

Physics 558: Introduction to Solid State Physics
Spring 2013
Instructor: Tony Dinsmore

Final Project Description

(updated 3/11/13 to include due dates, plus a note about academic honesty at the end)

The goal of the final project is an in-depth investigation of a single topic that is of interest to you. The topic that you choose should have a clear relation to solid state physics. You may think of the first part of the course and of Sidebottom's book as the springboard that can launch a deeper investigation of a topic that might not appear at all in the text, or that might be partially dealt with by the text. You might think of a topic that has interested you for a long time, or something that you heard about recently at a class or seminar or from a fellow student, the newspaper, or a device that you recently purchased.

There are four parts to this final project, each of which is described here with due dates. They are: statement of topic, outline, presentation to the class, and final document. Please do pay attention to these due dates so that we can stay on schedule (and avoid penalties for overdue work).

First step: Choosing a topic. This might be the most difficult part, so I suggest that you start very soon by developing a list of possibilities. Concerns such as "how would I know if this is a sufficiently rigorous or interesting topic" or "what if my topic turns out to be a dud" or "what if I can't think of enough to write" are natural – the same issues arise in research at all levels. The key is to get started learning about topics that are of potential interest; as you learn more you will find a way toward a well-defined and interesting topic. My experience is that research topics become *more* interesting and rewarding, not less, as one gets deeper into them.

You may not choose a topic on which you are doing a project for credit in another course, or a topic closely related to your thesis (if you are writing one). This is a standard rule for academic credit.

Second step: reading and becoming an expert in the topic: You might wish to start with two possible topics and read about them, then choose the more promising topic. Resources might include, in roughly this order of relevance:

- Read standard popular-level publications or other information resources: *Scientific American*, *Physics Today* (the publication of the American Physical Society), *American Journal of Physics*, and *Wikipedia* (but be wary about reliability and completeness). These can get you started; you can fill in details later. UMass has on-line subscriptions to these journals. Print any articles that appear to be even slightly useful; it is helpful to write in the margins. (I can print articles if it is awkward or costly for you to do so; send me pdfs or links to the pdf files.)
- Consult textbooks, especially Sidebottom's. There are many excellent solid-state texts out there and they do vary, so it's worth looking around. Ascroft and Mermin wrote a good one for a graduate-level course. Kittel wrote a good one for an undergraduate course; it might complement Sidebottom well. You can borrow textbooks from me, and there ought to be some in the library as well.
- Talk to people – your peers, graduate students or faculty working in the area of your interest, and especially to me. For the purposes of this project - unlike an exam - it is *not* considered 'cheating' to ask for outside help on a technical aspect of your project as long as (a) you list your sources in your final project and (b) you don't copy content wholesale from any sources.
- Visit the Web of Science (<http://www.library.umass.edu/ndl/view/subject/physics>) to find original research articles. This site offers a comprehensive, searchable database of published articles. After you know a little bit about your topic, you should look here to find details. In addition to the reference information (author names, abstract, journal information), there are links to the articles themselves. Sometimes you can find good introductory material if you search by topic and include "and review" in your search terms (review articles can be very useful, though

sometimes they are merely longer than regular articles without being more accessible). When you find a particularly relevant article, the Web of Science can give you a list of articles that have cited it – this is a very useful feature.

Keep notes as you go, especially a list of things you *don't yet* understand and a list of things that you *do* understand. Also keep a list of references that you come across, so that when the opportunity arises you can get copies and read them. You'll value these notes when the time comes to cite articles in your own document.

Make the physics your own as you go: push yourself to learn it clearly enough to explain it to someone else. Make sure you see the big picture and can describe it clearly, then move to providing derivations of equations.

Statement of Topic, due Thurs., March 28 in class: Turn in a short description of your chosen research topic. Include the following. These can be roughly one sentence each.

- (1) Brief summary of the topic and key topics that you wish to address. (1-2 sentences)
- (2) Brief statement of why this topic is interesting (a sentence)
- (3) Brief list of items you have learned and of items you have yet to learn.
- (4) List of 2 articles or textbook-sections that you have read, and 4 others that you will read next. (You'll need to read others too, but these 4 will get you going with details.)

(Exam will be on Wed. April 3)

More likely: Thurs 4/4 from 9:30 am to 12:00 noon, which was the most popular option. (I don't have a room yet)

Project outline, due Thurs., April 18 in class. (5 out of 40% of total grade) This should be an outline of your written document. Actually, you should *start* making an outline well before this, so that you can choose your reading materials to learn information that is essential for the logical flow of your project. By the time the outline is due, you will have essentially completed your reading on the project and will be prepared to write down what you know. (There might still be some details yet to figure out, but you'll need to have much of it done.)

Good organization with a clear logical flow is essential to an effective document or presentation. (You will find that some published articles are very hard to follow because they lack these things.) **Take this step seriously; it will be time very well spent when you write your document.** The more detail you put here, the more feedback I can give you prior to your presentation.

Oral Presentation, in-class. Start on Tues., April 30 (last day of this class). We will arrange one or two other times later that week. (15 out of 40%) Plan a half-hour presentation to your peers in the class. We will have a few of these per meeting time, allowing some time for questions during & after each one. Your peers and I will offer constructive suggestions after your presentations, which will be useful for your final document.

Your peers know what you know about basic solid-state physics concepts, but assume that they have no detailed knowledge of your topic.

Some suggestions:

- Emphasize the physical concepts; derivations of essential points are fine, but usually are done in less detail than they might be in your written article or during a class lecture.
- Show experimental data or results of simulations or calculations (depending on the nature of your project). If you describe experiments, describe the methods and apparatus carefully. Show schematic diagram(s) of apparatus and other concepts; you might want to make your own if you don't find suitable ones in the literature.
- Offer your own critical analysis of published work: did they assume things that might not be correct? Are there alternative interpretations of the data?

- Timing: you should plan to use computer-generated slides (I will have a projector available). For a 30-minute talk, you should probably have *approximately* 20-25 slides. Each slide should have one major point (with details). Feel free to use the blackboard as well; the combination of the two can be effective (if you first practice drawing on the board). The most important way to make the timing work out OK is to *practice* your talk aloud; ask one of your peers to be your practice audience.
- Citing: In presentations, you should list citations at the bottom of the relevant slide. For instance, if you describe a conclusion from an experiment or use an article for important background information, list its citation at the bottom of that slide. If you show a graphic from an article, write explicitly “plot/image/illustration from Jones *et al*, *PRL* **80**, 1234 (2009).” Listing all citations at the end is not helpful; don’t do that.

Final written document, due Thurs., May 9 by 5 pm (20 out of 40%)

This will be your final document, the culmination of a lot of learning. Please ask me questions in advance and get comments as needed, beyond my comments on the outline and presentation. As you learn a project, it is easy to get caught up in details and lose the bigger picture, so I urge you to ask friends and peers to read your document and offer you constructive criticism.

In judging length and depth, go for *quality* (clear descriptions of physical concepts) more than quantity. A reasonable length would be 10-15 pages, but longer is fine as you see fit. Shorter than 10 pages may be too short (consult with me if you think this will be the case).

Write for a reader who is generally interested in this area, but has no special knowledge of it. In particular, have in mind a peer who (a) knows physics at the senior-undergrad level (having taken QM and statmech, just as you did), (b) knows some basic concepts of solid state physics, such as the content of the first 2/3 of the course, and (c) has no other special knowledge. You might need to help the reader with some chemistry or mathematics or optics, etc.

Good organization and clear logical flow are essential for an effective document. You have already written an outline, but feel free to shift things around if it improves the document.

You may choose your own font and general format, but your final document should have the following in this order (look at an article in *Phys. Rev. Lett.* as a guide):

- A title
- Your name and affiliation
- An abstract (fewer than 150 words; 100 words is better)
- An introductory section that describes the overall topic, provides a motivation, and gives background with cited references
- The main text. Describe relevant experiments in words. When you show data, take the reader through it in words.

Equations will be necessary. You will need to justify them on physical grounds by describing the model and assumptions and approximations, which can be done using words. Show only non-trivial mathematical steps in the derivation (use your judgment here, but ask me for advice if you wish; generally you should include much more detail than in a typical PRL, for example, but not as much as in a homework assignment).

Figures should have captions that explain them, even if captions repeat some information given in the text. You should copy plots, images and other graphics from published articles but your caption must say “plot/image/illustration from Jones *et al*, *PRL* **80**, 1234 (2009).”

- A conclusion, which summarizes important points and offers perspective on open areas, future impact, etc. Put some of your own judgment here: is verification needed of some crucial assumptions? Is there some particular experiment that someone should do to clear up a mystery? Do you see some logical extension of this work in technology or in another area of science or materials?

- A list of cited references. At a minimum, you should use something like the style of Phys. Rev. Lett. (names, journal, volume, page, year), but I think it's useful to include the article titles as well. Web of Science will help with this.
- Appendices, if you wish to provide an extended derivation of something but don't wish to distract too much from the logical flow. This is not required, but can be useful. If you sweat over some important piece of the story, then others (like me!) probably will too and would appreciate some guidance.

A note about plagiarism and academic honesty: (added 3/11/13) In keeping with the standards of UMass and other universities in the U.S., your written text must be your own. If you copy phrases or sentences from another publication, then you *must* put quotation marks around it and refer to the source. Please note, however, that the goal here is to get you to explain things in your own words, which forces you to engage with the material (and is my goal in this assignment). To this end, I suggest that you make notes based on your reading, then write text based on your notes; resist the urge to look at articles as you write.

It is perfectly acceptable to include figures and plots from other sources, and of course this often helps you to make a point. Please note, however, that *any* graphic that you use must be accompanied by words such as “figure copied from...[citation]”, even if the graphic is from the web. Always seek authoritative sources for graphics (*e.g.*, a source that has a clearly identifiable author or institution behind it).

If you have any questions about citing or copying, please do not hesitate to ask me. Dealing with issues like this before you turn in a paper is part of what you need to learn.

Possible topics (but you may certainly choose others)

- Low-dimensional solids (quantum dots, wires, thin films); this is a broad area.
- single-electron device physics (*e.g.* single-electron transistors, boxes, pumps, ...)
- the Coulomb blockade effect
- semiconductor heterostructures (a big area).
- high- T_c superconductors.
- superconducting arrays
- flux vortices
- Josephson effect
- giant magnetoresistance (or ‘colossal MR’, etc)
- noise in solid-state systems
- quantum Hall effect
- carbon buckyballs, nanotubes, or graphene
- topological insulators (a currently hot topic)
- conducting polymers
- crystal growth and purification
- an advanced theory of electronic band-structure
- spin glasses
- electron scattering
- weak localization
- experimental techniques:
 - scanning tunneling microscopy, atomic force microscopy, FTIR spectroscopy, NMR spectroscopy, Raman or Brillouin scattering, x-ray photoemission spectroscopy.
- device physics: (many possibilities here)
 - Solid-state lasers, photodiodes, CCDs (charge-coupled device cameras), CMOS detectors, MOSFET, RAM devices or magnetic storage, SQUIDS, thermoelectric coolers/heaters, photovoltaic devices (solar cells)...