STATE UNIVERSITY OF NEW YORK AT BINGHAMTON
DEPARTMENT OF PHYSICS

Syllabus
PHYS. 411 (511)
Statistical Thermodynamics
Fall 2017 (8/23/17 – 12/08/17)
(Revised November 25, 2017)

Course Objectives: To understand the basic concepts underlying statistical mechanics and thermodynamics and to be able to independently solve corresponding problems.

Statistical thermodynamics (or thermal physics) deals with collections of large number of particles – typically 10^{23} or so. Examples include the air in a balloon, the electrons in a metal, and the photon coming from the sun. Anything big enough to see with our eyes has enough particles in it to qualify as a subject of thermal physics. Consider a metal, containing perhaps 10^{23} conduction electrons. We cannot possibly follow every detail of the motions of all these electrons. Instead, in thermal physics, we assume that the electrons just jostle about randomly, and we use the law of probability to predict how the metal as a whole ought to behave. Alternatively, we can measure the bulk properties of the metal (conductivity, heat capacity, magnetization, and so on). From these we infer something about the conduction electrons it is made of.

Some of the properties of bulk matter do not really depend on the microscopic details of atomic physics (or quantum physics). Heat always flows spontaneously from a hot object to a cold one, never the other way. Liquids always boil more readily at lower pressure. The maximum possible efficiency of an engine, working over a given temperature range, is the same dependent of the kind of working substances. These kinds of results and the principles that generalize them, comprise a subject called **thermodynamics**.

To understand matter in more detail, however, we must also take into account both the quantum behavior of atoms and the law of statistics that make the connection between one atom and 10^{23} atoms. Then we can not only predict the properties of metals and other materials, but also explain why the principles of thermodynamics are what they are – why heat flows from hot to cold, for example. This underlying explanation of thermodynamics, and the many applications that come along with it, comprise a subject called **statistical mechanics**.

It seems to me that instructors and textbook authors are in bitter disagreement over the proper content of a first course of statistical thermodynamics (or thermal physics). Some prefer to cover thermodynamics, it being less mathematically demanding and more readily applied to the every world. Others put a strong emphasis on statistical mechanics, with its spectacularly detailed predictions and concrete foundation in atomic physics (quantum mechanics). To some extent the choice depends on what application areas, one has in mind. Thermodynamics is often sufficient in **engineering** or earth science, while statistical mechanics is essential in **solid state physics**, **quantum mechanics (including quantum information)**, and **astrophysics**.The thrill of statistical thermodynamics comes from using it to understand the world we live in. Indeed, statistical thermodynamics has so many applications that no one can possibly be an expert on all of them, including such diverse area as solid state physics, astrophysics, chemistry, biology, low temperature physics, and so on.

In my lecture on Phys.411 (511) course in the Fall 2017, I will try to do justice to both thermodynamics and statistical mechanics, without giving undue emphasis to either. To this end, I use a textbook (Blundell and Blundell, The concept of thermal physics, Oxford). This book consists of part I (mainly thermodynamics) and part II (statistical mechanics). Although we need to discuss many topics in class, because of the limited times, I will choose important topics and concentrate for further discussion. This textbook is well written suitable for mainly undergraduate students of physics. The E-book version of this book is available from the Binghamton University Library. The homeworks which are chosen from this book, is relatively easy for solving.

CRN: 17078 (Phys.411) and 17085 (Phy.511)
Credit: 4.00

Instructor:

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Class hours (lectures):

T, R:	10:05 - 11:30 AM	SW-214	(Lecture)
W	10:50 – 11:50 AM	LH-004	(Discussion)

Office Hours:

M	9:00 – 10:45 AM	Smart Energy Room 2048 (or SII 157A)
F	9:00 – 11:00 AM	Smart Energy Room 2048 (or SII 157A)

Attendance

If the attendance percentage is less than 40 %, you are not allowed to take the final examination. It means that your grade will be automatically F. I put this condition for the first time since I joined the Department of Physics in 1986, sine some students show up only in the examination in Phys.421/508 Quantum Mechanics I (2012 and 2013). I will check the attendance every class. I will also warn students with less than 40% attendance in advance one month before the final examination.

Lecture Notes (Blackboard):

These notes are made from my experience of teaching in Statistical Thermodynamics since 1986. The contents of the notes are not always the same as those of the textbook (Blundell and Blundell), and are much more extensive.

Textbook:

Stephen J. Blundell and Katherine M. Blundell, Concepts in Thermal Physics, Second edition (Oxford University Press, 2013)
ISBN 978-019-956209-1 (Hbk): hard back
ISBN 978-0-19-956210-7 (Pbk): paper back

E-book

We have an E-book of Concepts in Thermal Physics, Second edition.
Go to the URL of the Binghamton University Library
http://www.binghamton.edu/libraries/

Text Coverage: Blundell-Blundell

Chapters (covered in class):

(a) Thermodynamics
1, 2, 3, 4, 5, 6, 7,
11, 12, 13, 14,
16

(b) Statistical Mechanics
17, 18
19, 20, 21, 22, 23
25, 26, 27, 28, 20, 30

Contents

It consists of two parts: thermodynamics and statistical mechanics

I. Thermodynamics

Thermodynamics first law, second law, third law, Carnot cycle)
Boltzmann kinetic theory
Maxwell-Boltzmann distribution function
Entropy, information theory
Exact differential
Maxwell's relation
Probability, combination, Gaussian distribution function
Energy equipartition theorem
Gibbs paradox

II. Statistical Mechanics

Partition function
Statistical mechanics of ideal gas
Micro-canonical ensemble, Ergodic theory
Canonical ensemble
Planck's distribution function
Black body radiation
Grand canonical ensemble
Chemical potential
Number fluctuation

Quantum Statistics	(identical particles in quantum mechanics)
Quantum ensemble	(density operator in quantum mechanics)
The Fermi gas	(Fermi-Dirac distribution function, Fermi energy)
The Bose gas	(Bose-Einstein distribution function)
Photon and phonon	(solid state physics)

Relativistic gases
White dwarf, neutron star
Bose-Einstein condensation
Superfluidity
Superconductivity
Cooling real gases
Phase transitions (critical phenomena, scaling hypothesis van der Waals equation of state)
Clausius-Clapeyron equation
The order parameter (Ginzburg-Landau theory)
Brown motion (diffusion equation)
Fluctuation-Dissipation theorem

List of books reserved in the Newcomb Reading Room in the Library North

1. F. Reif, Fundamentals of statistical and thermal physics (McGraw-Hill, 1965). ISBN-13: 978-1-57766-612-7
2. R. Kubo, Thermodynamics An Advanced Course with Problems and Solutions (North-Holland, 1968).
3. C. Kittel and H. Kroemer, Thermal Physics, second edition (W.H. Freeman and Company, 1980). ISBN: 0-7167-1088-9.
4. M. Toda, R. Kubo, and N. Saito, Statistical Physics I: Equilibrium Statistical Mechanics (Springer, 1983). ISBS-13: 978-3-642-96700-9.
5. K. Huang, Statistical Mechanics (John Wiley & Sons, 1987). ISBN: 0-471-81518-7
6. D.V. Schroeder, Introduction to Thermal Physics (Addison-Wesley, 2000). ISBN 0-201-38027-7.
7. S.J. Blundell and K.M. Blundell, Concepts in Thermal Physics (Oxford, 2006) ISBN 0-19-856769-3.

8. M. Kardar, Statistical Physics of Particles (Cambridge, 2007). ISBN-13 978-0-521-87342-0.
9. K. Huang, Introduction to Statistical Physics, second edition (CRC Press, 2010). ISBN: 978-1-4200-7902-9.

REFERENCES

Statistical mechanics (Introduction)

1. D.K.C. MacDonald, Introductory Statistical Mechanics for Physicists (John Wiley & Sons, 1963).
2. R. Kubo, Statistical Mechanics An Advanced Course with Problems and Solutions (North-Holland, 1965).
3. A. Ishihara, Statistical Physics (Academic Press, 1971).
4. P. Dennery, An Introduction to Statistical Mechanics (George Allen & Unwin, 1972).
5. D. Chandler, Introduction to Modern Statistical Mechanics (Oxford, 1987). ISBN 0-19-504276-X.
6. K. Huang, Statistical Mechanics (John Wiley & Sons, 1987). ISBN 0-471-81518-7
7. D.J. Amit and Y. Verbin, Statistical Physics, Introductory Course (World Scientific, 1995). ISBN: 981023192X
8. F. Bloch, Fundamentals of Statistical Mechanics (Imperial College & World Scientific, 2000). ISBN 981-02-4419-3
9. B. Widom, Statistical Mechanics, A Concise Introduction for Chemists (Cambridge, 2002). ISBN-13: 978-0-521-81119-4
10. T. Tanaka, Methods of Statistical Physics (Cambridge, 2002). ISBN-13: 978-0-521-58056-4.
11. I. Sachs, S. Sen, and J.C. Sexton, Elements of Statistical Mechanics with an Introduction to Quantum Field Theory and Numerical Simulation (Cambridge, 2006). ISBN-13: 978-0-521-84198-6
12. K. Stowe, An Introduction to Thermodynamics and Statistical Mechanics, second edition (Cambridge, 2007). ISBN-13: 978-0-521-86557-9
13. J.W. Halley, Statistical Mechanics: From First Principles to macroscopic Phenomena (Cambridge, 2007). ISBN-13 978-0-521-82575-7
14. D. Yoshioka, Statistical Physics: An Introduction (Springer, 2007). ISBN-13: 978-3-540-28605-9
15 K. Huang, Introduction to Statistical Physics, second edition (CRC Press, 2010). ISBN: 978-1-4200-7902-9.
16. R. Baierlein, Thermal Physics (Cambridge University Press, 2001).

Statistical Thermodynamics (thermal physics)

1. E. Fermi, Notes on Thermodynamics and Statistics (The University of Chicago, 1966).
2. J. Kestin and J.R. Dorfman, Statistical Thermodynamics (Academic Press, 1971).
3. C. Kittel and H. Kroemer, Thermal Physics, second edition (W.H. Freeman and Company, 1980). ISBN 0-7167-1088-9.
4. W. Greiner, L. Neise, and H. Stöcker, Thermodynamics and Statistical Mechanics (Springer, 1997). ISBN 0-387-94299-8.
5. D.V. Schroeder, Introduction to Thermal Physics (Addison-Wesley, 2000). ISBN 0-201-38027-7.
6. M.Le Bellac, F. Mortessagne, and G.G. Batrouni, Equilibrium and Non-equilibrium Statistical Thermodynamics (Cambridge, 2004). ISBN-10 0-521-82143-6 (Hardback).
7. N.M. Laurendeau, Statistical Thermodynamics Fundamentals and Applications (Cambridge, 2005) ISBN-13: 978-0-521-84635-6
8. S.J. Blundell and K.M. Blundell, Concepts in Thermal Physics (Oxford, 2006) ISBN 0-19-856769-3.
9. C.S. Herrich, Modern Thermodynamics with Statistical Mechanics (Springer, 2009). ISBN: 978-3-540-85417-3
10. A. Wassermann, Thermal Physics: Concepts and Practice (Cambridge, 2012). ISBN: 978-1-107-00649-2.
11. C.S. Helrich, Modern Thermodynamics with Statistical Mechanics (Springer, 2009). ISBN: 978-3-540-85417-0.

Thermodynamics (standard textbook)

1. A. Rex, Finn's Thermal Physics, Third edition (CRC Press, 2017)
2. E. Fermi, Thermodynamics (Dover, 1936).
3. H.B. Callen, Thermodynamics (John Wiley, 1960).
4. D. ter Haar and H. Wergeland, Elements of Thermodynamics (Addison-Wesley, 1966).
5. A.B. Pippard, Elements of Classical Thermodynamics (Cambridge, 1966).
6. C.J. Adkins, Equilibrium Thermodynamics, third edition (Cambridge, 1983).
7. R.P.H. Gasser and W.G. Richards, An Introduction to Statistical Thermodynamics (World Scientific, 1995).
8. M.W. Zemansky and R.H. Dittman, Heat and Thermodynamics An Intermediate Textbook, seventh edition (McGraw-Hill, 1997). ISBN 0-07-017059-2.
9. M. Kaufman, Principles of thermodynamic (MarcelDekker, 2002). ISBN: 0-8247-0692-7.
10. H. Gould and I. Tobochnik, Statistical and Thermal Physics with Computer Applications (Princeton University, 2010). ISBN: 9780691137445

11. R. Kubo, Thermodynamics An Advanced Course with Problems and Solutions (North-Holland, 1968).

Statistical Mechanics (standard textbooks)

1. J.W. Gibbs, Elementary principles in Statistical Mechanics (Scribner's son, 1902).
2. R. Tolman, The Principles of Statistical Mechanics (Oxford, 1938).
3. R. Fowler and E.A. Guggenheim Statistical Thermodynamics (1956)
4. C. Kittel, Elementary Statistical Physics (John Wiley & Sons, 1958).
5. F. Reif, Fundamentals of statistical and thermal physics (McGraw-Hill, 1965). ISBN-13: 978-1-57766-612-7
6. G.H. Wannier, Statistical Physics (Dover, 1966). ISBN 0-486-65401-X
7. G.S. Rushbrooke, Introduction to Statistical Mechanics (Oxford, 1967).
8. J.E. Mayer, Equilibrium Statistical Mechanics (Pergamon Press, 1968).
9. R.P. Feynman, Statistical Mechanics, A Set of Lectures (Benjamin/Cumming, 1972). ISBN 0-8053-2509-3.
10. L.D. Landau and E.M. Lifshitz, Statistical Physics (Pergamon Press 1976).
11. D.A. McQuarrie, Statistical Mechanics (Harper & Row, 1976). ISBN: 06-044366-9
12. M. Toda, R. Kubo, and N. Saito, Statistical Physics I: Equilibrium Statistical Mechanics (Springer, 1983). ISBS-13: 978-3-642-96700-9.
13. R. Kubo, M. Toda, and N. Hashitsume, Statistical Physics II (Springer, 1985). ISBS-13: 978-3-642-96703-0.
14. S.K. Ma, Statistical Mechanics (World Scientific, 1985). ISBN: 9971-966-06-9
15. D. ter Haar, Elements of statistical mechanics, third edition (Butterworth Heinemann, 1995). ISBN: 0-7506-2347-0.
16. R.E. Wilde and S. Singh, Statistical Mechanics Fundamentals and Modern Applications (John-Wiley & Sons, 1998). ISBN 0-471-16165-9.
17. G.F. Mazenko, Equilibrium Statistical Mechanics (John Wiley & Sons, 2000). ISBN 0-471-32839-1
18. L.P. Kadanoff, Statistical Physics, Dynamics and Renormalization (World Scientific, 2000). ISBN: 9810237588.
19. C. Hermann, Statistical Physics including applications to Condensed Matter (Springer, 2005). ISBN: 0-387-22660-5.
20. G.F. Mazenko, Nonequilibrium Statistical Mechanics (Wiley-VCH, 2006). ISBN-13: 978-3-527-40648-7.
21. F. Schwabl, Statistical Mechanics, second edition (Springer, 2006). ISBN-13: 978-3-540-32343-3
22. M. Kardar, Statistical Physics of Particles (Cambridge, 2007). ISBN-13 978-0-521-87342-0.

23. C.M. Van Vliet, Equilibrium and Non-equilibrium Statistical Mechanics (World Scientific, 2008). ISBN-13: 978-981-270-477-1.
24. H.J.W. Műller-Kirsten, Basics of Statistical Physics (World Scientific, 2010). ISBN-13: 978-981-4287-22-7.
25. R.K. Pathria and P.D. Beale, Statistical Mechanics, third edition (Elsevier, 2011). ISBN: 978-12-382188-1
26. L. Peliti, Statistical Mechanics in a Nutshell (Princeton University, 2011). ISBN 978-0-691-14529-7
27. I. Ford, Statistical Physics: An Entropic Approach (Wiley, 2013). ISBN 978-1-119-97531-1.

Mathematica 11.2: (not required):

You can get a Mathamatica 11-2 from the on-line. Binghamton University has a license for the Mathematica 11. The SUNY system gets a license to use the Mathematica 11 for all students and faculties in the Binghamton University. I will show how to use the Mathematica 11 during the class. As a part of the demonstration, I will also show the programs which I will make.

Homeworks:

All the homeworks are chosen from the problems in the text book (Blundell and Blundell). Homework solutions should be submitted before the due date. The problem numbers for each homework are listed below.

Exams:

There are three Hour Exams and one final exam. All problems will be chosen from the homeworks (Blundell and Blundell) and quizzes. I will let you know the detail before each examination. The problems of the examinations are not always the same. I will modify the problems and add several questions.

Final Grade Determination:

Your final grade will be based on an absolute scale. Your final grade will be based on the three one-hour examinations (actually two Exams out of three Exams), the final exam, the lab grade, the home work grade, and the discussion grade as follows:

200 points	for best two of the three one-hour exams (see below)
200 points	for the final exam
50 points	for the discussion grade (Quiz)
100 points	for the home work
50 points	attendance for lecture class
600 points	total possible points for the course

Grade:

Your final grade will be determined by the percentage of 600 total points you manage to attain. These grades may change depending on the graph of the number of people vs total points such as Gaussian distribution with a single peak or double peaks.

85-100	A
80-84	A^-
75-79	B^+
70-74	B
65-69	B^-
60-64	C^+
55-59	C
50-54	C^-
40-49	D
0-39	F

Discussion:

In discussion, concepts presented in lecture will be reviewed and new concepts and approaches to problem solving may be introduced. Try to use these sessions to get your questions answered. Your discussion grade will be based on: your performance in a series of short quizzes, and, possibly, on a judgment based upon your participation in discussion. The evaluation will be made from quizzes and attendance.

We discuss the solution of selected problems (nice problems) which are chosen from textbooks (Blundell and Blundell) and problems from (Reif, Kubo, Huang). All the problems will be listed in the **Blackboard**.

Exam solutions:

Solutions for examinations will be posted on Blackboard.

Blackboard:

We have established a system where you can access exam solutions and administrative announcements from any on or off campus computer.

Announcements, Lecture note, Solutions of homeworks, Mathematica programs, Web site links, E-mail, and so on

Schedule of Classes in Phys.411 and Phys.511 (Fall 2017):

	Date	Topics
Week-1		
	23 August	Chapter 1 Introduction

	W	Chapter 2 Heat
	24 August R	Chapter 2 Chapter 3 Probability
Week-2	29 August T	Chapter 3 Chapter 4 Temperature and the Boltzmann factor (Canonical ensemble)
	30 August W	Chapter 4 Chapter 5 The Maxwell-Boltzmann distribution Quiz-1
	31 August R	Chapter 5 Chapter 6 Pressure
Week-3	5 September T	Chapter 7 Molecular effusion Chapter 11 Energy (the first law)
	6 September W	Chapter 11 Chapter 12 Isothermal and adiabatic processes Quiz-2
	7 September R	Chapter 12 Chapter 13 Heat engines and the second law
Week-4	12 September T	Chapter 13 Chapter 14 Entropy
	13 September W	Chapter 14 Entropy Quiz-3
	14 September R	Chapter 14 Entropy Chapter 16 Thermodynamic potential
Week-5	19 September T	Chapter 16 Chapter 17 Rod, bubbles, and magnets
	20 September W	Chapter 17 Chapter 18 The third law Quiz-4
	21 September R	No Class Rosh Hashanah
Week-6	26 September T	Chapter 18 Chapter 19 Equipartition of energy
	27 September	Hour Exam-I

	W	Chapters 1-11
	28 September R	Chapter 19 Chapter 20 The partition function
Week-7	3 October T	Chapter 20
	4 October W	Chapter 20 Chapter 21 Statistical mechanics of an ideal gas Quiz-5
	5 October R	Chapter 21
Week-8	10 October T	Chapter 22 Chemical potential
	11 October W	Chapter 22 Quiz-6
	12 October R	Chapter 23 Photon
Week-9	17 October T	No class (Fall break)
	18 October W	Chapter 23 Quiz-7
	19 October R	Chapter 23
Week-10	24 October T	Chapter 24 Phonon
	25 October W	Exam-II **Chapters 12, 13, 14, 16, 17, 19, 20**
	26 October R	Chapter 24
Week-11	31 October T	Chapter 25 Relativistic gases
	01 November W	Chapter 25 Quiz-8
	02 November R	Chapter 26 Real gas
Week-12	7 November T	Chapter 26
	8 November W	Chapter 29 Bose-Einstein and Fermi-Dirac

		distributions Quiz-9
	9 November R	Chapter 29
Week-13	14 November T	Chapter 29
	15 November W	Chapter 29 Quiz-10
	16 November R	Chapter 30 Quantum gases and condensates
Week-14	21 November T	Chapter 30
	22 November W	No class (Thanksgiving)
	23 November R	No class
Week-15	28 December T	Chapter 30
	29 November W	Hour Exam-3 Chapters 22-25
	30 November R	Chapter 30 Chapter 27 Cooling real gas
Week-16	5 December T	Chapter 27 Chapter 28 Phase transitions
	6 December W	(Monday class) No class
	7 December R	Chapter 28
Final Exam	TBA	