# Multiscale Thermal Engineering (ME 4803)
# Course Outline and Syllabus (Fall 2013)

*George W. Woodruff School of Mechanical Engineering*
*Georgia Institute of Technology*

**Catalog description:** An introduction to emerging thermal technologies in energy, electronics cooling, transportation, and other relevant industry sectors and the fundamentals required to design such technologies from the nanoscale up.

**Credits/prerequisites:** 3 credit hours/Intro-Fluid & Thermal Engr (ME3720) or Heat Transfer (ME3345) with concurrency

**Course Objectives:**
1. **Thermal energy technology performance calculations.** Calculate the efficiency and/or capacity of several emerging technologies for thermal energy conversion, transport, and storage; and explain the basic operating principles and key performance limits in simple algebraic terms.
2. **Solid-state physics terminology.** Clearly describe the physical significance of terminology used often in the mathematical description of energy and material physics.
3. **Nanoscale physics calculations.** Explain how reducing the dimensions of structures to the nanoscale could affect the storage, transport, and conversion of basic energy carriers using specific examples that illustrate salient points in simple algebraic terms.
4. **Applied nanoscale physics and thermal systems design.** Balance form and function at subsystem levels to choose appropriate nanostructure assemblies to increase the efficiency and/or capacity of technologies used for thermal energy conversion, transport, and storage.
5. **Critical evaluation.** Critique the potential cost, health, and societal impacts of using nanostructures in technologies used for thermal energy conversion, transport, and storage.

**Textbook:** Course notes and handouts

**References:**
1. D. L. Schodek, P. Ferreira, M. F. Ashby, *Nanomaterials, Nanotechnologies and Design: An Introduction for Engineers and Architects*, Butterworth-Heinemann, 2009.
2. G. Chen, *Nanoscale Energy Transport and Conversion: A Parallel Treatment of Electrons, Molecules, Phonons, and Photons*, Oxford Press, 2005.
3. Z. M. Zhang, *Nano/Microscale Heat Transfer, McGraw-Hill*, New York, 2007

**Official course website:** GT T-Square.

**Class time and location:** Tu/Th 12:05-1:25 pm  Cherry Emerson 204

**Instructor:** Prof. Baratunde Cola / 316 Love / 404-385-8652 / cola@gatech.edu
**Office hours:** Tuesday 3:30-5:00 pm or by appointment

**Grading method:**
Homework: 30%; Project: 30%; Mid-term exams (2): 20% each

The overall grade in the course will be based not only on the absolute percentage obtained in the course, but also on the performance of the entire class. The grading will, however, not be strictly according to a normal distribution. Minimal requirements for passing or receiving a particular grade will be maintained irrespective of the class performance. Transitions between grades will be based on potential discrete demarcations between student scores.

**Homework (30%): In-class prerequisite quiz (3%) and 3 problem set assignments (27%).** Homework sets must be submitted before the start of class on the due dates scheduled below to receive full credit (you will lose 10% of total earned points if turned in late, yet before the end of class). **Late homework** may be turned in up to 48 hrs following the end of class at a **loss of an extra 15% credit for each day**. No credit is granted for homework submitted more than 48 hrs after the due date.

**Project (30%):** Detailed analysis of a thermal energy technology and a proposed enhancement using available nanostructures considering how the technology works, relevant energy length scales, calculation of performance limits, quantification of advantages gained going to the nanoscale, manufacturing; and potential cost, health, and societal impacts. The deliverable is a written proposal.

**Exams (40%):** There will be two in-class exams. The exams will be open notes. See the tentative schedule for examination dates. Please see the instructor immediately if a conflict arises. You will need a calculator for the exams. Discussion of grades for mid-term exams will be entertained up to 2 days after receipt of grades. The dates given for the mid-terms are ***tentative*** based on expectations for class progress. These dates might be changed during the course of the semester with at least ***one week's notice***.

If you will miss an exam, you must provide an appropriate documentation for the absence – examples include a doctor's certificate justifying the absence due to health reasons, or a letter from the appropriate academic authority requiring you to be present at some other university sanctioned activity during the exam time. Such notifications must be provided well in advance of the exam. Requests made after the exam for accommodating an absence will under almost all circumstances not be honored. For legitimate absences, if you miss a mid-term exam, the weight of the other exam will be increased proportionately. No make-up exams will be given.

**Instructor commitment:** You can expect your instructor to be courteous, punctual, well-organized, and prepared for lecture and other class activities; to answer questions clearly; to be available during office hours or to notify you beforehand if he is unable to keep them; to provide a suitable guest lecturer or assignment when he is traveling; and to grade uniformly and consistently according to the posted guidelines.

**Class expectations:** I expect you to be **creative**, **organized**, and **process focused** in the work you do. We **communicate** and **trust** in each other to fulfill our class responsibilities. We give our **best effort** always and approach our work with a **positive attitude**.

**General notes:** If you have any special learning needs, you must inform the instructor at the beginning of the course, with appropriate documentation, about what specific arrangements and accommodations are needed. Notifications of such needs after the semester is underway will not be deemed acceptable (unless they are diagnosed during the course of the semester).

Academic integrity issues will be handled in accordance with Institute Policies.

**TENTATIVE COURSE OUTLINE (SUBJECT TO CHANGE)**

| <u>**Topics**</u> | <u>**Sessions**</u> | <u>**Dates**</u> | <u>**Reading & Assignments**</u> |
|---|---|---|---|
| Energy, nanotechnology, and society: the challenges and opportunities | 1 | 8/20 | *TBA* |
| | 2 | 8/22 | |
| Introduction to energy at the nanoscale and energy quantization | 3 | 8/27 | *Ch. 1; Ch. 6* |
| | 4 | 8/29<br>*In-class prerequisite assessment, i.e., a quiz* | |
| Introduction to several emerging thermal energy storage, transport, and conversion technologies: fundamentals and limits | 5 | 9/3 | |
| | 6 | 9/5 | ***Project assigned (due 12/3)*** |
| | 7 | 9/10 | |
| Fundamentals of material structure | 8 | 9/12 | *Ch. 4.1, 4.2*<br>***HW1 (due 9/26)*** |
| | 9 | 9/17 | |
| Electronic and vibrational energy states in materials | 10 | 9/19 | |
| | 11 | 9/24 | |
| Thermal energy and heat capacity: energy storage | 12 | 9/26 | |
| Review | 13 | 10/1 | |
| **** Exam I ****** | **14** | **10/3** | |
| Quantum conductance, Boltzmann equation, and surface/interface resistance: energy transport | 15 | 10/8 | |
| | 16 | 10/10<br>*(10/15 – Fall break)* | |
| | 17 | 10/17 | |
| | 18 | 10/22 | ***HW2 (due 11/7)*** |
| The affect of nanostructuring on energy storage, transport, and conversion | 19 | 10/24 | *Ch. 7.7* |
| | 20 | 10/29 | |
| Nanomaterials synthesis, characterization, and product forms | 21 | 10/31 | *Ch. 8; Ch. 10.1, 10.4* |
| | 22 | 11/5<br>*In-class SEM activity* | |
| Design and material selection best practices | 23 | 11/7 | *Ch. 3.1-3.4; Ch. 5*<br>***HW3 (due 11/19)*** |
| | 24 | 11/12 | |
| | 25 | 11/14 | |
| Case studies and cost considerations | 26 | 11/19<br>*(11/21 – Thanksgiving break)* | *Ch. 9.1, 9.3, 9.7, 9.9* |
| Health and environmental considerations | 27 | 11/26 | *Ch. 11.1, 11.3, 11.4; NNI report* |
| **** Exam II ****** | **28** | 11/28 | |
| Project presentations | 29 | 12/3<br>*(dead week)* | *Project due* |
| Project discussions and critique of national nanotechnology priorities | 30 | 12/5<br>*(dead week)* | |