MASTER OF SCIENCE IN ENGINEERING (MS-E)

STUDENT HANDBOOK

School of Engineering & Technology

CENTRAL
MICHIGAN UNIVERSITY

Updated: October 30, 2020

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1. INTRODUCTION

1.1 About CMU

Welcome to Central Michigan University, a nationally ranked institution that fosters the transformative power of advanced learning while embracing a sense of community among our students, faculty, staff, and more than 235,000 alumni around the world.

Established in 1892, CMU has more than 16,000 students on its Mount Pleasant campus and more than 8,000 enrolled online and at more than 30 locations across North America. Among just five percent of U.S. universities in the highest two Carnegie research classifications, CMU offers approximately 300 academic programs at the undergraduate, master's, specialist, and doctoral levels.

CMU is a university where students, faculty, staff, and alumni learn to pursue excellence, live with compassion, and be leaders.

Fire Up Chips!

1.2 About Engineering & Technology

The School of Engineering & Technology (SET) at CMU fosters a culture of learning, exploration, and service in a range of engineering and technological disciplines. Our faculty are committed to providing programs of professional study that offer you the requisite training and knowledge to become successful in your career or additional studies.

1.3 Points of Contact

For more information about the Master of Science in Engineering program at CMU, please contact:

School of Engineering & Technology
ET Building 100
Central Michigan University
Mount Pleasant, MI 48859
989-774-3033
etdept@cmich.edu
se.cmich.edu/et

College of Graduate Studies
251 Foust Hall
Central Michigan University
Mt. Pleasant, MI 48859
989-774-3873
grad.cmich.edu

Admissions Processing
802 Industrial Drive
Mt. Pleasant, MI 48859
989-774-4444
apply@cmich.edu

1.4 Faculty

The MS-E Program is advised by 19 faculty members, with the information listed below:

- Dr. Ahmed Abdelgawad - Associate Professor, 989-774-2455, abdel1a@cmich.edu, ET 130A. Research interests: Low Power Embedded Systems, Signal Processing, Wireless Sensor Networks, VLSI & FPGA Design.
- Dr. Frank Cheng – Professor, 989-774-7898, cheng1fs@cmich.edu, ET 248. Research interests: Robotics and Automation, Industrial Automation, Applied Electronics, Fluid Power Technology.
- Dr. Brian DeJong – Professor, 989-774-1319, dejon1b@cmich.edu, ET 242. Research interests: Robotics - Sound Location, Mobile Robots, Human-Robot Interaction, Teleoperation, Haptics.
- Dr. Goksel Demirer – Professor, 989-774-2456, demir1g@cmich.edu, ET 236. Research interests: Anaerobic Environmental Biotechnology, Wastewater Engineering, Waste Valorization, Resource Efficiency, Sustainability, Pollution Prevention, Industrial Ecology.
- Dr. Waseem Haider – Associate Professor, 989-774-1125, haide1w@cmich.edu, BS 4110. Research interests: Additive Manufacturing, Titanium Oxide Nanoparticles/Nanotubes, Thin Films, Graphene-Based Nanocomposites, Piezoelectric Materials, Biomaterials, Surface Engineering, Photocatalysis, Electrochemistry.
- Dr. Yousef Haseli – Assistant Professor, 989-774-1779, hasel1y@cmich.edu, ET 141. Research interests: Advanced Energy Systems, Thermodynamics, Clean Energy/Fuel Production.
- Dr. Chanseok Jeong – Assistant Professor, 989-774-7683, jeong1c@cmich.edu, ET 133. Research Interests: Inverse Problems in Science and Engineering, Computational Mechanics, and Structural Dynamics and Wave Propagation Analysis.
- Dr. Ernur Karadogan – Associate Professor, 989-774-4053, karad1e@cmich.edu, ET 107. Research interests: Robotics, Haptics, Dynamic Systems & Control, Simulations in Virtual Environments, Biomechanics, Medical Education, Undergrad. Engineering Education.
- Dr. Joseph Langenderfer – Professor, 989-774-1911, lange1je@cmich.edu, ET 244. Research interests: Computational Modeling of Muscle and Joint Loads, Stochastic Biomechanics Modeling, In-Vivo, and in-Vitro Experimental Biomechanics.
- Dr. Terence Lerch – Professor, 989-774-7478, lerch1t@cmich.edu, ET 240. Research interests: Thermodynamics, Thermal Fluids, Fluid Mechanics, Statics.
- Dr. Itzel Marquez – Assistant Professor, 989-774-3657, itzel1l@cmich.edu, ET 232. Research interests: Contaminants of Emerging Concern, Wastewater reuse, Indirect and Direct Potable Reuse, Kinetic and transport mathematical modeling, Natural attenuation of contaminants in water.
- Dr. Adam Mock – Professor, 989-774-7702, mock1ap@cmich.edu, ET 130C. Research interests: Theoretical and Computational Electromagnetics, Micro and Nano-Scale Photonics, Parallel Computing.
- Dr. James Morrison – Professor, 989-774-3790, morri1j@cmich.edu, ET 130F. Research interests: Semiconductor manufacturing & Industry 4.0, Automation for smart production systems, Stochastic modeling & AI for decision making, Task allocation and design for systems of UAVs, Planning for systems of robots, Design for education and the environment.

- Dr. Ishraq Shabib – Associate Professor, 989-774-3692, shabi1i@cmich.edu, ET 254. Research interests: Deformation Behavior and Properties of Nanocrystalline Materials, Irradiation Induced Damage of Structural Materials, Atomistic and Multi-Scale Modeling of Crystal Defects.
- Dr. Donghyun Shin – Assistant Professor, 989-774-2138, shin1d@cmich.edu, ET 234. Research interests: Nanoscale Heat Storage and Transfer, Nanomaterial Design & Manufacturing, Thermal Energy Storage, Concentrated Solar Power.
- Dr. Maggie Williams – Assistant Professor, 989-774-7532, willi32m@cmich.edu, ET 137. Research interests: Molecular microbial ecology and environmental microbiology, Antimicrobial resistance tracking, Rate enhancement in biodegradation of toxicants, Communication of microbial communities, and their host or environment, High-throughput functional genomics tools development.
- Dr. Roderick Lammers – Assistant Professor, 989-774-3814, lamme1r@cmich.edu, ET 147. Research interests: Stormwater management; Stream restoration; Nitrogen and phosphorus pollution; Flood management; Natural infrastructure

2. MS-E PROGRAM

2.1 Program Objectives

The mission of the MS-E program at CMU is

- To prepare engineering students for industry or higher education, and advance the research and scholarly portfolio of the School of Engineering and Technology (SET).
- To institute advanced learning and teaching through fostering opportunities for CMU constituents to pursue graduate study in the interdisciplinary areas of Engineering.

The program is intended to enhance students' knowledge, research skills, critical thinking abilities, and communication skills. The expected student learning outcomes include advanced knowledge, analyze and solve engineering problems, advanced communication skills, research ethics in engineering, and designing/conducting engineering research experiments.

2.2 Prospective Students

Prospective students should apply through the CMU College of Graduate Studies (CGS) for the MS-E program. To apply, visit apply.cmich.edu. Applications are sent from the CGS to the graduate program coordinator and the school director for review. **March 1/Oct 1** is the deadline to submit the application for Fall/Spring, but rolling admission will continue.

2.3 Admission Requirements

To be considered for admission to the MS-E program, students must meet the following criteria:

- Students must have completed an undergraduate ABET-accredited engineering degree.
- Undergraduate cumulative GPA ≥ 3.3 (conditional admission GPA 3.0 - 3.3)
- 720/156+ GRE quantitative for minimum admission
- 563/223/84+ TOEFL & IELTS 6.5+ for international students
- *Three* strong reference letters
- Applicant statement of purpose

Students who have degrees from a non-ABET accredited school, or have an undergraduate degree in a different discipline, must show an average GPA of 3.3 in the following classes (or equivalent) to be admitted to the MS-E program:

- Science (13 credit hours)
- CHM 131, PHY 145, PHY 146, PHY 175
- Math (11 credit hours)
- MTH 132, MTH 133, MTH 232
- Engineering (15 credit hours)
- EGR 251, EGR 253, EGR 255, EGR 356, and EGR 358; or EGR 190, EGR 290, EGR 298, EGR 391, and EGR 396

If needed, you may be required to pass an entrance exam to show competency in the above subjects.

Additional Information

- Students who have an undergraduate engineering technology degree/background and wish to apply to the MS-E program must have completed Calculus III with a grade of C- or better.
- Students already having a Master's degree in engineering or a related field from any institution have the same admission criteria as other applicants.
- Students having a Ph.D. in Science of Advanced Materials (SAM) will not be considered for enrollment in the MS-E program.

2.4 International Student Admissions

Step One:

- Apply Online as an International student pursuing a graduate degree.
- Pay the $50 application fee online.

Step Two:

Applicants must provide official copies of **transcripts/individual mark sheets/diplomas** mailed in a sealed envelope for the school(s) you attended or have the schools send them directly to CMU at the address below or to transcripts@cmich.edu. Documents are required in the native language and a certified English translation is required. Copies uploaded to your application will not be accepted.

Mailing Address (transcripts, exam results, etc.):

Central Michigan University

Attn: International Applications Processing

802 Industrial Drive, Global North

Mount Pleasant, MI 48858 USA

Step Three:

Include all of the following required documents with your application:

- Standardized test scores (GRE, GMAT, MAT)
- TOEFL & IELTS scores (International Students Only)
- Three (3) Letters of recommendation
- Statement of Purpose

Step Four:

Once your application is complete it will be evaluated for acceptance. The most common mistake students make is submitting an incomplete application. Please be sure to verify your application is complete. You may do this by using the Track My App function in your online application or by emailing apply@cmich.edu or intlrecruit@cmich.edu. You will receive your admissions status notification electronically to the email you used in your online application.

Step Five:

- » Once you are admitted to the graduate program, the Office of Global Engagement (OGE) International Student and Scholar Services (ISSS) will contact you directly regarding immigration documents.
- » You will submit your financial documents (bank statements), financial support form (provided by ISSS), copy of passport or any other documents needed to the OGE ISSS. Note: scanned and emailed copies are acceptable. If the students are receiving funding, then they are not required to do this. Their funding offer letter will serve the purpose.
- » Once all required documents are received, the OGE ISSS will email you requesting payment to ship your welcome packet.

Step Six:

The OGE ISSS will mail your welcome packet once you have made the shipping payment. The packet will include admissions letter, I-20/DS-2019, and arrival information.

Admissions questions? Please contact: 989-774-4723 or apply@cmich.edu
Immigration/I-20/DS-2019 or visa questions? Please contact: 989-774-4308 or oiainfo@cmich.edu

Step Seven:

- » Report your arrival to SET main office located at ET 100.
- » Report to Faculty Personnel Services located at 308 Warriner Hall.
- » Obtain your Central ID card from 209 Bovee University Center
- » Apply for social security number (SSN) at 1940 Sweeney St, Mt Pleasant, MI 48858

2.5 English Proficiency

TOEFL, IELTS, MELAB, Pearson Test. See our English Language Standards.

Test scores can be sent using CMU's institution code: 1106

**** To view a list of English Language Proficiency Testing, Exempt Countries please click HERE.*

- » Test of English as a Foreign Language (TOEFL): 563/223/84+ is required for regular admission
- » International English Language Testing System (IELTS) Academic Module: A score of 6.5+ is required for regular admission.
- » ELI (CMU English Language Program): Successful ELI completion and confirmation by the ELI Office for regular admission.
- » Completion of courses that meet CMU's requirements for Oral English (i.e. COM 101) and Writing competency (i.e. ENGL 101/103 and ENGL 201).

Test scores are valid for two (2) years from the test date. When tests provide "best scores" in specific areas, CMU will use the composite score generated by using the highest from each solution.

3. DEGREE REQUIREMENTS

Within the MS-E Program at CMU, students have the option to pursue one of the two tracks for obtaining their degree. There is the *Thesis Plan* or the *Course Based Plan.* Specific requirements for each of these options can be found below.

3.1 Academic Advising

MS in Engineering majors is required to meet with their engineering advisor each semester to ensure students select appropriate courses to facilitate their progress through the program. Registration is not allowed until after this meeting. Prerequisites are strictly enforced for all engineering classes.

3.2 Thesis Plan

30 credit hours are required, which includes 24 hours of course work, 6 hours of thesis, and a successfully defended MS thesis.

By the end of the first semester, students will have to choose their thesis advisor and work with them to develop a plan addressing how the MS degree requirements will be met. The plan should be submitted to the graduate coordinator for review by the end of the first semester.

Coursework

1. **Required Courses I (6 hours)**
   EGR 600 - Advanced Engineering Analysis 3(3-0)
   EGR 601 - Advanced Engineering Experimentation 3(2-2)

2. **Required Courses II (3 hours)**
   EGR 685 - Seminar: Current Topics in Engineering 1-3(Spec)
   Note: must be taken three (3) times.

3. **Required Courses III (6-15 Hours)****
   Select 6-15 credit hours in consultation with the student's advisor and advisory committee.
   EGR 553 - Mechanical Vibrations 3(3-0)
   EGR 554 - Mechanical Controls 3(3-0)
   EGR 555 - Engineering Acoustics 3(3-0)
   EGR 576 - Mechanics of Composite Materials 3(3-0)
   EGR 578 - Advanced Mechanics of Materials 3(3-0)
   EGR 580: Fundamentals of Internet of Things 3(3-0)

EGR 585: Wireless Sensor Networks 3 (3-0)
EGR 588 - Photonics 3(3-0)
EGR 591 - CMOS Circuit Design 3(2-2)
EGR 594 - Power Electronics 3(3-0)
EGR 595 - Nanoscale Transistors 3(3-0)
EGR 597 - Special Topics in Engineering 1-6(Spec)
EGR 637 - Directed Research in Engineering 1-6(Spec)
EGR 697 - Special Topics in Engineering 1-6(Spec)
EGR 791 - Independent Research in Engineering 1-6(Spec)

4. **Elective Courses (0-9 hours)** ** *Graduate courses approved by the advisor and school director.*

5. **Thesis (6 hours)*****
   EGR 798 - Thesis Research 1-6(Spec)

** 1-6 credits EGR637 and any extra credits in EGR637 may be counted as elective.
Students may take EGR791 following 6 credits of EGR637.

****Students can only register for 3 hours of Thesis credit before their Prospectus has been received and approved by the committee chair and members, the department chairperson, AND by the Director of Graduate Studies*.

The prospectus must be completed by the end of second semester.

3.2.1 Thesis Committee

Three faculty members, one of which being the student's thesis advisor and serving as the chair, will form the thesis committee who will assess the thesis. It is the responsibility of the student to select the committee members in consultation with the thesis advisor. The thesis advisor must be a graduate faculty member from SET. These can be found listed within this document.

The candidate will receive a grade (credit or no credit) in EGR 798 only after satisfactory completion of the entire six hours and after the acceptance of the thesis by the committee. A "Z" grade will be recorded in EGR 798 until the final grade is assigned.

3.3 Course based Plan

30 credit hours are required, including 18-27 credit hours of required courses along with 3-12 credit hours of electives that focus on independent study and/or research projects.

Coursework

1. **Required Courses I (6 hours)**
   EGR 600 - Advanced Engineering Analysis 3(3-0)
   EGR 601 - Advanced Engineering Experimentation 3(2-2)

2. **Required Courses II (3 hours)**
   EGR 685 - Seminar: Current Topics in Engineering 1-3(Spec)
   Note: must be taken three (3) times.

3. **Required Courses III (9-18 hours)**
   Select 9-18 credit hours in consultation with the student's advisor and advisory committee.
   EGR 553 - Mechanical Vibrations 3(3-0)
   EGR 554 - Mechanical Controls 3(3-0)

EGR 555 - Engineering Acoustics 3(3-0)
EGR 576 - Mechanics of Composite Materials 3(3-0)
EGR 578 - Advanced Mechanics of Materials 3(3-0)
EGR 580: Fundamentals of Internet of Things 3(3-0)
EGR 585: Wireless Sensor Networks 3 (3-0)
EGR 588 - Photonics 3(3-0)
EGR 591 - CMOS Circuit Design 3(2-2)
EGR 594 - Power Electronics 3(3-0)
EGR 595 - Nanoscale Transistors 3(3-0)
EGR 597 - Special Topics in Engineering 1-6(Spec)
EGR 637 - Directed Research in Engineering 1-6(Spec)
EGR 697 - Special Topics in Engineering 1-6(Spec)
EGR 791 - Independent Research in Engineering 1-6(Spec)

4. **Electives (3-12 hours)** *Graduate courses approved by the advisor and school director*.
   Students can take courses from other departments and colleges. Students must submit an approved Plan B paper demonstrating either research, project, independent study, or internship (3-6 hours).

3.4 Accelerated MS in Engineering

Up to 9 credit hours may be double-counted from appropriate courses in undergraduate degree for an accelerated MS in Engineering Program at CMU. Contact the Office of Graduate Studies for more information regarding admission for accelerated programs.

The Accelerated Master's Degree Programs (AMDP) is intended for a) CMU undergraduate students who possess a strong academic background; b) are maintaining a "B" average in their undergraduate coursework; c) are generally going into their senior year; d) plan to complete their graduate degree at CMU. The program allows specific graduate-level courses that, upon successful completion and graduation, will apply to the student's graduate record at CMU.

3.5 Retention & Termination Standards

To remain in the MS-E program, a student must meet the following criteria:

- Students must select courses in consultation with an engineering advisor.
- Students may not take courses required for this degree Credit/No Credit (*except EGR 798*).
- At least 24 credits must be taken at CMU to graduate with this degree.
- If a student does not continue to meet the retention standards, s/he may be asked to withdraw. *The school maintains the right to terminate a student if s/he is not progressing satisfactorily.*
- Students who do not meet degree requirements by the end of the 4th year will be terminated.

3.6 Transfer credits

The MS-E committee will consider transferring graduate credits from other institutions. If considered, the transfer must be decided upon before admission and stated in the offer letter.

4. GRADUATION

4.1 Deadlines

Students should submit a graduation application by the semester before their anticipated graduation date. Graduation Applications must be submitted via *Degree Progress* on CentralLink. Degrees are conferred six times each year in March, May, June, August, October, and December. Applications should be submitted based on the following timeline, however late applicants may be able to graduate.

October 1st for spring graduation
February 1st for summer graduation
April 1st for fall graduation

**Students must apply for graduation, even if they will not participate in commencement ceremonies. Applying for graduation generates an audit of the student's academic file and notifies the university that the student intends to graduate.*

Note to Graduate Degree Applicants
At the time of filing the graduation application, it is the responsibility of the student to determine whether his/her advisor will be available to approve the thesis or any other papers necessary for graduation. For updated deadline information, visit the College of Graduate Studies website.

4.2 I-20 Extension

International students that do not graduate in two years (finishing up thesis) must contact the Office of Global Engagement at 989-774-4308 or oiainfo@cmich.edu to get their I-20's extended.

4.3 Required Submissions

Prospectus – Theses, Dissertations, and Journal Article(s)

- Students may not enroll for more than three thesis credits and work on the project may not begin until the project has been approved by the appropriate research review board (if applicable) AND the Prospectus has been approved by the committee chair and members, the department chairperson, AND by the Director of Graduate Studies.
- A two-page, double-spaced synopsis of the project
- Approval memo/letter/email from the appropriate review board (if applicable)
- Submit all of the above items to the **SET office** for School Director approval then the appropriate forms will be sent to CGS for final approval.

For theses/dissertations/journal article(s) to meet the Graduate Studies submission deadline, the following document must electronically accompany the student's final document:

Dissertation/Journal Article(s) Completion Sign-Off Form OR Plan A Completion Sign-Off form.

- Once the student has successfully completed the oral defense of his/her project, this form is signed by the student's committee and the department chairperson.
- Submit all of the above items to the **SET office** for School Director approval then the appropriate forms will be sent to CGS for final approval.

Allow 14 business days for the initial document review by Graduate Studies.

Updated Thesis/Dissertation/Journal Article Information including templates, can be found on the CGS website.

5. FINANCIAL SUPPORT

5.1 Graduate Teaching Assistants (TAs)

TA selection will also follow the same process as the student selection, outlined in section 2.3. However, a maximum of **one TA** will be assigned to a research advisor at a given time. TA support will be given for a 9-month period during each academic year. The workload is twenty hours per week for a full-time Graduate Teaching Assistant. Tuition remission of up to a total of twenty (20) hours of graduate study per academic year (Fall, Spring, and Summer terms).

Full-time enrollment with no financial support is 9 credit hours per semester. Full-time enrollment with financial support is 6 credit hours per semester.

Any summer support will be on a case-by-case basis and will be determined by the advisor, school director, and the student.

5.2 Graduate Research Assistants (RAs)

Graduate Research Assistants are assigned to faculty to conduct research projects to the faculty's expertise. The workload is twenty hours per week for a full-time Graduate Research Assistant. Tuition remission of up to twenty (20) hours of graduate study per academic year (Fall, Spring, and Summer terms).

Research Assistant positions will be handled on a separate case-by-case basis by faculty recommendation and are subject to funding & grant availability.

5.3 Graduate Student Grants

The school, college, and Office of Research and Graduate Studies (ORGS) provides several grants to support research and travel to attend a conference.

- ORGS GA Conference Grant. $200.
    - Must apply before the conference. For TAs only
- ORGS Presentation Grant: $100.
    - Matching fund needed
- ORGS Research and Creative Endeavors Grant: $800
- CSE Student Meeting Grant: $350 for Research Presentation. $100 for Conference attendance
- SET conference travel/supply grant: twice during the program. Amount depends on the availability of the fund.

5.4 Other Hourly Employment

Working on campus is another way to earn funds to support your studies at CMU. International students who are not receiving any form of financial support are permitted to work on campus up to 20 hours per week during the fall and spring semesters, and 40 hours per week during the breaks.

Domestic Student employees may work a maximum of 40 hours per week during the Summer Semester. *(Effective Aug. 25, 2019).*

Specific information for International Student On-Campus employment can be found on the Office of Global Engagement website.

Available on-campus job opportunities can be found on the Student Employment Services Website at ses.cmich.edu

5.5 Tuition Waiver

Students should complete their tuition waiver form as soon as possible once they have registered for courses and the courses show up on the CMU billing to avoid late payment fees.

Students apply for the tuition waiver online-thru Central link. However, make sure that your application states "Graduate Students", as there is a difference between the application for Graduate Students and Faculty/Staff.

6. FREQUENTLY ASKED QUESTIONS

» *Where can I find the graduate bulletin?*

The Graduate bulletin can be found on the CMU website under "*My Account*" on *CentralLink*

» *I am an international student and have not applied to CMU and I have questions, whom should I contact?*

Graduate International Admissions at 989-774-1619 or intlrecruit@cmich.edu

» *I have already applied to CMU and I have questions, whom should I contact?*

Admissions at 989-774-3076 or apply@cmich.edu

» *Where can I find the forms I need?*

All forms can be found on the Graduate Studies website or in the appendix of this document.

» *Can I take a tour of campus virtually?*

Yes! Visit tour.cmich.edu to view our campus and explore your Life at Central.

» *How can I pay my application fee?*

Your application fee can be paid online via credit card, check or money order.

» *What calendar does CMU follow?* For more information, visit our academic calendar.

- Fall semester (August-December)
- Spring semester (January-May)
- First Summer semester (May-June, optional six-week session)
- Second Summer semester (June-August, optional six-week session)

7. IMPORTANT FORMS & DOCUMENTS

Many of the necessary forms can be found here on the CGS website at grad.cmich.edu

Course Registration Deadlines

Course Substitution Request

Dissertation/Doctoral Project/Journal Article Sign Off Approval

Example Thesis/Dissertation Template

Graduate Assistant Training

Graduate Bulletin

Graduation Deadlines

Graduate Program Plan Authorization

Graduate Student Orientation

Plan A (Thesis/Journal Article) Completion Approval Form

Plan B (Research/Projects) Completion Approval Form

Prospectus

FOR FACULTY & STAFF

Student, Advisor, & Front Office Responsibilities

STUDENT	ADVISOR	ET OFFICE
Take care of all holds on account. Be in contact with the advisor on course selection and complete the Program Plan. And submit advising form and EGR 637 form (if applicable- **COMPLETED**)	Have communication with the student after agreeing to be their advisor that will help them determine what their 3rd class should be and complete the program plan. If the 3rd course is EGR 637, the advisor will make sure that the form is **COMPLETED** and it is turned in for registration.	Send email welcoming them to CMU, advising them of any holds on their account, asking them to have their advisor let them know what courses should be taken. First-semester students typically should take EGR 601 (Fall) or EGR 600 (Spring), EGR 685 (1 credit), and 3 credits of EGR 637 or a 3 credit course that will assist them in their research. (Advisor is copied in on the email.) This email instructs students to complete their tuition waiver form once registration has been completed.
Complete tuition waiver (on Central Link)		Enter Program Plan into Degree Progress

MSE Grad Advising Guidelines:

- Program Plan should be signed before the end of the first semester.
- The prospectus should be signed before the end of the second semester.
  - Graduate Students are the ***first students allowed to register***. They should ***not wait until just before classes start to register*** unless they just got here.
- The student must be registered for a minimum of 6 credit hours for Fall and Spring semesters to retain their GA status.
- All forms should be turned into the Front Office.

Sent 12-6-19 (CoRK) COPY

CMU CENTRAL MICHIGAN UNIVERSITY | Office of Research & Graduate Studies

PROSPECTUS

Theses, Doctoral Projects, Dissertations, and Journal Articles

The *Prospectus* is not approved until **ALL** signatures have been obtained.

ALL PROSPECTUS AND SUPPORTING DOCUMENTS MUST BE SUBMITTED ELECTRONICALLY as ONE PDF FILE TO CGSTHESIS@CMICH.EDU. Hard copies are no longer accepted.

Before beginning the project and enrolling for more than three thesis/dissertation credits, a *Prospectus* must receive approval from the appropriate review board (if applicable), the student's committee, and the Vice Provost of Research & Graduate Studies. Projects may be denied and deemed invalid that are undertaken prior to receiving approval from all three. Completed theses/doctoral projects/ dissertations/journal articles are not reviewed by the Office of Research & Graduate Studies until the *Prospectus* has been approved.

Name: ______ **ID #:** ______

Email Address: @cmich.edu **Expected Graduation Date:** ■ May ☐ August ☐ December **Year:** 2020

Type of Document: ☐ Traditional Thesis ☐ Doctoral Project ☐ Traditional Dissertation

☑ Journal Article(s) in place of a Traditional Thesis

☐ Journal Article(s) in place of a Traditional Dissertation

This project is being proposed to fulfill the thesis/dissertation requirement for the following degree and department:

☐ MA ☐ MM ■ MS ☐ MBA ☐ MPA ☐ MSA ☐ EdS ☐ SPsyS ☐ DET ☐ DHA ☐ PhD ☐ AuD ☐ EdD

Department: School of Engineering and Technology

Project Title: Integration and Performance Evaluation of Blockchain technology in IoT enabled Pharmaceutical Delivery System

Research involving the groups listed below require approval from the appropriate committee:

- Human Subjects: Institutional Review Board (IRB)
- Animals: Institutional Animal Care & Use Committee (IACUC)
- Recombinant DNA: Institutional Biosafety Committee (IBC) approval

■ Research did not involve human subjects, animals, or recombinant DNA

Human Subjects	Animals	Recombinant DNA
☐ Yes (attach copy of IRB approval)	☐ Yes (attach copy of IACUC approval)	☐ Yes (attach copy of IBC approval)

Synopsis: A brief (no more than two pages, double-spaced) project description. Synopses longer than this will not be reviewed.

Required Signatures				CGS ONLY (Grad Faculty Status)
Committee Chair	Signature	Kumar Yelamarthi Print Name	Date	Exp. Month/Year
Faculty Member	Signature	Print Name	Date	Exp. Month/Year
Faculty Member	Signature	Print Name	Date	Exp. Month/Year
Faculty Member	Signature	Print Name	Date	Exp. Month/Year
Department Chair	Signature	Print Name	Date	
ORGS	Signature	Print Name	Date	

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Internet of Things (IoT) is a network of interconnected devices that collect various sensitive information depending on the application, and exchange data between other objects and cloud for precise decision, enabling intelligent operation of services. The permeating quality of IoT is a consequence of low power and resource-constrained design of smart objects which is a major cause for security vulnerabilities in IoT systems as traditional means of enforcing security is infeasible. Many research efforts are focused on using blockchain technologies inherent qualities to improve the security and privacy in IoT applications as blockchain's inherent qualities like immutability, irreversibility, and decentralization are desirable in many IoT applications [1]. Blockchain is a distributed ledger system where blocks contain immutable transaction history, stored locally on every machine/node in the network. Blocks are verified by miner nodes through a consensus algorithm and, after verification, the new block is added to the local chain of every node in the network [2]. Established methods of reaching consensus throughout the network are Proof of Work (PoW), Proof of Stakes (PoS), and Proof of Activity (PoA) [1]. As this phase requires significant resources and time, the challenge of implementing blockchain in IoT applications lies in optimizing consensus algorithm. Puthal et al. proposed a lightweight consensus algorithm called Proof-of-Authentication (PoAh) that utilizes the media access control (MAC) address of each node in the network for reaching consensus. The trusted nodes, analogous to miner nodes, are elected dynamically and verify the transactions based on the authenticated device addresses [3]. An optimized consensus algorithm can reduce the latency and energy consumption for each transaction. As of now, there is no empirical data demonstrating the efficacy of PoAh in an IoT environment and therefore, this work implemented PoAh and obtained promising empirical data.

Initial testing was done to assess the feasibility of Blockchain in IoT environment. The nodes (N) in the blockchain network are classified into three entities: Sensor-nodes (S), Aggregator-nodes (A), and Trusted-nodes (T). Each node consists of one A/T-node and k number of S-nodes (S_1, S_2, . . . , S_k). T-nodes are not connected to S-nodes in Fig. 1 for legibility. S-nodes collect environmental data and send them to A/T-node via low power wireless technology. Each S-node has a MAC address and each A/T-node has a list of authenticated S-nodes. Upon receiving the data from an S-node, A/T-nodes validate the address to ensure that the data is coming from authenticated S-nodes. A/T-node has a locally stored blockchain, which it updates independently. After receiving a specific amount of data from S nodes, the A-node creates a block consisting of the data, corresponding timestamps, and its own MAC address and sends it throughout the network. The T-nodes have the list of MAC addresses of the A-nodes, and after receiving a new block request, T-node adds the block to its chain or rejects it depending on the address list. A-nodes update their local chain accordingly.

The main challenge of employing blockchain in IoT is the computationally expensive operations involved in the consensus algorithm. The lightweight PoAh is targeted towards resource-constrained IoT edge nodes in a private network, and the major impact of this algorithm is the low latency and energy consumption. The latency and energy were measured during block validation which is from the instance the T-node received a block from A-node to when the block was added in the local chain. Furthermore, block addition latency and energy were measured, which is from the instance A-node compiled the data it received from S-nodes into a block to when A-node added the block to its local chain. The instance when an unverified block was received by the T-node and the instance when the block was added to the local chain were timestamped. Current and voltage were measured during this operation to obtain power and energy consumed during block validation.

Blockchain technology has the potential to aid privacy and security in IoT applications. However, the computationally complex and energy-demanding consensus algorithm is unsuitable for IoT edge nodes that do not have the required memory, computation capability, and energy at its disposal. Lightweight consensus algorithm PoAh has shown immense promise in making blockchain technology to be used in IoT paradigm. The significant reduction in latency enables many time-critical services and applications. In a conventional PoW consensus algorithm, the blocks are generated in 10 minutes whereas PoAh can reduce the latency down to milliseconds. As both the T nodes and A nodes are relatively low power devices, the energy consumed is reduced to tens of milli-joules, all the while providing local chain storage at the network edges to maintain the decentralized nature of blockchain. As the latency and energy in achieving consensus throughout the network are greatly reduced, the inherent qualities of blockchain strengthen the security in IoT networks and increase transparency in many services and applications. The decentralized nature of both IoT and blockchain draws many researchers to investigate the feasibility and efficacy of blockchain-based IoT services and applications. After validating the significant improvement of PoAh in terms of latency and energy consumption, the focus shifts to an optimized IoT architecture from a blockchain perspective and implementing an application where security and transparency are desired. Pharmaceutical delivery and storage system would greatly benefit from the security, immutability, and transparency brought in by blockchain technology which can improve trust, reduce operation costs and eliminate involvement of a third party for notoriety. Hence, implementing the PoAh for decentralized storage across authorities as well as pharmacies, hospitals and evaluating the feasibility is the next step towards solidifying the usage of blockchain in IoT applications.

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[1] T. M. Fernandez-Caram ´ es and P. Fraga-Lamas, "A review on the use of blockchain for the internet of things," IEEE Access, vol. 6, pp. 32 979–33 001, 2018.

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[3] D. Puthal and S. P. Mohanty, "Proof of authentication: IoT-friendly blockchains," IEEE Potentials, vol. 38, no. 1, pp. 26–29, Jan 2019.

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ENGINEERING & TECHNOLOGY INDEPENDENT STUDY FORM

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IET ☐ EGR ☑ 637

3
Credit Hours

Fall ☐ Spring ☑ Summer I ☐ Summer II ☐ 2019
Year

Campus ID Number

Student Name

E-Mail Address @cmich.edu

Local Address

Telephone

Application of ML at Edge Devices
Proposed Title

The attached proposal should summarize the following:

1. Statement of the problem or area to be studied
2. Statement of the sub-problems and limits of the study
3. Rationale for the study
4. Tentative procedure to be used in the study
5. Sources of information and resources
6. Conclusion outcomes of the study (evaluation instrument, plans for publication, teaching aids developed, prototype, etc.)
7. Statement of criteria for (a) successful completion; and, (b) quality of the study, to be determined with the project advisor

05/10/19
Completion Date

1) ________ 2) ________ 3) ____
Conference Dates with Project Advisor

Culminating activity will be: ☑ Written Report ☐ Written Exam ☐ Prototype ☐ Other ________

ACCEPTED:

[redacted]
Student Signature

Printed Name

04/24/19
Date

~~Academic~~ Project Advisor Signature

Printed Name

[redacted]
Date

~~Project~~ Academic Advisor Signature

Printed Name

Date

Copies to: Student
Academic Advisor
Project Advisor

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Internet of Things is a wireless network where sensors and actuators are connected by some wireless communication link to a central server. The "Thing" in IoT can be anything from toasters, thermostats, smart energy efficient houses, wearable electronics, and assistive technologies for the disabled and the elderly, medical & healthcare equipment, automotive applications such as V2V communication, SHM, environmental monitoring, agriculture, industrial automation, access control systems and so on. In a broad sense the "Thing" can be any physical object connected to a wide network to collect and exchange data. Everything around us is collecting data, analyzing it in some way and acting upon the reached conclusion based on those data. IoT enabled devices help us make better, more accurate data which interpreted appropriately, cuts down on waste and improves efficiency. This opens up a lot of possibilities for improving how we consume and utilize resources.

Machine learning is a new paradigm in computing and is rapidly making its way in to IoT. It gives computers a new way to carry out complicated tasks without being explicitly programmed by humans. Machine learning is helping us make more accurate decisions based on streaming data collected by IoT devices. As IoT enabled devices gather more data, machine learning algorithms take advantage of the abundance of real life data to make more accurate models to deal with problems. Models in machine learning are developed based on examples and experience. As IoT devices and wireless sensor platform constantly acquire information about the environment, the volume of data is inevitably very large. Transmitting such amount of data wirelessly consumes enormous amount of energy and in some cases the sensor platforms are in such remote places that network strength is not powerful or reliable enough to provide such facilities.

Our goal is to use machine learning techniques to analyze the acquired data before the data is sent out so that some preliminary analysis is already done on the edge devices and the size of the data to be transmitted is somewhat reduced. The current literature is evidence enough to support that employing machine learning to diverse applications has improved the performance by a significant margin but ML algorithms requires vast computation resources which most edge node devices lack. Therefore, our challenge is to implement such ML technique so that the amount of data to be transmitted is curtailed and the algorithm can run on resource-constraint hardware without affecting the primary purpose of the node. The use of machine learning is as ubiquitous as the applications of IoT and together these technologies have the potential to vastly improve our lives, reduce waste and maintain proper utilization of resources.

Deliverables:

Conference/Journal Paper describing the findings.

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ENGINEERING & TECHNOLOGY INDEPENDENT STUDY FORM

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CRN ______ IET ☐ EGR ☑ 791 ______ Credit Hours 3

Fall ☐ Spring ☑ Summer I ☐ Summer II ☐ Year 2020 ______ Campus ID Number ______

Student Name ______ E-Mail Address @cmich.edu

Local Address ______ Telephone ______

Proposed Title: Lightweight PoAh Consensus Algorithm Evaluation

The attached proposal should summarize the following:

1. Statement of the problem or area to be studied
2. Statement of the sub-problems and limits of the study
3. Rationale for the study
4. Tentative procedure to be used in the study
5. Sources of information and resources
6. Conclusion outcomes of the study (evaluation instrument, plans for publication, teaching aids developed, prototype, etc.)
7. Statement of criteria for (a) successful completion; and, (b) quality of the study, to be determined with the project advisor

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Completion Date: May 20

Conference Dates with Project Advisor: 1) ______ 2) Bi-weekly 3) ______

Culminating activity will be: ☐ Written Report ☐ Written Exam ☐ Prototype ☐ Other ______

ACCEPTED:

Student Name ______	Printed Name ______	Date ______
Academic Advisor Signature ______	Printed Name: Kumar Yelamarthi	Date ______
Project Advisor Signature ______	Printed Name: Kumar Yelamarthi	Date ______

Copies to: Student
Academic Advisor
Project Advisor

Internet of Things is a wireless network where sensors and actuators are connected by some wireless communication link to a central server or to each other. The "Thing" in IoT can be anything from toasters, thermostats, smart energy efficient houses, wearable electronics, and assistive technologies for the disabled and the elderly, medical & healthcare equipment, automotive applications such as V2V communication, SHM, environmental monitoring, agriculture, industrial automation, access control systems, to name a few [1] – [3]. In a broad sense, the "Thing" can be any physical object connected to a wide network to collect, exchange data and process generated data [4], [5]. As the system collects and exchanges sensitive, private data; ensuring security across all levels of the architecture is essential yet most IoT devices have significant security flaws. Most of the time IoT devices are small in memory size, have limited power and lack the computational capabilities to implement traditional encryption algorithms without burdening the restrained resources [6], [7]. Researchers are constantly focusing their efforts to solve these security risks and provide a more robust and secure IoT for public services.

The distributed nature of IoT often draws parallel with another rising technology, Blockchain. Since the turn of this decade, Bitcoin and cryptocurrencies have become a major talking point in general public, businesses and researchers alike. The fundamental idea behind Blockchain, fosters distributed storage of ledgers, in a transparent, trustless network. Many research efforts are focused on using Blockchain technologies inherent qualities to improve the security and privacy in IoT applications [8 - 11]. In fact a lot of IoT applications can be benefitted from the inherent qualities of Blockchain technologies and evidently Blockchain based IoT (BIoT) applications are on the rise [8, 12 - 15].
Distributed ledger of records such as transactions to tackle issues such as security, transparency, and efficiency [16]. Some inherent characteristics of blockchain that give this technology an edge in many applications are –

- Immutability
- Irreversibility
- Decentralization
- Persistence
- Anonymity

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This technology has been around since the early 90s but has re-emerged with much public attention due to Satoshi Nakamoto's bitcoin cryptocurrency in 2009. Although blockchain has demonstrated immense usability and promise in the world of finance and currency exchange, the fundamentals of this technology can be employed in vast and diverse applications. Some applications such as notary (stampd.io), Internet of Things, odometer monitoring (Bosch IoT lab), digital voting (Agora.vote), patents, intellectual properties, food industry (IBM, Walmart), tracking packages (IBM, Maersk), product authentication/counterfeit product detection, medical data record storage and access authentication, vehicle insurance tracking, etc.

However, this technology is not without its own flaws. Some of the obvious disadvantages to using blockchain are –

➢ Delay in achieving consensus throughout large networks. The delay in the consensus process means that the transactions are low latency and in fact only 6 to 7 transactions are confirmed in a second

- The limited block size compounds the problem of scalability. The entire blockchain needs to be present in order to perform consensus or validate blocks requiring a lot of storage
- Energy consumption in computation during the mining operation is significant and in fact the energy consumption for each bitcoin transaction is equivalent to 80,000X of energy consumed for credit card processing
- Storage of entire chain of records for verification on each and every node

Miners are special nodes in bitcoin system. When a transaction is initiated but not authorized, the miners will race among themselves to verify the transaction and whichever node verifies the transaction and adds it to the ledger first will receive a financial incentive which is in the form of new bitcoins. This is the only way new bitcoins can be generated. To add a transaction to the ledger, a miner has to do two tasks -

- Validate the transaction by investigating whether the payer has the mentioned amount
- Find a unique value (a key, a nonce, one-time number) and add the latest transaction to the existing ledger and lock it in place which is done with proof-of-work consensus algorithm

There are several ways the consensus algorithm can be implemented. Popular methods are proof of work (PoW, prone to centralization), proof of stakes (PoS, prone to 51% stake issue), and proof of activity (PoA). The distributed ledger in blockchain needs expensive computational calculations to solve mathematical puzzles to validate a new unverified transaction [17]. The process of validating the transaction is what is called PoW. Mining is essentially the inverse of hash functions. In standard blockchain the parameters are updated fortnightly and new blocks are generated in every 10 minutes. PoS is more energy efficient compared to PoW because unlike PoW, PoS follows limited search space to compute hash values. As this stage requires significant resources, the challenge to implement blockchain in IoT applications lies in optimizing and modifying this section of the process for resource constraint devices. One such lightweight consensus algorithm is the proof of authentication (PoAh) which is suited for resource constrained devices. PoAh follows traditional blockchain model with lightweight block verification [17].

BIoT is still a relatively new research field and consequently there are many potential research opportunities. Dr. Puthal et al. proposed a new consensus algorithm called Proof of Authenticity (PoAh) which considers the media access control (MAC) address of each device in the Blockchain network and trusted nodes which are elected dynamically, verify the transactions based on the authenticated device addresses [17]. Pharmaceutical products (for eg. insulin) have to be kept at a specific environment and breaching the environmental parameters may result in damaged medicine/drugs. We want to employ blockchain technology to keep track of the temperature and humidity in the storage chambers of the drugs while they are being transported. This ensures maximum transparency and also reduces operation costs and time. We have modified the architecture and the components to suit our application as seen in Fig. 1. The IoT edge nodes will acquire data and send it to the gateway device which is the blockchain node in our architecture. The gateway device will authenticate the data using the same PoAh algorithm and compile a block containing 100 data points but the block will not contain the MAC ID of all the sensor nodes. Once it has compiled the block, the gateway device will transmit the block to the network. One elected trusted node will verify the MAC address of the gateway device and authenticate the block. Once the block has been authenticated, all the other nodes in the network will add this block to their local chain.

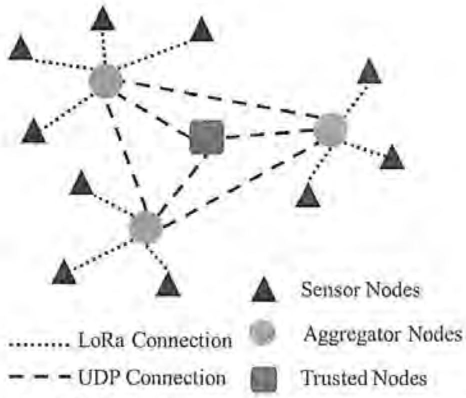

Fig 1. Basic architecture of the BIoT application

We have replicated the Raspberry Pi implementation in our lab using Node-Red. The IoT edge nodes are connected to 433 MHz radio transceivers. The premise of our work is to explain the inherent advantages of using blockchain in the pharma-delivery application and improving latency and energy consumption of BIoT application as seen in Fig. 2. As the basic implementation is done, I will now focus on measuring latency and energy consumption at each stage. Based on the initial results, we have decided on an architecture which incorporates Blockchain at the edge nodes. In the proposed architecture as seen in Fig. 1, there are two entities in the Blockchain network namely, Aggregator nodes (A), and Trusted nodes (T). Every A-node has multiple Sensor nodes (S). T nodes might or might not have S nodes connected to them. The S nodes collect information and send it to the A node wirelessly. The A node creates a block of data with these sensor information. Next, the A node sends this block of information throughout the network. The T nodes receive this data and start authenticating the block. After the block has been authenticated, all A and T nodes will add this block to their local chain.

The block validation at the T node latency (T_{bv}) and energy consumption (E_{bv}) is given by (1) and (2) respectively where T_{rv} is the instance when unverified block was received by the T node and T_{db} is the instance when the block was added to the local chain. We also evaluate the block addition latency and energy. Current and voltage were measured during this operation and multiplied to obtain power P_{bv}.

$$T_{bv} = T_{db} - T_{rv} \quad (1)$$
$$E_{bv} = P_{bv} \times T_{bv} \quad (2)$$

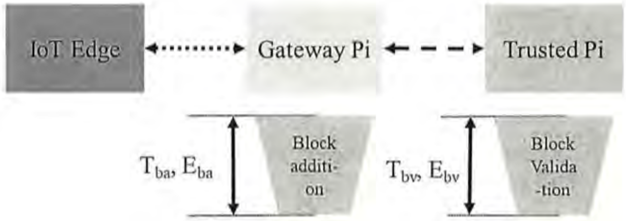

Fig 2. Parameters of interest for performance evaluation

As explained in the previous sections, the consensus algorithm is the single most challenging aspect for researchers to adopt Blockchain technology in an IoT system. To reap the benefits of Blockchain, the consensus algorithm must be optimized for running on significantly slower, simpler, and overall less powerful devices for the mining operation. Preliminary results are promising as we have measured the block validation and addition latency and energy consumption. We are expecting to see significant improvements in latency and energy consumption compared to standard use of Blockchain technology through other consensus algorithms. If successful, we want to implement the BIoT solution to pharmaceutical delivery system to raise transparency and trust and also reduce operational costs of storing and delivering of pharmaceutical goods.

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9. EXAMPLE DEGREE MAPS

9.1 Research Track

Degree Map			
BULLETIN YEAR: 2020-2021	**Degree: M.S.**	**Major:** ENGINEERING	**Track:** RESEARCH

The major map illustrates one path to completing your major, based on faculty members' advice on course sequence and a school tentative plans for scheduling courses. This document provides general direction. For more specific advice and up to date schedules, it is expected that students will regularly discuss their plans of study with academic advisors and monitor the current class schedules as students are responsible for ensuring that all requirements for graduation have been met.

Course	Cr. Hrs.	Course	Cr. Hrs.
FIRST YEAR			
Semester: Fall Total Credit Hours:	7	Semester: Spring Total Credit Hours:	7
EGR 601: Advanced Engineering Experimentation	3	EGR 600: Advanced Engineering Analysis	3
EGR 685: Seminar Current Topics in Engineering Research	1	EGR 685: Seminar Current Topics in Engineering Research	1
EGR 637: Directed Research in Engineering	3	EGR 637: Directed Research in Engineering	3

Course	Cr. Hrs.	Course	Cr. Hrs.
SECOND YEAR			
Semester: Fall Total Credit Hours:	10	Semester: Spring Total Credit Hours:	6
EGR 685: Seminar Current Topics in Engineering Research	1	EGR 791: Directed Research in Engineering	3
EGR 637: Directed Research in Engineering	3	EGR 798: Thesis Research	3
EGR 791: Independent Research in Engineering	3		
EGR 798: Thesis Research	3		

30 hours minimum required for graduation **15 hours 600 level or above required**

Notes Here

9.2 Course based - Photonics

Degree Map			
BULLETIN YEAR: 2020-2021	**Degree: M.S.**	**Major:** ENGINEERING	**Track:** Photonics

The major map illustrates one path to completing your major, based on faculty members' advice on course sequence and a school tentative plans for scheduling courses. This document provides general direction. For more specific advice and up to date schedules, it is expected that students will regularly discuss their plans of study with academic advisors and monitor the current class schedules as students are responsible for ensuring that all requirements for graduation have been met.

Course	Cr. Hrs.	Course	Cr. Hrs.
FIRST YEAR			
Semester: Fall Total Credit Hours:	10	Semester: Spring Total Credit Hours:	10
EGR 601: Advanced Engineering Experimentation	3	EGR 600: Advanced Engineering Analysis	3
EGR 685: Seminar Current Topics in Engineering Research	1	EGR 685: Seminar Current Topics in Engineering Research	1
EGR 588: Photonics	3	EGR 597M: Mechanics of Composite Materials	3
MTH 534: Applied Mathematics and Differential Equations	3	PHY 554: Optics	3

Course	Cr. Hrs.	Course	Cr. Hrs.
SECOND YEAR			
Semester: Fall Total Credit Hours:	10	Semester: Spring Total Credit Hours:	
EGR 685: Seminar Current Topics in Engineering Research	1		
EGR 597K: Metamaterials Antenna Theory	3		
PHY 634: Advanced Electricity and Magnetism	3		
EGR 791: Independent Research in Engineering	3		

30 hours minimum required for graduation **15 hours 600 level or above required**

Notes Here

9.3 Course based - Internet of Things (IoT) Track

Degree Map			
BULLETIN YEAR: 2020-2021	**Degree: M.S.**	**Major:** ENGINEERING	**Track:** IoT

The major map illustrates one path to completing your major, based on faculty members' advice on course sequence and a school tentative plans for scheduling courses. This document provides general direction. For more specific advice and up to date schedules, it is expected that students will regularly discuss their plans of study with academic advisors and monitor the current class schedules as students are responsible for ensuring that all requirements for graduation have been met.

Course	Cr. Hrs.		Course	Cr. Hrs.
FIRST YEAR				
Semester: Fall Total Credit Hours:	10		Semester: Spring Total Credit Hours:	10
EGR 601: Advanced Engineering Experimentation	3		EGR 600: Advanced Engineering Analysis	3
EGR 685: Seminar Current Topics in Engineering Research	1		EGR 685: Seminar Current Topics in Engineering Research	1
EGR 580: Fundamentals of Internet of Things	3		EGR 697: Special Topics in Engineering	3
CPS 510: Software Systems Engineering	3		CPS 585: Applied Data Engineering	3
Course	Cr. Hrs.		Course	Cr. Hrs.
SECOND YEAR				
Semester: Fall Total Credit Hours:	10		Semester: Spring Total Credit Hours:	
EGR 685: Seminar Current Topics in Engineering Research	1			
EGR 585: Wireless Sensor Networks	3			
EGR 597A: Hardware-Assisted Security	3			
EGR 791: Independent Research in Engineering	3			

30 hours minimum required for graduation **15 hours 600 level or above required**

Notes Here

9.4 Course based – Electrical and Computer Engineering(ECE)

Degree Map			
BULLETIN YEAR: 2020-2021	**Degree: M.S.**	**Major:** ENGINEERING	**Track:** ECE

The major map illustrates one path to completing your major, based on faculty members' advice on course sequence and a school tentative plans for scheduling courses. This document provides general direction. For more specific advice and up to date schedules, it is expected that students will regularly discuss their plans of study with academic advisors and monitor the current class schedules as students are responsible for ensuring that all requirements for graduation have been met.

Course	Cr. Hrs.		Course	Cr. Hrs.
FIRST YEAR				
Semester: Fall Total Credit Hours:	10		Semester: Spring Total Credit Hours:	10
EGR 601: Advanced Engineering Experimentation	3		EGR 600: Advanced Engineering Analysis	3
EGR 685: Seminar Current Topics in Engineering Research	1		EGR 685: Seminar Current Topics in Engineering Research	1
EGR 580: Fundamentals of Internet of Things	3		EGR 591: CMOS Circuit Design	3
EGR 588: Photonics	3		EGR 697: Special Topics in Engineering	3

Course	Cr. Hrs.		Course	Cr. Hrs.
SECOND YEAR				
Semester: Fall Total Credit Hours:	10		Semester: Spring Total Credit Hours:	
EGR 685: Seminar Current Topics in Engineering Research	1			
EGR 585: Wireless Sensor Networks	3			
EGR 597K: Metamaterials Antenna Theory	3			
EGR 791: Independent Research in Engineering	3			

30 hours minimum required for graduation **15 hours 600 level or above required**

Notes Here

9.5 Course based – Mechanical Engineering (ME)

Degree Map

BULLETIN YEAR: 2020-2021 **Degree: M.S.** **Major:** ENGINEERING **Track:** ME

The major map illustrates one path to completing your major, based on faculty members' advice on course sequence and a school tentative plans for scheduling courses. This document provides general direction. For more specific advice and up to date schedules, it is expected that students will regularly discuss their plans of study with academic advisors and monitor the current class schedules as students are responsible for ensuring that all requirements for graduation have been met.

Course	Cr. Hrs.		Course	Cr. Hrs.
FIRST YEAR				
Semester: Fall Total Credit Hours:	10		Semester: Spring Total Credit Hours:	10
EGR 601: Advanced Engineering Experimentation	3		EGR 600: Advanced Engineering Analysis	3
EGR 685: Seminar Current Topics in Engineering Research	1		EGR 685: Seminar Current Topics in Engineering Research	1
EGR 553: Mechanical Vibrations	3		EGR 554: Mechanical Controls	3
EGR 576: Mechanics of Composite Materials	3		EGR 697: Special Topics in Engineering	3
Course	Cr. Hrs.		Course	Cr. Hrs.
SECOND YEAR				
Semester: Fall Total Credit Hours:	10		Semester: Spring Total Credit Hours:	
EGR 685: Seminar Current Topics in Engineering Research	1			
EGR 578: Advanced Mechanics of Materials	3			
Elective	3			
EGR 791: Independent Research in Engineering	3			

30 hours minimum required for graduation **15 hours 600 level or above required**

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