ATTACHMENT B.1 – COURSE ACTIVITIES

Michigan Technological University
College of Engineering
http://www.mtu.edu/engineering/

Course Number MEEM 5990
Advanced Propulsion for Hybrid Vehicles with Concentration in Battery Engineering

Course Description, Syllabus and Schedule

Offered by Michigan Tech in Collaboration with
AVL and Engineering Society of Detroit (ESD)

2009 Fall Semester*
3 credit hours: 2 Lecture + 1 laboratory
Sept. 3 – Dec. 11, 2009

Application Details
http://ww2.esd.org/EDUCATION/2009-09-FreeTraining.htm

Lectures:

MTU:
Course not available at MTU for Fall Semester*

Distance Learning:
Thur: 5:00 : 8:00 PM**
ESD, Southfield Michigan
http://ww2.esd.org/

Laboratories:
See Laboratory Syllabus

Instructor: **Team Taught**

Lead Instructor: Jeffrey D. Naber
ME-EM Dept
jnaber@mtu.edu
906.487.1938

Textbook: **None**

Usage of MTU's digital library including electronic papers and journals (e.g., SAE papers) will be used to support the lecture material. Additional reference and supplemental material to be supplied via MTU's Blackboard. https://courses.mtu.edu/

Office Hours: TBD

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* Also to be offered in Spring 2010 semester.
See: http://www.mtu.edu/registrar/students/calendars/academic/ for semester schedules.

** Two hours of lecture will occur between 5:00 – 7:00 PM. An additional hour is available for group discussion and work.

Course Description:

This is a Distance Learning (DL) course offered with a laboratory component in which all activities will be conducted in the Detroit Metro Area with course material and recorded lectures also available via MTUs web based instructional tools.

This course covers advanced vehicle propulsion systems within hybrid electric vehicle (HEV) context with a focus on application, integration, testing, and development of battery systems. It is a 3 credit hour graduate level course with 2 lecture hours per week and the equivalent of 2 hours of laboratory instruction per week course[**]. Additional course material including instruction on analysis and simulation tools, and homework and laboratory exercises will be available via MTU's internet instructional portal Blackboard. Course topics and learning objectives include the following (see also detailed weekly syllabus below):

- Vehicle and powertrain systems requirements, regulations, design, implementation, calibration, and validation and verification,
- Energy storage, conversion and power systems from the perspective of HEV propulsion systems,
- Model based design, simulation, control, and diagnostics utilizing Matlab/Simulink
- HEV high voltage sub-systems including electrical drive systems, electric machines, batteries, and their safety aspects,
- Batteries in application to HEV's including, chemistries, energy densities, costs, rate dependent charge and discharge characteristics, heat generation and dissipation, and their design, analysis, models, simulation, control, and testing,
- Vehicle dynamics coupled with HEV propulsion systems, simulation, control and calibration.

The laboratory classes will focus on battery monitoring and control, regeneration and series charging, powertrain calibration, and hybrid vehicle instrumentation, control, and calibration. The final lab project in the course will be to calibrate a hybrid vehicle optimizing trade-offs in fuel mileage and drivability. Deliverables for the final project will be a report and presentation, combined with vehicle test results for each team. The overall success will be evaluated by a team faculty and industry specialists. See laboratory syllabus for details.

Prerequisites for the course are a BS degree in engineering or similar physical sciences area. The course lectures will be offered distance learning through collaboration with ESD. The laboratory work will be conducted at facilities in the Detroit Metro Area including AVL's Powertrain Test Facility (see laboratory syllabus for details). The lecture and laboratory work will relay on MathWorks Matlab/Simulink tools. A working knowledge of these tools will be an important component of the course. Supplemental learning materials including video tutorials are available on Blackboard for those who need to learn or build their expertise in these tools. Matlab/Simulink is available through the Michigan Tech network on a set of terminal servers that can be operated on computers with a web connection.

The course will be team taught by a group of Michigan Tech faculty and staff from the College of Engineering and key experts in industry providing guest lectures with Associate Professor Jeffrey D.

[**] Consolidated laboratory sessions will held in the DL course to efficiently utilize AVL and other facility resources and student time.

Naber being the lead instructor. Coordination of the course with the State and ESD will be handled by Professor Carl Anderson, Associate Dean of Graduate Studies, College of Engineering. The distance learning (DL) will be coordinated by Patty Lins, Director of Distance Learning.

Table 1. Instructional faculty and staff listing.

Faculty/Staff	Int.	Area of Expertise
Jeffrey D. Naber, Associate Professor ME-EM	JDN	Vehicle and Powertrain Management Development, Control, Calibration and OBD
Jeffrey S. Allen, Assistant Professor ME-EM	JSA	Energy-Thermo-Fluids and Energy Systems
John E. Beard, Associate Professor ME-EM	JEB	Design of mechanical systems and hybrid electric powertrains, Model based designed, vehicle dynamics and simulation
Jeffrey B. Burl, Associate Professor Elect. & Comp. Eng	JBB	Control systems and theory with applications to powertrain
Stephen A. Hackney, Professor Material Sci. & Eng.	SAH	Batteries, materials and chemistries, surface and interface dynamics, electro-chemical thermodynamics, thin films and nanostructures, diffusional instabilities and applications of electron microscopy.
Jason M. Keith, Associate Professor Chem. Eng	JMK	Alternative energy systems, modeling of composite chemical/electrical/mechanical systems, engineering education
Wayne Weaver, Assistant Professor Elect. & Comp. Eng	WWW	Analysis, control and design of power electronics systems model based simulation and control
Jeremy Worm, Research Engineer ME-EM	JJW	Hybrid electric powertrains, powertrain and vehicle calibration and testing
Industry Experts	TBA	Leadership, product design, vehicle requirements, HEV, batteries, testing, ...

Course Outline*

Wk	Instr.	Lecture Topic
1	JDN, JJW TW	Course Overview, Learning Objectives, Laboratory Overview (JDN & JJW) Leadership (TW)
2	JDN	Vehicle and Powertrain Requirements, Design and Integration, Energy, Powertrain Systems, and System Development Process
3	JJW JDN	Subsystems, Powertrain, and Vehicle Testing and Instrumentation Vehicle Standards: Emissions, Fuel Economy, Chemical Energies, CO2, OBD, & Safety
4	JEB WWW, JDN	Dynamic modeling and solution methods of sets of ODE's MatLab/Simulink for Analysis, Simulation and Control
5	JBB JDN	Digital Control, Embedded Software, and Control Systems in HEV Powertrains
6	JSA SAH	Energy Systems: Chemical Energy, Conversion and Storage Processes and Their Thermodynamic Relations
7	SAH	Battery chemistries, electrochemical cell kinetics, energy capacity and power
8	SAH	PHEV/HEV battery requirements and testing, dynamic battery models applied to PHEV/HEV battery design and simulation
9	WWW	High voltage electrical systems and electrical machines
10	WWW JEB, JDN	Coupled Electrical and Thermal Analysis, Control, and Simulation of Batteries and E-Machines in HEV Powertrains
11	JEB JBB	Vehicle Hybrid Powertrain Systems: Architectures, Energy Flows, Vehicle Simulation
12	JEB JDN	Vehicle Hybrid Powertrain Systems: Architectures, Energy Flows, Vehicle Simulation
13	JDN JEB	Hybrid Vehicle Control and Calibration
14	JMK JSA	Hybrid Vehicle Control and Calibration (Continued) Power Systems: Fuel Cells, Alternative Energy Storage, Powerplants and Fuels
Finals		Final Course Project and Laboratory Challenge

* The above are the regularly scheduled lectures; however, we realize from previous courses of this nature where students from diverse backgrounds are in the course that additional background is needed. Significant supplemental material will be available including streaming video of tutorials in Matlab/Simulink, vehicle dynamics, and supplemental homework. Additionally Faculty, Staff and Graduate students with backgrounds in Mechanical, Electrical, Chemical and Materials Science and Engineering will be available for assistance through email and web meetings.

Course Grades

The following percentages will be used to determine the final grade:

Individual Homework Assignments,	10%
Team Analysis and Simulation Projects	30%
Team Laboratory, Final Report and Presentation on Chief's Challenge	40%
Exams with individual / team portions (2 equally weighted)	20%

GRADING: A: 90-100, AB: 85-89, B: 80-84, BC: 75-79, C: 70-74, CD: 65-69, D: 60-64

Details of Battery Learning Objectives

An understanding of the internal processes of a battery is required to fully analyze the design, optimization and diagnostic testing of electric vehicles. The battery component of the proposed course will introduce the phenomenological treatment of applicable concepts in chemical thermodynamics and transport required to understand cell voltage, state of charge, power, capacity and impedance. These concepts will be taught to develop the basis behind equivalent circuit models and other physical analogy models with the goal that the students be able to integrate and calibrate equivalent circuit models into the system level model of an electric vehicle. As such, battery design concepts based on cell attributes and the power requirements of the vehicle will be developed[1]. These concepts allow a determination of battery size and configuration based on the voltage : state of charge and delta voltage : delta state of charge correlation using equivalent circuit models. In addition to the integration of physical principles of electrochemical cell function with equivalent circuit models as a basis for battery design, this approach allows for a critical comparison of various battery chemistries for HEV/PHEV applications as determined by certified DOE battery operation and testing standards[2]. The laboratory activities associated with the battery component of the course will also be based on DOE certified testing procedures and will reinforce concepts introduced in lecture by examining cell and battery performance in a variety of controlled discharge/charge profiles and cycling conditions. This active learning experience will focus on the concepts of:

(1) Open-Circuit Voltage and Resistances versus Depth-of-Discharge,

(2) Pulse Power Capability vs. Depth-of-Discharge,

(3) Calendar Life Test Profile,

(4) Finding a Battery Size Factor Using Device-Level Results.

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[1] For example see formaluation provided in "A simplified model for determining capacity usage and battery size for hybrid and plug-in hybrid electric vehicles," Paul Albertus, John Newman, Journal of Power Sources 183 (2008) 376–380.

[2] Battery Test Manual for Plug-In Hybrid Electric Vehicles, March 2008 INL/EXT-07-12536.