COURSE OUTLINE OF RECORD

<table>
<thead>
<tr>
<th>Number: AUTO G173</th>
<th>TITLE: Electric Vehicles</th>
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<tbody>
<tr>
<td>ORIGINATOR: Bryan Kramer</td>
<td>EFF TERM: Spring 2016</td>
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<tr>
<td>FORMERLY KNOWN AS:</td>
<td>DATE OF REVIEW: 03-27-2015</td>
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<tr>
<td>CROSS LISTED COURSE:</td>
<td>TOP NO: 0948.00</td>
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<td>CONTACT HRS TOTAL: 126.0</td>
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<td>CATALOG DESCRIPTION:</td>
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<td>This course furthers the student's skills in electric vehicle (EV) theory and provides an introduction to advanced EV designs and propulsion systems. The course includes: EV design and construction; the testing, assembly, operation and maintenance of EVs; the influence of battery management design; advanced technology batteries and intelligent charging systems; and alternative EV drive systems. Appropriate safety related instruction will be included in each segment. This course is designed to help the field technician prepare for the Automotive Service of Excellence (ASE) Light Duty Hybrid / Electric Vehicle Specialist (L3) exam. Students will also need to complete Automotive Technology G170 to prepare for the ASE (L3) exam.</td>
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<td>PREREQUISITES:</td>
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<tr>
<td>• AUTO G120: Electrical/Electronic Systems: Introductory with a minimum grade of B or better</td>
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<td>COREQUISITES:</td>
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<td>• AUTO G170: Hybrid Vehicles</td>
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<td>Automotive technology</td>
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<td>Electric Vehicle Specialist</td>
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<td>CSU GE Area B: Scientific Inquiry and Quantitative Reasoning</td>
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<td>B1 - Physical Science</td>
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COURSE LEVEL STUDENT LEARNING OUTCOME(S) Supported by this course:

1. Perform precision measurements of electrical charge components to assess efficiency.
2. Identify High Voltage systems and components.
3. Analyze and diagnose battery storage condition.

COURSE OBJECTIVES:
1. Examine the battery management system efficiency.
2. Analyze and diagnose power train system performance.
3. Evaluate the condition of the battery storage system.

COURSE CONTENT:

LECTURE CONTENT:

Lecture Content:

A. Systems Integration and Analytical Tools
B. Safety, Testing, Regulations, and Standards
C. Architecture of Battery Management
D. Electrochemistry and Battery Materials Design
E. Power Electronics
F. Electric Motors
G. High Voltage Battery Charging Methods & Some Aspects of Battery Pack Design
H. Lithium-Ion Battery Design
I. Lithium-Ion Battery Modeling Thermal Management for Batteries and Power Electronics

I. Systems Integration and Analytical Tools

1. Hybrid Components and Architectures
   a. Major components used in EV powertrain
   b. Overview of controls and subsystems
   c. Component sizing and integration trade-offs
   d. EV architecture overview from different model platforms

B. System Design and Development Considerations

   a. Vehicle integration (ex. performance, drivability, noise / vibration / harshness)
   b. Powertrain integration (ex. energy, power, efficiency, torque, thermal management)
   c. High Voltage /Low Voltage electrical systems (ex. safety, Direct Current/Alternating Current voltage, charging system, efficiency, cables, connectors, fuses)
   d. Chassis (ex. braking, vehicle dynamics, powertrain to chassis dynamics, ride and handling, steering, fuel system)
   e. Displays and driver information (ex. messages, information aids, usage efficiency aids)
   f. Heating Ventilation and Air Conditioning (ex. HV compressor, HV heater, cabin comfor efficiency considerations)

C. Verification and Validation Considerations
a. Verification and validation test requirements and planning
b. Component test considerations
c. System test considerations
d. Fleet testing

II. Safety, Testing, Regulations, and Standards

1. Standards Roadmap for Electric Vehicles
   a. Performance and Safety (example: Society of Automotive Engineers, Underwriter Laboratories, IEC)

B. Applicable Battery Standards
   a. Battery Transportation
   b. Battery Safety
   c. Battery Pack: SAE J2464/J2929
   d. Compare and Contrast the various industry standards

C. Vehicle and Charging Standards
   a. FMVS
   b. Electric Vehicle Supply Equipment (EVSE) Description
   c. Governing Bodies for Regulations
   d. Certification Requirements and Options

D. Performance Standards
   a. Charging interface
   b. SAE J1772 charge protocol
   c. USABC/FREEDOMCAR
   d. Battery Characterization and life cycle testing

E. High Voltage Safety
   a. Mechanical Shock
   b. Short Circuit
   c. Overcharge
   d. Fire Exposure

III. Architecture of Battery Management

1. Block Diagram - Main Functions of a Battery Management System

B. Sensing Requirements
   a. Battery Cell and Battery Module level: cell voltage, cell/module temperature, (humidity, smoke, air/fluid flow)
   b. Pack level: current, pre-charge temperature, bus voltage, pack voltage, isolation

C. Control Requirements
   a. Contactor control, pre-charge circuitry
   b. Thermal system control

D. Cell Balancing: Active versus passive strategies

E. Estimation Requirements
   a. Strategies: different approaches and benefits of model-based approach
   b. How to create a model via cell test
   c. State of Charge estimation
d. State of Health estimation  
e. Power estimation  
f. Energy estimation (range estimation)

F. Electronics Topologies
   a. Monolithic versus master/slave versus daisy-chai  
b. Implications of battery pack topologies: parallel strings versus series modules  
c. Available chipsets for designing electronics

G. Other Requirements: Controller Area Network communication, data logging, EV charger control, failure modes/detection, thermal systems control

H. Future Directions for Battery Management, Degradation Control

IV. Electrochemistry and Battery Materials Design
   A. Electrochemical Principles of Energy Storage Systems  
   B. General Overview; Physics and Chemistry of Advanced Lithium Battery Materials  
   C. Advanced Positive and Negative Electrodes  
   D. Advanced Electrolytes and Recent Developments  
   E. Battery Failure Modes, Capacity Fading, and Safety Aspects  
   F. Future Trends and New Concepts in Battery Materials and Design

V. Power Electronics
   1. Introduction – EV and electric propulsion  
   B. Overview of Power Density  
      a. Effects of air vs. liquid cooling for powertrain and EV components  
      b. Effects of efficiency  
   C. Converter Topology  
      a. Electrical demands on High Voltage and Low Voltage side  
      b. Switching and controlling  
   D. Inverter Topology  
      a. Rotary vs. electrical  
      b. Changes Direct Current to Alternating Current  
      c. Doesn't create electricity, but changes it  
   E. Potential loss in Electric Propulsion  
      a. Conduction, switching, leakage, and control losses  
   F. Semiconductors used in power controls  
      a. Insulated Gate Bi-polar Transistor (IGBT)  
      b. Metal-Oxide-Silicon Field Effect Transistor (MOSFET)  
      c. Emerging technologies: Moore’s law, silicon carbide

VI. Electric Motors
   1. Magnetic Circuits  
      a. The basic concepts of magnetic circuit
b. Governing laws of magnetic circuit
   c. Magnetic material behavior
   d. Losses and minimization of losses

B. Direct Current Motors
   a. Basic concepts of DC motor
   b. Governing law
   c. Construction
   d. Permanent magnet and separately excited motors

C. Permanent Magnet Alternating Current Synchronous Motors
   a. Construction and generation of magnetic field
   b. 3-phase behavior
   c. Torque generation
   d. Control
   e. Miscellaneous issues

VII. High Voltage Battery Charging Methods and Some Aspects of Battery Pack Design
   1. Basic Battery Reaction
   2. Consequences of Overcharge
   3. Design Consideration
   4. Thermal Considerations
   5. Charging Infrastructure/methods
   6. Conductive Charging
   7. Method
   8. Standards
   9. Inductive Charging
   10. DC Charging
   11. Definition
   12. Issues: Infrastructure, Thermal, and Life
   13. Grid Infrastructure
   14. Basic infrastructure
   15. Grid interactions: bi-directional communication and power flow
   16. Aspects of Battery Pack Design

VIII. Lithium-Ion Battery Design
   1. Overview of Battery Design
   2. Major Cell Components
   3. Overview of Battery Modeling and Simulation
   4. Lithium-Ion Cell Design Examples

IX. Lithium-Ion Battery Modeling Thermal Management for Batteries and Power Electronics
   1. Introduction
   2. Thermal control in vehicular battery systems: battery performance degradation at low and high temperatures
   3. Passive, active, liquid, air thermal control system configurations for Hybrid-Electric Vehicles and Electric Vehicles applications
   4. Brief Review of Thermodynamics, Fluid Mechanics, and Heat Transfer related to lithium-Ion batteries
   5. First Law of Thermodynamics for open and closed systems; internal energy, enthalpy, and specific heat
   6. Second Law of Thermodynamics for closed systems
   7. Fluid mechanics: pressure and temperature relationships
   8. Heat transfer: simple conduction, convection, and radiation relationships
9. Battery Heat Transfer
10. Introduction to battery management: tracking current demand, voltage, and State of Charge as functions of time for given drive cycles
11. Development of thermodynamic relationships for cell heat generation
12. Lumped cell and pack models for transient temperature response to drive cycles
13. Model parametric study results
14. Thermal Management Systems
15. Overall energy balance to determine required flowrates
16. Temperature control and heat transfer using phase change materials
17. Thermal Management of Power Electronics

LABORATORY CONTENT:

Lab Content / Skills:

A. Battery System

B. Internal Combustion Engine

C. Drive Systems

D. Power Electronics

E. Hybrid Supporting Systems

A. Battery System

1. Perform high voltage disconnect procedure; reconnect/enable high voltage system.

2. Select, test and use proper safety gloves.
3. Select, qualify and use proper DMM and leads.

4. Retrieve and diagnose Diagnostic Trouble Codes (DTCs); determine needed repairs.

5. Diagnose problems caused by damaged or failed harnesses, connectors, terminals and fuses.

6. Diagnose high voltage (HV) battery pack malfunctions.

7. Remove and install high voltage battery pack.

8. Test, diagnose and repair high voltage leaks/loss of isolation.

9. Test, diagnose and repair high voltage battery pack heating and cooling systems.

10. Test, diagnose, repair or replace high voltage battery pack internal components.

B. Internal Combustion Engine

1. Retrieve and diagnose Diagnostic Trouble Codes (DTCs); determine needed repairs.

2. Determine if the internal combustion engine (ICE) is in CRANK mode or RUN mode.

3. Differentiate between driveability problems caused by the internal combustion engine and/or hybrid drive system.

4. Perform internal combustion engine cranking compression test.

5. Keep the internal combustion engine running during service.

6. Diagnose internal combustion engine no-crank condition.
7. Diagnose internal combustion engine cranks/no-start condition.

8. Interpret vacuum and compression readings on Atkinson cycle engines.

9. Identify engine start/stop strategy; diagnose malfunctions.

10. Service engine cooling system.

C. Drive Systems

1. Perform high voltage disconnect procedure; reconnect/enable high voltage system.

2. Select, test and use proper safety gloves.

3. Select, qualify and use proper DMM and leads.

4. Retrieve and diagnose DTCs; determine needed repairs.

5. Diagnose problems caused by damaged or failed harnesses, connectors, and terminals.

6. Test, diagnose and repair high voltage leaks/loss of isolation.

7. Remove and install rotor from stator.

8. Diagnose motor-rotor position sensor (Resolver or Encoder type).

9. Diagnose drive/traction motor-generator assembly for improper operation (such as an inoperative condition, noise, shudder, overheating, etc.).
10. Diagnose improper electrically actuated parking pawl operation; determine needed repair.

11. Identify transmission fluid and coolant fluid requirements; verify fluid levels.

D. Power Electronics

1. Perform high voltage disconnect procedure; reconnect/enable high voltage system.

2. Select, test and use proper safety gloves.

3. Select, qualify and use proper DMM and leads.

4. Retrieve and diagnose DTCs; determine needed repairs.

5. Diagnose problems caused by damaged or failed harnesses, connectors, and terminals.

6. Identify procedures necessary to establish the proper vehicle operational power mode during service (OFF, ACCESSORY, POWER ON, READY TO DRIVE).

7. Diagnose the cause of a hybrid system warning displayed on the instrument panel, and/or a driveability complaint.


9. Diagnose AC/DC inverter overheating; determine needed repair.

10. Diagnose AC/DC inverter failure; determine needed repair.

11. Replace AC/DC inverter cooling pump.
12. Remove and install AC/DC inverter.

13. Diagnose failures in the data communications bus network; determine needed repair.

14. Locate and test the voltage level of capacitors.

15. Diagnose, locate and safely disable/enable safety interlocks.


17. Remove and install DC/DC converter.

18. Test high voltage cable integrity and loss of isolation.

19. Perform 12-volt battery testing.

20. Diagnose system main relay (SMR)/contactor malfunctions; determine needed repairs.

E. Hybrid Supporting Systems

1. Perform high voltage disconnect procedure; reconnect/enable high voltage system.

2. Select, test and use proper safety gloves.

3. Select, qualify and use proper DMM and leads.

4. Retrieve and diagnose DTCs; determine needed repairs.

5. Diagnose problems caused by damaged or failed harnesses, connectors, and terminals.
6. Inspect, test and diagnose EVAP emission system components; determine needed repairs.

7. Observe and interpret driver indicators, power flow display and energy monitor; determine necessary action.

8. Test and diagnose high voltage air conditioning compressor malfunctions; diagnose system problems; determine needed repairs.

9. Remove and install high voltage air conditioning compressor; identify and select proper system oil.

10. Diagnose cabin heating system performance problems; determine needed repairs.

11. Diagnose and repair electric/electronic steering systems.

12. Diagnose brake system performance problems; differentiate between braking problems caused by hydraulic system and regenerative system malfunctions; determine needed repairs.

13. Deactivate brake system self-test prior to service.

14. Service liquid cooling system(s).

METHODS OF INSTRUCTION:

A. Lecture:
B. Lab:

INSTRUCTIONAL TECHNIQUES:

Instructional technique will be through lecture material with power point. There will also be lecture-demo in some cases where specific measurements are performed before the students are allowed in the lab.

In the lab setting, all work will be completed as a hands-on assignment that will require specific measurements and critical thinking responses.

COURSE ASSIGNMENTS:

Reading Assignments
Daily reading assignments will have review questions at the end of each chapter.

Out-of-class Assignments
Daily reading assignments will have review questions at the end of each chapter.

Writing Assignments
Daily reading assignments will have review questions at the end of each chapter. Assignments may
include written essays.

METHODS OF STUDENT EVALUATION:
Midterm Exam
Final Exam
Short Quizzes
Written Assignments
Essay Examinations
Problem Solving Exercises
Skills Demonstration

Demonstration of Critical Thinking:
The student must be able to demonstrate their knowledge about a particular subsystem and recall expected voltage values in a normal circuit. The student must also be able to theorize predicted voltage values if a specific fault were in the circuit (example: open circuit, short-to-ground, short-to-voltage, etc.).

Required Writing, Problem Solving, Skills Demonstration:
The student must be able to explain through writing how the principles of electromagnetic induction are used to generate voltage.

The student will be assigned a school vehicle and will be asked to measure the voltage output from a generator that uses electromagnetic induction to re-charge the battery.

TEXTS, READINGS, AND RESOURCES:

TextBooks:

Other:
1. Materials provided on blackboard supplied by instructor.

LIBRARY:

Adequate library resources include: Online Materials

Comments:
There will be lab assignments and assessments used in blackboard. The students may use the library to view the material.

Attachments:
Attached Files