# Foundational Problems of Thermodynamics and Statistical Mechanics: Suggested Paper Topics

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http://strangebeautiful.com/lmu/2017-winter-thermo-sm.html

***N.b.***: these topics are only suggested. You are not required to write on one of them. If you want to write on a topic markedly different from one of these, however, please do consult with me first about your proposed topic. In any event, I strongly encourage you to make an appointment with me and talk in person about your paper (before I leave town on 03. Feb).

1. I argued in lecture that the fundamental asymmetry in thermodynamics, entropy non-decrease, is grounded in an asymmetry between the possibility of transforming heat into work and vice-versa, as encoded in the Clausius, Kelvin, Planck Postulates. Explain the claim. Do you think it is a good argument? If so, explain the relationship in thermodynamics between this asymmetry and the arrow of time. If not, is it a fundamental time-asymmetry that explains the thermodynamical asymmetry (or vice-versa)?

2. What is statistical mechanics? Is it a physical theory or a framework within which one formulates physical theories? Pick a philosophical problem associated with statistical mechanics that we've discussed in the course and explain how the interpretation of the problem and different ways of trying to address it depend on one's answer to this question.

3. Describe and define macro- versus micro-probabilities in Boltzmannian statistical mechanics, as sketched in Frigg (2008, pp. 12–13 (arXiv version)) and the lectures. How do they differ and how are they related? what are the problems with each with respect to interpreting "highly probable" (with regard to the temporal evolution of states) in the statement of H-theorem? Can those problems be ameliorated (or exacerbated!) by adopting one or another approach to or interpretation of "probability" in the framework of Boltzmannian statistical mechanics?

4. Explain the criticisms Jaynes (1967) levels against the frequency interpretation of probability as used by the ergodic program (up to the time of that paper) in trying to interpret probability in Gibbsian statistical mechanics. Are they decisive? What is Jaynes' own solution to interpreting probability in the theory? Does it resolve the problems as he claims it does? What are its problems? (To answer this, you will need to discuss the problem of how phase averages are to represent observed macro-quantities in Gibbsian statistical mechanics.)

5. Explain the criticisms Jaynes (1967) levels against the frequency interpretation of probability as used by the ergodic program (up to the time of that paper) in trying to interpret probability in Gibbsian statistical mechanics. Does the use of the ergodic program by Malament and Zabell (1980) successfully avoid and address Jaynes' criticisms? How successful is their interpretation compared to that of Jaynes? (To answer this, you will need to discuss the problem of how phase averages are to represent observed macro-quantities in Gibbsian statistical mechanics.)

6. What is the problem of trying to apply Gibbsian statistical mechanics to non-equilibrium systems? Is there a way to successfully address it? If so, what philosophical and physical assumptions can or must one make to do so? If not, what philosophical and physical principles prevent one from doing so? How compelling are these assumptions or principles?

7. Work through the arguments of Sommerfeld (1964, ch. IV, §30, pp. 221–227; ch. V, §§41–43, pp. 293–323) that claim to reduce Navier-Stokes equations to, or perhaps more precisely to derive them from, molecular kinetic theory. Do they work? Are all the assumptions consistent with the uses to which they are put? Are they all consistent with each other? Is this a case of Nagelian reduction, or anything close to it? If so, why, and if not, how does it fail to be? What is the philosophical interest of that fact?

8. At the end of Sklar (1999), he discusses two ways in which thermodynamical principles and knowledge seem to "infect" the foundations of statistical mechanics in such a way, he suggests, as to make it questionable whether anything we have in our current state of knowledge can really be considered a "reduction" of thermodynamics to statistical mechanics. Explain what Sklar means. Discuss one of the examples he gives in detail. Evaluate his suggested claim: do these epistemic and methodological issues make a true reduction impossible in our current epistemic state? If you have time and interest, discuss the relevance of the claims that Callender (2001) makes.

9. I claimed in lecture that Butterfield (2011) is ambiguous about the place and role of the limiting procedure in his analysis of the reduction of phase transitions in thermodynamics to statistical mechanics, specifically with regard to the logical entailment presumably involved in the "Nagelian" reduction he claims to be relying on. Is the limiting procedure supposed to occur before the logical entailment or as part of it? Discuss problems with both of those options. Is there really a *deduction* at the heart of the construction playing a significant enough role to justify the description of the procedure as "Nagelian"? What are the philosophical consequences of these problems for his account? Is there way a for Butterfield to improve his arguments so as to avoid these problems?

10. There are several different forms of entropy, appearing in different theories (thermodynamics, Boltzmannian statistical mechanics, Gibbsian statistical mechanics, Shannon, von Neumann, black-hole thermodynamics). Pick 3 (though one must be thermodynamics), and discuss how they are related to each other, and also the ways they are similar and how they differ. Is this a problem for physics? What can this teach us about the way that the "same" physical quantity can be represented in different theories, and about inter-theoretical relations in general?

11. I argued in lecture that entropy in statistical mechanics is fundamentally a modal notion. Explain this. What are the modalities involved? How does this make it different from other physical quantities? Pick an account of modality that you think is well suited for the task and explain the modal character of entropy in its terms. How does this account ameliorate the philosophical problems?

12. It is sometimes said that the Second Law (at least in its thermodynamical guise, and in the context of Boltzmannian statistical mechanics and Gibbsian statistical mechanics) raises problems for the possibility of prediction. Explain this. I argued in lecture that it, in conjunction with the Minus-First Law, also makes problems for retrodiction (the approach to equilibrium). Explain this. Which is worse? Why? What consequences do these problems have for the possibility of doing physics?

13. What is the irreversibility at the heart of the Second Law in statistical mechanics? In thermodynamics? Compare them. If you think they are fundamentally different, discuss the problems this raises for the possibility of reducing thermodynamics to statistical mechanics. If you think they are fundamentally the same, explain why, taking into account the fact that it is difficult to incorporate and represent a robust notion of temporal evolution in thermodynamics.

14. Explain the reversibility and the recurrence objections as they appear in Boltzmannian statistical mechanics, and their philosophical import. What do you think the best arguments are for resolving them, and why? If you think there are no good arguments, explain why.

15. Uffink (2001, 2003) argues that, on the Planckian approach to characterizing irrecoverability, there is a troubling circularity because of the necessity of explicitly representing the state of the environment. Explain what the putative circularity is. Is it fatal to a Planckian program? In lecture, I argued that one may be able to micitgate the viciousness of the circularity by relying on an unerstanding of the definition of theoretical quantities as being a "dialectical" process, rather than an axiomatic or stipulative one. Explain what I meant. Do you think my proposal works? Base your arguments on an explicit working through of the way that a Planckian would use irrecoverability to define entropy.

16. Uffink (2001, 2003) claims that (in essence) time-reversal invariance of a theory is not equivalent to the recoverability of every allowable dynamical process. Why does he claim this? Is it too cheap or easy an argument? Is there a substantive, though perhaps not strictly logical, sense in which time-reversal invariance implies recoverability? What is the relevance of this for the issue of determining the kind of irreversibility at the heart of the Second Law in thermodynamics?

17. Pick two different formulations of the idea of the "arrow of time". What is the relationship between the irreversibility in thermodynamics and each of those arrows? Do the same for one of Gibbsian statistical mechanics and Boltzmannian statistical mechanics. If you think there is an intimate, substantive relation, does the irreversibility "explain" the arrow of time, or vice-versa? Does one of the arrows do better than the other? If so, why? If not, why does the difference between the formulations not matter?

18. What can it mean to say that different arrows of time "point in the same direction"? Pick one, discuss the arrows it clearly applies to, those it clearly does not (if any), and those that are problematic cases, and explain why for all. What should one conclude philosophically from the existence of problematic cases?

19. Is the Past Hypothesis in cosmology necessary to explain the validity of the Second Law in thermodynamics? In statistical mechanics? If so, explain. If not, what do you think does explain it?

20. What does (or can) the claim mean, that black holes are really thermodynamical objects? Are they? Either way, what are the philosophical and physical consequences for our understanding of their physics and for the physics of gravity in general?

## References


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