**PURDUE UNIVERSITY**

**REQUEST FOR ADDITION, EXPIRATION, OR REVISION OF A GRADUATE COURSE**

**DEPARTMENT** Mechanical Engineering  
**EFFECTIVE SESSION** Spring, 2013

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

- [x] New course with supporting documents (complete proposal form)
- Add existing course offered at another campus
- Expiration of a course
- Change in course number
- Change in course title
- Change in course credit/type
- Change in course attributes
- Change in instructional hours
- Change in course description
- Change in course requisites
- Change in semesters offered
- Transfer from one department to another

**PROPOSED:**

<table>
<thead>
<tr>
<th>Subject Abbreviation</th>
<th>ME</th>
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<tbody>
<tr>
<td>Course Number</td>
<td>59104</td>
</tr>
<tr>
<td>Long Title</td>
<td>Powertrain Integration</td>
</tr>
<tr>
<td>Short Title</td>
<td>Powertrain Integration</td>
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**EXISTING:**

Terms Offered: Check all that apply:
- [x] Fall
- Spring
- Summer

**COURSE DESCRIPTION (INCLUDE REQUISITES/RESTRICTIONS):**

The holistic view of powertrain development that includes engine, transmission, and driveline is now well accepted. Current trends indicate an increasing range of engines and transmissions in the future with, consequently, a greater diversity of combinations. This course discusses engines, transmissions, and drivelines in relation to their interfaces with chassis systems. This course also explores various aspects of powertrain integration. Novel concepts relating, for example, to continuously variable transmissions (CVTs) and hybridization as well as approaches to modeling, analysis, and simulation will be discussed.

**CREDITS TYPE**

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**SCHEDULE TYPE**

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| Weeks Offered | 15 |
| % of Credit Allocated | 100 |

**TERMS OFFERED**

Check All That Apply:  
- Fall  
- Spring  
- Summer

**CAMPUS(ES) INVOLVED**

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<td>Indianapolis</td>
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**CROSS-LISTED COURSES**

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<tbody>
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<td>West Lafayette Department Head</td>
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<tr>
<td>Graduate Area Committee Convener</td>
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**OFFICE OF THE REGISTRAR**
Supporting Document for a New Graduate Course

To: Purdue University Graduate Council
From: Faculty Member: Sohel Anwar
Department: Mechanical Engineering
Campus: IUPUI
Date: July 20, 2012
Subject: Proposal for New Graduate Course-Documentation
Required by the Graduate Council to Accompany Registrar's Form 40G

Contact for information if questions arise:
Name: Sohel Anwar
Phone Number: 317-274-7640
E-mail: soanwar@iupui.edu
Campus Address: 723 W Michigan St, SL 260, Indpls, IN 46202

Course Subject Abbreviation and Number: ME 50104
Course Title: Powertrain Integration

A. Justification for the Course:

- Provide a complete and detailed explanation of the need for the course (e.g., in the preparation of students, in providing new knowledge/training in one or more topics, in meeting degree requirements, etc.), how the course contributes to existing majors and/or concentrations, and how the course relates to other graduate courses offered by the department, other departments, or interdisciplinary programs.

- Justify the level of the proposed graduate course (50000- or 60000-level) including statements on, but not limited to: (1) the target audience, including the anticipated number of undergraduate and graduate students who will enroll in the course; and (2) the rigor of the course.

B. Learning Outcomes and Method of Evaluation or Assessment:

- Describe the course objectives and student learning outcomes that address the objectives (i.e., knowledge, communication, critical thinking, ethical research, etc.).

- Describe the methods of evaluation or assessment of student learning outcomes. (Include evidence for both direct and indirect methods.)

- Grading criteria (select from dropdown box); include a statement describing the criteria that will be used to assess students and how the final grade will be determined.

Criteria: Exams and Quizzes
• Identify the method(s) of instruction (select from dropdown box) and describe how the methods promote the likely success of the desired student learning outcomes.

| Method of Instruction | Lecture |

C. Prerequisite(s):

• List prerequisite courses by subject abbreviation, number, and title.

• List other prerequisites and/or experiences/background required. If no prerequisites are indicated, provide an explanation for their absence.

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?  ✔ Yes  ❌ No
(If the answer is no, indicate when it is expected that a request will be submitted.)

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 or 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.

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.

G. Library Resources

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

H. Example of a 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 Programs. See Appendix K.)

Powertrain Integration course was offered for the first time at IUPUI in Spring 2009 with a temporary number ME 59700. It has since then been offered regularly in the Spring semester at IUPUI as well as video streamed. Since the course is going to be offered regularly and video streamed for the graduate students, it is required that the course be given a permanent number.

**Justification for the Course:**
The course is designed to address the need for graduate / undergraduate education of Powertrain systems and their integration in an automobile in order to meet today’s transportation challenges. The holistic view of powertrain development that includes engine, transmission, and driveline is now well accepted. Current trends indicate an increasing range of engines and transmissions in the future with, consequently, a greater diversity of combinations. This course discusses engines, transmissions, and drivelines in relation to their interfaces with chassis systems. Novel concepts relating, for example, to continuously variable transmissions (CVTs) and hybridization as well as approaches to modeling, analysis, and simulation will be discussed. The proposed course was taught as dual level course in 2009, 2010, and 2011. The average enrollment was about 20. Half of the students were from Industry while rest were full time students. Clearly, the enrollment shows a great level of interest from the students who want to take such a course. There are a number of automotive companies (e.g. Delphi, Cummins, Allison Transmission, Honda, Toyota) in and around Indianapolis area. The course serves the industry (most of whom have hybrid electric vehicle programs and / or products) well by training its technical professionals in Powertrain Integration.

**Learning Outcomes and Method of Evaluation or Assessment**
Describe the course objectives and student learning outcomes that address the objectives (i.e., knowledge, communication, critical thinking, ethical research, etc.).

Course Objectives:
1) Apply basic knowledge of powertrain integration to design improved engine mounts.
2) Apply basic concepts of vehicle performance requirements and fuel economy to optimally determine powertrain components sizes.
3) Apply mathematical methodologies to analyze vehicle data to evaluate vehicle performance.
4) Explain various architectures associated with hybrid electric vehicle design.
5) Analyze fundamental requirements of engine intake and exhaust system for optimal performance.
6) Apply basic concepts in of control to engine, driveline, and traction control.
7) Solve engineering problems presented in class and homework; orally communicate some results in class discussions.

Learning Outcomes

i. Explain current state of automotive powertrains and their integration in vehicles [e].
ii. Analyze powertrain mount types and various mounting configurations [e, a4].
iii. Analyze automotive fuel and accessory systems [e].
iv. Synthesize driveline components and system, and powertrain driver interfaces [e].
v. Solve various aspects of engine system: Air Induction; Exhaust; Turbo/super-Charging; Speed Control; Knock Control; Fuel Injection timing control; Ignition control of SI engines [a4].
vi. Analyze Transmission: Transmission/driveline modeling; Transmission control for gear shifting [a4].

vii. Design Driveline control: Traction control; On-demand All-Wheel-Drive control [a4].

viii. Analyze hybrid electric vehicle (HEV) powertrain system [e, a4].

ix. Analyze powertrain integration concepts [e, a4].

Describe the methods of evaluation or assessment of student learning outcomes. (Include evidence for both direct and indirect methods.)

Evaluation and Grading:
Homework (30%)
One Examination (30%)
One Project (40%)

Grading Criteria
A Students doing excellent in all three evaluation criteria will receive this grade
B Students with good overall performance will receive this grade
C Student with slightly below average will receive this grade
D Not given
F Student with poor performance will be given this grade

Identify the method(s) of instruction (select from dropdown box) and describe how the methods promote the likely success of the desired student learning outcomes.

Lecture is offered live as well as via video streaming. Students can watch the lecture again if materials are not clear. This is likely to improve the success rate of a student taking this class.

Prerequisites:
Since MATLAB/SIMULINK is used extensively in this course, it is desirable that the students are familiar with this software package. Only undergraduate seniors or graduate students are allowed to take this course. Alternatively, the instructor can give permission to register at his/her discretion.

Course Instructor:
Dr. Sohel Anwar, Ph.D., P.E. is an associate professor of mechanical engineering at Purdue School of Engineering and Tech., IUPUI. Dr. Anwar has over 9 years of automotive related experience and is the primary instructor for the course. He developed the course curriculum for this course.
Course Outline:

1. INTRODUCTION
   Components of Powertrain and Interfaces
   Physical content of each system
   Powertrain requirements: Functional, Performance, Balancing
   Material selection and Packaging considerations
   Powertrain Calibration
   Powertrain-chassis integration
   Cost alternatives
   Technology trends

2. FUEL DELIVERY SYSTEMS
   Fuel types, basics, chemistry, alternatives
   Fuel Delivery
     Pressure, flow, enrichment
     Pumping
     Storage – level sensing
     Noise & Vibration
   Statutes, legislative regulations
     Emissions, permeation, tailpipe, fill, MVSS, crash

3. POWERTRAIN MOUNTING
   Impact of mounting metrics
     Noise and vibration, Isolation, vehicle dynamics,
     Crash, Safety, Quality Reliability and Durability (QRD)
   Functional requirement of mounting systems
   Types of mounting systems
   Mounting component types
     Hydraulic, elastomeric, active (controlled)

4. ENGINE

   4A. AIR INDUCTION
      Engine airflow management
        Pressure loss
        Air flow measurement
        Air filtration
        HC emissions
      Management of engine noise out of Air Induction System
        Noise prevention, reduction, cancellation
      Structural integrity
        Flow and noise
      Legislative regulations
        Exterior noise, emissions

   4B. EXHAUST
      Engine exhaust management
        Backpressure
        Emissions
        Thermal
      Engine noise management
        Noise prevention, reduction, cancellation
      Types of exhaust
        Gasoline, diesel, E-85
      Structural integrity
Legislative regulations
   Exterior noise, emissions

4C. ENERGY CONVERSION
Combustion management
   Fuel efficiency, emissions, losses
   Ignition and fuel injection control
   Knocking and control
Emission control
   Exhaust gas recirculation (EGR)
   Catalytic converter
Efficiency
   Turbo-charging, variable geometry turbo
   Supercharging
Interfaces
Legislative regulations
   Emissions, CAFE, noise and vibration

5. TRANSMISSION
Types of transmission
   Manual, automatic (countershaft and planetary), CVT
Interfaces
   Engine, driveline, chassis
Structural Integrity
   Noise, vibration, jerk, durability

6. DRIVELINE SYSTEMS
Classification of driveline systems:
   Front Wheel Drive (FWD), Rear Wheel Drive (RWD), All Wheel Drive (AWD)
Types of AWD systems
   Part time, active, full time, on-demand
Half shafts, propeller shafts, differentials, axles, joints and couplings

7. POWERTRAIN DRIVER INTERFACE
Shift controls and pedals
   Types (Adjustable, etc.)
   Ergonomics and packaging
      Effort, travel, spacing and location
      Efforts and linkage kinematics
Cable attachment systems
   Technology progression
      Shift by wire, electronic throttle control
   Regulations – MVSS

8. INTEGRATION OF POWERTRAIN SYSTEM
   Hybrid Electric Vehicle Powertrain Component Fundamentals
   Hybrid Electric Vehicle powertrain integration challenges
   Modeling and simulation tool to analyze the impact of design change on integration
   Introduction of design methodologies to address issues relating integration
   Existing and novel ideas
   New technologies on PT integration
**Reading List:**
Class notes authored by the instructor is considered a required reading material. Additional reading of scientific articles may be assigned by the instructor over the period of course delivery.

**Library Resources**
Required journal and technical articles are available through the IUPUI library, via online resources, or will be provided to the students.

**Example of Course Syllabus**
See attached.
ME 50104: Powertrain Integration
Syllabus

(3 Credit hours, Spring 2011)

Goals: To provide students with a perspective on the challenges of the powertrain interface
design and integration of various powertrain components.

Instructor: Dr. Sohel Anwar, P.E., Associate Professor, Mechanical Engineering Dept., IUPUI.
E-mail: soanwar@iupui.edu.

Lecture Hrs: TR 4:30PM - 5:45PM (SL 010)
Office Hrs: MW 2:00PM – 4:00PM (SL 260N), Phone, and E-mail.

Textbook: Lecture Note Materials.

Prereq.: Graduate standing or Instructor’s consent. Familiarity with MATLAB / SIMULINK
software package.

Catalog Description: The holistic view of powertrain development that includes engine, transmission, and
driveline is now well accepted. Current trends indicate an increasing range of engines and transmissions in the future with, consequently, a greater diversity of combinations. This course discusses engines, transmissions, and drivelines in relation to their interfaces with chassis systems. This course also explores various aspects of powertrain integration. Novel concepts relating, for example, to continuously variable transmissions (CVTs) and hybridization as well as approaches to modeling, analysis, and simulation will be discussed.

Homework: Homework problems will be assigned approximately once every 3 weeks in order
for you to understand course materials covered in the lectures. Distance students can submit homework online. Late submissions are not accepted.

Projects: A class project will be assigned. The project includes a formal report and a
presentation. For distance learning students, a Powerpoint presentation (preferably
with audio recording) would be sufficient (online submission).

Exams: One final exam will be given. The final will be comprehensive.

Academic Misconduct: Any cheating in the exams will result in a grade of “F” automatically.
Refer to the section on “Academic Misconduct” outlined in the IUPUI Code of
Student Rights, Responsibilities, and Conduct for details.
http://www.iupui.edu/code/CSR_0106.pdf

Grading: Homework 30%, Class Project 40%, Final Exam 30%.
### Grading Scale

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**Americans with Disabilities Act:**
If you need any special accommodations due to a disability, please contact Adaptive Educational Services at (317)-274-3241. The office is located in CA 001E.

**Course Content:**

1. **INTRODUCTION**
   Components of Powertrain and Interfaces
   Physical content of each system
   Powertrain requirements: Functional, Performance, Balancing
   Material selection and Packaging considerations
   Powertrain Calibration
   Powertrain-chassis integration
   Cost alternatives
   Technology trends

2. **FUEL DELIVERY SYSTEMS**
   Fuel types, basics, chemistry, alternatives
   Fuel Delivery
   - Pressure, flow, enrichment
   - Pumping
   - Storage – level sensing
   - Noise & Vibration
   Statutes, legislative regulations
   - Emissions, permeation, tailpipe, fill, MVSS, crash

3. **POWERTRAIN MOUNTING**
   Impact of mounting metrics
   - Noise and vibration, Isolation, vehicle dynamics,
   - Crash, Safety, Quality Reliability and Durability (QRD)
   Functional requirement of mounting systems
   Types of mounting systems
   Mounting component types
   - Hydraulic, elastomeric, active (controlled)

4. **ENGINE**
4A. AIR INDUCTION
Engine airflow management
  - Pressure loss
  - Air flow measurement
  - Air filtration
  - HC emissions
Management of engine noise out of Air Induction System
  - Noise prevention, reduction, cancellation
Structural integrity
  - Flow and noise
Legislative regulations
  - Exterior noise, emissions

4B. EXHAUST
Engine exhaust management
  - Backpressure
  - Emissions
  - Thermal
Engine noise management
  - Noise prevention, reduction, cancellation
Types of exhaust
  - Gasoline, diesel, E-85
Structural integrity
Legislative regulations
  - Exterior noise, emissions

4C. ENERGY CONVERSION
Combustion management
  - Fuel efficiency, emissions, losses
  - Ignition and fuel injection control
  - Knocking and control
Emission control
  - Exhaust gas recirculation (EGR)
  - Catalytic converter
Efficiency
  - Turbo-charging, variable geometry turbo
  - Supercharging
Interfaces
Legislative regulations
  - Emissions, CAFE, noise and vibration

5. TRANSMISSION
Types of transmission
  - Manual, automatic (countershaft and planetary), CVT
Interfaces
  - Engine, driveline, chassis
Structural Integrity
  - Noise, vibration, jerk, durability

6. DRIVELINE SYSTEMS
Classification of driveline systems:
  - Front Wheel Drive (FWD), Rear Wheel Drive (RWD), All Wheel Drive (AWD)
Types of AWD systems
  - Part time, active, full time, on-demand
Half shafts, propeller shafts, differentials, axles, joints and couplings
7. POWERTRAIN DRIVER INTERFACE
Shift controls and pedals
  Types (Adjustable, etc.)
  Ergonomics and packaging
    Effort, travel, spacing and location
    Efforts and linkage kinematics
Cable attachment systems
  Technology progression
    Shift by wire, electronic throttle control
Regulations – MVSS

8. INTEGRATION OF POWERTRAIN SYSTEM
Gap analysis between functional requirements and interface issue
  Modeling and simulation tool to analyze the impact of design change on integration
Introduction of design methodologies to address issues relating integration
  Existing and novel ideas
New technologies on PT integration

Course Outcomes:

Upon successful completion of the course, students should be able to:
  i.  Explain current state of automotive powertrains and their integration in vehicles [e].
  ii. Analyze powertrain mount types and various mounting configurations [e, a4].
  iii. Analyze automotive fuel and accessory systems [e].
  iv.  Synthesize driveline components and system, and powertrain driver interfaces [e].
  v.   Solve various aspects of engine system: Air Induction; Exhaust; Turbo/super-Charging; Speed Control;
        Knock Control; Fuel Injection timing control; Ignition control of SI engines [a4].
  vi.  Analyze Transmission: Transmission/driveline modeling; Transmission control for gear shifting [a4].
  vii. Design Driveline control: Traction control; On-demand All-Wheel-Drive control [a4].
  viii. Analyze hybrid electric vehicle (HEV) powertrain system [e, a4].
  ix.  Analyze powertrain integration concepts [e, a4].
**New Course IN ME-ME 50104**

**Course Request Key Fields**

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<tr>
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<td>School: ENGR-Purdue School of Engineering</td>
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<td>Subject: ME-Mechanical Engineering</td>
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**Course Catalog Attributes**

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<td>15</td>
<td>Prerequisites/Corequisites (Information Only): Graduate standing or Instructors consent</td>
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<td>Course Description: The holistic view of powertrain development that includes engine, transmission, and driveline is now well accepted. Current trends indicate an increasing range of engines and transmissions in the future with, consequently, a greater diversity of combinations. This course discusses engines, transmissions, and drivelines in relation to their interfaces with chassis systems. This course also explores various aspects of powertrain integration. Novel concepts relating, for example, to continuously variable transmissions (CVTs) and hybridization as well as approaches to modeling, analysis, and simulation will be discussed.</td>
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**Course Attributes for Scheduling**

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Instruction Mode (select all that apply):
- Audiovisual-live
- Audiovisual-recorded
- Face-To-Face

Instructor Name: Sohel Anwar

Estimated Enrollment: 15

Estimated Enrollment Percent Expected to be Graduate Students: 80

Frequency of Schedule: Once Per Year

Course Typically Offered: Spring Term

Will this course be required for majors? No

Justification for New Course:
The proposed course was taught as dual level course in 2009, 2010, and 2011. The average enrollment was about 20. Half of the students were from Industry while rest were full time students. Clearly, the enrollment shows a great level of interest from the students who want to take such a course.

Does this course overlap with existing courses? No

Please explain:

Have you contacted the appropriate department, school, etc. affected by the overlap? Yes

Are the necessary reading materials currently available in the appropriate library? Yes

Do you anticipate this course will require a special fee? (Information Only) No
1. INTRODUCTION
Components of Powertrain and Interfaces
Physical content of each system
Powertrain requirements: Functional, Performance, Balancing
Material selection and Packaging considerations
Powertrain Calibration
Powertrain-chassis integration
Cost alternatives
Technology trends

2. FUEL DELIVERY SYSTEMS
Fuel types, basics, chemistry, alternatives
Fuel Delivery
Pressure, flow, enrichment
Pumping
Storage level sensing
Noise & Vibration
Statutes, legislative regulations
Emissions, permeation, tailpipe, fill, MVSS, crash

3. POWERTRAIN MOUNTING
Impact of mounting metrics
Noise and vibration, Isolation, vehicle dynamics,
Crash, Safety, Quality Reliability and Durability (QRD)
Functional requirement of mounting systems
Types of mounting systems
Mounting component types
Hydraulic, elastomeric, active (controlled)

4. ENGINE
4A. AIR INDUCTION
Engine airflow management
Pressure loss
Air flow measurement
Air filtration
HC emissions
Management of engine noise out of Air Induction System
Noise prevention, reduction, cancellation
Structural integrity
Flow and noise
Legislative regulations
Exterior noise, emissions

4B. EXHAUST
Engine exhaust management
Backpressure
Emissions
Thermal
Engine noise management
Noise prevention, reduction, cancellation
Types of exhaust
Gasoline, diesel, E-85
Structural integrity
Legislative regulations
Exterior noise, emissions

4C. ENERGY CONVERSION
Combustion management
Fuel efficiency, emissions, losses
Ignition and fuel injection control
Knocking and control
Emission control
Exhaust gas recirculation (EGR)
Catalytic converter
Efficiency
Turbo-charging, variable geometry turbo
Supercharging
Interfaces
Legislative regulations
Emissions, CAFE, noise and vibration

5. TRANSMISSION
Types of transmission
Manual, automatic (countershaft and planetary), CVT
Interfaces
Engine, driveline, chassis
Structural Integrity
6. DRIVELINE SYSTEMS
Classification of driveline systems:
- Front Wheel Drive (FWD), Rear Wheel Drive (RWD), All Wheel Drive (AWD)
Types of AWD systems
- Part time, active, full time, on-demand
- Half shafts, propeller shafts, differentials, axles, joints and couplings

7. POWERTRAIN DRIVER INTERFACE
Shift controls and pedals
- Types (Adjustable, etc.)
- Ergonomics and packaging
- Effort, travel, spacing and location
- Efforts and linkage kinematics
- Cable attachment systems
- Technology progression
- Shift by wire, electronic throttle control
- Regulations MVSS

8. INTEGRATION OF POWERTRAIN SYSTEM
- Gap analysis between functional requirements and interface issue
- Modeling and simulation tool to analyze the impact of design change on integration
- Introduction of design methodologies to address issues relating integration
- Existing and novel ideas
- New technologies on PT integration

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### Representative Bibliography or Resources:


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### Teaching and Learning Methods:

Lecture with video streaming

### Learning Outcome/Objectives:

Upon successful completion of the course, students should be able to:
- i. Explain current state of automotive powertrains and their integration in vehicles [e].
- ii. Analyze powertrain mount types and various mounting configurations [e, a4].
- iii. Analyze automotive fuel and accessory systems [e].
- iv. Synthesize driveline components and system, and powertrain driver interfaces [e].
- v. Solve various aspects of engine system: Air Induction; Exhaust; Turbo/super-Charging; Speed Control; Knock Control; Fuel Injection timing control; Ignition control of SI engines [a4].
- vi. Analyze Transmission: Transmission/driveline modeling; Transmission control for gear shifting [a4].
- vii. Design Driveline control: Traction control; On-demand All-Wheel-Drive control [a4].
- viii. Analyze hybrid electric vehicle (HEV) powertrain system [e, a4].
- ix. Analyze powertrain integration concepts [e, a4].

### Learning Assessment:

Homework 30%, Class Project 40% (Project Report 30% and Presentation 10%), Final Exam 30%.

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### PUL - Major emphasis (Mandatory)

- Information Only:

### PUL - Moderate emphasis (Optional)

- Information Only:

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IUPUI Campus Specific Questions
### University Graduate School Specific Questions

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<th>Answer</th>
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<td>b.</td>
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<td>Please list the joint-listed (combined section) courses:</td>
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### Student Enrollment Services

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