Ph.D. program in Materials Science and Engineering.
- Professional path: Students who plan to enter the technical marketplace after M.S. completion will find this path most beneficial as it requires independent graduate-level research in collaboration with an external technical organization. The research may be in the form of a traditional M.S. six-hour research topic and thesis, or may instead be in the form of two three-hour independent research efforts resulting in written reports with the clarity, style, analysis, and conclusions expected of a journal paper submission. Both the thesis and the written reports will be orally defended before the appropriate student committee. Students in this path will also be required to complete at least one internship of at least six weeks duration to experience a non-academic technical environment. Students completing this path may be considered by the Graduate Studies Committee for admission

to the Ph.D. program in Materials Science and Engineering based on the strength of their academic course grades, their independent research depth, and the quality of the written research document.

- Non-thesis path: Students who are funded by personal resources or by graduate assistantships not associated with research or educational grants may complete an M.S. degree with additional course work in place of independent research. While there may be specific narrow career options where this is an appropriate path, the Materials Science and Engineering program strongly recommends the Professional or Academic paths as providing a much better overall career preparation for working in a technical position. Students completing this path cannot be accepted into the Ph.D. program in Materials Science and Engineering.

Students will form either a thesis committee or an advisory committee after they have chosen their M.S. path, defined any independent research areas, and have been accepted into a research group if appropriate. A thesis committee will be made up of at least three faculty members, with at least one faculty member each from the Fulbright College of Arts and Sciences and the College of Engineering (the student's research professor will chair the thesis committee). The advisory committee will include at least one member from the Graduate Studies Committee, the supervising faculty member for a research experience, and one additional faculty member. If the student is in the Professional path, then either committee must also include at least one technical professional from the partner external organization as an adjunct faculty member or an ex officio committee member.

Students in this degree program can choose an Academic path, a Professional path, or a Non-thesis path. The course hours to meet the minimum requirements for each paths are as follows:

Subject Area	Academic Path/ Hours	Professional Path/Hours	Non-Thesis Path/Hours
MSEN 5733L Fabrication at the Nanoscale OR ELEG 5243L Microelectronic Fabrication Techniques and Procedures OR ELEG 5293L Integrated Circuits Fabrication Laboratory OR MEEG 5633 Additive Manufacturing	3	3	3
MEEG 5343 Computational Materials Science	3	3	3
MSEN 5322 Materials Characterization (Core)	2	2	2
MSEN 5313 Fundamentals of Materials Science (Core)	3	3	3
MSEN 5383 Research Commercialization and Product Development	3	3	3
MSEN 5811 / MSEN 5911 / MSEN 6811 / MSEN 6911 Operations Management Seminar Series (Core)	4	4	4
Technical Electives from Concentration List	9	9	9
MSEN 600V Research Thesis	6	(Option) 6	0
MSEN 5513 Applied Research in External Technical Organizations	Not Available	(Or Option) 3 + 3	Not Available
MSEN 5323 Applied On-Campus Collaborative Research with External Organizations	Not Available	(Or Option) 3 + 3	Not Available
MSEN 555V Internship in External Technical Organization or GNEG 5811 Alternating Cooperative Education	Optional (hours do not apply to degree requirement)	>/= 1	Optional (hours do not apply to degree requirement)
MSEN 5821 Ethics for Scientists and Engineers	Applied in Ph.D. Curriculum	1	1
Additional Technical Elective	0	0	>/=2
MSEN 5253 Emerging Technologies in Industry	Recommended in PhD studies	Recommended in PhD studies	3
MSEN 5393 Product Development Process	Not Available	Not Available	3

If a University of Arkansas undergraduate student is pursuing a Bachelor of Science degree in a department that has implemented an accelerated B.S./M.S. program (typically allowing six hours of graduate-level course work to be shared between the two degrees), the student may implement

the same acceleration for a B.S. departmental degree/M.S. Materials Science degree set. Both the undergraduate department and the MSEN program Director must approve the shared courses prior to enrollment.

As part of each student's curriculum, nine hours of coursework must be taken through one of the following concentrations. Courses not listed in the concentration list, but clearly pertaining to the concentration area, may be substituted with the approval of the student's research adviser and the MSEN program Director. Students who have acquired the knowledge contained in any of the required courses through prior education may petition the MSEN program Director for permission to substitute other classes for these required courses.

Additional core courses to develop operations management skills also have been defined for MSEN students. During year one of their graduate studies at the University of Arkansas, students are required to take MSEN 5811 1st Year Operations Seminar - Infrastructure Management and MSEN 5911 1st Year Operations Seminar - Personnel Management in the fall and spring semesters and MSEN 5821 Ethics for Scientists and Engineers in their first summer. During year two, students are required to take MSEN 6811 2nd Year Operations Seminar - Management and Leadership and MSEN 6911 2nd Year Operations Seminar - Advanced Management and Leadership in the fall and spring semesters, respectively. Students who begin their graduate studies at the University of Arkansas during the spring semester will be required to take MSEN 5811 in the fall semester following their completion of MSEN 6911 or to take MSEN 5811 concurrently with MSEN 6811.

Students are required to attend monthly MSEN Research Communication Seminars during the first three semesters of their M.S. degree program, and will enroll in MSEN 5611 Research Communication Seminar of MS Students in their third semester. Students working more than 20 hours per week in a non-local technology-based professional position approved by the MSEN Director will not be required to be enrolled in this class or attend the monthly seminars as a condition for graduation.

Research thesis hours will be chosen from the student's research adviser's section (MSEN 600V) and will require a written thesis successfully defended in a comprehensive oral exam given by the thesis committee.

A research thesis is required for Academic path students, and is optional for Professional path students. Professional path thesis research must include direct collaboration with an external technical organization.

A student in the Professional path may substitute two Applied Research efforts for a thesis under MSEN 5513 (External location) or MSEN 5523 (Internal on-campus location), provided each semester's research is of graduate-level quality and is reported at the end of the semester through a written paper and in an oral presentation to the advisory committee (note that the written paper must match the clarity, style, analysis, and conclusions expected of a journal paper submission). Regardless of where the research is performed, it must include direct collaboration with an external technical organization.

If a student is taking either a special problems independent study course (such as MSEN 588V) or a special topics course (such as MSEN 587V) to meet partial requirements for their M.S. degree, the instructor must supply the MSEN program office with a syllabus of that class to be included in their program records. The syllabus must include at least the course title, semester, instructor name, a list of specific course objectives, a list of student learning outcomes, sources of content knowledge, and method by which the student's mastery of the learning objectives is demonstrated.

Each student is required to enroll in at least one hour of course work each fall and spring semester until the M.S. degree is issued. If all required course work has been completed, the student may enroll in one hour of master's thesis, or in one hour of a special problems course for credit only.

Students should also be aware of Graduate School requirements with regard to master's degrees (http://catalog.uark.edu/graduatecatalog/degreerequirements/#mastersdegreestext).

Concentration in Materials Modeling

Choose nine hours of the following:		9
CVEG 5383	Finite Element Methods in Civil Engineering	
MEEG 5343	Computational Material Science	
MEEG 5733	Advanced Numerical Methods	
MSEN 6323	Materials Engineering Design	
PHYS 5093	Applications of Group Theory to Physics	
PHYS 5363	Scientific Computation and Numerical Methods	
PHYS 5713	Condensed Matter Physics I	
PHYS 6713	Condensed Matter Physics II	

Requirements for Ph.D. in Materials Science and Engineering

Students choosing this degree program will be assigned an initial adviser upon acceptance to the program. Students will work with the Materials Science and Engineering Program Director to define their dissertation committee after they are accepted by a research faculty for a research project. This committee will be made up of at least four faculty members, with at least one faculty member each from the Fulbright College of Arts and Sciences and the College of Engineering. The student's research professor will chair the dissertation committee.

Candidates for the Ph.D. program are expected to have completed a Master of Science degree in either engineering or science, with each candidate's academic background being evaluated by the Graduate Studies Committee of the Materials Science and Engineering program. Doctoral candidates in Materials Science and Engineering are expected to have proficiency in the core curriculum of the Master of Science in Materials Engineering or Master of Science in Materials Science at the University of Arkansas. This core is described in the requirements for the Master of Science in Materials Engineering and the Master of Science in Materials Science, as well as in the handbook of the Materials Science & Engineering program.

Students who have graduated with a Master of Science degree in Materials Engineering or a Master of Science degree in Materials Science will be expected to take the Materials Science and Engineering Ph.D. candidacy exam. The Materials Science and Engineering Ph.D. candidacy exam is a detailed Ph.D. research proposal and it must be accepted by the student's committee before the end of the 30th month after the start date of the student's first semester as a Ph.D. student, or the student will be removed from the Ph.D. program. The student is to complete the candidacy exam process after having completed MSEN 5383 Research Commercialization and Product Development and MSEN 6323 Materials Engineering Design.

A Ph.D. curriculum will be defined to meet each student's research interests as well as ensure the Materials Science and Engineering program's core courses have been taken. The course plan for each student must include a minimum of 27 hours of graduate coursework beyond the Master of Science degree requirements. Specific courses will

be chosen by the student and must be approved by the student's major professor and the MSEN Program Director. The coursework list for the Ph.D. degree will be dependent upon the M.S. degree with which the student enters the program:

Subject Area	M.S. in Materials Engineering or Materials Science from UA/Hours	M.S. in Materials Engineering or Materials Science from another institution/ Hours	Other Science or Engineering M.S. degrees/ Hours
MSEN 6313 Advanced Materials Science & Engineering	3	3	3
BENG 5703 Design and Analysis of Experiments for Engineering Research OR INEG 5333 Design of Industrial Experiments OR other Design of Experiments course	3	3	3
MSEN 5821 Ethics for Scientists and Engineers	1 (Applied from MS curriculum)	1	1
MSEN 6323 Materials Engineering Design	If not taken in MS curriculum	3	3
MSEN 5811 / MSEN 5911 / MSEN 6811 / MSEN 6911 Operations Management Seminar Series (Core)	Taken in MS curriculum	4	4
MSEN 5383 Research Commercialization and Product Development	Taken in MS curriculum	3	3
5000- and 6000-level elective courses in science and engineering	17-20	10	5
MSEN 5322 Materials Characterization	Taken in MS curriculum	Recommended elective	2
MSEN 5313 Fundamentals of Materials Science	Taken in MS curriculum	Recommended elective	3
MSEN 5253 Emerging Technologies in Industry	Recommended elective	Recommended elective	Recommended Elective
MSEN 700V Dissertation	21	21	21
Total	48	48	48

If a student is taking either a special problems independent study course, such as MSEN 588V, or a special topics course, such as MSEN 587V, to meet partial requirements for their Ph.D. degree, then the instructor must supply the Materials Science and Engineering program office with a syllabus of that class to be included in their program records. The syllabus must include at least the course title, semester, instructor name, a list of specific course objectives, a list of student learning outcomes, sources of content knowledge, and method by which the student's mastery of the learning objectives is demonstrated.

Students are required to attend monthly Materials Science and Engineering Research Communication Seminars during the first five semesters of their Ph.D. degree program, and will enroll in MSEN 6611 Research Communication Seminar of PhD Students in their fifth semester.

The dissertation format must meet all Graduate School published guidelines and the guidelines as listed in the Materials Science and Engineering Graduate Student Handbook. Students may use bound published papers for their dissertation provided that:

1. It contains a minimum of three peer-reviewed archival journal articles which have been published or accepted for publication;
2. The Ph.D. candidate is first author on all articles used; and,
3. It contains additional text to connect the articles in the context of the overall research effort in accordance with the Graduate School guidelines and must include program required front matter and appendices.

If submission of a third paper is held up due to an intellectual property filing, or IP filing, the third paper prepared for submission for a peer-reviewed archival journal may be included in the dissertation to meet the three paper requirement if a patent disclosure covering the intellectual property has been approved for provisional filing by the University of Arkansas patent committee. The patent disclosure and documentation of approval for provisional filing must be contained within an appendix to the dissertation.

Students should also be aware of Graduate School requirements with regard to doctoral degrees (http://catalog.uark.edu/graduatecatalog/degreerequirements/#phdandedddegreestext).

Graduate Faculty

Balachandran, Kartik, Ph.D., M.S. (Georgia Institute of Technology), B.S. (National University of Singapore), Associate Professor, Department of Biomedical Engineering, 2012, 2018.

Barraza-Lopez, Salvador, Ph.D. (University of Illinois-Urbana-Champaign), B.S. (Instituto Politecnico Nacional de Mexico), Associate Professor, Department of Physics, 2011, 2016.

Bellaiche, Laurent, Ph.D., M.S., B.S. (University of Paris VI, France), Distinguished Professor, Department of Physics, 1999, 2016.

Benamara, Mourad, Ph.D., M.S. (University of Toulouse III, France), Assistant Professor, Nanotechnology, 2007.
Chen, Jingyi, Ph.D. (University of Washington), M.A. (State University College at Buffalo), B.S. (Zhongshan University), Professor, Department of Chemistry and Biochemistry, 2010, 2019.
Chen, Zhong, Ph.D. (North Carolina State University), M.Eng. (National University of Singapore), B.S. (Zhejiang University), Assistant Professor, Department of Electrical Engineering, 2015.
Churchill, Hugh O.H., Ph.D., A.M. (Harvard University), B.A. (Oberlin College), B.M. (Oberlin Conservatory of Music), Associate Professor, Department of Physics, 2015, 2021.
Coridan, Robert, Ph.D., M.S. (University of Illinois-Urbana-Champaign), B.S. (The Ohio State University), Associate Professor, Department of Chemistry and Biochemistry, 2015, 2021.
Di, Jia, Ph.D. (University of Central Florida), M.S., B.S. (Tsinghua University), Professor, Department of Computer Science and Computer Engineering, 21st Century Research Leadership Chair, 2004, 2014.
Dix, Jeffrey, Ph.D., M.S., B.S.E.E., (University ot Tennessee, Knoxville), Assistant Professor, Department of Electrical Engineering, 2018.
Dong, Bin, Ph.D. (Iowa State University), B.S. (Xiamen University), Assistant Professor, Department of Chemistry and Biochemistry, 2022.
Edwards, Martin, Ph.D., M.Sc., M.Math. (University of Warwick), Assistant Professor, Department of Chemistry and Biochemistry, 2020.
El-Shenawee, Magda O., Ph.D. (University of Nebraska-Lincoln), M.S., B.S. (Assiut University, Egypt), Professor, Department of Electrical Engineering, 2001, 2010.
Fritsch, Ingrid, Ph.D. (University of Illinois-Urbana-Champaign), B.S. (University of Utah), Professor, Department of Chemistry and Biochemistry, 1992, 2005.
Fu, Huaxiang, Ph.D., M.S. (Fudan University), B.S. (University of Science and Technology of China), Professor, Department of Physics, 2002, 2017.
Gea-Banacloche, Julio R., Ph.D. (University of New Mexico), Licenciado en Ciencias Fisicas (Universidad Autonoma de Madrid), Professor, Department of Physics, 1989, 2000.
Heyes, Colin David, Ph.D. (Georgia Institute of Technology), B.S. (Loughborogh University), Professor, Department of Chemistry and Biochemistry, 2008, 2021.
Hu, Jin, Ph.D. (Tulane University), B.S. (University of Science and Technology of China), Assistant Professor, Department of Physics, 2017.
Huitink, David, Ph.D., M.S.M.E., B.S.M.E. (Texas A&M University), Associate Professor, Department of Mechanical Engineering, 2016, 2022.
Jensen, Morten O., Ph.D. (University of Aarhus, Denmark), M.Sc. (Georgia Institute of Technology), Associate Professor, Department of Biomedical Engineering, 2014.
Kim, Jin-Woo, Ph.D. (Texas A&M University), M.S. (University of Wisconsin-La Crosse), B.S. (University of Iowa), Professor, Department of Biological and Agricultural Engineering, 2001, 2011.
Kohanek, Julia, Ph.D. and M.S. (University of Illinois Urbana-Champaign), B.S. (University of Michigan), Instructor, Department of Chemistry and Biochemistry, 2019, 2022.
Kumar, Pradeep, Ph.D. (Boston University), M.Sc. (Indian Institute of Technology, Mumbai, India), Associate Professor, Department of Physics, 2013, 2019.
Leftwich, Matthew, Ph.D., M.S. and B.S. (University of Arkansas), M.B.A. (Webster University), Research Professor, Department of Physics, 2021.
Li, Jiali, Ph.D., M.S. (The City College of the City University of New York), M.S. (University of Science and Technology of China), B.S. (Hei Long Jiang University), Professor, Department of Physics, 2002, 2016.
Li, Yanbin, Ph.D. (Pennsylvania State University), M.S. (University of Nebraska-Lincoln), B.S. (Shenyang Agricultural University), Distinguished Professor, Department of Biological and Agricultural Engineering, Tyson Endowed Chair in Biosensing Engineering, 1989, 2003.
Manasreh, Bothina H., Ph.D., M.Sc. (University of Jordan), Research Assistant Professor, Department of Physics, 2017.
Manasreh, Omar, Ph.D. (University of Arkansas), M.S. (University of Puerto Rico-Rio Piedras), B.S. (University of Jordan), Professor, Department of Electrical Engineering, 2003.
Mantooth, Alan, Ph.D. (Georgia Institute of Technology), M.S., B.S. (University of Arkansas), Distinguished Professor, Department of Electrical Engineering, Twenty-First Century Chair in Mixed-Signal IC Design and CAD, 1998, 2011.
McCann, Roy A., Ph.D. (University of Dayton), M.S.E.E., B.S.E.E. (University of Illinois), Professor, Department of Electrical Engineering, 2003, 2009.
Meng, Xiangbo, Ph.D. (University of Western Ontario), M.S.E.E. (China University of Petroleum), B.S.C.E. (Northwestern University), Associate Professor, Department of Mechanical Engineering, 2016, 2022.
Millett, Paul, Ph.D., M.S. (University of Arkansas), B.E. (Vanderbilt University), Associate Professor, Department of Mechanical Engineering, Twenty-First Century Professor, 2013, 2019.
Moradi, Mahmoud, Ph.D. (North Carolina State University), M.S., B.S. (Sharif University of Technology), Associate Professor, Department of Chemistry and Biochemistry, 2015, 2021.
Nair, Arun, Ph.D. (Virginia Polytechnic State University), M.S. (Colorado State University), B.T. (Mahatma Gandhi University), Associate Professor, Department of Mechanical Engineering, 2013, 2019.
Nakamura, Hiroyuki, Ph.D., M.S., B.S. (University of Tokyo), Assistant Professor, Department of Physics, 2019.
Naseem, Hameed A., Ph.D., M.S. (Virginia Polytechnic State University), M.Sc. (Panjab University), University Professor, Department of Electrical Engineering, 1985.
Oliver, William, Ph.D., M.S. (University of Colorado-Boulder), B.S. (University of Arizona), Associate Professor, Department of Physics, 1992, 1998.
Pohl, Edward A., Ph.D., M.S.R.E. (University of Arizona), M.S.S.E. (Air Force Institute of Technology), M.S.E.M. (University of Dayton), B.S.E.E. (Boston University), Professor, Department of Industrial Engineering, Twenty-First Century Professorship in Engineering, 2004, 2013.
Porter, Errol, M.S.E.E., B.S.E.E. (University of Arkansas), Research Associate, Microelectronics-Photonics, 1997, 1999.
Salamo, Gregory J., Ph.D. (City University of New York), M.S. (Indiana University-Purdue University-Indianapolis), B.S. (City University of New York, Brooklyn College), Distinguished Professor, Department of Physics, 1975, 2005.
Selvam, R. Panneer, Ph.D. (Texas Tech University), M.S.C.E. (South Dakota School of Mines and Technology), M.E., B.E. (University of Madras, India), University Professor, Department of Civil Engineering, James T. Womble Professor of Computational Mechanics and Nanotechnology Modeling, 1986, 2010.
Servoss, Shannon, Ph.D. (Northwestern University), B.S.Ch.E. (University of Michigan-Ann Arbor), Associate Professor, Ralph E. Martin Department of Chemical Engineering, 2007, 2014.
Singh, Surendra P., Ph.D., M.A. (University of Rochester), M.Sc., B.Sc. (Banaras Hindu University, India), University Professor, Department of Physics, 1982, 2016.
Stenken, Julie A., Ph.D. (University of Kansas), B.S. (University of Akron), Professor, Department of Chemistry and Biochemistry, 21st Century Chair of Proteomics, 2007.
Tian, Ryan, Ph.D. (University of Connecticut), B.S. (Fudan University, Shanghai), Associate Professor, Department of Chemistry and Biochemistry, 2004, 2010.
Tung, Steve, Ph.D., M.S.M.E. (University of Houston), B.S.M.E. (National Taiwan University), Professor, Department of Mechanical Engineering, 2000, 2013.

Walters, Keisha, Ph.D., M.S., B.S. (Clemson University), Professor, Ralph E. Martin Department of Chemical Engineering, 2021.
Wang, Feng, Ph.D. (University of Pittsburgh), Ph.D. (Kutztown University of Pennsylvania), B.S. (Peking University), Associate Professor, Department of Chemistry and Biochemistry, Charles E. and Clydene Scharlau Endowed Professor, 2012.
Wang, Yong, Ph.D., M.S. (University of California, Los Angeles), B.S. (University of Science and Technology of China), Assistant Professor, Department of Physics, 2016.
Ware, Morgan, Ph.D. (North Carolina State University), B.S. (Florida State University), Assistant Professor, Department of Electrical Engineering, 2005.
Wejinya, Uchechukwu C., Ph.D., M.S., B.S. (Michigan State University), Associate Professor, Department of Mechanical Engineering, Twenty-First Century Professor, 2008, 2014.
Wickramasinghe, Ranil, Ph.D. (University of Minnesota-Twin Cities), M.S., B.S. (University of Melbourne, Australia), Distinguished Professor, Ralph E. Martin Department of Chemical Engineering, Ross E. Martin Chair in Emerging Technologies, 2011, 2021.
Yu, Fisher, Ph.D. (Arizona State University), M.S., B.S. (Peking University), Associate Professor, Department of Electrical Engineering, 2008, 2014.
Zhou, Wenchao, Ph.D. (Georgia Institute of Technology), M.S.M.E. (Xi'an Jiaotong University, Xi'an, China), B.S.M.E. (Huazhong University of Science and Technology, Wuhan, China), Associate Professor, Department of Mechanical Engineering, 2014, 2020.
Zou, Min, Ph.D., M.S.M.E. (Georgia Institute of Technology), M.S.A.E., B.S.A.E. (Northwestern Polytechnical University), Professor, Department of Mechanical Engineering, Twenty-First Century Chair in Materials, Manufacturing and Integrated Systems, 2003, 2013.

Courses

MSEN 5253. Emerging Technologies in Industry. 3 Hours.
Business leaders present technologies used by their companies. Focusing on Arkansas-based companies, technology needs for the industry and innovative ideas for solutions or advancements are discussed. Students work to develop solutions to address company needs or further develop a company's current technology. (Typically offered: Fall and Spring) May be repeated for up to 9 hours of degree credit.

MSEN 5313. Fundamentals of Materials Science. 3 Hours.
Fundamentals of Materials Science provides an overview of materials science and engineering and is foundational for graduate study in the field. The structures of materials at the atomic scale, nanoscale, microscale, and macroscale are studied and the impact of this organization of matter on its physical and chemical properties are examined. Principles for measurement and characterization of material structure and properties are introduced. Emphasis is placed on materials important for use for electronic, photonic, energy, and biological applications. Advances in nanoscale materials as established fundamentals of macroscale structural materials are covered. Prerequisite: Graduate standing or consent of the instructor. (Typically offered: Fall)

MSEN 5322. Materials Characterization. 2 Hours.
Lecture and hands-on experience for using characterization tools to study the properties of materials. Techniques covered will include x-ray diffraction, x-ray photoelectron spectroscopy, scanning electron microscope, transmission electron microscope, and others. Use of these techniques for studies of material failure and reliability will also be examined. Corequisite: Lab component. Prerequisite: MSEN 5313 or instructor consent. (Typically offered: Fall)

MSEN 5383. Research Commercialization and Product Development. 3 Hours.
This survey course examines research commercialization through analysis of IP, technology space, market space, manufacturability, financials, and business plans. Entrepreneurial behaviors and product development within large companies are also discussed. A case study using a current UA faculty member's research commercialization effort will be developed. Prerequisite: Graduate Standing. (Typically offered: Spring)

MSEN 5393. Product Development Process. 3 Hours.
Demonstration of a student's technical and management knowledge integration by creating a commercially viable product development process to meet a new societal need, with the technical solution based on micro to nanoscale technology. Final grade based on a detailed written report and oral presentation to a panel. Non-thesis students only. Pre- or Corequisite: MSEN 5383. Prerequisite: Instructor permission. (Typically offered: Spring)

MSEN 5513. Applied Research in External Technical Organizations. 3 Hours.
A one semester narrow focus graduate level research effort while working at an external technical organization's site. Requires a final report of style and quality suitable for journal submission. This course available only to Professional Path M.S. MSEN students, and may substitute for an MSEN 588V External Internship. (Typically offered: Fall, Spring and Summer) May be repeated for up to 6 hours of degree credit.

MSEN 5523. Applied On-Campus Collaborative Research with External Technical Organizations. 3 Hours.
A one semester narrow focus graduate level on-campus research effort performed in collaboration with an external technical organization. Requires a final report of style and quality suitable for journal submission. This course available only to Professional Path M.S. MSEN students. Prerequisite: Instructor consent. (Typically offered: Fall, Spring and Summer) May be repeated for up to 6 hours of degree credit.

MSEN 555V. Internship in External Technical Organization. 1-3 Hour.
Used to document a MSEN grad student internship experience in an external technical organization for a minimum duration of six weeks (6-9 weeks=one hour, 10-12 weeks=two hours, and 13-15 weeks=three hours). It may not be used to meet the research requirements of a M.S. degree. Prerequisite: Graduate standing. (Typically offered: Fall, Spring and Summer)

MSEN 5611. Research Communication Seminar of MS Students. 1 Hour.
This course serves as a forum for MS students to develop oral presentation skills and to exchange research ideas. Research presentations will be on various topics in the area of micro to nanoscale materials, processing, and devices, with research management and planning also being addressed. Prerequisite: Graduate standing. (Typically offered: Fall and Spring)

MSEN 5713. Advanced Nanomaterials Chemistry. 3 Hours.
Science and engineering graduates are using more nanomaterials, and modern industry demands that its scientists and engineers have materials chemistry knowledge. Materials from the micro to nanoscale will be examined in this course from the perspective of fundamental chemistry principles to build a picture of tomorrow's materials. (Typically offered: Irregular) May be repeated for up to 3 hours of degree credit.

MSEN 5733L. Fabrication at the Nanoscale. 3 Hours.
This hands-on lab course will cover the disciplines needed to make active electronic and photonic devices utilizing nanoscale structures and fabrication techniques presently used in research and industry. Prerequisite: Graduate standing and permission of the instructor. (Typically offered: Spring)

MSEN 5811. 1st Year Operations Seminar - Infrastructure Management. 1 Hour.
Weekly seminar for 1st year Materials Science and Engineering graduate students to discuss issues that increase professional performance in technology-centered organizations. The discussions will focus on issues that affect organizational infrastructure, career planning, organizational structures, and may include examples from current events. Prerequisite: Graduate standing. (Typically offered: Fall)

MSEN 5821. Ethics for Scientists and Engineers. 1 Hour.
This course will introduce methods useful in the practice of ethical decision making in the high technology academic and industrial work place. An emphasis will be placed on applying the methods discussed in the text to student and instructor past professional experiences. Prerequisite: Graduate standing. (Typically offered: Summer)

MSEN 587V. Special Topics in Materials Science and Engineering. 1-4 Hour.
Consideration of current materials science and engineering topics not covered in other courses. One section will be created for each topic only after a syllabus is submitted to the MSEN office by the faculty member teaching the course. (Typically offered: Irregular) May be repeated for up to 9 hours of degree credit.

MSEN 588V. Special Problems in Materials Science and Engineering. 1-3 Hour.
Opportunity for individual study of advanced subjects related to a graduate degree in Materials Science and Engineering to suit individual requirements. One section will be created for each student only after a syllabus is submitted to the MSEN office by the supervising faculty member. (Typically offered: Irregular) May be repeated for up to 6 hours of degree credit.

MSEN 5911. 1st Year Operations Seminar - Personnel Management. 1 Hour.
Weekly seminar for 1st year Materials Science and Engineering graduate students to discuss issues that increase professional performance in technology-centered organizations. The discussions will focus on issues that affect personnel management, team building and structures, and may include examples from current events. Prerequisite: Graduate standing. (Typically offered: Spring)

MSEN 600V. Master's Thesis. 1-6 Hour.
Master's Thesis. Prerequisite: Graduate standing. (Typically offered: Fall, Spring and Summer) May be repeated for degree credit.

MSEN 626V. Emerging Technologies in Industry Practicum. 1-3 Hour.
Students engage in demand-driven research projects inspired by Arkansas companies as part of the interdisciplinary IGNITE (Industry Generating New Ideas and Technology through Education) program. These projects, which often result from interactions with companies during MSEN 5253, include visiting company locations; developing project goals, budgets, and timelines; and performing research. (Typically offered: Fall, Spring and Summer) May be repeated for up to 9 hours of degree credit.

MSEN 6313. Advanced Materials Science and Engineering. 3 Hours.
This course will introduce students to the core principles of the design, nature and processing of advanced materials and the mechanisms of failure of materials. The course also integrates materials behavior and materials processing relevant to a wide range of industrial sectors while it covers traditional structural materials, functional materials, nanomaterials and biomaterials. Students learn to achieve enhanced functionality through convergence and integration of biological, organic, electronic, and structural materials; self-assembly creation of new materials; and tailoring of interfaces to produce nanocomposites. In this way, it will provide students with a depth of core knowledge and skills allowing students to make informed choices concerning applications, selection and design of advanced materials. Prerequisite: MSEN 5313 and permission of the Instructor. (Typically offered: Spring)

MSEN 6323. Materials Engineering Design. 3 Hours.
This course will provide concrete training on the generation of a sound prototype design and R&D plan, in addition to the generation of a quality proposal based on specific federal solicitation criteria. Finally, each student will pick a topic/prototype for which they will prepare a full preliminary design, R&D plan and federal grant proposal from a list of real, suitable topics. The students will be required to follow the specific topic/solicitation instructions provided by the federal agency supporting the research. Prerequisite: Graduate standing or consent of the instructor. (Typically offered: Fall)

MSEN 6611. Research Communication Seminar of PhD Students. 1 Hour.
This course serves as a forum for Ph.D. students to develop oral presentation skills and to exchange research ideas. Research presentations will be on various topics in the area of materials, processing, and devices, with research management and planning also being addressed. Prerequisite: Graduate standing. (Typically offered: Fall and Spring)

MSEN 6811. 2nd Year Operations Seminar - Management and Leadership. 1 Hour.
Weekly seminar for 2nd year Materials Science and Engineering graduate students to discuss issues that increase professional performance in technology-centered organizations. The discussions will focus on issues that affect management and leadership effectiveness and efficiency, and may include examples from current events. Prerequisite: Graduate standing. (Typically offered: Fall)

MSEN 6911. 2nd Year Operations Seminar - Advanced Management and Leadership. 1 Hour.
Weekly seminar for 2nd year Materials Science and Engineering graduate students to discuss advanced issues that increase professional performance in technology-centered organizations. The discussions will focus on the complex issues that affect management and leadership effectiveness and efficiency, and may include examples from current events. Prerequisite: Graduate standing. (Typically offered: Spring)

MSEN 700V. Doctoral Dissertation. 1-21 Hour.
Doctoral dissertation. (Typically offered: Fall, Spring and Summer) May be repeated for degree credit.