Syllabus of 《Thermodynamics and Statistic Physics》

一、课程基本信息

英文名称	Thermodynamics and Statistical Physics	**课程代码**	PHYS3127
课程性质	Degree course	**授课对象**	Physics (International Class)
学　分	3 Credits	**学　时**	72 Classes
主讲教师	Tianhui Zhang	**修订日期**	Sep. 2021
指定教材	S. J. Blundell and K. K. Blundell，《Concepts in thermal physics》，Oxford University Press，2006.		

二、课程目标

（一）总体目标：

The objective of this course is to provide third-or fourth year physics students with a solid introduction to the classical and statistical theories of thermodynamics. In this course, students are supposed to achieve a full knowledge about the theoretical framework of the classic thermodynamics, and how the macroscopic phenomenon can be understood with the microscopic properties of the components.

（二）课程目标：

Objective 1: Understand the macroscopic properties of thermal systems. Have a full knowledge about the general principles and the relations between state functions and state variables

Objective 2：Develop a clear understanding and firm grasp of the basic principles of statistical physics. Develop some necessary skills to work with probability theory.

Objective 3：Have a full and clear picture about the historic development of thermodynamics. Develop an intuitive feel about the way to explore and find out the underlying principles of phenomenon. Be able to think and solve scientific problems independently.

（三）课程目标与毕业要求、课程内容的对应关系

表 1：课程目标与课程内容、毕业要求的对应关系表

课程目标	对应课程内容	对应毕业要求（及对应关系说明）	
Objective 1	Ch00 Equilibrium and State variables Ch01 The first law of Thermodynamics and Applications Ch02 The Second law of Thermodynamics and Applications Ch03 Thermodynamic potentials Ch04 Real gas and Phase transition		Understand the macroscopic properties of thermal systems. Have a full knowledge about the general principles and the relations between state functions and state variables
Objective 2	Ch05 Statistical Basis of Thermodynamics Ch06 Ensemble and Thermal average Ch07 Properties of Classical ideal gas Ch08 Occupation number of Ideal Quantum Gases Ch09 Bose statistics Ch10 Fermi statistics Ch11 Theoretical models of Phase transition		Develop a clear understanding and firm grasp of the basic principles of statistical physics. Develop some necessary skills to work with probability theory.
Objective 3	Ch02 The Second law of Thermodynamics and Applications Ch05 Statistical Basis of Thermodynamics Ch08 Occupation number of Ideal Quantum Gases Ch09 Bose statistics Ch10 Fermi statistics Ch11 Theoretical models of Phase transition		Have a full and clear picture about the historic development of thermodynamics. Develop an intuitive feel about the way to explore and find out the underlying principles of phenomenon. Be able to think and solve scientific problems independently.

三、教学内容

Introduction：Equilibrium sate and state variables

1.Purpose

Understand the basic concepts of thermodynamics

2.Key points:

Equilibrium state; Reversible process

3.Content

Equilibrium state； State variables; Work

4.Teaching method

Talk and discussion

5.Evaluation

Assignment.

Chapter 1 The Frist law and Applications

1.Purpose

Understand the First law and solve simple problems with it.

2.Key points:

Mathematical forms of the first law and the limitation for different forms.

3.Content

3.1 The first law

Internal energy; heat and work.

3.2 Isothermal process of ideal gas

Ideal gas; isothermal expansion of ideal gas

3.3 Adiabatic process of ideal gas

Adiabatic equation of ideal gas

4.Teaching method

Talk and discussion

5.Evaluation

Assignment.

Chapter 2 The second law and entropy

1.Purpose

Understand properties of Carnot cycle; Develop a full picture of the definition of the

efficiency of engine; Understand the different statements of the second law.

2.Key points:

Statement of the second law; entropy

3.Content

3.1 Carnot cycle

Work and heat in each step of Carnot cycle

3.2 The second law

Statements of the second law

3.3 Reversible engine；

Efficiency of reversible engines

3.4 Entropy；

Definition of entropy;

3.5 Application of the second law；

The change of entropy in reversible processes; the entropy of dieal gas

4.Teaching method

Talk and discussion

5.Evaluation

Assignment.

Chapter 3 Thermodynamic potentials

1.Purpose

Understand the definitions and their roles of thermodynamic potentials

2.Key points:

Enthalpy; Free energy; Maxwell relations

3.Content

3.1 Thermodynamically potentials：

Internal energy; entropy; Free energy

3.2 Maxwell relations；

Derive the Maxwell relations。

4.Teaching method

Talk and discussion

5.Evaluation

Assignment.

Chapter 4 Real gas and phase transition

1.Purpose

Understand the limitations of ideal gas model; develop a deep understanding of phase transitions

2.Key points:

Gibbs's phase rule; Maxwell construction

3.Content

3.1 van der Waals' equation of state：

Effect of Attraction on pressure

3.2 Phase diagram of real gas；

Maxwell construction of phase diagram; types of phase transitions；

3.3 Clausius–Clapeyron Equation

Boundaries between phases

4.Teaching method

Talk and discussion

5.Evaluation

Assignment.

Chapter 5 Statistical Basis of Thermodynamics

1.Purpose

Develop a deep understanding of the kinetic theory of macroscopic systems; Establish a bridge between classic thermodynamics and statistic theory.

2.Key points:

Microscopic state; Statistical explanation of entropy

3.Content

3.1 Microscopic state：

Description of microscopic states

3.2 Equilibrium conditions

Microscopic definition of entropy

4.Teaching method

Talk and discussion

5.Evaluation

Assignment;

Chapter 6 Ensemble theory

1.Purpose

Understand the concept of ensemble and the relation between ensemble averages and macroscopic variables;

2.Key points:

Phase space; Liouwill's theorem;

3.Content

3.1 Phase space：

Microscopic states and phase space；

3.2 Liouwill's theorem；

Density of states in phase space; Derivation of Liouwill's theorem；

3.3 Microcanonical ensemble and Entropy

Calculation of the entropy in Microcanonical ensemble

3.4 Canonical ensemble

Ensemble average and Fluctuation

3.5 Grand Canonical ensemble

4.Teaching method

Talk and discussion

5.Evaluation

Assignment;

Chapter 7 Classical ideal gas and Maxwell-Boltzmann Distribution

1.Purpose

Find out the speed distribution and the equation of state;

2.Key points:

Equipartition of energy

3.Content

3.1 Speed distribution of ideal gas：

Density of state; speed distribution；

3.2 Equipartition of energy；

Derive the equipartition of energy；

3.3 Equation of state of ideal gas

Pressure of ideal gas；

3.4 Function of state

Entropy; Partition function; Free energy;

4.Teaching method

Talk and discussion

5.Evaluation

Assignment;

Chapter 8 Basis of Quantum Statistics

1.Purpose

Understand the difference between Classic gas and Quantum gas; Understand the Quantum statistics;

2.Key points:

Quantum state; Density of Quantum state

3.Content

3.1 Quantum state of free particles：

Energy level of Quantum particles；

3.2 Occupation number of Bose gas；

3.3 Occupation number of Fermi gas

3.4 Classical limitation of Quantum gases

4.Teaching method

Talk and discussion

5.Evaluation

Assignment;

Chapter 9 Bose Statistics

1.Purpose

Understand properties of Bose gases; Bose-Einstein condensation

2.Key points:

Bose-Einstein condensation; Black-body radiation

3.Content

3.1 Bose-Einstein condensation：

Bose-Einstein condensation; The critical temperature；

3.2 Black-body radiation；

Dependence of wavelength on temperature

3.3 Heat capacity of solid；

Einstein model; Debye model；

4.Teaching method

Talk and discussion

5.Evaluation

Assignment;

Chapter 10 Fermi statistics

1.Purpose

Understand properties of Fermi gases; Fermi energy level

2.Key points:

Fermi energy level;

3.Content

3.1 Chemical potential of Fermi gas：

Dependence of the chemical potential on T;

3.2 Fermi energy level；

4.Teaching method

Talk and discussion

5.Evaluation

Assignment;

Chapter 11 Theoretical models of phase transitions

1.Purpose

Develop a full understanding of Ising model and Mean field theory of phase transition.

2.Key points:

Solution of Ising model;

3.Content

3.1 1D Ising Model：

Solution of 1D Ising model；

3.2 2D Ising Model：

Solution of 2D Ising model；

3.3 Mean field theory

Bragg-Williams approximation; Critical temperature

4.Teaching method

Talk and discussion

5.Evaluation

Assignment;

四、学时分配

表 2：各章节的具体内容和学时分配表

章节名称	内容	学时分配
Ch00	**Equilibrium and State variables**	**4**
Ch01	**The first law of Thermodynamics**	**4**

Ch02	**The Second law of Thermodynamics**	**8**
Ch03	**Thermodynamic potentials**	**4**
Ch04	**Real gas and Phase transition**	**4**
Ch05	**Statistical Basis of Thermodynamics**	**4**
Ch06	**Ensemble and Thermal average**	**4**
Ch07	**Microcanonical ensemble**	**8**
Ch08	**Basis of Quantum Statistics**	**4**
Ch09	**Bose statistics**	**12**
Ch10	**Fermi statistics**	**4**
Ch11	**Theoretical models of Phase transition**	**4**

五、教学进度

表 3：教学进度表

周次	章节名称	内容提要	授课时数	作业及要求	备注
1	**Ch00**	**Thermal equilibrium state; State variables; The zeroth law of thermodynamics**	**4**	**Assignment 0**	
2	**Ch01**	**The first law and applications**	**4**	**Assignment 1**	
3	**Ch02**	**Carnot circle and The second law**	**4**	**Assignment 2**	
4	**Ch02**	**Reversible Engine and Engtropy**	**4**		
5	**Ch03**	**Thermodynamic potentials**	**4**	**Assignment 3**	
6	**Ch04**	**Real gas and Phase transition**	**4**	**Assignment 4**	
7	**Ch05**	**Statistical Basis of Thermodynamics**	**4**	**Assignment 5**	
8	**Ch06**	**Ensemble and Thermal average**	**4**	**Assignment 6**	
9	**Ch07**	**Canonical Ensemble**	**4**	**Assignment 7**	
10	**Ch07**	**Maxwell-Boltzmann Distribution of Classical ideal gas**	**4**		
11	**Ch08**	**Basis of Quantum Statistics**	**4**	**Assignment 8**	
12	**Ch09**	**Bose Statistics**	**4**	**Assignment 9**	

13	**Ch09**	**Bose-Einstein condensation; Black-body radiation**	**4**		
14	**Ch09**	**Practices on BE distribution**	**4**		
15	**Ch10**	**Fermi statistics**	**4**	**Assignment 10**	
17	**Ch10**	**Occupation number derived from Grand Canonical distribution**	**4**		
18	**Ch11**	**Theoretical models of Phase transition**	**4**		

六、教材及参考书目

1. B. Cowan, 《Topics in statistical mechanics》, Elsevier, 2011
2. K. Huang, 《Introduction to Statistical Physics》, CRC press, 2001.
3. R. H. Swedsen,《An Introduction to Statistical Mechanics and Thermodynamics》, Oxford University Press, 2012.

七、教学方法

Teaching is mainly conducted via lectures with PPt. Discussion and self-studying are employed and encouraged.

八、考核方式及评定方法

（一）课程考核与课程目标的对应关系

表 4：课程考核与课程目标的对应关系表

课程目标	考核要点	考核方式
Objective 1	Related topics	Chapter quiz + Class performance
Objective 2	Related topics	Chapter quiz + Class performance
Objective 3	Related topics	Chapter quiz + Class performance

（二）评定方法

1．评定方法

Chapter quiz (5-10 times): 80%;

Other performance(Assignments + discussion): 20%。

2．课程目标的考核占比与达成度分析

表 5：课程目标的考核占比与达成度分析表

考核占比 / 课程目标	平时	过程化考试	总评达成度
Objective 1	40%	40%	0.2 x Others + 0.8xChapter quiz
Objective 2	50%	50%	
Objective 3	10%	10%	

（三）评分标准

课程目标	评分标准				
	90-100	80-89	70-79	60-69	＜60
	优	良	中	合格	不合格
	A	B	C	D	F
Objective 1	Develop a complete and full understanding of thermodynamics; Develop an excellent ability to solve problems; Be excellent in independent thinking and working.	Develop a good understanding of thermodynamics; Be able to solve problems independently;	Have a general understanding of thermodynamics ; Be able to solve problems with some suggestions.	Have a general understanding on the key points of thermodynamics;	Fail to develop a general picture about the knowledge of thermodynamics

课程 目标	评分标准				
	90-100	80-89	70-79	60-69	＜60
	优	良	中	合格	不合格
	A	B	C	D	F
Objective 2	Develop a complete and full understanding of statistical physics; Develop an excellent ability to apply the principles to solve problems; Be excellent in independent thinking and working.	Develop a good understanding of statistic thermodynamics; Be able to solve problems independently;	Have a general understanding of the distributions of particles; Be able to solve problems with some suggestions.	Have a general understanding on the key points of statistic thermodynamics;	Fail to develop a general picture about the knowledge of statistical thermodynamics
Objective 3	Develop an excellent ability to explore the solution for problems and challenges。	Be willing to find out the solution for problems and challenges。	Be able to make some progress independently when encouraged。	Be able to make some progress as helped by others.	Fail to develop the ability and the willing to explore the solution of problems.