Prof. Raghuveer Parthasarathy
University of Oregon
Physics 353 – Spring 2008

FINAL PROJECT & PRESENTATION

last modified April 8, 2008 – RP

OVERVIEW

Working in groups of two, complete a final project that explores some topic in statistical mechanics beyond the material covered in class. Each pair of students will create a 15 minute **presentation** to be delivered to the class during the last week ("dead week") of the quarter, and will also submit a **one-paragraph abstract plus list of references**.

GOALS

There are several main goals underlying this assignment. (1) The skills you've developed during this and the preceding courses equip you to explore and appreciate many interesting topics in contemporary science. I want you to implement these skills, and I hope you'll impress yourself with what you're able to learn. (2) Related to the preceding goal, it is important to learn what **not** to worry about when investigating new topics. Unlike the standard course content, many of the suggested topics contain issues that you are not expected to master, e.g. detailed theoretical derivations. Learning how to "skip over" these issues while retaining a grasp of what the premises and conclusions are is useful. (3) It is very important to be able to succinctly describe scientific topics to others. (A high fraction of my time is spent writing papers and grant proposals and preparing presentations, for example.) This project will ask you to distill a scientific topic into a short presentation that is **comprehensible by your peers.** (4) You'll gain some practice searching through the scientific literature.

SCHEDULE

A decision on a topic plus a list of at least three references **must** be completed by the end of **Week 6**. I strongly recommend exploring topics and choosing one well before this. Note that I do not want the same topic to be covered by more than one group, and selection is "first come first served."

SOURCES / REFERENCES

There are many sources of papers and books available to you.

Books. The UO Science Library is quite good, and its web site has the standard searching mechanisms. If books you are interested in are checked out, **don't be shy about recalling them!** Your need for them, I assure you, is as good or probably better than those of the person who has them checked out. If you're interested in a book that is not available at Oregon, search on "Summit," the multi-university Pacific

Northwest library consortium. If another library has the book, it will be delivered to you by inter-library loan, typically within a few days. I have used this many times – it is rare to find a book that isn't available at some Summit library. Again, don't be shy about requesting books.

Articles: Useful journals. UO has on-line subscriptions to most journals of interest, and print copies as well. For on-line access, if you're searching from off-campus, you may need to use the "proxy server" so that the journal recognizes you as having an institutional subscription. I do not know how to set this up. Some good journals to look in for "review" articles are *Reviews of Modern Physics* and *Physics Today* (which has a poor search engine). Note that I've tried to suggest articles from these journals in my list below. It is also often interesting to scan the "prestigious" journals: *Science*, *Nature*, and *PNAS* (*Proceedings of the National Academy of Sciences*), whose articles are often accompanied by commentaries that explain why they are interesting. Another source of articles is "the archive" (http://arxiv.org/) a free, on-line article server that is especially popular with theoretical physicists. (I generally find its quality very hit-or-miss, but it's not a bad place to search for review papers.)

Articles: Searching. Thanks to the wonders of the information age, it is remarkably easy to search for papers across many journals, searching by title, author, topic, year, etc. Some popular search engines:

- **INSPEC.** Inspec searches the physical science databases.
- **ISI Web of Science.** Web of science, in addition to finding articles, can tell you which articles cite a particular article. This is often useful for "looking forward" from an article to see what work it influenced.
- **Google scholar.** Google's science search engine.
- UO Library's "article finder."

PRESENTATION

Each group will present a **15 minute presentation** (+ 1-2 minutes of questions) to the class. The presentation may be computer-based (Powerpoint), or involve writing on the blackboard, or a combination of the two. You are responsible for the smooth operation of any computer presentation. I recommend giving me the Powerpoint (or PDF) files, so that I can run them all sequentially off of my computer, avoiding delays between presentations. This way, we can also check beforehand that the slides will play properly. The format of the presentation is up to you.

The key aspect of the presentations is that they be comprehensible and informative to your **classmates.** They, not I, are the target audience. Ask yourself: what is important to convey to them? What will they learn? See also the "grading" section.

In addition, each group will hand in a **one-paragraph abstract** or summary of their topic plus a list of **references**. This should be submitted as a Word or PDF file. I will put these together into one document to be posted on the web site, so that anyone interested in learning more can have a place to look.

SCHEDULING

We will schedule presentations for the last week of the term, which should fit 9 presentations. This will leave 5 to go elsewhere. We will discuss an extra meeting time (or times) when most students can gather.

GRADING

CLARITY OF PRESENTATION – 50%. The presentation should clearly convey information to the audience. To better assess this, your **classmates** will note comments and provide a grade for the presentation. I will examine all these scores. (I may re-scale them; student evaluations of other students are notoriously harsh.)

SCIENTIFIC CONTENT, ACCURACY, BREADTH – 30%.

CLARITY OF SLIDES – 10%. The graphical clarity of the slides (or blackboard work).

ONE-PAGE ABSTRACT / SUMMARY – 5%.

REFERENCES (APPROPRIATENESS) – 5%.

List of Suggested Topics

The list below contains suggested topics. Topics outside the list **are** certainly allowed, but must first be discussed with me. For each topic I've listed a few references that you might use as starting points, but you should certainly explore beyond them – see the "Sources and References" section. I have also written a few brief comments. Note that some topics involve computer programming.

CHOOSING A TOPIC. Choose a topic that interests you – an obvious, but important, point! Of course, you may not know what interests you until you start exploring. Please note: **There is a limit of "one group per topic,"** meaning that more than one group cannot choose the same topic. This will prevent repetitious presentations for the class, and maximize our exposure to areas of science. There are a few "exceptions" noted below, which are topics that are broad enough for multiple groups; groups must still coordinate with me which aspects of the topic they are considering.

1 POLYMER PHYSICS

Comments: We've briefly explored the statistical mechanics of polymers in Physics 352, and noted connections between polymers and random walks. There's a lot more to examine in this rich and fascinating area. A good project would be to explain one or two chapters in either the Witten or de Gennes (1980) books.

Readings:

- Thomas A. Witten, "Structured fluids: polymers, colloids, surfactants," Oxford University Press (2004). A recent book by one of the contemporary giants in the field.
- P. G. de Gennes, "Scaling Concepts in Polymer Physics," Cornell University Press (1980). A classic, and an unusual book – simultaneously very simple and very complex. de Gennes won the Nobel Prize in Physics in 1991 for his work on polymer physics, especially his illumination of the connection between polymer behavior and phase transitions.
- S. F. Edwards, Proc. Phys. Soc. **85**, 613 (1965).
- Pierre-Gilles de Gennes and Jacques Badoz, "Fragile Objects. Soft Matter, Hard Science, and the Thrill of Discovery," Copernicus Books, Springer-Verlag (1996). A good "popular science" book – at a considerably lower level than this course. Quite entertaining.

2 MONTE-CARLO SIMULATION OF A TWO-DIMENSIONAL ISING MODEL

Comments: For this project you must **write a Monte Carlo computer simulation** of the Ising model on a 2D square lattice. Your program should calculate the magnetization, M, at temperature τ; you should then calculate $M(\tau)$ and show that it reveals a phase transition at some particular temperature, τ_C. Explore the dependence of your results on lattice size. Model any other features of the magnet you find interesting. Your presentation should explain the Monte Carlo algorithm and your results, and also compare τ_C to the "mean-field" value discussed in class. Also: send me a copy of your program.

Readings: Monte Carlo methods are discussed in countless places; you may find textbooks on computational physics a good place to start. The UO library has several.

- K. P. N. Murthy, *An Introduction to Monte Carlo Simulation of Statistical Physics Problems*, http://arxiv.org/abs/cond-mat/0104167 (2003).
- Werner Krauth, *Introduction To Monte Carlo Algorithms*, http://arxiv.org/abs/cond-mat/9612186
- David Chandler, *Introduction to modern statistical mechanics***,** New York: Oxford University Press, 1987. [*The library's copy seems to be missing; it's available through SUMMIT, however.*]
- M.E.J. Newman and G.T. Barkema *Monte Carlo Methods in Statistical Physics*, Oxford University Press, Oxford, 1999. [See chapters 2-3].

3 BOSE-EINSTEIN CONDENSATION OF ATOMIC GASES

Comments: Bose-Einstein condensation is a remarkable phenomenon affecting bosons at low temperature, in which they "condense" into one quantum state. We'll discuss the basic physics of this in 353. For this project, review the recent experimental realizations of this new state of matter. (Or discuss other topics beyond what is covered in class, e.g. cold fermion gases.)

Readings: The *Physics Today* articles are good places to start. There are also books available on the topic (not listed).

- W. Ketterle, "Experimental studies of Bose-Einstein condensation in a gas," *Physics Today*, Dec. 1999, 30-35.
- K. Burnett et al., "The theory of Bose-Einstein condensation of dilute gases," *Physics Today*, Dec. 1999, 37-42.
- E.A. Cornell and C.E. Wieman, [Nobel Lecture], *Rev. Mod. Phys.* **74**, 875 (2002)
- J.R. Anglin and W. Ketterle, "Bose-Einstein condensation of atomic gases," *Nature* **416**, 211 (2002)

4 RECENT TOPICS IN NON-EQUILIBRIUM STATISTICAL MECHANICS

Comments: Recent years have seen a lot of interest in statistical mechanics away from equilibrium, especially for "small N" systems. Explore this topic. I recommend focusing on recent experiments, describing the means by which they measure various quantities of interest. You are not expected to derive complex theoretical results.

Readings: I suggest starting with the *Physics Today* article.

- Bustamante, C., Liphardt, J., and Ritort, F. "The Nonequilibrium Thermodynamics of Small Systems." *Phys. Today* **58**, 43-48 (2005).
- Liphardt, J., Dumont, S., Smith, S. B., Tinoco, I. Jr, and Bustamante, C. "Equilibrium information from nonequilibrium measurements in an experimental test of Jarzynski's equality." *Science* **296**, 1832-1835 (2002).
- Trepagnier, E. H., Jarzynski, C., Ritort, F., Crooks, G. E., Bustamante, C. J., and Liphardt, J. "Experimental test of Hatano and Sasa's nonequilibrium steady-state equality." *Proc. Natl. Acad. Sci. USA* **101**, 15038-15041 (2004).
- Y. Oono, Prog. Theor. Phys. Supp. **99**, 165-205 (1989).

5 BIG BANG NUCLEOSYNTHESIS

Comments: Explore the chemical equilibria that determined the composition of the universe.

Readings: This list may not be ideal, but there are plenty of places to explore the topic.

- David Boal's lectures on Astrophysics, #35 (http://www.sfu.ca/~boal/390.html). Prof. Boal, of Simon Fraser University, has a large set of lectures notes available on-line. These are from an undergraduate astrophysics course.
- E. W. Kolb & M. S. Turner, "The Early Universe," (Perseus, Cambridge, MA) 1994. – Chapter 4. See also the references at the end of the chapter, on experimental observations. An advanced book, but an authoritative description of the early universe.
- Bradley W. Carroll and Dale A. Ostlie, *An Introduction to Modern Astrophysics*, Addison-Wesley, Reading, MA, 2007. [I haven't looked at this – RP.]
- D. N. Schramm and M. S. Turner, "Big bang nucleosynthesis enters the precision era," *Reviews of Modern Physics*, **70**, 303-318, 1998.
- H. Kragh, "Cosmology and controversy : the historical development of two theories of the universe," *Cosmology and Controversy*, Princeton University Press, Princeton, NJ, 1996, pp. 295–305, 338–355. [I haven't looked at this; it is cited in Schramm (1998) as providing a historical view. – RP.]

6 WHITE DWARF STARS AND NEUTRON STARS

Comments: We will have discussed the "degeneracy pressure" of fermions in class. These play a large role in stellar interiors.

Readings: Any book on stellar astrophysics should discuss this.

- David Boal's lectures on Astrophysics, #29 (http://www.sfu.ca/~boal/390.html). Prof. Boal, of Simon Fraser University, has a large set of lecture notes available on-line from an undergraduate astrophysics course.
- S.A. Kaplan, *The Physics of stars*, Wiley, Chichester, 1982, chapters 5 and 6
- R.K. Pathria, *Statistical Mechanics*, Butterworth-Heinemann, Oxford, 1996, section 8.4

7 GLASSES, THE GLASS TRANSITION, AND JAMMING

Comments: Glasses are disordered like liquids and resist forces like solids. Whether or not they form a separate phase from solids and liquids – i.e. whether there is a phase transition to a glassy state – remains controversial. The behavior of glasses can be generalized to a great many physical systems, from magnetic spins to the structure of proteins. Recently, a concept of "jamming" has been proposed that connects glasses to still more systems. There are several possibilities for projects here, including (i) discussing glassiness – a topic with a long history; (ii) focusing on particular sets of experiments that explore glasses (look up, e.g., papers by S. R. Nagel); and (iii) discussing jamming (see the Liu and Nagel paper, and also look up papers that cite it).

Readings:

- E. Donth, *The Glass Transition*, Springer, 2001
- J. C. Dyre, "The glass transition and elastic models of glass-forming liquids," *Rev. Mod. Phys.* **78**, 953 (2006).
- Liu, Andrea J and Nagel, Sidney R "Jamming is not just cool any more." *Nature* **396**, 21-22 (1998).

8 EFFECTIVE TEMPERATURES IN GRANULAR SYSTEMS

Comments: We know about Brownian motion and the thermal vibrations of molecules, and how these can determine phenomena like diffusion. What about systems that are subjected to non-thermal random motions, such as a shaken container of sand, or any such "driven" system? Can we translate our "thermal" ideas to non-thermal systems? This remains an open question.

Readings:

- C. Song, P. Wang, and H. A. Makse, "Experimental measurement of an effective temperature for jammed granular materials," *Proc. Natl. Acad. Sci USA* **102,** 2299-2304 (2005).
- H. M. Jaeger and S.R. Nagel, **"**Physics of the Granular State" *Science* **255**, 1523 – 1531 (1992).
- G. D'Anna, P. Mayor, A. Barrat, V. Loreto & Franco Nori*,* "Observing brownian motion in vibration-fluidized granular matter" *Nature* **424**, 909-912 (2003).
- Liu, Andrea J and Nagel, Sidney R "Jamming is not just cool any more." *Nature* **396**, 21-22 (1998).

9 THE STATISTICAL MECHANICS OF DNA MELTING

Comments: DNA is a remarkable molecule, and its statistical mechanics have both a tremendous richness and a great practical importance. One interesting issue the "melting" (i.e. separation) of the two strands that make up double-stranded DNA, which builds on our "zipper problem" of last term. See the Kittel and Tinoco readings. Also look up polymerase chain reaction (PCR) and explain how it works, and its importance. The paper by Braun (2003) may be interesting to discuss. (Other DNA-related topics can be found in Nelson's book.)

Readings:

- Kittel, C. Phase Transition of a Molecular Zipper. *American Journal of Physics* **37**, 917-920 (1969).
- Tinoco, I., Sauer, K., Wang, J. C., and Puglisi, J.D., *Physical Chemistry: Principles and Applications in Biological Sciences*, Prentice Hall, New Jersey, 2002.
- Braun, D., Goddard, N. L., and Libchaber, A. Exponential DNA replication by laminar convection. *Phys. Rev. Lett.* **91**, 158103 (2003).
- Nelson, P. *Biological Physics: Energy, Information, Life* (W. H. Freeman, New York, 2003)

10 Refrigerators

Comments: Explore the means by which refrigerators work. There are several possibilities for projects here. These can include the liquid and vapor pumping schemes of "conventional" refrigerators, or more exotic techniques that are employed to reach temperatures near absolute zero (e.g. adiabatic demagnetization, helium dilution refrigerators). You don't need to explore all these techniques; any one is certainly sufficient.

Readings: Look up books on low temperature physics for the "exotic" techniques.

- Daniel V. Schroeder, *Thermal Physics*, Addison Wesley Longman, San Francisco, 2000. Contains good discussions of "real refrigerators" (Chapter 4)

11 Critical phenomena and the renormalization group – experiments & theory

Comments: In class we considered the "mean-field" treatment of phase transitions. This correctly captures the existence of critical points, but gets everything else about their properties quite wrong. In the 1950s-1970s, experiments discovered that the critical exponents describing transitions are "universal," and independent of the details of the system. Theoretical insights that culminated in a remarkable methodology known as the "renormalization group" succeeded in explaining this universality, and calculating critical exponents. In this project, explore critical phenomena and the renormalization group. You do not have to understand renormalization group calculations, but you should be able to roughly describe "what they do" and what their predictions are. Also note measurements of critical exponents.

Readings: Many books on critical phenomena or phase transitions will contain an overview of this topic.

- M. E. Fisher**, "**Renormalization group theory: Its basis and formulation in statistical physics," Rev. Mod. Phys. **70**, 653 (1998). [A more historical review. It doesn't discuss experiments in much detail – look up some of its references.]
- M. E. Fisher**,** "The renormalization group in the theory of critical behavior," *Rev. Mod. Phys.* **46**, 597 (1974). [A more advanced review.]
- Shang-Keng Ma, *Modern Theory of Critical Phenomena*, Westview Press, 2000. [See especially the first, introductory, chapter.]
- Chaikin, P. M. & Lubensky, T. C. *Principles of Condensed Matter Physics* (Cambridge University Press, Cambridge, UK, 1995). This is an advanced book – use it to learn what the predictions of renormalization group models are, and also try to glean the mechanism by which it works.

12 REAL-SPACE RENORMALIZATION GROUP CALCULATION FOR A 2D ISING MODEL

Comments: Renormalization group calculations (see #11) tend to be fairly complex. Maris and Kadanoff (1978) developed a simpler "real space" method for performing a renormalization group calculation that describes the magnetic phase transition of a **2D Ising model**. Chandler (1987) discusses this as well. Perform these calculations (Chandler, sections 5.6 and 5.7), deriving the appropriate recursion relations, calculating the critical exponent for the magnet's heat capacity and also the value of the critical temperature. See also Plischke & Bergersen *Note:* your presentation should describe these calculations. You'll have to think about how much detail to include, and how best to convey the calculations in a clear, interesting manner. *Note:* This project is more mathematically challenging than most.

Readings:

- Shang-Keng Ma, *Modern Theory of Critical Phenomena*, Westview Press, 2000. [See especially the first, introductory, chapter, for a general overview of the topic]
- David Chandler, *Introduction to modern statistical mechanics***,** New York: Oxford University Press, 1987. [*The library's copy seems to be missing; it's available through SUMMIT, however. Also, I can make a photocopy of my copy for this project.*]
- Maris, Humphrey J. and Kadanoff, Leo P. Teaching the renormalization group. *American Journal of Physics* **46**, 652-657 (1978).
- M. Plischke & B. Bergersen: *Equilibrium Statistical Physics*, World Scientific, Hackensack, NJ, 2006. Chapter 6.

13 QUANTUM PHASE TRANSITIONS

Comments: There has been a lot of interest recently in phase transitions driven not by temperature, but by some quantum parameter underlying a system's behavior. Phenomena like high-temperature superconductivity are suspected to be related to "quantum phase transitions." Discuss some of these issues and experiments. This topic is probably best undertaken if one has some prior exposure to quantum mechanics.

Readings:

- S. Sachdev, "Quantum Phase Transitions," *Physics World* **12**, No 4, 33 (April 1999). It may be a bit difficult to access the Physics World archive. An on-line version of the article is at Subhir Sachdev's web site: *http://sachdev.physics.harvard.edu/physworld/index.html*
- T. F. Rosenbaum and G Aeppli, "Quantum critical behaviour for a model magnet," *Phys. Rev. Lett.* **77** 940-943 (1996).
- S. L. Sondhi, S. M. Girvin and J. P. Carini, D. Shahar, "Continuous quantum phase transitions," Rev. Mod. Phys. 69, 315 - 333 (1997).
- J.A. Hertz, Phys. Rev. B. 14, 1165 (1976).
- Subir Sachdev, "Quantum Phase Transitions" Cambridge University Press, 2001. [An advanced text.]

14 THE GREENHOUSE EFFECT, CLIMATE, AND CLIMATE CHANGE

Comments: This is a very important topic, but also a vast one to explore for a short presentation. One approach may be to discuss the simple physics of the greenhouse effect, and then briefly discuss issues in climate modeling and conclusions that have been reached regarding issues of climate change.

Readings: On climate change, the reports from the Intergovernmental Panel on Climate Change are very good (available at *http://www.ipcc.ch/*); there is a chapter on "The physical science basis" (LeTreut *et al.* 2007).

- Daniel V. Schroeder, *Thermal Physics*, Addison Wesley Longman, San Francisco, 2000. [Contains a brief exercise on the greenhouse effect (this can be found in other books, too.) I can photocopy this if needed.]
- G. A. Schmidt, "The physics of climate modeling," *Physics Today*, January 2007, 72-73. [Very short]
- Le Treut, H., R. Somerville, U. Cubasch, Y. Ding, C. Mauritzen, A. Mokssit, T. Peterson and M. Prather, 2007: Historical Overview of Climate Change. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

15 MAXWELL'S DEMON AND RECENT EXPERIMENTS

Comments: "Maxwell's Demon" is a thought-experiment, devised by Maxwell,' in which the eponymous demon seeks to reduce the entropy of a system without doing work. Discuss the meaning and history of the demon, as well as contemporary experiments that relate to it.

Readings:

- Harvey S. Leff and Andrew F. Rex, ed., *Maxwell's demon : entropy, information, computing*, Princeton University Press, Princeton, N.J.,1990.
- Serreli, V., Lee, C. F., Kay, E. R., and Leigh, D. A. "A molecular information ratchet." *Nature* **445**, 523-527 (2007).
- J. Eggers, "Sand as Maxwell's Demon," *Phys. Rev. Lett.* **83**, 5322 - 5325 (1999).

16 ELECTROSTATICS IN WATER

Comments: Electrostatic forces in aqueous solutions (like salt water, or the interiors of your cells) are dramatically affected by the "gas" of ions that surrounds charged objects. Electric fields, for example, don't decay as $1/r^2$, but rather exponentially with distance. Explore these issues.

Readings:

- Israelachvili, J. *Intermolecular and Surface Forces (2nd edition)*, Academic Press, New York, 1991. [Chp. 12]
- Nelson, P. *Biological Physics: Energy, Information, Life* (W. H. Freeman, New York, 2003). [Section 7.4]
- Witten, T. A. & Pincus, P. A. *Structured Fluids: Polymers, Colloids, Surfactants* (Oxford University Press, Oxford, 2004).

17 PHASE TRANSITIONS IN BIO-MEMBRANES

Comments: Cellular membranes are two-dimensional fluids. The somewhat contentious "lipid raft hypothesis" states that membranes phase-separate into regions of different compositions. Explore (i) the basic physics of miscibility transitions; (ii) lipid phase separation in artificial membranes; and (iii) briefly, arguments on the existence of lipid rafts in cells.

Readings:

- Nelson, P. *Biological Physics: Energy, Information, Life* (W. H. Freeman, New York, 2003). [for a brief overview of membrane structure]
- Veatch, S. L. and Keller, S. L. Organization in lipid membranes containing cholesterol. *Phys. Rev. Lett.* **89**, 268101 (2002).
- Veatch, S. L. , Polozov, I. V., Gawrisch, K., and Keller, S. L. Liquid domains in vesicles investigated by NMR and fluorescence microscopy. *Biophys. J.* **86**, 2910-2922 (2004).
- McConnell, H. M. and Vrljic, M. Liquid-liquid immiscibility in membranes. *Annu. Rev. Biophys. Biomol. Struct.* **32**, 469-492 (2003).
- Edidin, M. Lipids on the frontier: a century of cell-membrane bilayers. *Nat. Rev. Mol. Cell Biol.* **4**, 414-418 (2003).
- Simons, K. and Vaz, W. L. Model systems, lipid rafts, and cell membranes. *Annu. Rev. Biophys. Biomol. Struct.* **33**, 269-295 (2004).
- Mayor, S. and Rao, M. Rafts: scale-dependent, active lipid organization at the cell surface. *Traffic* **5**, 231-240 (2004).

---

* MORE TOPICS *

Topics for which I'm not writing comments & a detailed reference list, but which are still "officially suggested."

CRYSTALLIZATION. When a liquid cools, what governs the formation of crystals? Keywords to look up: *Crystallization*, *nucleation*.

SINGLE MOLECULE BIOPHYSICS. The past decade or so has seen an explosion of experiments exploring biomolecules like DNA by manipulating single molecules. Authors to look up: *C. Bustamante*, *S. Block*, *K. Kinosita*.

HEAT ENGINES, ALTERNATIVE ENERGY SOURCES, ETC. There are lots of topics to explore related to the thermodynamics of engines, power generation, etc. (E.g. geothermal energy: how does it work?) As long as your topic deals with thermodynamic issues, it's probably good. Please see me to confirm.

MISC. BIOPHYSICS AND "SOFT" CONDENSED MATTER. There are lots of topics to explore related to biophysics and "soft" materials. Nearly any topic encountered in the following two books is probably good. Please see me to confirm.

- Nelson, P. *Biological Physics: Energy, Information, Life* (W. H. Freeman, New York, 2003).
- *Molecular Driving Forces*, by Ken Dill and Sarina Bromberg (2003). [On reserve]

SUPERFLUIDITY IN LIQUID HELIUM. A very interesting topic. There are lots of references on this, and its physics are similar to that of Bose-Einstein condensation. See e.g.

- T. Guenault, *Basic superfluids*, Taylor and Francis, London, 2003, chapters 1 and 2
- R. P. Feynman, "Statistical Mechanics," W. Benjamin, 1973, Chapter 11.

SUPERCONDUCTIVITY. A very interesting topic. There are lots of references on this, and its physics are similar to that of Bose-Einstein condensation.

LIQUIDS. To learn about liquid structure, see "Statistical Mechanics" by Benjamin Widom, or "Theory of simple liquids" by Hansen and McDonald. If you're interested in writing a Monte Carlo simulation of a 2D liquid, see D. Chandler's book, cited in e.g. Section 12 above.

STATISTICAL MECHANICS OF LIQUID CRYSTALS. See e.g. P.G. de Gennes and J. Prost, "The Physics of Liquid Crystals."