



## Subject card

|   |  |   |                                     |            |  |         |     |
|---|--|---|-------------------------------------|------------|--|---------|-----|
| Subject name and code                       | Thermodynamics, PG_00052074  |   |                                     |            |  |         |     |
| Field of study                              | Nanotechnology   |   |                                     |            |  |         |     |
| Date of commencement of studies             | October 2020   | Academic year of realisation of subject   |                                     |            | 2021/2022  |         |     |
| Education level                             | first-cycle studies  | Subject group   |                                     |            | Obligatory subject group in the field of study<br>Subject group related to scientific research in the field of study |         |     |
| Mode of study                               | Full-time studies  | Mode of delivery  |                                     |            | blended-learning   |         |     |
| Year of study                               | 2  | Language of instruction   |                                     |            | Polish   |         |     |
| Semester of study                           | 3  | ECTS credits  |                                     |            | 6.0  |         |     |
| Learning profile                            | general academic profile   | Assessment form   |                                     |            | assessment   |         |     |
| Conducting unit                             | Department of Solid State Physics -> Faculty of Applied Physics and Mathematics  |   |                                     |            |  |         |     |
| Name and surname of lecturer (lecturers)    | Subject supervisor   | prof. dr hab. inż. Jarosław Rybicki   |                                     |            |  |         |     |
|   | Teachers   | prof. dr hab. inż. Jarosław Rybicki   |                                     |            |  |         |     |
| Lesson types and methods of instruction     | Lesson type  | Lecture   | Tutorial                            | Laboratory | Project  | Seminar | SUM |
|   | Number of study hours  | 30.0  | 30.0                                | 0.0        | 0.0  | 0.0     | 60  |
|   | E-learning hours included: 30.0  |   |                                     |            |  |         |     |
|   | Address on the e-learning platform: <a href="https://enauczanie.pg.edu.pl/moodle/course/view.php?id=9298">https://enauczanie.pg.edu.pl/moodle/course/view.php?id=9298</a><br>Adresy na platformie eNauczanie:<br>Termodynamika_21/22 - Moodle ID: 18995<br><a href="https://enauczanie.pg.edu.pl/moodle/course/view.php?id=18995">https://enauczanie.pg.edu.pl/moodle/course/view.php?id=18995</a> |   |                                     |            |  |         |     |
| Learning activity and number of study hours | Learning activity  | Participation in didactic classes included in study plan  | Participation in consultation hours | Self-study | SUM  |         |     |
|   | Number of study hours  | 60  | 5.0                                 | 85.0       | 150  |         |     |
| Subject objectives                          | The purpose of the subject is to familiarize students with the basics of phenomenological thermodynamics, in particular with 0-th, 1-st and 2-nd principle of thermodynamics. The principles will be illustrated with many various examples of applications.   |   |                                     |            |  |         |     |
| Learning outcomes                           | Course outcome   | Subject outcome   |                                     |            | Method of verification   |         |     |
|   | K6_U02   | The student can calculate the basic thermo-mechanical properties of matter using the underlying equations of state  |                                     |            | [SU4] Assessment of ability to use methods and tools   |         |     |
|   | K6_W03   | The mentioned fields of physics are presented within other courses, here their thermodynamical aspects have been highlighted.   |                                     |            | [SW1] Assessment of factual knowledge  |         |     |
|   | K6_W06   | The mentioned fields of physics are presented within other courses, here their thermodynamical aspects have been highlighted.   |                                     |            | [SW1] Assessment of factual knowledge  |         |     |
|   | K6_W05   | The student understands and can formulate and discuss the three fundamental laws of thermodynamics  |                                     |            | [SW1] Assessment of factual knowledge  |         |     |
|   | K6_U01   | Phenomenological thermodynamics formulates very general law. Numerous examples of applications (to magnetism, superconductors, defects in solids, etc.) show the efficiency of thermodynamic rules. |                                     |            | [SU3] Assessment of ability to use knowledge gained from the subject   |         |     |

| Subject contents                 | <p>LECTURE: Basic concepts. The 0-th law of thermodynamics. The first law of thermodynamics as the energy conservation principle. The second law of thermodynamics. Entropy. Thermodynamical potentials. Basic thermodynamics of chemical systems. Chemical potential. Mass action law. Gibbs phase rule.</p> <p>EXERCISES: Properties of ideal, semi-ideal and real gases. Gas laws. Thermal and caloric equation of state. Thermodynamic processes of ideal gas. Thermodynamics gas cycles. Entropy. Equilibrium conditions. Thermodynamical potentials and their properties. Examples of applications of thermodynamics in materials science.</p> |  |  |                          |                   |                               |                        |       |       |                                  |       |       |
|----------------------------------|--|--|--|--------------------------|-------------------|-------------------------------|------------------------|-------|-------|----------------------------------|-------|-------|
| Prerequisites and co-requisites  |  |  |  |                          |                   |                               |                        |       |       |                                  |       |       |
| Assessment methods and criteria  | <table border="1"> <thead> <tr> <th data-bbox="454 423 796 454">Subject passing criteria</th> <th data-bbox="799 423 1141 454">Passing threshold</th> <th data-bbox="1144 423 1482 454">Percentage of the final grade</th> </tr> </thead> <tbody> <tr> <td data-bbox="454 459 796 490">Written exam in theory</td> <td data-bbox="799 459 1141 490">51.0%</td> <td data-bbox="1144 459 1482 490">50.0%</td> </tr> <tr> <td data-bbox="454 495 796 526">Written test in problem solution</td> <td data-bbox="799 495 1141 526">51.0%</td> <td data-bbox="1144 495 1482 526">50.0%</td> </tr> </tbody> </table>  |  |  | Subject passing criteria | Passing threshold | Percentage of the final grade | Written exam in theory | 51.0% | 50.0% | Written test in problem solution | 51.0% | 50.0% |
| Subject passing criteria         | Passing threshold  | Percentage of the final grade  |  |                          |                   |                               |                        |       |       |                                  |       |       |
| Written exam in theory           | 51.0%  | 50.0%  |  |                          |                   |                               |                        |       |       |                                  |       |       |
| Written test in problem solution | 51.0%  | 50.0%  |  |                          |                   |                               |                        |       |       |                                  |       |       |
| Recommended reading              | Basic literature   | <p>1. K. Gumiński, Termodynamika, PWN 1982</p> <p>2. Sychev, Thermodynamics of complex systems</p>   |  |                          |                   |                               |                        |       |       |                                  |       |       |
|                                  | Supplementary literature   | <p>1. Mayhew R., Engineering thermodynamics/Work &amp; Heat Transfer. J. Wiley &amp; Sons Inc. 1993. USA.</p>  |  |                          |                   |                               |                        |       |       |                                  |       |       |
|                                  | eResources addresses   | <p>Termodynamika_21/22 - Moodle ID: 18995<br/> <a href="https://enauczanie.pg.edu.pl/moodle/course/view.php?id=18995">https://enauczanie.pg.edu.pl/moodle/course/view.php?id=18995</a></p> |  |                          |                   |                               |                        |       |       |                                  |       |       |

Example issues/  
example questions/  
tasks being completed

Define the concepts of the thermodynamic system, thermodynamic phase, uniform and non-uniform phase.

Define and discuss the concept of thermodynamic equilibrium.

Define the concepts of the adiabatic boundary and diathermic boundary.

Formulate the so-called zero principle of thermodynamics. Define the empirical temperature.

Discuss in detail the concept of quasi-equilibrium processes. Explain their importance in thermodynamics.

Formulate and discuss the postulate of existence of internal energy. Formulate the first principle of thermodynamics.

Discuss the concepts of elementary work and heat. What is the relation of these values with infinitesimal changes in internal energy? Pay attention to the mathematical nature of the discussed small increments.

Give the Planck's classic counterexample proving that constant heat  $Q_{el}$  is not a total differential.

Define the concept of enthalpy. Formulate the first principle of thermodynamics with the help of enthalpy.

Discuss the direct conclusions arising from the first principle of thermodynamics applied to isochoric processes in single-phase systems.

Formulate and derive Hess's and Kirchhoff's laws for isochoric processes.

Discuss the direct conclusions arising from the first principle of thermodynamics applied to isobaric processes in single-phase systems.

Formulate and derive Hess's and Kirchhoff's laws for isobaric processes.

Discuss the concept of specific heat at constant volume and at constant pressure. Derive the general relation between them and give its physical sense. Apply the obtained results to ideal gas.

Discuss the equation of state for an ideal gas. What is the gas constant? What does its numerical value physically correspond to?

Quote Carathéodory's theorem and explain its fundamental importance for the mathematical formalism of phenomenological thermodynamics.

Formulate the postulate of existence of entropy and the integrating factor for  $dQ$ . What is the physical meaning of the integrating factor?

Demonstrate that the entropy of nature does not change in reversible transformation.

Demonstrate that the entropy of nature increases in irreversible transformation.

Discuss the direct conclusions arising from the second principle of thermodynamics applied to isothermal processes (6 conclusions in total).

Discuss the direct conclusions arising from the second principle of thermodynamics applied to isothermal-isochoric processes.

Discuss the direct conclusions arising from the second principle of thermodynamics applied to isothermal-isobaric processes.

isentropic-isobaric processes.

Discuss the direct conclusions arising from the second principle of thermodynamics applied to isentropic and

Discuss the conditions of thermodynamic equilibrium in light of the second principle of thermodynamics and define the thermodynamic potentials.

Discuss the relation between the thermodynamic potentials  $U(V,S)$ ,  $H(S,p)$ ,  $F(V,T)$ ,  $G(p,T)$ .

Assuming that free enthalpy is known as a function of  $T$  and  $p$ , calculate  $S$  and  $V$  and also  $F$ ,  $H$  and  $U$ .

Assuming that free energy is known as a function of  $T$  and  $V$ , calculate  $S$  and  $p$  and also  $G$ ,  $U$  and  $H$ .

Define thermodynamic functions for chemical systems.

Characterize the intensive and extensive qualities in general.

Introduce the concept of chemical potential.

Define the concept of chemical activity and Lewis activity coefficients.

Define the concepts of ideal, perfect ideal and non-ideal phases. Give examples.

Discuss the three basic properties of perfect gas mixtures (Dalton's, Joule's and Planck's laws).

Formulate, derive and discuss the Gibbs phase rule.

Formulate a general law of equilibrium shifts in thermodynamic systems.

Work placement

Not applicable