TEACHING INSTRUCTIONAL DESIGN (BRP)

COURSE

STATISTICAL PHYSICS

Unnofficial Translation

by

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PREFACE

The Teaching Instructional Design (BRP) of Statistical Physics is prepared to be used as a reference for the subject of Statistical Physics in Physics Graduate Program of FMIPA UI which is followed by physics student of 5th semester with the requirement that the students have taken thermodynamics course, Mathematics Physics 2, and Physics Mathematics 3. In the Statistical Physics course, students will be taught to apply the principles of statistics, the concepts of quantum mechanics, and the semiclassical approach to systems consisting of many particles to provide a microscopic explanation of commonly used thermodynamic macroscopic principles and phenomena known, and provides a systematic microscopic modeling procedure to predict the various thermodynamic properties of a system. It is expected that this BRP can be a reference or reference on the learning process for both lecturers as faculty and students as participants of the course so that the material is delivered well and perfectly.

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Depok, 15 December 2017

Dedi Suyanto, Ph.D.

I. General Information

1.	Name of Program / Study Level	:	Physics / Undergraduate
2.	Course Name	:	Statistical Physics
3.	Course Code	:	SCFI603110
4.	Semester	:	5
5.	Credit	:	4 credits
6.	Teaching Method(s)	:	Lecturing, individual-assignment, written exam
7.	Prerequisite course(s)	:	Thermodynamics, Mathematical Methods in Physics 2, Mathematical Methods in Physics 3
8.	Requisite for course(s)	:	Solid State Physics 2, Advanced Laboratory, Capita Selection of Condensed Matter
9.	Integration Between Other Courses	:	None
10.	Lecturer(s)	:	1. Dedi Suyanto, Ph.D. 2. Dr. Budhy Kurniawan 3. Dede Djuhana, Ph.D.
11.	Course Description	:	Statistical Physics is one of compulsory courses in Undergraduate Program in Physics. The content of this course consist of: canonical and microcanonical ensembles, chemical potential, classical partition function, equipartition energy, Gibbs paradox, entropy, ideal gas on grand canonical ensemble, Maxwell-Boltzmann distribution, diatomic gas, interacting gas, density of states, blackbody radiation, Planck distribution, Debye model, Bose-Einstein distribution, Bose-Einstein condensation, fermion, Pauli paramagnetism, Landau diamagnetism, phase transition, mean-field theory, Ising model, and Landau-Ginzburg theory.

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II. Course Learning Outcome (CLO) and Sub-CLOs

A. CLO

Students are able to apply general concepts of statistical physics in the area of condensed-matter, material, nuclear and particle, instrumentation, and medical physics. (ELO(s) 1, 2, 5, 6, 7)

B. Sub-CLOs

1. To calculate basic distribution function using random walk method (C3).
2. To relate the concept of canonical and microcanonical ensembles with thermodynamics quantities (C3).
3. To calculate chemical potential, classical partition function, equipartition energy, and entropy and apply them to the concept of Gibbs paradox (C3).
4. To apply Maxwell-Boltzmann distribution function on diatomic gas and interacting gas and calculate the density of states (C3).
5. To apply Planck distribution function on blackbody radiation and Debye model and apply Bose-Einstein distribution function on Bose-Einstein condensation (C3).
6. To apply Fermi-Dirac distribution function on fermion, Pauli paramagnetism, and Laudau diamagnetism (C3).
7. To apply grand canonical ensemble on ideal gas, phase transition, phase transition level one and two, and Landau-Ginzburg theory (C3).
8. To apply mean-field theory on one dimensional Ising model (C3)

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III. Teaching Plan

Week	Sub-CLO	Study Materials	Teaching Method	Time Required	Learning Experiences (*O-E-F)	Sub-CLO Weight on Course (%)	Sub-CLO Achievement Indicator	References
1	1	Random walk, binomial, Gaussian, and Poisson distributions, distribution of many-variables probability, continuous distribution, and expectation value	Lecturing	200 minutes	60% O, 20%E, 20% F	5	To calculate distribution function using random walk method	No. 1 Ch. 1
2	2	Thermal and mechanical interactions between two particles, relation between microcanonical ensemble with thermodynamics, and monoatomic ideal gas	Lecturing	200 minutes	60% O, 20%E, 20% F	5	To relate microcanonical ensemble with thermodynamics quantities	No. 2 Ch. 4
3	2	Ideal half-spin paramagnet, Einstein vibration, two-states particle, and Boltzmann gas	Lecturing	200 minutes	60% O, 20%E, 20% F	5	To apply canonical ensemble	No. 2 Ch. 5
4	3	Chemical potential, classical partition function, equipartition energy, Gibbs paradox, and entropy	Lecturing	200 minutes	60% O, 20%E, 20% F	10	To calculate chemical potential, partition function, equipartition energy, and entropy and use them on Gibbs paradox concept	No. 1 Ch. 7
5	4	Maxwell-Boltzmann distribution, diatomic gas, interacting gas, and density of states	Lecturing	200 minutes	60% O, 20%E, 20% F	10	To apply Maxwell-Boltzmann distribution function and calculate the density of states	No. 1 Ch. 7
6	5	Blackbody radiation, Planck distribution, and Debye model	Lecturing	200 minutes	60% O, 20%E, 20% F	5	To calculate Planck distribution function and use it on blackbody	No. 1 Ch. 9; no. 2 Ch. 10

							radiation and Debye model	
7	5	Bose-Einstein distribution and Bose-Einstein condensation	Lecturing	200 minutes	60% O, 20%E, 20% F	10	To calculate Bose-Einstein distribution function	No. 1 Ch. 9; no. 2 Ch. 10
8	**Mid-Term Exam**							
9	6	Fermi-Dirac distribution, fermion, Pauli paramagnetism, and Landau diamagnetism	Lecturing	200 minutes	60% O, 20%E, 20% F	5	To use Fermi-Dirac distribution function on Pauli paramagnetisme and Landau diamagnetisme	No. 1 Ch. 9; no. 2 Ch. 9
10	7	Grand canonical ensemble on ideal gas	Lecturing	200 minutes	60% O, 20%E, 20% F	10	To apply grand canonical ensemble on ideal gas	No. 1 Ch. 8; no. 2 Ch. 7; no. 3 Ch. 9
11	7	Grand canonical ensemble on phase transition	Lecturing	200 minutes	60% O, 20%E, 20% F	5	To apply grand canonical ensemble on phase transition	No. 1 Ch. 8; no. 2 Ch. 7; no. 3 Ch. 9
12	7	Grand canonical ensemble on phase transition level one and two	Lecturing	200 minutes	60% O, 20%E, 20% F	5	To apply grand canonical ensemble on phase transition level one and two	No. 1 Ch. 8; no. 2 Ch. 7; no. 3 Ch. 9
13	7	Grand canonical ensemble on Landau-Ginzburg theory	Lecturing	200 minutes	60% O, 20%E, 20% F	5	To apply grand canonical ensemble on Landau-Ginzburg theory	No. 1 Ch. 8; no. 2 Ch. 7; no. 3 Ch. 9
14	8	Mean-field theory	Lecturing	200 minutes	60% O, 20%E, 20% F	5	To explain the mean-field theory	No. 2 Ch. 13
15	8	One dimensional Ising model	Lecturing	200 minutes	60% O, 20%E, 20% F	5	To use mean-field theory on one dimensional Ising model	No. 2 Ch. 13
16	**Final Exam**							

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*) O : Orientation
E : Exercise
F : Feedback

References:

1. F. Reif, *Fundamentals of Statistical and Thermal Physics*, McGraww-Hill Book Company, 1985.
2. S. R. Salinas, *Introduction to Statistical Physics*, Springer-Verlag, 2001.
3. H. B. Callen, *Thermodynamics and an Introduction to Thermostatistics 2nd Edition*, John Wiley & Sons, 1985.

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IV. Assignment Design

Week	Assignment Name	Sub-CLO	Assignment	Scope	Working Procedure	Deadline	Outcome
1	Individual Assignment 1	1	Problem set	Random walk, binomial, Gaussian, and Poisson distributions, distribution of many-variables probability, continuous distribution, and expectation value	Homework	1 week	Homework answer sheet
3	Individual Assignment 2	2	Problem set	Thermal and mechanical interactions between two particles, relation between microcanonical ensemble with thermodynamics, monoatomic ideal gas, ideal half-spin paramagnet, Einstein vibration, two-states particle, and Boltzmann gas	Homework	1 week	Homework answer sheet
4	Individual Assignment 3	3	Problem set	Chemical potential, classical partition function, equipartition energy, Gibbs paradox, and entropy	Homework	1 week	Homework answer sheet
5	Individual Assignment 4	4	Problem set	Maxwell-Boltzmann distribution, diatomic gas, interacting gas, and density of states	Homework	1 week	Homework answer sheet
7	Individual Assignment 5	5	Problem set	Blackbody radiation, Planck distribution, Debye model, Bose-Einstein distribution, and Bose-Einstein condensation	Homework	1 week	Homework answer sheet
9	Individual Assignment 6	6	Problem set	Fermi-Dirac distribution, fermion, Pauli paramagnetism, and Landau diamagnetism	Homework	1 week	Homework answer sheet
13	Individual Assignment 7	7	Problem set	Grand canonical ensemble on ideal gas, phase transition, phase transition level one and two, and Landau-Ginzburg theory	Homework	1 week	Homework answer sheet
15	Individual Assignment 8	8	Problem set	Mean-field theory and one dimensional Ising model	Homework	1 week	Homework answer sheet

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V. Assessment Criteria (Learning Outcome Evaluation)

Evaluation Type	Sub-CLO	Assessment Type	Frequency	Evaluation Weight (%)
Individual Assignment	1-8	Answer sheet	8	30
Mid-Term Exam	1-5	Answer sheet	1	35
Final Exam	6-8	Answer sheet	1	35
Total				**100**

VI. Rubric(s)

A. Criteria of Assignment and Exam Score

Score	Answer Quality
100	Answer is very precise and all the concept and main component are explained completely
76-99	Answer is fairly precise and the concept and main component are explained fairly complete
51-75	Answer is less precise and the concept and main component are explained less complete
26-50	Answer is poorly precise and the concept and main component are explained poorly complete
<25	Answer is wrong

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VII. Appendix: Example of Exam Problems

A. Mid-Semester Exam

1. Suppose a typo occurs randomly, 600 pages of book has 600 errors. Use a Poisson distribution to calculate:
   i. probability of a page that is not typo
   ii. the probability of a page there are three typos.

2. An isolated system composed of N noninteracting particles with spins 1/2, has a magnetic moment μ which can be parallel or opposite to the external magnetic field H. The system energy is $E = -(n_1 - n_2)\mu H$ with n_1 the number of paralleled particles to the field and n_2 of the number of particles in opposite direction with the field. Calculate the number of states $\Omega(E)$ in the interval E and $E + \delta E$, assume $\delta E \ll E$, but $\delta E \gg \mu H$

3. A box is separated by a separator so that the volume comparison is 3: 1, the largest part is 1000 Ne while the small part there are 100 molecules He. The separator hollowed and waited until equilibrium. Asked:

   a) what is the average of Ne and He molecules in the large volumes
   b) Calculate the probability of obtaining 1000 Ne molecules in large portions and 100 He molecules in small portion

4. 1 kg of water at 0°C is closer to the 100°C heat reservoir. After the temperature of the water is 100°C, calculate the entropy changes of:
   a. water
   b. hot reservoir
   c. the overall system (water and heat reservoir)

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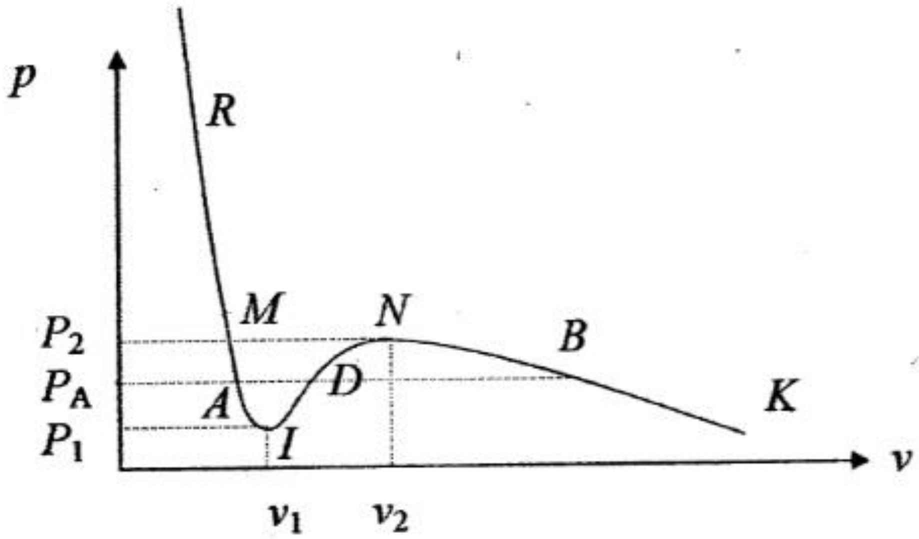
B. Final-Semester Exam

1. What is the Gibbs paradox?
2. See the picture below, the lowest is the isothermal curve, this curve contains enough information. Explain what information can be obtained?



3. What is the equipartition theorem?
4. Review 2 particles with 3 probability of quantum state $s = 1, 2, 3$.
    a) Draw the probability matrix for all three statistics: Maxwell-Boltzmann, Bose-Einstein, and Fermi-Dirac
    b) Calculate the probability ratio of finding particles in different states for all three statistics: Maxwell-Boltzmann, Bose-Einstein, and Fermi-Dirac
    c) What is the physical interpretation from the ratio above

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