**PURDUE UNIVERSITY**

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

**DEPARTMENT**: Mechanical Engineering  
**EFFECTIVE SESSION**: Spring 2012  
**Graduate Council Doc. No. 10-16d**

**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

**PROPOSED**

- **Subject Abbreviation**: ME
- **Course Number**: 51100
- **Long Title**: Heat Transfer in Electronic Systems
- **Short Title**: Heat Transfer Elec Sys

**EXISTING**

- **Course Number**: ________
- **Long Title**: ________
- **Short Title**: ________

**TERMS OFFERED**

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

**CAMPUS(ES) INVOLVED**

- [ ] Calumet  
- [ ] Cont Ed  
- [x] Ft. Wayne  
- [ ] Indianapolis  
- [ ] N. Central  
- [x] Tech Statewide  
- [x] L. W. Lafayette

**CREDIT TYPE**

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<th>Meetings Per Week</th>
<th>Weeks Offered</th>
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**COURSE ATTRIBUTES**: Check All That Apply

- [ ] Pass/Not Pass Only
- [ ] Satisfactory/Unsatisfactory Only
- [ ] Repeatable
- [ ] Maximum Repeatable Credit: ________
- [ ] Credit by Examination
- [ ] Special Fees
- [ ] Registration Approval Type
- [ ] Instructor
- [ ] Department
- [ ] Variable Title
- [ ] Honors
- [ ] Full Time Privilege
- [ ] Off Campus Experience

**COURSE DESCRIPTION (INCLUDE REQUISITES/RESTRICTIONS):** ME 51100 Heat Transfer in Electronic Systems, Sem. 2 (alternate years), Class 3, cr. 3. Prerequisite: ME 31500 or consent of instructor. This course covers both traditional and more innovative methods for heat extraction in electronic systems and the effectiveness and applicability of these methods over a wide range of scales. Special emphasis is given to industry-related applications with experts often attending and presenting material as part of class instruction. Professor Garimella.

**Calumet Department Head**  
**Date**: ________  
**Calumet School Dean**  
**Date**: ________

**Fort Wayne Department Head**  
**Date**: ________  
**Fort Wayne School Dean**  
**Date**: ________

**Indianapolis Department Head**  
**Date**: ________  
**Indianapolis School Dean**  
**Date**: ________

**North Central Department Head**  
**Date**: ________  
**North Central School Dean**  
**Date**: ________

**West Lafayette Department Head**  
**Date**: ________  
**West Lafayette College/School Dean**  
**Date**: ________

**Graduate Area Committee Convenor**  
**Date**: ________

**OFFICE OF THE REGISTRAR**

**Calumet Undergrad Curriculum Committee**  
**Date**: ________

**Fort Wayne Chancellor**  
**Date**: ________

**Undergrad Curriculum Committee**  
**Date**: ________

**APPROVED**  
**Date**: 2/17/11

**Date Approved by Graduate Council**  
**Date**: 2/18/11

**Graduate Council Secretary**  
**Date**: 3/11/11

**West Lafayette Registrar**  
**Date**: 3/11/11

**SEE ATTACHED COPY FOR SIGNATURES**
### Mechanical Engineering

#### INSTRUCTIONS:
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

#### PROPOSED:
- **Subject Abbreviation**: ME
- **Course Number**: 504
- **Course Title**: Heat Transfer Elec Sys

#### EXISTING:
- **Subject Abbreviation**:
- **Course Number**

#### TERMS OFFERED
- **EFFECTIVE SESSION**: Fall 2009
- **CAMPUS(ES) INVOLVED**:
  - Calumet
  - Fort Wayne
  - Indianapolis

#### Heat Transfer in Electronic Systems

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<th>Minimum Cr. Hrs</th>
<th>Maximum Cr. Hrs</th>
<th>% of Credit</th>
<th>Delivery Method</th>
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#### COURSE DESCRIPTION

**ME 504 Heat Transfer In Electronic Systems, Sem. 2 (alternate years), Class 3, cr. 3. Prerequisite: ME 315 or consent of instructor.**

This course covers both traditional and more innovative methods for heat extraction in electronic systems and the effectiveness and applicability of these methods over a wide range of scales. Special emphasis is given to industry-related applications with experts often attending and presenting material as part of class instruction.
TO: The Engineering Faculty

FROM: The Faculty of the School of Mechanical Engineering

RE: New Course – ME 504 Heat Transfer in Electronic Systems

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

ME 504 Heat Transfer in Electronic Systems
Sem. 2 (alternate years), Class 3, cr. 3
Prerequisite: ME 315 or consent of instructor

This course covers both traditional and more innovative methods for heat extraction in electronic systems and the effectiveness and applicability of these methods over a wide range of scales. Special emphasis is given to industry-related applications with experts often attending and presenting material as part of class instruction.

Reason: This course has been taught three times on an experimental basis with the following enrollments: spring 2003 - 18 students, spring 2005 – 22 students, and spring 2007 - 9 students. This course introduces concepts in thermal management of electronics, demonstrates the application of first principles to electronics cooling problems, and provides students with sound tools to approach existing industrial applications while also raising awareness of emerging and novel approaches.

James D. Jones, Associate Head/Professor
School of Mechanical Engineering

APPROVED FOR THE FACULTY
OF THE SCHOOLS OF ENGINEERING
BY THE ENGINEERING
CURRICULUM COMMITTEE

ECC Minutes # 11
Date 12/14/09
Chairman ECC R. Cypri
HEAT TRANSFER IN ELECTRONIC SYSTEMS

Course Outcomes

1. To introduce concepts in thermal management of electronics to senior undergraduate and graduate students and practicing engineers.
2. To provide an appreciation for the applications of first principles to electronics cooling and packaging problems in industry.
3. To provide students with sound tools to approach existing packaging and cooling applications, while also raising awareness of novel techniques at the cutting edge.

Introduction to Packaging & Heat Transfer Principles (4 wks)

1. Introduction to thermal management
2. Heat transfer modes
3. Thermal spreading and contact resistance
4. Natural convection and radiation
5. Forced convection
6. Boiling and condensation
7. Microscale heat transfer

Cooling Technologies (4 wks)

1. Fin analysis; heat sink design and optimization
2. Air and liquid jet impingement
3. Immersion cooling
4. Phase change energy storage
5. Multi-mode heat transfer problems
6. Case studies and applications

Systems Analysis (2.5 wks)

1. Thermal systems analysis
2. Cold plates and heat exchangers
3. Flow network modeling
4. Thermodynamic analysis of cooling systems; economic analysis
5. Compact models
6. Acoustics and mechanical design issues

Emerging Technologies (3 wks)

1. Heat pipes and thermosyphons
2. Microchannel heat exchangers
3. Thermoelectric and thermoacoustic cooling
4. Piezoelectrics
5. Other
6. Thermal challenges and trends

Thermal Measurements (1.5 wks)

1. Temperature, pressure, flow, sound, strain and other measurements
2. Microscale measurement techniques
3. Uncertainty in experimental measurements
**COURSE NUMBER:** ME 504  
**COURSE TITLE:** Heat Transfer in Electronic Systems

**REQUIRED COURSE OR ELECTIVE COURSE:** Elective

**TEXTBOOK/REQUIRED MATERIAL:** None

**COORDINATING FACULTY:** S. V. Garimella

**COURSE DESCRIPTION:** This course covers both traditional and more innovative methods for heat extraction in electronic systems and the effectiveness and applicability of these methods over a wide range of scales. Special emphasis is given to industry-related applications with experts often attending and presenting material as part of class instruction.

**ASSESSMENTS TOOLS:**
1. Homework assignments.
2. Exams.
3. Projects to be done both individually and in group settings.

**PROFESSIONAL COMPONENT:**
1. Engineering Topics: Engineering Science – 1 credit (67%)
   Engineering Design – 2 credits (33%)

**NATURE OF DESIGN CONTENT:** Several short-term design projects involving open-ended problems and case studies, needing computational analysis, using commercial codes and solvers.

**COMPUTER USAGE:** Required for analysis needed in homework assignments and class projects.

**COURSE STRUCTURE/SCHEDULE:**
1. Lecture – 2 days per week at 75 minutes each.

**PREPARED BY:** S. V. Garimella  
**REVISION DATE:** June 13, 2007
A. Justification for the Course:

- This course has been taught three times on an experimental basis with the following enrollments: spring 2003 – 18 students, spring 2005 – 22 students, and spring 2007 – 9 students. This course introduces concepts in thermal management of electronics, demonstrates the application of first principles to electronics cooling problems, and provides students with sound tools to approach existing industrial applications while also raising awareness of emerging and novel approaches.

- The proposed ME 50400 course covers advanced topics in heat extraction in electronic systems. This course builds off the fundamental principles in ME 31500 and is intended for entry-level graduate students, although some undergraduates may take the course. The course will be taught in alternate years with an anticipated enrollment of 15-20 students, mostly graduate students.

B. Learning Outcomes and Methods of Evaluation or Assessment:

- 1) To introduce concepts in thermal management of electronics to senior undergraduate and graduate students and practicing engineers, 2) To provide an appreciation for the applications of first principles to electronics cooling and packaging problems in industry, and 3) To provide students with sound tools to approach existing packaging and cooling applications, while also raising awareness of novel techniques at the cutting edge.
• Homework assignments, exams, and projects to be done both individually and in group settings.
• 1. Engineering Topics: Engineering Science – 1 credit (67%) & Engineering Design – 2 credits (33%)
  o Criteria:
    | ☒ Exams and Quizzes | ☒ Papers and Projects |
    | ☒ Homework          | ☐ Laboratory Exercises |
    | ☐ Attendance and Class Participation | ☐ Extra Credit Policies |
• This course is taught by lecture and the program outcomes are described in the program map.
  o Method of Instruction:
    | ☒ Lecture | ☐ Recitation |
    | ☐ Presentation | ☐ Laboratory |
    | ☐ Lab Prep | ☐ Studio |
    | ☐ Distance | ☐ Clinic |
    | ☐ Experimental | ☐ Research |
    | ☐ Ind. Study | ☐ Pract/Observe |
    | ☐ Seminar |

C. Prerequisite(s):
• ME 31500 – Heat and Mass Transfer
• Required for analysis needed in homework assignments and class projects.

D. Course Instructor(s):
• Suresh Garimella, R. Eugene and Susie E. Goodson Distinguished Professor of Mechanical Engineering
• Is the instructor currently a member of the Graduate Faculty? ☒ Yes ☐ No Click here to enter text.
  (If the answer is no, indicate when it is expected that a request will be submitted.)

E. Course Outline:
• Introduction to Packaging & Heat Transfer Principles (4 weeks), Cooling Technologies (4 weeks), System Analysis (2.5 weeks), Thermal Measurements (1.5 weeks), and Emerging Technologies (3 weeks)

F. Reading List (include course text):
• No textbook required.
• No textbook required.

Library Resources:

• No resources needed.

H. Example of a Course Syllabus:

_Tentative Schedule - Spring 2009_ [1]

[1] Some of the lectures will be delivered by invited guest speakers who are experts in the field.

<table>
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<th>Period</th>
<th>Date</th>
<th>Topic[1]</th>
<th>Important Due Date</th>
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<tr>
<td>1</td>
<td>T 13</td>
<td>Heat transfer fundamentals – review of conduction, convection and radiation</td>
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<td>Th 15</td>
<td>&quot;Thermal management of electronic systems: Challenges and opportunities,&quot; Guest Lecture, Dr. Ravi Mahajan, Intel Corp.</td>
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<td>4</td>
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<td>Conjugate conduction and thermal spreading</td>
<td>HW 1</td>
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<td>T 27</td>
<td>Fin analysis, heat sink design</td>
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<td>6</td>
<td>Th 29</td>
<td>Natural convection in electronics packaging</td>
<td>Design Project 1</td>
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<td>February</td>
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<td>Radiation in electronic packages</td>
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<td>T 10</td>
<td>Forced convection in electronics</td>
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<td>10</td>
<td>Th 12</td>
<td>Boiling and condensation</td>
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<td>T 17</td>
<td>Phase change energy storage with PCMs</td>
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<td>12</td>
<td>Th 19</td>
<td>&quot;Liquid cold plates for electronics cooling,&quot; Guest Lecture, Dr. Sukhvinder Kang, Aavid Thermalloy</td>
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<td>&quot;Immersion cooling of electronics,&quot; Guest Lecture, Dr. Phil Tuma, 3M Corp.</td>
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<td>&quot;Introduction to heat pipes,&quot; Guest Lecture, Dr. Mark North, Thermacore</td>
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