Module name: Thermodynamics of irreversible processes and nonequilibrium phenomena

Academic year: 2019/2020  Code: ZSDA-3-0071-s  ECTS credits: 3

Faculty of: Szkoła Doktorska AGH
Field of study: Szkoła Doktorska AGH  Specialty: —
Study level: Third-cycle studies  Form and type of study: Full-time studies
Lecture language: English  Profile of education: Academic (A)  Semester: 0
Course homepage: —

Responsible teacher: dr hab. inż. Tkacz-Śmiech Katarzyna (smiech@agh.edu.pl)

Module summary
The course allows a doctoral candidate gaining knowledge within modern thermodynamics of irreversible processes and non-equilibrium phenomena. Theoretical fundamentals are integrated with solving the problems in practical applications. Linear (chemical reactions, multi-component diffusion, heat transport, multi-component fluid) and nonlinear irreversible systems (oscillatory structures, non-Newtonian fluid) are discussed.

Description of learning outcomes for module

<table>
<thead>
<tr>
<th>MLO code</th>
<th>Student after module completion has the knowledge/ knows how to/is able to</th>
<th>Connections with FLO</th>
<th>Method of learning outcomes verification (form of completion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M_K001</td>
<td>Is aware of the importance of basic research in every discipline, including technology.</td>
<td>SDA3A_K01</td>
<td>Case study</td>
</tr>
</tbody>
</table>

Skills: he can

| M_U001   | Is able to use knowledge in the field of thermodynamics of irreversible processes in the description of physicochemical phenomena and technological processes. | SDA3A_U01            | Case study                                                 |
| M_U002   | Actively participates in the discussion regarding the fundamental laws of nature. | SDA3A_U04            | Activity during classes                                   |

Knowledge: he knows and understands

| M_W001   | Understands the essence of irreversible processes and their relationship with time. | SDA3A_W05            | Activity during classes                                   |
**Number of hours for each form of classes**

<table>
<thead>
<tr>
<th>Suma</th>
<th>Lectures</th>
<th>Auditorium classes</th>
<th>Laboratory classes</th>
<th>Project classes</th>
<th>Conversation seminar</th>
<th>Seminar classes</th>
<th>Practical classes</th>
<th>Fieldwork classes</th>
<th>Workshops</th>
<th>Prace kontrolne i przejściowe</th>
<th>Lektorat</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>20</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**FLO matrix in relation to forms of classes**

<table>
<thead>
<tr>
<th>MLO code</th>
<th>Student after module completion has the knowledge/ knows how to/is able to</th>
<th>Form of classes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lectures</td>
<td>Auditorium classes</td>
</tr>
<tr>
<td><strong>Social competence: is able to</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M_K001</td>
<td>Is aware of the importance of basic research in every discipline, including technology.</td>
<td>+</td>
</tr>
<tr>
<td><strong>Skills: he can</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M_U001</td>
<td>Is able to use knowledge in the field of thermodynamics of irreversible processes in the description of physicochemical phenomena and technological processes.</td>
<td>-</td>
</tr>
<tr>
<td>M_U002</td>
<td>Actively participates in the discussion regarding the fundamental laws of nature.</td>
<td>+</td>
</tr>
<tr>
<td><strong>Knowledge: he knows and understands</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M_W001</td>
<td>Understands the essence of irreversible processes and their relationship with time.</td>
<td>+</td>
</tr>
<tr>
<td>M_W002</td>
<td>Knows the basis of modern thermodynamics of nonequilibrium phenomena.</td>
<td>+</td>
</tr>
</tbody>
</table>
Student workload (ECTS credits balance)

<table>
<thead>
<tr>
<th>Student activity form</th>
<th>Student workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Udział w zajęciach dydaktycznych/praktyka</td>
<td>40 h</td>
</tr>
<tr>
<td>Preparation for classes</td>
<td>5 h</td>
</tr>
<tr>
<td>przygotowanie projektu, prezentacji, pracy pisemnej, sprawozdania</td>
<td>3 h</td>
</tr>
<tr>
<td>Realization of independently performed tasks</td>
<td>2 h</td>
</tr>
<tr>
<td>Contact hours</td>
<td>1 h</td>
</tr>
<tr>
<td>Summary student workload</td>
<td>51 h</td>
</tr>
<tr>
<td>Module ECTS credits</td>
<td>3 ECTS</td>
</tr>
</tbody>
</table>

Additional information

Module content

Lectures
Topics covered in this course
1) The formalism of modern thermodynamics
   - Thermodynamic systems: equilibrium and nonequilibrium, open, biological
   - Legendre transforms of thermodynamic potentials
   - The second law of thermodynamics, entropy
   - Extremum principles
   - Thermodynamic quantities for liquids and solids
2) Nonequilibrium systems
   - Local equilibrium, local entropy production
   - Nonequilibrium Maxwell relations
   - Nonequilibrium effects
3) Linear irreversible thermodynamics
   - Linear phenomenological laws and Onsager reciprocal relations
   - Examples: diffusion, heat conduction, electrical conduction, chemical reactions, thermoelectric phenomena
4) Nonlinear irreversible thermodynamics
   - Symmetry breaking transitions and dissipative structures
   - Oscillatory structures and phenomena
5) The nonequilibrium nature of life

Seminar classes
Solving problems
Presentations covering the topics selected individually

Teaching methods and techniques:
Lectures: The lecture is presented in the form of a multimedia presentation combined with a classical blackboard lecture.
Seminar classes: In seminar classes, the basis is a multimedia and oral presentation by students. Discussion and problem solving are another important element of education.
Warunki i sposób zaliczenia poszczególnych form zajęć, w tym zasady zaliczeń poprawkowych, a także warunki dopuszczenia do egzaminu:
To pass the course, a student has to present at least one presentation, show activity during the seminars (discussion and solving the problems) and attend at least 6 from 10 lectures.

Zasady udziale w poszczególnych zajęciach, ze wskazaniem, czy obecność studenta na zajęciach jest obowiązkowa:
Lectures:
- Attendance is mandatory: No
- Participation rules in classes: Lectures present the content in accordance with the syllabus. Some time at the end of the lecture is reserved for questions and discussion. Students receive multimedia materials in advance. In the case of frequent absences from the lecture, the student has to pass a test exam.
Seminar classes:
- Attendance is mandatory: Yes
- Participation rules in classes: Presentations covering additional topics selected individually for students according to their research interest.
Solving typical problems of irreversible thermodynamics.
Presentation of the application of irreversible thermodynamics in technology and materials science.

Method of calculating the final grade
A final grade is provided a grade for the seminar, calculated in proportion to the number of points scored.
A student can get points for:
- the presentation – max. 20 points
- activity – max 20 points

Sposób i tryb wyrównywania zaległości powstałych wskutek nieobecności studenta na zajęciach:
A student can present his/her presentation in another convenient time. He/she can take an additional test of the lectures’ content during consultation hours.

Prerequisites and additional requirements
The elementary basis of inorganic chemistry and physical chemistry.

Recommended literature and teaching resources

Scientific publications of module course instructors related to the topic of the module

Additional information
None