Subject: Co-convening lectures for ECE 412/512 (Hybrid Electric Vehicle Drives) and MMAE 453 (Electrified Vehicle Powertrains)

Departments: ECE and MMAE
Faculty: Prof. Mahesh Krishnamurthy (ECE) and Prof. Carrie Hall (MMAE)

Requested: Lectures for both classes should be listed in the same room and at the same time (Monday 5 pm to 7:40 pm) for Spring 2023

MMAE 453 has been offered in the ECE and MMAE department in the for the last ~10 years. The MMAE course originally had a stronger focus on conventional vehicles but has evolved to focus more on electrified powertrains including electric and hybrid vehicles following the ongoing changes in the automotive sector. ECE 412/512 was offered by the ECE department as a course that focused exclusively on electric motor drives for over 12 years but was evolved into a course that deals with powertrain components in electric and hybrid electric vehicles.
The two courses have a significant alignment in terms of the content with a stronger emphasis on the mechanical and electrical aspects of vehicles in the respective departments. We would like to co-convene ECE 412/512 and MMAE 453 in Spring 2023 to provide the students with a more comprehensive course on electrified transportation, which provides depth on both the mechanical and electrical aspects of modern cars. Prof. Krishnamurthy will lead the lectures that are focused on electrical features (motors, batteries, ...) and Prof. Hall will lead the lectures focused on mechanical features (engines, transmissions,...). This format will allow mechanical and electrical students to more closely interact and learn from each other and be instructed by faculty conducting active research in the area.

Impact on existing courses: None. ECE 412 includes a lab component, which will not be affected in this plan, since the content is substantively being maintained with some minor reorganization to the content. Learning outcomes from each course will stay within the parameters set by both departments.

ECE 412/512: Hybrid Electric Vehicle Drives– Course Outline

Tentative Course Schedule- Spring 2022

Instructor: **Dr. Mahesh Krishnamurthy**
Office: Siegel Hall 225
EML: kmahesh@iit.edu
URL: http://www.drives.ece.iit.edu/

Course Schedule

Lecture	Topic
01/10	Introduction to Electric and Hybrid Electric Vehicles Vehicle Dynamics
01/17	**No class: MLK Day**
01/24	Electromagnetic energy conversion and magnetic circuits Introduction to Electric machines (***Term Project Assignment)***
01/31	Torque, power and speed requirements in HEVs/EVs
02/07	*Brushed DC Motors for auxiliary loads in automotives* Principles of DC Motors (Sen: 4.1 – 4.2) Types of DC motors and fundamentals of speed control (Sen: 4.4 – 4.5)
02/14	Electronic speed control of DC motors (Sen: 4.5) DC Generators (Sen: 4.3)
02/21	Automotive Power Electronics *Traction motors for PHEVs and EVs* Induction machines and modeling (Sen: 5.1 – 5.7) (***Graduate Project Proposal Due)***
02/28	Induction motor testing (Sen: 5.8) Speed Control of Induction motors (Sen: 5.13 – 5.14)
03/07	Performance characteristics of induction motors (Sen: 5.9 – 5.10) ***Midterm Exam***
03/14	**No class: Spring Break**
03/21	Permanent magnet synchronous machines and modeling (Chau: Chapter 4)

	Inverters for PM Brushless Motors (Chau: 4.4 – 4.5)
03/28	PMSM control methods: MTPA technique, Field Weakening (Contd. Nam, IEEE papers) Switched Reluctance Machines: Fundamentals and converters (Sen: 6.14, IEEE Papers)
04/04	*Practical Design Considerations in EV traction* Fundamentals of energy storage
04/18	EV Motor Design Issues (Nam: Chapter 14) Vibration and acoustic noise issues in traction motors (IEEE Papers) Thermal fundamentals and cooling in electric machines (IEEE Papers)
04/25	Design evaluation for drivetrains for select popular HEVs using experimental reports (ORNL Reports) Graduate Project Presentation
Final EXAM: TBA	

ECE 412 – Hybrid Electric Vehicle Drives
Spring 2022

Instructor: **Dr. Mahesh Krishnamurthy**
Office: Siegel Hall 225
EML: kmahesh@ece.iit.edu
URL: http://www.drives.ece.iit.edu/

Time: **M 5:00 PM to 7:40 PM**
Office Hrs: **M 4:30 PM to 5:00 PM and 7:45 PM to 8:15 PM and by appointment**

GTA: TBA
EML: TBA
Office Hours: TBA

Course Description: **Fundamentals of drivetrains for electric vehicles and hybrid electric vehicle drives are studied with a brief introduction to different machine topologies. Applications of semiconductor switching circuits to adjustable speed drives, robotics, and traction applications are explored. Selection of motors and drives, calculating the ratings, speed control, position control, starting, and braking are also covered. Simulation mini-projects and lab experiments are based on the lectures given.**

Course Purpose: The purpose of this design course in hybrid electric vehicle technologies is to use the HEV and EV as a platform to integrate fundamental concepts from electric machines, micro-controllers, signal processing and control theory. It will give an overview of the major components of powertrains in Hybrid, Plug-in Hybrid and Electric Vehicles. Operation of the electric motor drive (including electric machine and power electronics) will be explored in the context of power, torque and performance in this high-efficiency system. It will evaluate the design electric machines, control of adjustable speed drives for electrified transportation systems with industry-relevant examples and problems.

Pre-requisite: **ECE 308, ECE 311, ECE 319**

Text Book:

T1: ***Principles of Electric Machines and Power Electronics,*** **3rd Edition, P. C. Sen, Wiley Press, ISBN-10: 9781118078877**

Reference Text:

R1. ***AC Motor Control and Electrical Vehicle Applications*****, K. H. Nam, 2nd Edition, CRC Press, ISBN: 9781351778183, 2018.**

R2. ***Electric Vehicle Machines and Drives: Design, Analysis and Application*, K. T. Chau, 1st Edition, Wiley – IEEE Press, 2015.**

Grading:

Mid-Term Exam	**15%**
Homework	**15%**
Major Design Project	**20%**
Lab Experiments and Reports	**25%**
Final Exam	**25%**
Course Grade	**100%**

Class Policy:

- There is a **zero tolerance** policy in regards to plagiarism. Copying of homework, reports, and other assignments, previous semesters, classmates or World Wide Web constitutes academic dishonesty. Occurrence of such cases results in a (failing) grade of "E" for the course. Furthermore, instructor may report academic dishonesty to judicial affairs of IIT.
- You are welcome to seek clarifications regarding exams up to **one week** from when you receive it.
- Class participation is an important component of the course. Absence from class will be considered as non-participation.
- Use of electronic devices in class is not allowed. This includes cell phones, IPODs. IPAD or Laptop may be used ONLY IF it is for taking lecture notes. If you need to make an important call, you are welcome to step out and rejoin the class once the call is over.
- Smoking or chewing tobacco in class is not allowed. Eating is permitted as long as it doesn't disturb the class (loud, crunchy items should be avoided).

- Reasonable accommodations will be made for students with documented disabilities. In order to receive accommodations, students must obtain a letter of accommodation from the Center for Disability Resources and make an appointment to speak with me as soon as possible.

The Center for Disability Resources is located in the Life Sciences Building, room 218, 312-567-5744 or disabilities@iit.edu.

- Illinois Tech's Sexual Harassment and Discrimination Information:

Illinois Tech prohibits all sexual harassment, sexual misconduct, and gender discrimination by any member of our community. This includes harassment among students, staff, or faculty. Sexual harassment of a student by a faculty member or sexual harassment of an employee by a supervisor is particularly serious. Such conduct may easily create an intimidating, hostile, or offensive environment.

Illinois Tech encourages anyone experiencing sexual harassment or sexual misconduct to speak with the Office of Title IX Compliance for information on support options and the resolution process.

You can report sexual harassment electronically at iit.edu/incidentreport, which may be completed anonymously. You may additionally report by contacting the Title IX Coordinator, Virginia Foster at foster@iit.edu or the Deputy Title IX Coordinator at eespeland@iit.edu.

For confidential support, you may reach Illinois Tech's Confidential Advisor at (773) 907-1062. You can also contact a licensed practitioner in Illinois Tech's Student Health and Wellness Center at student.health@iit.edu or (312)567-7550

For a comprehensive list of resources regarding counseling services, medical assistance, legal assistance and visa and immigration services, you can visit the Office of Title IX Compliance website at https://www.iit.edu/title-ix/resources.

MMAE 453 Syllabus

ADVANCED AUTOMOTIVE POWERTRAINS

Fall 2019

Instructor: Carrie Hall
Office: RE 252D
E-mail: chall9@iit.edu
Office Hours: 10-11am and 5-6pm Monday and Wednesday

Michael Duoba

1. **OBJECTIVES:** The objectives of this course are as follows:
   - To provide a thorough understanding of the working principles of internal combustion engines, hybrid powertrains, and electric vehicles
   - To develop the skills and tools for analyzing different vehicle powertrain architectures and predicting the energy requirements of these powertrains;
   - To gain experience in analyzing system and component efficiency based on vehicle test data
   - To acquire a comprehensive view of the current challenges in the automotive transportation sector

2. **TEXTBOOK:** Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design by Mehrdad Ehsani, Yimin Gao, and Ali Emadi, 2nd Edition, 2009.

   Additional reference text: Lino Guzzella and Antonio Sciarretta, Vehicle Propulsion Systems: Introduction to Modeling and Optimization, Springer, 2013. (An electronic version of this book is available for free to IIT students through the IIT library.)

3. **PREREQUISITE:** MMAE 321 (Applied Thermodynamics)

4. **HOMEWORK:** Homework problems are assigned each week for you to work outside of class. **No late homework is accepted.** The homework problems will be posted on blackboard and solutions to the assignments will be posted following the due date for the assignment. Copying homework directly from a friend or from a file (or other such resource) will be considered cheating. Any form of dishonesty (including cheating) will result in a grade of zero for that assignment.

5. **EXAMINATIONS:** There will be one in-class midterm examination. If you are ill (with acceptable medical proof from a physician) or have an emergency, you must resolve this conflict with your instructor.

   IMPORTANT NOTE: The use of PDAs, smartphones/iPhones, Blackberry-type devices, cell phones, tablet/laptop computers, or any other sources of communication (wireless or otherwise) are strictly prohibited during examinations. Using your phone during an exam will be considered a form of cheating and treated as such. **Any form of dishonesty (including cheating) on an examination, results in a grade of zero for that examination.**

6. **EXAMINATION PREPARATION:** In order to be properly prepared for examinations, you should be: (1) attending and participating in all lectures; (2) reading the textbook and reviewing your class notes on a regular basis; and (3) completing and studying all the homework assignments. In order to perform well on examinations, you must not only understand how to solve new problems, but you must be comfortable with the basic concepts of the material. This is because the examinations are developed to test your understanding of the topics through problem solving, short answer, conceptual, and other types of questions.

7. **PROJECT:** The course will include two projects. Topics for the projects and additional details regarding the requirements will be given out mid semester.

8. **COURSE GRADING:** Your course grade is based on the following distributions:

Homework	25%
Midterm Examination	25%
Project 1	25%
Project 2	25%

   Course grading will not be more stringent than a straight-scale (90-100 for an A, 80-90 for a B, etc.).

9. **POLICY ON ACADEMIC HONESTY:** The Department of Mechanical, Materials, and Aerospace Engineering at Illinois Institute of Technology considers academic training to be apprenticeship for practice in the professions. Students are expected to demonstrate a code of moral integrity and ethical standards commensurate with the high expectations that society places upon professional practice.

   Accordingly, it is the policy of the department to maintain the highest standard of academic honesty and integrity. The department prohibits any form of cheating that contributes, or is intended to contribute, to a student's grade in a course. This includes copying or unauthorized collaboration on homework, reports, computer programs, projects, etc., collaboration of any kind on an examination or quiz, or the unauthorized possession or use of any material or machine-stored information during an examination. It is a violation for a student, whether or not currently enrolled in the university, to knowingly engage or attempt to engage in the acquisition, without permission, of tests, answer sheets, problem solutions or other academic material when such material has been withheld from distribution by the instructor.

   Students judged guilty of such offenses are subject to either of the following sanctions:

   1. **Expulsion from a course.** The student is assigned a punitive failing grade of E for the course and can no longer participate in the course or receive evaluation of coursework from the instructor.
   2. **Reduction in Grade.** A reduction in grade for the assignment or exam involved or for the course may be applied.

   In addition, the incident will be reported to the Designated Dean for Academic Discipline, who may make a recommendation for further disciplinary action. The report of the incident will be placed in the student's permanent academic record. An offense may warrant a recommendation to initiate dismissal proceedings.

   This policy will apply not only to a student guilty of any form of academic dishonesty, but also to any party who knowingly allows his or her work to be plagiarized.

   This policy is consistent with the IIT Code of Academic Honesty (http://www.iit.edu/student_affairs/handbook/)

MMAE 453
Tentative Course Schedule – Fall 2018

Lecture	Day	Date	Topic	Reading from Text
1	M	8/19	Syllabus, Background & Introduction	Ch 1
2	W	8/21	Longitudinal Vehicle Dynamics	2.1-2.4
3	M	8/26	Drive Cycles, Vehicle Spd, Wheel τ, ω	2.5
4	W	8/27	Vehicle Modeling Intro, Simple Electric Vehicle	2.1, 2.2
	M	9/2	No Class – Labor Day	
5	W	9/4	Vehicle Performance, Component Sizing	2.7
6	M	9/9	Internal Combustion (IC) Engines	3.1
7	W	9/11	Modeling IC Engines, Maps, Willans Line	
8	M	9/16	Conventional Vehicle Powertrains	3.1.7, 3.2
9	W	9/18	Conventional Vehicle Powertrains	
10	M	9/23	Motors, Types, Modeling	6.0
	W	9/25	Batteries, Types, Modeling	
11	M	9/30	Electric Vehicle (EV)	4.1 to 4.4
12	W	10/2	Midterm Exam	
	M	10/7	No Class – Fall Break Day	
13	W	10/9	Modeling Battery Electric Vehicle (BEV)	
14	M	10/14	Series Hybrid Electric Vehicle (HEV)	7.3, 7.4
15	W	10/16	Simple Series HEV Model	
16	M	10/21	HEV Basic Energy Management	
	W	10/23	Other HEV configurations	8.0 to 8.2.2
17	M	10/28	Power-Split HEV	9.0, 9.1
18	W	10/30	Project 1 Help Day	
19	M	11/4	Project 1 Due Plug-in HEV (PHEV)	10
20	W	11/6	Fuel Cell and Hydrogen-Fueled Vehicles	14
21	M	11/11	Vehicle Modeling	
22	W	11/13	Vehicle Modeling	
23	M	11/18	Future Powertrains	
24	W	11/20	Project 2 Help Day	
25	M	11/25	Fuel Economy Testing – Argonne Visit	
	W	11/27	No Class- Thanksgiving Break	
Final Exam: Presentations for Project 2				