Universitat Autònoma de Barcelona

2020/2021

Thermodynamics and Statistical Mechanics

Code: 100157
ECTS Credits: 9

Degree	Type	Year	Semester
2500097 Physics	OB	3	A

The proposed teaching and assessment methodology that appear in the guide may be subject to changes as a result of the restrictions to face-to-face class attendance imposed by the health authorities.

Contact

Name: Vicenç Mendez Lopez

Email: Vicenc.Mendez@uab.cat

Use of Languages

Principal working language: catalan (cat)

Some groups entirely in English: No

Some groups entirely in Catalan: Yes

Some groups entirely in Spanish: No

Teachers

Daniel Campos Moreno

Prerequisites

Some course of introduction to thermodynamics is preferred

Objectives and Contextualisation

1. To understand the conditions of a thermodynamical systems

2. To identify system and environment

3. Distinguish between state variables and process variables

4. To interpret the different kinds of thermal processes

5. To understand the concept of the thermodynamical limit

6. To derive the partition function of a system and find the state equations from it

7. To apply the energy equipartition theorem

8. To distinguish between reversible and irreversible processes

9. To change the fundamental equation of representation

10.To understand the microscopic concept of pressure of a gas

11. Interpret the stability criteria and relate them with the onset of phase ransitions

12. To analyze the first and second order phase transitions. Understand the Landau theory for phase transitions

13. To construct the Ising model. Apply the mean field approximation, the interactions between nearest neighbours and the method of transfer matrix

14. To distinguish between ideal and real gases. Connect the intermolecular potential with the virial expansion

15. To understand the processes of cooling gases

16. To interpret the electromagnetic radiation as a gas of bosons and obtain the equations of state

17. Make use of the grancanonical ensable to study the fluctuations in the number of particles and the phase equilibrium

Competences

- Develop strategies for analysis, synthesis and communication that allow the concepts of physics to be transmitted in educational and dissemination-based contexts
- Formulate and address physical problems identifying the most relevant principles and using approximations, if necessary, to reach a solution that must be presented, specifying assumptions and approximations
- Know the fundamentals of the main areas of physics and understand them
- Take account of social, economic and environmental impacts when operating within one's own area of knowledge.
- Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
- Use mathematics to describe the physical world, selecting appropriate tools, building appropriate models, interpreting and comparing results critically with experimentation and observation

Learning Outcomes

1. Analyse limits at low and high temperature for any given system.
2. Analyse the information contained in the distinct phase diagrams in equilibrium.
3. Calculate the number of microstates for classic and discrete systems.
4. Calculate the partition function of a system in any group.
5. Calculate the second virial coefficient from the interaction potential.
6. Clarify the need for a classic or quantum statistical description for an ideal gas.
7. Deduce the equations of state within a system from the partition function.
8. Deduce the fundamental equation in different representations.
9. Describe the information contained in the different equations of state within a system.
10. Describe the physical information contained in virial coefficients.
11. Describe the properties that differentiate real behaviour from ideal in a gas.
12. Distinguish between the domains of action in thermodynamics and statistical mechanics.
13. Establish the thermodynamic variables describing equilibrium states for different systems and propose the corresponding Gibbs equation.
14. Identify the social, economic and environmental implications of academic and professional activities within ones own area of knowledge.
15. Physically interpret the partial derivatives of the distinct thermodynamic quantities.
16. Relate stability criteria to the principles of thermodynamics and verify the stability of a thermodynamic system.
17. Transmit, orally and in written format, physical concepts of a certain complexity, making them understandable to non-specialist settings.
18. Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments

Content

1. Formal structure of Thermodynamics

1.0. Review of the laws of Thermodynamics
1.1. The fundamental equation
1.2. Euler's form of internal energy. Gibbs-Duhem equation
1.3. Legendre Transform. Thermodynamic potentials
1.4. Maxwell relations for a fluid
1.5. Stability conditions

2. Microscopic description of macroscopic systems

2.1. Microstates and Macrostates. Phase space
2.2. Ensembles
2.3. Microcanonics ensemble
2.4 Thermal equilibrium Thermodynamic-Statistical Mechanical Connecti
2.5. Application to the ideal monatomic gas
2.6. Maxwell-Boltzmann distribution
2.7. Pressure
2.8. Effusion
2.9. Gibbs-Shannon entropy and Boltzmann entropy

3. Canonical ensemble

3.1. Partition function. Degeneration of energy
3.2. The equipartition of energy theorem. Applications and limitations
3.3. Systems with discrete energy distributions. Continuous limit

4. Magnetic systems

4.1. Thermodynamics and statistical mechanics of magnetic systems
4.2. Classic paramagnetism
4.3. Paramagnetism of spin 1/2. Microcanonical and canonical treatment
4.4. Adiabatic desimanation

5. Phase transitions

5.1. Classification. P- V, P - μ and P - T diagrams. Clapeyron equation
5.2. Vapour-phase condensed equilibrium
5.3. The critical point
5.4. Ising model. Mean field approximation. Transfer Matrix.

6. Real gases

6.1. Compressibility factor. The virial expansions
6.2. Interaction potential. Configurational partition function
6.3. The virial second coefficientl. Van der Waals equation
6.4. Law of corresponding states
6.5. Expansions of Joule and Joule-Kelvin

7. Photons

7.1. Statistics of bosons andfermions
7.2 Energy density. Degeneration of states
7.3. Planck distribution
7.4. Equations of state of the radiation of a gas of photons in equilibrium

8. Macrocanonical ensemble

8.1. Partition function
8.2. Connection with thermodynamics

Methodology

METHODOLOGY IN CASE OF NORMAL TEACHING

Classroom activities

1 Teaching lectures

The lectures will be taught by the theory teacher where the concepts, developments and basic principles of the subject will be presented.

2 Teaching Problems

The problem's teacher will solve in class some of the problems of the collection that previously the student will have had to try to solve

3 Tutorial activities

In case of virtual teaching along the seasons of tutorial activites questions of theory and practical will be solved in class

Authonomous activities

1 Troubleshooting

The teacher of problems will deliver (will also be posted on the virtual campus) a list of problems and computer practices that each student must solve individually and deliver it on the established date

2 Study

We have counted that the student must dedicate 2 hours of study for each hour of master class.

METHODOLOGY IN CASE OF TOTAL OR PARTIAL LOCKDOWN

The teaching methodology in case of lockdown will be adapted in order to get the normal progress of the course. Therefore, the theory lectures will become virtual and if the lockdown is partial there will be tutorials in alternated groups. Along the virtual sessions the students will work the contents weekly established by the theory's teacher. These contents will consist in theoretical lessons as well as practical problems to solve. To this end the students will may make use of the notes made by the teachers, books and problem sheets with solutions. All this material is available at the CV. The emerging doubts due to the students work will can be asked to the theory and problems teachers according to the established schedule by email or Discord. Furthermore, the teacher will program a virtual meeting with Teams if necessary. If the lockdown is partial there will be possible to solve the doubts in class where the teacher will also deal with other contents.

Activities

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Problems	30	1.2	
Teaching lectures	45	1.8	
Type: Autonomous			
Problems solving	49	1.96	
Study	92	3.68	

Assessment

Partial exams and final exam
There will be two partial exams. The first one will evaluate the first part of the course while the second will evaluate the rest. in case the mean of the qualifications is less than 4 the student must do the final exam. To be examined in the final exam is compulsery to be examend in the first and second partial exams.

Remedial exam

Those who have been evaluated in the partial exams obtaining a qualification lower than 4 (compulsory) or those who want to improve their marks (optional) may do the remedial exam. In the latter case, the final mark will be the best of the marks obtained from the remidial and partials examams

Homework

The homowork problems will be evaluated and their solutions will be published at the virtual campus. This part cannot be remedied

Final mark

The finals mark will be calculated from the specific weights only if the student has passed the partials or the final exam. The final mark will be the 70% of the fianl exam/mean of partials plus the 30% of the homework if the final exam mark is equal or higher than 4. Otherwise, the studend does not pass

NOTE

In case of complete or partial methodology the evaluation process will be the same as in the case of normal teaching.

Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Final exam	70%	3	0.12	1, 2, 3, 5, 4, 8, 7, 9, 10, 11, 12, 13, 15, 6, 18, 16, 17

First part exam	35%	3	0.12	3, 4, 8, 7, 9, 11, 12, 13, 15, 6, 16
Homework	30%	0	0	14, 18
Second part exam	35%	3	0.12	1, 2, 5, 10, 11

Bibliography

Modern texts

- Robert H Swendsen, An Introduction to Statistical Mechanics and Thermodynamics (Oxford Univ. Press, 2012)
- S. K. Roy, Thermal Physics And Statistical Mechanics (New Age International Publishers, 2001)
- K. Huang, *Introduction to Statistical Physics*, CRC, 2001
- D. V. Schroeder, *An Introduction to Thermal Physics*, Addison Wesley, 2000
- S. J. Blundell and K. M. Blundell, *Concepts in Thermal Physics*, Oxford UP, 2006
- M. Criado-Sancho y J. Casas-Vázquez, *Termodinámica química y de los procesos irreversibles*, Pearson/Addison Wesley, Madrid, segona edició, 2004.
- Yi-Chen Cheng, Macroscopic and Statistical Thermodynamics (World Scientific, 2006)

Classical texts

- J. J. Brey, J. de la Rubia, J. de la Rubia, *Mecánica Estadística*, UNED, 2001
- R. Kubo, *Thermodynamics*, North Holland, Amsterdam, 1968.
- F. Reif, *Fundamentals of Statistical Physics and Thermal Physics*, McGraw-Hill, 1985
- D. A. McQuarrie, *Statistical Mechanics*, Harper Collins, 1976
- M.W. Zemansky y R.H. Dittman, *Calor y Termodinámica*, McGraw-Hill, Madrid, 1990.
- C.J. Adkins, *Termodinámica del equilibrio*, Reverté, Barcelona, 1977.
- P.W. Atkins, *La Segunda ley*, Prensa científica, Barcelona 1992.