The problem set this week has only two exercises, both of which require you to read some articles and answer some questions.

1. **Properties of individual nanotubes.**
   
   a) Go read *Bachilo et al., Science* **298**, 2361 (2002) (there’s a link to it on the “schedule” page of the course website.). This paper discusses the recent breakthrough in assaying nanotube types by optical characterization. One particular innovation made this work possible. What was it, and why, without that technical step, would this experiment have failed? Like many semiconductor systems, optical absorption is due to the formation of electron-hole pairs. A mutually bound electron-hole pair is called an *exciton*. It turns out, as speculated at the end of the article, that “strong exciton effects” (nonperturbative electron-hole, electron-electron, and hole-hole interaction corrections) are important in understanding the optical properties of these systems. Furthermore, optical processes in these micelle-suspended tubes are also strongly affected by the pH of the solvent (concentration of ions). There is some physics mentioned in class that suggests why both of these phenomena are plausible. What is it, and how are both of the above effects tied to it?

   b) Look at *Mann et al., Nano Letters* **3**, 1541 (2003) (also linked on the website) for more discussion of ballistic transport in metallic nanotubes. What is the reason for the resonances in the conductance shown in Fig. 1(c) and Fig. 2(c)? How do you think the authors justify the assertion that the mean free path for impurity scattering can be as large as 4 microns in these devices?

   c) Read over *Freitag et al., Phys. Rev. Lett.* **93**, 076803 (2004). Explain briefly why light is emitted in these devices. Why does the physical spot where the emission occurs move with applied bias? Knowing what the maximum possible conductance is for a single tube, how many photons would you naively expect to be generated at a source-drain bias of 0.1 V?

2. **Nanocrystals and nanowires.** Much progress has been made lately on chemical methods of synthesizing nanostructured materials. Here I ask you to read some of the seminal papers on this topic, and answer some questions.

   a) First, take a look at *Murray et al., Annu. Rev. Mat. Sci.* **30**, 545 (2000) (cited 354 times). This long review article is a good overview for how large numbers of nanocrystalline materials may be produced by supersaturated solution methods (sometimes half-jokingly called
“molecular beaker epitaxy”). What is the process mentioned that improves (lowers) the size dispersity, and (in a couple of sentences) how/why does it work? (You should not have to read the whole 75 page document to figure this out. I’m pointing you to this paper because it’s a great reference.)

b) Now consider Peng et al., Nature 404, 59 (2000) (cited 600 times). This paper describes how the methods outlined in (a) can be modified to control the shapes of the resulting nanocrystals. How does this shape control work? Do you think that the process in (a) for lowering size dispersity would work as well for long, skinny nanocrystals? Why or why not?

c) Lastly, read Morales and Lieber, Science 279, 208 (1998) (cited 995 times!). This paper reports a fairly general technique for producing long semiconducting nanowires. To see an example of how this can be useful, also please read Cui et al., Science 293, 1289 (2001) (cited 430 times). Why do you think the conductance in these nanowires is so sensitive to both pH changes in surrounding solvent, and to individual binding events?