TEACHING INSTRUCTIONAL DESIGN (BRP)

COURSE

STATISTICAL PHYSICS

by

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PREFACE

The Teaching Instructional Design (BRP) for the Statistical Physics course was prepared to be used as a reference for learning the Statistical Physics subject in the Undergraduate Physics Study Program of the Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Indonesia which will be attended by 5th semester physics students on the condition that the student had taken Thermodynamics, Mathematical Physics 2, and Mathematical Physics 3. In the Statistical Physics course, students will be taught to apply statistical principles, quantum mechanical concepts, and a semi-classical approach to systems consisting of many particles to provide microscopic explanations of common thermodynamic macroscopic principles and phenomena known, as well as providing systematic microscopic modeling procedures for predicting various thermodynamic properties of a system. It is hoped that this BRP can become a reference in the learning process for both lecturers as teachers and students as course participants so that the material is conveyed properly and perfectly.

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)	:	In-class lectures, individual assignments, written tests
7.	Prerequisite course(s)	:	Thermodynamics, Mathematical Physics 2, Mathematical 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	:	The Statistical Physics course is one of the compulsory subjects in the Undergraduate Physics Study Program. The subject matter includes: canonical and microcanonic ensemble, chemical potential, classical partition function, equipartition energy, Gibbs paradox, entropy, ideal gas in large canonical ensemble, Maxwell-Boltzmann distribution, diatomic gas, interacting gas, state density, black body radiation. , Planck distribution, Debye model, Bose-Einstein distribution, Bose-Einstein condensation, fermion, Pauli paramagnetism, Landau diamagnetism, phase change, mean field theory, Ising model, and Landau-Ginzburg theory.

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

A. CLO

Students are able to apply the basic concepts of statistical physics in the fields of solids, materials, nuclear and particles, instrumentation, and medicine. (ELO(s) 1, 2, 5, 6, 7).

B. Sub-CLOs

1. Calculating the basic distribution function with a random path (C3).
2. Connect the concepts of canonical and microcanonic ensemble with thermodynamic quantities (C3)
3. Calculating chemical potential, classical partition function, equipartition energy, and entropy and applying it to the Gibbs paradox concept (C3).
4. Applying the Maxwell-Boltzmann distribution function to diatomic gases and interacting gases and calculating the state density (C3).
5. Apply the Planck distribution function to black body radiation and the Debye model and apply the Bose-Einstein distribution function to the Bose-Einstein (C3) condensation.
6. Applying the Fermi-Dirac distribution function to fermions, Pauli paramagnetism, and Landau diamagnetism (C3).
7. Applying the large canonical ensemble of ideal gases, phase changes, phase changes one and two, and the Landau-Ginzburg theory (C3).
8. Applying the average field theory to the one-dimensional Ising model (C3).Distinguishing the crystal structure of a solid substance (C4)
9. Explain the vibrational motion of atoms in the solid matter (C4)
10. Classifying the electronic structure of solids (C4)
11. Identifying the optical phenomenon of solids (C4)

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 path, binomial, Gaussian, and Poisson distributions, multi-variable probability distribution, continuous distribution, and mean price	In-class lecture	200 minutes	60% O, 20% E, 20% F	5	Calculates the distribution function by random path	[1] Ch. 1
2	2	Thermal and mechanical interaction between two systems, microcanonic ensemble relationship with thermodynamics, and monatomic ideal gases	In-class lecture	200 minutes	60% O, 20% E, 20% F	5	Relating the microcanonic ensemble with thermodynamic quantities	[2] Ch. 4
3	2	Paramagnetic ideal spin ½, Einstein model vibrations, particles with two states, and Boltzmann gas	In-class lecture	200 minutes	60% O, 20% E, 20% F	5	Apply the canonical ensemble	[2] Ch. 5
4	3	Chemical potential, classical partition function, equipartition energy, Gibbs paradox, and entropy	In-class lecture	200 minutes	60% O, 20% E, 20% F	10	Calculating chemical potential, partition function, equipartition energy, and entropy and applying them to the Gibbs paradox concept.	[1] Ch. 7
5	4	Maxwell-Boltzmann distribution, diatomic gases, interacting gases, and density	In-class lecture	200 minutes	60% O, 20% E, 20% F	10	Applying the Maxwell-Boltzmann distribution function and calculating the density of states	[1] Ch. 7
6	5	Blackbody radiation, the Planck distribution, and the Debye model	In-class lecture	200 minutes	60% O, 20% E, 20% F	5	Computes the Planck distribution function and applies it to the	[1] Ch. 9; [2] Ch. 10

							blackbody radiation and Debye models	
7	5	The Bose-Einstein distribution and the Bose-Einstein condensation	In-class lecture	200 minutes	60% O, 20% E, 20% F	10	Calculate the Bose-Einstein distribution function	[1] Ch. 9; [2] Ch. 10
8	**Mid-Term Exam**							
9	6	Fermi-Dirac distribution, fermion, paramagnetic Pauli and Landau diamagnetism	In-class lecture	200 minutes	60% O, 20% E, 20% F	5	Applying the Fermi-Dirac distribution function to Pauli paramagnetism and Landau diamagnetism	[1] Ch. 9; [2] Ch. 9
10	7	Large canonical ensemble and ideal gas in a large canonical ensemble	In-class lecture	200 minutes	60% O, 20% E, 20% F	10	Applying a large canonical ensemble on ideal gases	[1] Ch. 8; [2] Ch. 7; [3] Ch. 9
11	7	Large canonical ensemble on phase change	In-class lecture	200 minutes	60% O, 20% E, 20% F	5	Apply a large canonical ensemble on phase changes	[1] Ch. 8; [2] Ch. 7; [3] Ch. 9
12	7	Large canonical ensemble on the first and second level phase changes	In-class lecture	200 minutes	60% O, 20% E, 20% F	5	Apply the large canonical ensemble at stage one and second stage changes	[1] Ch. 8; [2] Ch. 7; [3] Ch. 9
13	7	Large canonical ensemble on Landau-Ginzburg theory	In-class lecture	200 minutes	60% O, 20% E, 20% F	5	Applied the great canonical ensemble of Landau-Ginzburg theory	[1] Ch. 8; [2] Ch. 7; [3] Ch. 9
14	8	Average field theory	In-class lecture	200 minutes	60% O, 20% E, 20% F	5	Describe the average field theory	[2] Ch. 13
15	8	One-dimensional Ising model	In-class lecture	200 minutes	60% O, 20% E, 20% F	5	Applying the average field theory to the one-dimensional Ising model	[2] Ch. 13
16	**Final Exam**							

*) 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.

IV. Assignment Design

Week	Assignment Name	Sub-CLOs	Assignment	Scope	Working Procedure	Deadline	Outcome
1	Individual assignment 1	1	Problem set	Random path, binomial, Gaussian, and Poisson distributions, multi-variable probability distribution, continuous distribution, and mean price	Homework	1 week	Answer sheet
3	Individual assignment 2	2	Problem set	Thermal and mechanical interactions between two systems, microcanonic ensemble relationships with thermodynamics, monatomic ideal gases, spin ½ ideal paramagnets, Einstein model vibrations, particles with two states, and Boltzmann gas	Homework	1 week	Answer sheet
4	Individual assignment 3	3	Problem set	Chemical potential, classical partition function, equipartition energy, Gibbs paradox, and entropy	Homework	1 week	Answer sheet
5	Individual assignment 4	4	Problem set	Maxwell-Boltzmann distribution, diatomic gases, interacting gases, and density	Homework	1 week	Answer sheet
7	Individual assignment 5	5	Problem set	Black body radiation, Planck distribution, Debye model, Bose-Einstein distribution, and Bose-Einstein condensation	Homework	1 week	Answer sheet
9	Individual assignment 6	6	Problem set	Fermi-Dirac distribution, fermion, paramagnetic Pauli and Landau diamagnetism	Homework	1 week	Answer sheet
13	Individual assignment 7	7	Problem set	Large canonical ensemble and ideal gas in a large canonical ensemble, large canonical ensemble on phase change, phase change one and two, Landau-Ginzburg theory	Homework	1 week	Answer sheet
15	Individual assignment 8	8	Problem set	Average field theory and the one-dimensional Ising model	Homework	1 week	Answer sheet

V. Assessment Criteria (Learning Outcome Evaluation)

Evaluation Type	Sub-CLO	Assessment Type	Frequency	Evaluation Weight (%)
Individual Assignments	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	The answer is very precise and all the concept and main component are explained completely
76-99	The answer is fairly precise and the concept and main component are explained fairly complete
51-75	The answer is less precise and the concept and main component are explained less complete
26-50	The answer is poorly precise and the concept and main component are explained poorly complete
<25	Wrong answer

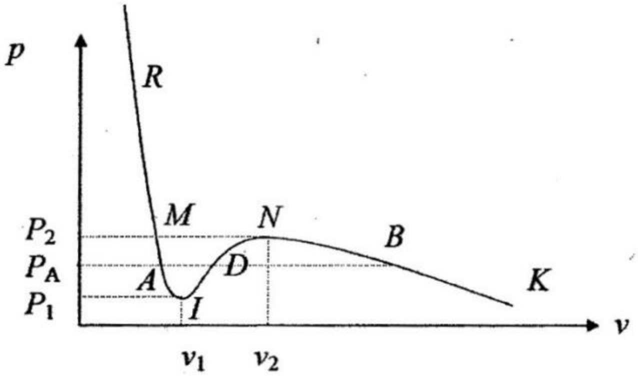
VII. Appendix: Example of Exam Problems

Appendix 1. Mid-Term Exam

1. Imagine typing error occurs randomly, a book consists of 600 pages has 600 mistakes. Use Poisson distribution to calculate: a) the probability of a page has no typing error, and b) the probability of a page has three typign errors.
2. An isolated system consists of non-interacting N particles with a spin of 1/2 having a magnetic moment that can be parallel to or against the direction of the external magnetic field H. The system energy is $E = -(n_1-n_2)\mu H$ with n_1 the number of particles parallel to the field and n_2 the number of particles opposite the direction of the field. Calculate the number of states $\Omega(E)$ in the intervals E and $E + \delta E$, assuming $\delta E \ll E$ but $\delta E \gg \mu H$.
3. A box is separated into two rooms with volume ratio of 3: 1 where the large part contains 1000 Ne molecules and the small one is 100 He molecules. The separator is perforated and waited for it to be balanced. What is: a) the average number of Ne and He molecules in the large volume portion and b) the probability of obtaining 1000 Ne molecules in the large part and 100 He molecules in the small portion.
4. 1 kg of water at 0 °C is brought to a hot reservoir at 100 °C. After the water has a temperature of 100 °C, calculate the entropy change of a) water, b) hot reservoir, and c) the whole system (water and hot reservoir).

Appendix 2. Evaluation Examples

1. What is the Gibbs paradox?
2. We consider, for example, the very bottom isothermal curve. This curve contains quite a lot of information. Explain what information can be obtained?



3. What is the equipartition theorem?
4. Consider the case of 2 particles with quantum states where there can be s = 1, 2, 3.
    a. Draw the probability matrix for the three statistics of Maxwell Boltzman, Bose Einsten, and Fermi Dirac.
    b. Calculate the probability ratio of finding particles in the same state to the probability of finding particles in different states for the three statistics of Maxwell Boltman, Bose Einsten, and Fermi Dirac.
    c. What is the physical meaning of the above ratio?