**COURSE SYLLABUS -- Physics 5335, Fall, 2008, *Physics of Semiconductors***

1:00-2:20 pm, Tuesday and Thursday, Science Room 103

**Instructor:** Dr. C.W. Myles, Professor, Dept. of Physics. **Office:** Sc. Rm 18. **Phone:** 742-3768.

**Office Hours:** 10am – noon + 3pm – 4pm MWF & ***by appointment***.

**Web Page:** http://www.phys.ttu.edu/~cmyles/. **Email:** Charley.Myles@ttu.edu**.** A class distribution list will be developed & we can have email discussions (homework, etc.). I make announcements by email! Make sure that I have your correct email address, that you check email ***DAILY*** & that you tell me if you change email addresses!

**Course Web Page:** http://www.phys.ttu.edu/~cmyles/Phys5335/5335.html

**Objective:** Introduce students to ***the basic physics of semiconductor materials. Emphasis will be on the microscopic properties most relevant to their use as electronic materials.*** This ***ISN'T*** a device course! If you want such a course, this isn't it! (**PHYS 5336 IS** a device course!). This course is designed to ***complement & supplement*** **PHYS 5304** (Solid State) ***NOT*** to replace it! This course should ***NOT*** be taken instead of 5304!

***Student Responsibilities: Come to class prepared, do the homework, read the material before I lecture over it, and keep up as we go along.***

**Physics Level:** This course is both for MS & PhD students doing semiconductor research & students in the MS-Internship program. Engineering students are welcome! Some knowledge of elementary quantum mechanics & elementary statistical physics is assumed. Some knowledge of elementary solid state physics would be helpful, but isn't essential. This is a ***graduate*** course. It would help (but isn't vital) if you had (at least) a senior level solid state course at the level of the book by C. Kittel. Our text level is between some undergrad & graduate texts.

**Textbook:** ***Semiconductor Physics and Applications***, by M. Balkanski & R.F. Wallis, Oxford U. Press, Latest Edition. It's available from local bookstores & on-line. It's available in hardbound or paperback. New & used versions may be available. A search finds prices from $132 - $275!! ***I urge you to shop for it & to find the best price for you***.

**Supplements: 1.** ***Fundamentals of Semiconductor Physics*** ("Physics and Materials Properties"), by P. Yu & M. Cardona. Springer-Verlag. **2.** ***Semiconductor Physics*** ("An Introduction"), by K. Seeger, Springer-Verlag.

**Lectures:** From Balkanski & Wallis, supplemented by material from other sources such as the supplemental texts, research notes, & published papers.

**Other Possible Supplements:** There are ***many*** books on semiconductors & devices at various levels of depth & difficulty (see p. 4). In Rm. 18, I have shelves full of them! The library has many more. Mine are available to look at & check out. In a **graduate** course, ***I expect you to go to sources other than the texts*** to obtain different treatments of the material! I sometimes lecture from outside the text (e.g. from the literature or my own research notes). The text & the supplements have extensive bibliographies for each chapter. ***USE THEM*****!** Pages 3&4 have web resources.

**Course Topics:** Survey of basic semiconductor materials physics. As a survey, topics must be covered rapidly. A ***goal*** is to cover, as an overview, selected topics in Chs. 1-10 of text. Detailed coverage will be announced as we go. ***An approximate*** schedule of topics is on the next page.

**Grades**: **Homework = 40%, Midterm Exam = 30%, Project = Paper + Presentation = 30%.**
Grades are based on homework, one exam & a project with a paper and a class presentation.

***Homework:*** Will be assigned regularly. Doing it is your best means of learning physics! It is impossible to do this without working problems! Homework is due at 5pm on the due date. To keep up, do assignments as soon as material is covered. Problems are ***NON-TRIVIAL!*** If you wait to the last day, you likely will run into trouble! ***No late homework will be accepted.*** Homework may be done individually or in consultation with others. **The latter is encouraged; this is how scientists work in real situations!**

***Exam:*** There will be one exam near midterm. This will have an in class portion with several qualitative questions aimed at evaluating the students' grasp of the physics & identification of the most relevant physical processes. Also, it will have a take home portion with problems to assess progress in using relevant mathematical tools.

***Semester Project: Library Research Paper + Presentation:*** On an advanced topic or application of semiconductor physics that we don't have time for in class. The paper is due near the end of the semester. Oral presentations on the same subject will take place then. ***You should have the topic picked by mid-semester.*** **Topics must be approved by me before you begin**. The paper should be 5 to 10 typed pages & written in the style of a scientific paper, with all (several) sources properly cited. The presentation should be about 0.5 hour long. It can be (but isn't required to be!) done in Power Point.

***Approximate*** **Grade Scale: 100 ≥ A ≥ 88 > B ≥76 > C ≥ 64 > D ≥ 52 > F ≥ 0**

***NOTE*****: *I reserve the right to slightly alter these cutoffs! I reserve the right to assign a higher grade to any student whose efforts may not be reflected in their total points. This decision is mine alone to make. You can't receive a lower grade than indicated by the total points.***

## *Approximate* Lecture Schedule

(Balkanski & Wallis = B, Yu & Cardona = Y, Seeger = S)

| Topic: | Chapters | *Approx.* No. of Lectures |
|---|---|---|
| 1. Introduction & Survey: | B, Ch. 1; Y, Ch 1; S, Ch 1 | 2 |
| 2. Electronic Energy Bands (Basics): | B, Ch. 2; Y, Ch 2; S, Ch 2 | 2 |
| 3. Electronic Energy Bands (Semiconductors): | B, Ch. 3; Y, Ch 2; S, Ch 2 | 3 |
| 4. Kinematics & Dynamics of Electrons & Holes: | B, Ch. 4; Y, Ch. 5; S, Ch. 4 | 2 |
| 5. Electronic Effects of Impurities & Defects: | B, Ch. 5; Y, Ch 4 | 3 |
| 6. Semiconductor Statistics: | B, Ch. 6; S, Ch 3 | 2 |
| 7. Lattice Vibrations; Phonons: | B, Ch. 7; Y, Ch 3 | 3 |
| 8. Charge Carrier Scattering/Transport (selected): | B, Ch. 8; Y, Ch. 5; S, Chs. 4, 5 | 3 |
| 9. Diffusion (selected): | S: Ch. 5 | 1 |
| 10. Surfaces and Interfaces: | B, Ch. 9; Y, Ch. 8 (selected); S, Ch 14 | 2 |
| 11. Optical Properties (selected): | B, Ch. 10; Y, Chs 6 & 7; S, Chs 11 & 12 | 3 |
| 12. "Hot" Electrons & Breakdown: | Y, Ch 5; S, Chs. 6, 10 | 1 |
| 13. Quantum Confinement: | B, Ch. 20; Y, Ch 9; S, Chs 9 & 14 | 1 |
| **TOTAL** | | 28 |

This is not meant to be rigid, but to give us an idea where we are going. Some topics in some chapters may be omitted; some topics from outside sources will be included.

**IMPORTANT DATES:** **Thurs., Aug. 28:** Last day to add. **Mon., Sept. 1:** Labor Day, ***NO CLASSES!*** **Wed, Sept. 10**: Last drop date with full refund. **Mon., Sept. 22:** Last withdrawal from TTU with refund. **Wed., Oct. 8:** I'm out of town. **Thurs., Oct. 16:** I'm out of town. **Mon., Oct. 20:** Mid-Semester. Exam will be given about this time. **Mon., Oct. 27:** Last drop date. **Wed., Nov. 26 – Sun., Nov. 30:** Thanksgiving Holiday, ***NO CLASS!*** **Wed., Dec. 2:** Last class. **TO BE SCHEDULED: Fri., Dec. 5-Wed., Dec. 10** (Final Exam time): Student presentations. **Mon, Dec. 15:** Grades are due!

**ACADEMIC INTEGRITY:** Academic dishonesty (cheating, etc.) won't be tolerated. Students caught in this type of behavior will be punished to the fullest extent allowed by TTU. See TTU Catalogue.

**CIVILITY IN THE CLASSROOM:** Students are expected to assist in maintaining an environment which is conducive to learning. To assure that all students have an opportunity to gain from class time, students are prohibited from using cell phones/beepers, eating/drinking in class, making offensive remarks, reading newspapers, sleeping or engaging in any other form of distraction. ***Inappropriate behavior in the classroom shall result in, minimally, a request to leave class.***

***Any student who, because of disabling conditions, may require some special arrangements in order to meet the course requirements should contact the instructor as soon as possible so that necessary accommodations can be made.***

***Proper documentation must be presented from the Dean of Students Office!***

***PARTIAL* listing of some World Wide Web resources on Semiconductor Physics**

**NOTE:** There is a lot of material on the web which is potentially useful for semiconductor physics. I have not had time to check out the details of most of these. I am listing some here just to give you an idea what is out there and to help you to get started searching yourself. For example, you might want to search on particular semiconductor topics as we get to them in class. If you do this and find some sources that are interesting and useful, please let me and / or the rest of the class know by email or orally in class. Thanks!

**A. General Physics resources which might give useful semiconductor links.**

1. **TIPTOP.** (The Internet Pilot to Physics). Go to http://physicsweb.org/TIPTOP/. Click on Search for a Physics link. This leads to **Physics Web,** a search engine for physics. (This is based in the U.K., so it has a U.K.–European flavor). Under "Fields of Interest", choose "Semiconductors". This leads to 33 entries! These range from very elementary to very advanced resources, including some research journals.

2. **THE AMERICAN PHYSICAL SOCIETY.** Go to the http://www.aps.org/. Click on Physics Internet Resources. Follow the links to Physics by Fields, to Solid State, to Semiconductors. There are a lot of other links that can be followed, but I have not taken the time to do so. Alternatively, put in "semiconductors" in the search engine on the APS homepage. This gives 5,434 documents!! **NOTE:** APS is a 40,000 + member organization of professional physicists from around the world. Everyone who wants to be a professional physicist should join! If you are not a member yet, you should join. There is ***NO*** excuse for not doing this! ***For students, the first year's membership is free*** (ask the office for an application form, which must be signed by the Chairman). You get free Physics Today, APS News, discounted journals.

3. **THE MATERIALS RESEARCH SOCIETY.** Go to http://www.mrs.org/. Click on "Materials Connections". Put "semiconductor" in the search engine. This gives a number of further links to pages with various types of semiconductor links & info. **NOTE:** MRS is also a worthwhile professional organization to join for professional materials researchers. It is multidisciplinary & has members whose education is in physics, electrical engineering, mechanical engineering, chemical engineering, chemistry, materials science, and others.

4. **THE AMERICAN INSTITUTE OF PHYSICS.** Go to http://www.aip.org/. Click on "Search". Put "semiconductors" in the search engine. This gives 14,204 documents!

5. **COMPERCIAL SEARCH ENGINES. GOOGLE:** http://www.google.com/. Type "Semiconductor Physics" into this and you will get millions of web pages! Other commercial search engines are obviously also possible.

**Amusing Semiconductor Physics site:**

"Britney Spears' guide to Semiconductor Physics": http://britneyspears.ac/lasers.htm

**B. Web pages with interactive Java Applets in semiconductor / or solid state physics.**
Below, I list a few web pages I have found which have Java Applets or "Physlets" which have interactive exercises which might be useful in learning some basic semiconductor and / or basic solid state physics concepts. These are only the ones which I found after searching the web for about an hour. There certainly may be others. I urge you to try some of these out and to try to find others. If you find some which are particularly interesting and useful, please share them with me and the class! Thanks. These Applets can be fun and entertaining, as well as educational.

1. **A Guide to Semiconductors:** http://www.techlearner.com/Semiconductors.htm
2. **The Semiconductor Physics Applet Service:** http://jas.eng.buffalo.edu/
3. **Automated Internet Measurement Laboratory; Semiconductor Device Measurements Using the Internet:** http://nina.ecse.rpi.edu/shur/Remote/
4. **Purdue University's ECE 557 Home Page:** http://shay.ecn.purdue.edu/~ee557/oldIndex.html
5. **Martindale's Calculators:** http://www.martindalecenter.com/Calculators4A_1_Semi.html

**A *PARTIAL* listing of some books on Semiconductor Physics**


1. Bube, R.H. Photoelectronic Properties of Semiconductors. Cambridge U. Press, 1992.
2. Greenaway and Harbeke. Optical Properties and Band Structures of Semiconductors. 1985.
3. Sapoval, B. and Hermann, C. Physics of Semiconductors. Springer-Verlag, 1994.
4. Shockley, W. Electrons and Holes in Semiconductors. Van Nostrand, 1950.
5. Smith, R.A. Semiconductors, 2nd ed. Cambridge, England: Cambridge U. Press, 1978.
6. Sze, S. M. (Ed.). Modern Semiconductor Device Physics. Wiley, 1997.
7. Sze, S. M. Semiconductor Devices, Physics and Technology. Wiley, 1985.
8. Schubert, E.F. Doping in III-V Semiconductors. Cambridge U. Press, 1993.
9. Landsberg, P.T. Recombination in Semiconductors. Cambridge U. Press. 1991.
10. Shimura, F. Semiconductor Silicon Crystal Technology. Academic. 1989.
11. Nag, B.R. Electron Transport in Compound Semiconductors. Springer-Verlag. 1980.
12. Long, D. Energy Bands in Semiconductors. Interscience. 1968.