Thermoelectric Effect, Materials, Measurement and Application

Energy conservation, use and efficiency are increasing important issues in the daily lives of all people in the modern world. Recent increases in energy costs here in the United States, industrial growth throughout the world, plus the steady decline of traditional energy supplies encourages a call for new technological solutions for an impending energy short fall. One avenue forward, towards improving efficient energy conversion, is through the broader use and development of thermoelectric materials.

All thermoelectric materials rely on a phenomenon called the thermoelectric effect in which a temperature difference creates an electric potential (Seebeck Effect) or an electric potential creates a temperature difference (Peltier Effect). While all materials have a nonzero thermoelectric effect, in most materials it is too small to be useful. Developing low cost materials that have a sufficiently strong thermoelectric effect could be used for applications including power generation, refrigeration and a variety of other applications.

In order to educate our students about the importance of energy conservation and this type of "green" technology, I propose to re-focus four lectures from PH183, Fundamentals of Physics on this topic. In addition to the lectures each student will be assigned a journal article on this topic and be required to submit a brief written summary of the article.

i) Energy Use and the Physics of the Seebeck and Peltier Effect.
ii) Thermoelectric Materials: Past and Present
iv) Thermoelectric Applications: Satellites, Exhaust Pipes, Wine Coolers

In addition to the lectures each student will be assigned a journal article on this topic and be required to give a written summary.
Scheduled class meeting times:
Tuesday 1:30-2:45 PM and Thursday 1:30-2:45 PM
Room = Higgins Hall 310


Instructor: Fr. Cyril P. Opeil, S.J., Ph.D.
Assistant Professor
Office: Higgins 330J, 617-552-8450
Laboratory: Higgins 130, 617-552-3589

Office Hours: As posted at 330J:
Tuesday 3:15-5:00 PM
Thursday 3:15-5:00 PM

To contact Fr. Opeil, S.J. outside of class the most efficient way is via email: opeil@bc.edu, please feel free to call at 2-8450 or 2-3589 but do not leave a phone message.

Graduate Assistants/Home Work Grader:
Zhensong Ren (2-3436, Higgins 160, renzd@bc.edu) is the teaching assistant assigned to this class. His primary job is to grade homework assignments, provide assistance on homework problems upon request, and assist the instructor in correcting the exams.

Pre-requisites: There are no Boston College pre-requisites for this course. A high-school algebra, calculus and/or a previous course in high school physics will prove to be a very helpful background.

Co-requisites: Students should also be enrolled in Physics Laboratory.

Grading:
- 3 mid-term exams (15% each) 45%
- 1 final exam (comprehensive) 20%
- homework 25%
- Biographical essay 10%

Course Description: Foundations in Physics PH183 is a three-credit course designed to provide a basic understanding of the physical world through a combination of simple theoretical models, controlled experiments and mathematics. The ability to solve word problems will be integral to success in this course. In the first part the physics of mechanics is introduced which involves one and two-dimensional motion and the effects of gravity on free falling bodies. Newton’s three laws of motion are of particular interest here. In the second part of the course the concept of thermal energy is explored and how energy is transferred in matter. The third part of this course investigates simple harmonic motion, planetary motion and wave behavior as a means of energy transfer. Finally, several lectures will be given on Energy Use and Sustainability. The primary
focus of these lectures will be on the physics associated with thermoelectric materials and devices.

Course Goals: The first semester goals of this course are: (1) to understand the fundamental principles (forces, motion, potential and kinetic energy) governing: freely falling bodies in one and 2 dimensions, thermal energy transfer and how vibrations transmit energy (2) to formulate these principles in mathematical terms; and (3) to be able to use these mathematical expressions to predict the behavior of simple systems (4) to make the student aware of energy sources and efficient use in the modern world.

Attendance, Participation and Academic Honesty: Continuity and active participation are crucial to the success of this course. You are responsible for all information from each class lecture session whether you attend or not. Absences due to excused absence sports activities are to be discussed with the instructor prior to the planned absence.

Academic honesty is expected at all times in accordance with published Boston College policies. Discussion of the concepts and problem-solving techniques between students, and with the instructor and grader, is strongly encouraged. However, under no circumstances is it acceptable to copy and turn in solutions taken from ANY source – all work must be your own. Please review the Boston College Standards of Academic Integrity that are published in the university catalog and on the web at: http://www.bc.edu/offices/stserv/academic/resources/policy/#integrity. It is your responsibility to ensure that all work you submit is in accordance with university policies. If you have any questions, please consult with me. Violations will be reported to the Deans' Office and reviewed by the College's Committee on Academic Integrity. Sanctions for violating this policy include the possibility of failing this course.

Textbook Reading Assignments: Members of this course are responsible for reading particular pages in the textbook on a daily/weekly basis. Textbook sections listed in the schedule are to be read prior to attending class. Any changes in the textbook reading assignments schedule will be announced in class.

Homework Exercises: Expect homework assignments each week, note particular schedule below. Homework solutions are due on Friday afternoon in the instructor’s office (Higgins 330J) by 4:45 PM. The instructor will be in Higgins 330J from 4:15-4:45 to collect the homework assignments. Homework turned in after that time, e.g. 4:46 PM will be graded, but worth a maximum of 50% of the normal credit. Homework solutions will be available to the students after homework assignments are collected. Emailing the instructor with the solutions prior the deadline also acceptable.

In order to receive FULL CREDIT for your problem solutions you must fully explain your solutions: briefly outline the logic of your approach to the solution in words, and write out all equations used to obtain your solution. For multiple-questions, the answer requires more than a letter choice, you must include an explanation why that choice is correct. Please be neat: if we can’t read it, we can’t grade it properly. Homework exercises are worth 10 points each and are given partial credit for incomplete answers.
Students are strongly encouraged to discuss problems with the instructor – during office hours – they are posted. The course calendar/schedule below lists when assignments are due. Actually doing the problems is not the equivalent of copying the problems from another student's solution.

Homework solutions may be emailed to the instructor (Opeil@bc.edu) prior to this date and time if the student plans not hand-in homework assignments for any reason. Homework assignments will not be accepted for full credit after the time on the assigned dates. For problem set details see schedule below. Corrections and emendations to the homework schedule may be made by the instructor as the course progresses.

Class participation: Students are expected to participate in class discussions and exercises, and will be given a grade based on that participation. Clearly you need to attend class to participate, and attendance in classes will be monitored and will count towards your grade.

Midterm and Final Exams: Three written midterms (75 minutes each) and a cumulative final exam (two hours) are to be given according to the Course Schedule listed below. Midterm exams cover all material discussed in class, example problems, assigned readings in the textbook and problems assigned for homework. No one is allowed to take the final exam at any other time without written permission of the A & S Dean. Anyone not taking the final exam will receive a grade of zero for that exam and the grade will be averaged in with the other grade components.

Disabilities: If you have a disability and will be requesting accommodations for this course, please register with Kathy Duggan [kathleen.duggan@bc.edu], Associate Director, Academic Support Services, The Connors Family Learning Center (learning disabilities and ADHD) or Suzy Conway [suzy.conway.1@bc.edu], Assistant Dean for Students with Disabilities (all other disabilities). Advanced notice and appropriate documentation are required for accommodations.

Eating and Drinking: Absolutely no food or beverages are to be brought into or consumed in the lecture room. Not consuming of food and or beverages in the lecture hall is a matter of simple courtesy and civility toward the professor and fellow students.

Extra Help:
Please see the instructor during his regularly scheduled office hours if you have any questions or concerns about this course, homework or course material. See graduate student graders or teaching assistants assigned to this course for additional help. Also, there are additional resources. You may drop in on afternoons without an appointment to the Department of Physics’ “Undergraduate Resource Room” (URR), located in the Higgins Atrium. On the 2nd floor of O’Neill Library, the Connors Family Learning Center has tutors available for introductory physics. Sessions are free of charge, but you must make your appointments in advance.

Physics Laboratory:
There are many laboratory sections that run concurrent with this lecture course. Please, consult your academic advisor if you should be enrolled in one of them. The lecture and laboratory courses are completely independent to accommodate student schedules.

**Energy and Thermoelectric Essay:** Each student is to write a short essay. The topic of this brief essay will be chosen from the list of articles given below. Your essay must answer the following questions.

1) What general type of materials are currently used in making thermoelectric materials/devices?
2) Describe how the use of thermoelectric materials can sustain our energy resources?
3) In the scientific article you read, what is its application and how might it be improved?
4) What applications can you imagine thermoelectric materials could be used that have not been mentioned in the literature you have researched.

The essay is to be typed, 12 point Times New Roman, double-spaced, with (approximately) one-inch margins (left and right) and include a complete bibliography. The length is minimum two pages and maximum of five pages. The absolute deadline for this essay is Monday, 29 November at 5:00 PM for full credit. Essays must be emailed to opeil@bc.edu.

You may use Wikipedia and the WWW to begin your research but do not use it as a resource nor include Wikipedia in the bibliography. Copying materials directly from the WWW is strictly forbidden in writing your essay.

See list of articles at the end of syllabus.

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**Semester Schedule for Fall 2010**

- **M-06Sept**  Labor Day no classes  
- **T-07Sept**  L01-Semester classes begin. Syllabus Review, Sec. 1.1-1.5  
- **Th-09Sept**  L02-Sec. 1.6, 1.7, 1.8, 2.1  
- **F-10Sept**  HW1: 1-4, 1-12, 1-26, 1-33, 1-36, 1-39  
- **T-14Sept**  L03-Sec. 2.2, 2.3, 2.4, 2.5, 2.6  
- **W-15Sept**  Last day for UG to declare P/F or drop class online  
- **Th-16Sept**  L04-Sec. 3.1, 3.2, 3.3, 3.4, 3.5 (Holy Spirit Mass 12:00-1:30PM)  
- **F-17Sept**  HW2: 2-11, 2-21, 2-31, 2-45, 3-3, 3-13, 3-25, 3-35  
- **T-21Sept**  L05-Sec. 4.1, 4.2, 4.3, 4.4  
- **Th-23Sept**  L06-Sec. 4.5, 4.6, 5.1, 5.2  
- **F-24Sept**  Parents weekend begins. HW3: 4-9, 4-11, 4-13, 4-17, 4-36, 4-53, 5-3, 5-11  
- **Sa-25Sept**  Parents weekend.  
- **Su-26Sept**  Parents weekend ends.  
- **T-28Sept**  L07-Sec. 5.3, 5.4, 5.5, 5.6  
- **Th-30Sept**  L08-Sec. 6.1, 6.2, 6.3, 6.4  

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- **F-01Oct**  HW4: 5-9, 5-23, 5-33, 5-53, 5-61, 6-3, 6-11, 6-24
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<thead>
<tr>
<th>Date</th>
<th>Event</th>
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<tr>
<td>T-05Oct</td>
<td>Last day to drop class through A &amp; S Dean</td>
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<td>Th-07Oct</td>
<td>1st Mid-term Exam</td>
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<td>F-08Oct</td>
<td>L09-Sec. 6.5, 7.1, 7.2, 7.3, 7.4</td>
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<td>M-11Oct</td>
<td>No classes. Columbus Day celebration.</td>
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<td>T-12Oct</td>
<td>L10-Sec. 7.5, 7.6</td>
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<td>Th-14Oct</td>
<td>L11-Review of example problems.</td>
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<td>T-19Oct</td>
<td>L12-Sec. 8.1, 8.2, 8.3, 8.4</td>
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<td>Th-21Oct</td>
<td>L13-Sec. 8.5, 8.6, 8.7</td>
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<td>F-22Oct</td>
<td>HW5: 6-49, 7-3, 7-5, 7-17, 7-27, 7-35, 7-43</td>
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<td>T-26Oct</td>
<td>L14-Sec. 9.1, 9.2, 9.3, 9.6</td>
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<td>Th-28Oct</td>
<td>L15-Sec. 10.1, 10.2, 10.3</td>
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<td>F-30Oct</td>
<td>HW7: 9-5, 9-13, 9-21, 10-3, 10-13, 10-23, 10-27, 10-33</td>
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<td>T-02Nov</td>
<td>L16-Sec. 10.4, 10.5, 11.1, 11.2</td>
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<td>Th-04Nov</td>
<td>L17-Sec. 11.3, 11.4, 11.5, 12.1</td>
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<td>F-05Nov</td>
<td>HW8: 10-45, 11-1, 11-11-11-15, 11-21, 11-27, 12-1</td>
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<td>T-09Nov</td>
<td>2nd Mid-term Exam</td>
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<td>Th-11Nov</td>
<td>L18-Sec. 12.2, 12.3, 12.4, 12.5</td>
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<td>F-12Nov</td>
<td>HW9: 12-7, 12-15, 12-35, 12-49</td>
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<td>T-16Nov</td>
<td>L19-Sec. 13.1, 13.2, 13.3, 13.4, 13.5, 13.6</td>
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<td>Th-18Nov</td>
<td>L20-Sec. 13.7, 13.8, 13.9, 13.10, 13.11</td>
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<td>T-23Nov</td>
<td>L21- Energy Use and the Physics of the Seebeck and Peltier Effect</td>
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<td>W-24Nov</td>
<td>Thanksgiving holidays begin. No classes.</td>
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<tr>
<td>Th-25Nov</td>
<td>Thanksgiving holidays. No classes.</td>
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<tr>
<td>M-29Nov</td>
<td>Last day to withdraw from a course. Essay on Thermoelectric material Due.</td>
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<td>T-30Nov</td>
<td>L22- Thermoelectric Materials: Past and Present</td>
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<td>Th-02Dec</td>
<td>L23- Measurement and Development of Thermoelectric Material Properties</td>
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<tr>
<td>F-03Dec</td>
<td>HW11: Questions on Energy Use and Waste</td>
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<td>T-07Dec</td>
<td>L24- Thermoelectric Applications: Satellites, Exhaust Pipes, Wine Coolers</td>
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<td>Th-09Dec</td>
<td>3rd Mid-term Exam, Last day of class.</td>
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<td>F-10Dec</td>
<td>Study day no classes</td>
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<td>M-13Dec</td>
<td>Study day no classes</td>
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<tr>
<td>T-14Dec</td>
<td>Final examinations</td>
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<td>W-15Dec</td>
<td>Final examinations</td>
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<td>Th-16Dec</td>
<td>Final examinations</td>
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<td>F-17Dec</td>
<td>Final exam given on this day.</td>
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<td>M-20Dec</td>
<td>Final examinations</td>
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<tr>
<td>T-21Dec</td>
<td>Final examinations</td>
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<td>Date of final examination for PH183 available online</td>
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[21] Gelbstein, Y.; Dashevsky, Z.; Dariel, M. P. In-doped Pb$_{0.5}$Sn$_{0.5}$Te p-type samples prepared by power metallurgical processing for thermoelectric applications. *Physica B* 396, 16-21, 2007.


THE OLDER I GET THE FASTER TIME SEEMS TO PASS. THAT'S JUST ONE MORE SIDE EFFECT OF GLOBAL WARMING.

THREE-MARTINI SCIENCE

"I miss the palm tree, too, but at least we can have a refrigerator."
"Good start, Maxwell. Now concentrate a bit more on aesthetics."

"I cook everything with an alternative energy source, so it may take a while."