TO: The Faculty of the College of Engineering

FROM: School of Electrical and Computer Engineering of the College of Engineering

RE: New Graduate Course, ECE 51018 Hybrid Electric Vehicles

The faculty of the School of Electrical and Computer Engineering has approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

ECE 51018 Hybrid Electric Vehicles
Sem. 2, Lecture 3, Cr. 3.

Prerequisite: MA266 & MA265 or MA262

Prerequisite by Topic: Familiarity with matrix algebra, MATLAB, Elementary differential equations.

Description: Introduction to architectures and technologies associated with electric and hybrid electric vehicles including their constituent components. Specific topics include electric and hybrid electric drive trains, energy storage (batteries/ultracapacitors, fuel cells), electromechanical energy conversion (induction and permanent magnet motors and generators), power electronics, vehicle-level modeling and control, and optimization.

Reason: The intent of this course is to introduce graduate students from various engineering disciplines to the rapidly growing area of hybrid electric vehicles. The subject is multidisciplinary in nature involving topics from mechanical, electrical, material science, and chemical engineering. Topics covered include vehicle architectures, kinematics, electromechanics, power electronics, energy storage, power management, control, and simulation methods. Whereas more specialized courses exist in most of these topics, this course presents an integrated view of hybrid and electric vehicles and serves graduate students who are at an early stage in their program as a stepping stone to more advanced study in each of the topics.

Michael R Melloch

Michael R. Melloch, Associate Head
School of Electrical and Computer Engineering

Approved for the faculty of the Schools of Engineering by the Engineering Curriculum Committee
ECC Minutes #8 Date 12/2/16
Chairman ECC

Office of the Registrar
FORM 40G REV. 4/13

PURDUE UNIVERSITY
REQUEST FOR ADDITION, EXPIRATION, OR REVISION OF A GRADUATE COURSE (50000-60000 LEVEL)

DEPARTMENT: Electrical and Computer Engineering
EFFECTIVE SESSION: Spring 2017

INSTRUCTIONS: Please check the items below which describe the purpose of this request.

- [x] 1. New course with supporting documents (complete proposal form)
- [ ] 2. Add existing course offered at another campus
- [ ] 3. Expiration of a course
- [ ] 4. Change in course number
- [ ] 5. Change in course title
- [ ] 6. Change in course credit/type
- [ ] 7. Change in course attributes
- [ ] 8. Change in instructional hours
- [ ] 9. Change in course description
- [ ] 10. Change in course requisites
- [ ] 11. Change in semesters offered
- [ ] 12. Transfer from one department to another

PROPOSED:
Subject Abbreviation: ECE
Course Number: 51018
Long Title: Hybrid Electric Vehicles
Short Title: Hybrid Electric Vehicles
Abbreviated title will be entered by the Office of the Registrar if omitted. (30 CHARACTERS ONLY)

EXISTING:
Subject Abbreviation:
Course Number:

TERMS OFFERED
Check All That Apply:
- [ ] Fall
- [x] Spring
- [ ] Summer

CAMPUS(ES) INVOLVED
- [ ] Calumet
- [ ] Cont Ed
- [ ] Ft. Wayne
- [ ] Indianapolis
- [ ] N. Central
- [ ] Tech Statewide
- [x] W. Lafayette

CREDIT TYPE
1. Fixed Credit: Cr. Hrs. 3
2. Variable Credit Range:
   Minimum Cr. Hrs
   (Check One) To [ ] Or [ ]
   Maximum Cr. Hrs
3. Equivalent Credit: Yes [ ] No [x]
4. Thesis Credit: Yes [ ] No [x]

COURSE ATTRIBUTES: Check All That Apply
1. Pass/Not Pass Only [ ]
2. Satisfactory/Unsatisfactory Only [ ]
3. Repeatable [ ]
   Maximum Repeatable Credit: [ ]
4. Credit by Examination [ ]
5. Fees [ ] Coop [ ] Lab [ ] Rate Request
   Include comment to explain fee
6. Registration Approval Type
   Department [ ] Instructor [ ]
7. Variable Title [ ]
8. Honors [ ]
9. Full Time Privilege [ ]
10. Off Campus Experience [ ]

Schedule Type	Minutes Per Mtg	Meetings Per Week	Weeks Offered	% of Credit Allocated
Lecture	3	50	16	100
Recitation				
Presentation				
Laboratory				
Lab Prep				
Studio				
Distance				
Clinic				
Experiential				
Research				
Ind. Study				
Pract/Observ				

Cross-Listed Courses

COURSE DESCRIPTION (INCLUDE REQUISITES/RESTRICTIONS):
Introduction to architectures and technologies associated with electric and hybrid electric vehicles including their constituent components. Specific topics include electric and hybrid electric drive trains, energy storage (batteries/ultracapacitors, fuel cells), electromechanical energy conversion (induction and permanent magnet motors and generators), power electronics, vehicle-level modeling and control, and optimization.

*COURSE LEARNING OUTCOMES:
i. Understanding of the principal architectures of electric and hybrid electric vehicles (a)
ii. Ability to analyze performance characteristics and understand limitations of each architecture (a, c)
iii. Understanding of the principal components of an HEV including the energy storage, conversion, transmission, and control subsystems (a)

Calumet Department Head	Date	Calumet School Dean	Date	Calumet Director of Graduate Studies	Date
Fort Wayne Department Head	Date	Fort Wayne School Dean	Date	Fort Wayne Director of Graduate Studies	Date
Indianapolis Department Head	Date	Indianapolis School Dean	Date	IUPUI Associate Dean for Graduate Education	Date
North Central Department Head	Date	North Central School Dean	Date	North Central Director of Graduate Studies	Date
Michael R Melloch West Lafayette Department Head	10/7/16 Date	Michael T. Harris West Lafayette College/School Dean	12/14/16 Date	Date Approved by Graduate Council	Date
Graduate Area Committee Convener	Date	Graduate Dean	Date	Graduate Council Secretary	Date
				West Lafayette Registrar	Date

OFFICE OF THE REGISTRAR

Supporting Document to the Form 40G
for a New Graduate Course

To: Purdue University Graduate Council

From: Faculty Member: Oleg Wasynczuk

Department: Electrical and Computer Engineering

Campus: West Lafayette

Date:

Subject: Proposal for New Graduate Course

Contact for information if questions arise:
Name: Matt Golden
Phone: 494-3374
Email: goldenm@purdue.edu
Address: EE Building, Room 135

Course Subject Abbreviation and Number: ECE 51018

Course Title: Hybrid Electric Vehicles

Course Description:

Introduction to architectures and technologies associated with electric and hybrid electric vehicles including their constituent components. Specific topics include electric and hybrid electric drive trains, energy storage (batteries/ultracapacitors, fuel cells), electromechanical energy conversion (induction and permanent magnet motors and generators), power electronics, vehicle-level modeling and control, and optimization.

Semesters Offered:

For the benefit of graduate student plan of study development, how frequently will this prototype be offered? Which semesters?
Each Spring

A. Justification for the Course:

This intent of this course is to introduce graduate students from various engineering disciplines to the rapidly growing area of hybrid electric vehicles. The subject is multidisciplinary in nature involving topics from mechanical, electrical, material science, and chemical engineering. Topics covered include vehicle architectures, kinematics, electromechanics, power electronics, energy storage, power management, control, and simulation methods. Whereas more specialized courses exist in most of these topics, this course presents an integrated view of hybrid and electric vehicles and serves graduate students who are at an early stage in their program as a stepping stone to more advanced study in each of the topics.

The target audience includes first-year graduate students and potentially seniors who wish to pursue graduate study from the Schools of ECE, ME, MSE, ABE, and ChE. The course is presently in its fourth offering and has had an enrollment of 25-40 students per semester.

Although multidisciplinary in nature, the topics are covered in a depth commensurate with other 500-level graduate courses. Required background includes classic physics (Ampere's, Gauss', Faraday's, and Kirchoff's laws, conservation of power/energy, Newtonian mechanics) freshman-level chemistry, sophomore-level electric circuit theory, and collegiate mathematics (multivariable calculus, ordinary differential equations).

Use the following criteria:
Graduate Council policy requires that courses at the 50000 level in the Purdue system should be taught at the graduate level and meet four criteria: a) the use of primary literature in conjunction with advanced secondary sources (i.e., advanced textbooks); b) assessments that demonstrate synthesis of concepts and ideas by students; c) demonstrations that topics are current, and; d) components that emphasize research approaches/methods or discovery efforts in the course content area (reading the research, critiquing articles, proposing research, performing research). Such courses should be taught so that undergraduate students are expected to rise to the level of graduate work and be assessed in the same manner as the graduate students.

- Anticipated enrollment
  - Undergraduate 2-5
  - Graduate 20-25

B. Learning Outcomes and Method of Evaluation or Assessment:

ECE Graduate Learning Outcomes:

a. Knowledge and Scholarship (thesis/non-thesis)
b. Communication (thesis/non-thesis)
c. Critical Thinking (thesis/non-thesis)
d. Ethical and Responsible Research (thesis) or Professional and Ethical Responsibility (non-thesis)

- List Learning Objectives for this course and map each Learning Objective to one or more of the ECE Learning Outcomes (a-d, listed above):

i. Understanding of the principal architectures of electric and hybrid electric vehicles (a)
ii. Ability to analyze performance characteristics and understand limitations of each architecture (a, c)
iii. Understanding of the principal components of an HEV including the energy storage, conversion, transmission, and control subsystems (a)
iv. Ability to integrate disparate subsystem models to form end-to-end vehicle model (c, d)

Methods of Instruction

- Lecture

- Will/can this course be offered via Distance Learning?

In the future, yes.

- **Grading Criteria**

The grades are based on three components

- Four Matlab/Simulink-based projects
- Midterm Exam
- Final Exam

The project grades are based on (1) documentation of models used, (2) correctness of results, and (3) discussion/analysis of results.

The weights assigned to each component are:

Midterm Exam: 20%
Final Exam: 20%
Four Projects: 60% (15% each)

C. Prerequisite(s):

List prerequisites and/or experiences/background required. If no prerequisites are indicated, provide an explanation for their absence. Add bullets as needed.

- ECE 321 and ECE 433, or Graduate Standing
- Prerequisite by Topic: Energy conversion and power electronics

D. Course Instructor(s):

Provide the name, rank, and department/program affiliation of the instructor(s). Is the instructor currently a member of the Graduate Faculty? (If the answer is no, indicate when it is expected that a request will be submitted.) Add rows as needed.

Name	Rank	Dept.	Graduate Faculty or expected date
Oleg Wasynczuk	Professor	ECEN	Yes

E. Course Outline:

Provide an outline of topics to be covered and indicate the relative amount of time or emphasis devoted to each topic. If laboratory of field experiences are used to supplement a lecture course, explain the value of the experience(s) to enhance the quality of the course and student learning. For special topics courses, include a sample outline of a course that would be offered under the proposed course. **(This information must be listed and may be copied from syllabus).**

Lectures	Principal Topics
3	Introduction to architectures (series, parallel, split)
5	Powertrain fundamentals
5	Battery characteristics, limitations, and management
3	Ultra capacitors and fuel cells
6	Power train electronics
6	Motor drives (induction, permanent magnet)
6	Vehicular control and overall energy management
3	Sizing and optimization
3	Regenerative braking
3	Modeling and simulation tools
1	Midterm exam

F. Reading List (including course text):

A primary reading list or bibliography should be limited to material the students will be required to read in order to successfully complete the course. It should not

be a compilation of general reference material.

A secondary reading list or bibliography should include material students may use as background information.

- Primary Reading List
    - C. Mi, A. Masrur, and D. W. Gao, Hybrid Electric Vehicles with Practical Perspectives, IEEE/Wiley, 2011
- Secondary Reading List
    - Selected papers and notes to be posted on Blackboard

G. Library Resources

Describe any library resources that are currently available or the resources needed to support this proposed course.

H. Course Syllabus

(While not a necessary component of this supporting document, an example of a course syllabus is available, for information, by clicking on the link below, which goes to the *Graduate School's Policies and Procedures Manual for Administering Graduate Student Program.*
See Appendix K.
http://www.purdue.edu/gradschool/faculty/documents/Graduate_School_Policies_and_Procedures_Manual.pdf