240052 - Thermodynamics

Coordinating unit: 240 - ETSEIB - Barcelona School of Industrial Engineering
Teaching unit: 724 - MMT - Department of Heat Engines
Academic year: 2017
Degree: BACHELOR'S DEGREE IN MATERIALS ENGINEERING (Syllabus 2010). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN INDUSTRIAL TECHNOLOGY ENGINEERING (Syllabus 2010). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN CHEMICAL ENGINEERING (Syllabus 2010). (Teaching unit Compulsory)
ECTS credits: 6
Teaching languages: Catalan

Teaching staff
Coordinator: XAVIER RAMIS JUAN
Others: XAVIER FERNÁNDEZ FRANCOS
OSMAN KONURAY
JOSEP L. MARTÍN GODOY
JOSEP M. MORANCHO LLENA
JOSEP M. SALLA TARRAGÓ

Degree competences to which the subject contributes

Specific:
1. Knowledge on applied thermodynamics and heat transfer. Basic principles and their application to solve engineering problems.

Teaching methodology

During theory and problem sessions main theoretical aspects of each topic will be explained and problems with a practical application will be solved. Some of these problems will be solved by students, individually or in small groups, and the necessary data will obtained from charts or graphics. Students will also be proposed to execute design exercises with opened end, out of class time, in which they will have to think how a certain process takes place, raising the application of theoretical knowledge and proceeding to their numerical solution. To solve this type of problems certain computer software, such as EEES or similar, will be allowed to use. Both for exercises done by students in or outside class will be suitable of being part of the subject's continuous evaluation.

Students will execute five practical sessions in the laboratory (three hours each sessions). All laboratory sessions will consist in executing an experimental practice.

Learning objectives of the subject

The subject's main objective is to apply Thermodynamics principles into processes with an industrial interest, such as energy transformation. Special attention will be placed on thermodynamic cycles of power production, cold and heat production and thermodynamics of combustion reactions and humid air.

At the end of the course the student should be able to:
- Raising and solving energy balances, entropy and exergy of thermodynamic cycles and devices and simple processes related with energy transformation.
- Using charts and graphics of thermodynamic properties and other tools that allow to find these properties.
- Analysing the obtained results, once a problem is solved, are coherent with the studied system.
- Experimentally measuring properties of phenomena related with the subject's contents.
## Study load

<table>
<thead>
<tr>
<th></th>
<th>Hours large group:</th>
<th>50h</th>
<th>33.33%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours medium group:</td>
<td>0h</td>
<td></td>
<td>0.00%</td>
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<tr>
<td>Hours small group:</td>
<td>10h</td>
<td></td>
<td>6.67%</td>
</tr>
<tr>
<td>Guided activities:</td>
<td>0h</td>
<td></td>
<td>0.00%</td>
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<tr>
<td>Self study:</td>
<td>90h</td>
<td></td>
<td>60.00%</td>
</tr>
</tbody>
</table>

**Total learning time:** 150h
## 240052 - Thermodynamics

### Content

<table>
<thead>
<tr>
<th>Topic 1. Properties of pure substances</th>
<th>Learning time: 34h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 5h</td>
</tr>
<tr>
<td></td>
<td>Practical classes: 6h</td>
</tr>
<tr>
<td></td>
<td>Laboratory classes: 2h</td>
</tr>
<tr>
<td></td>
<td>Self study: 21h</td>
</tr>
</tbody>
</table>

**Description:**

**Related activities:**
- Activity 8. Resolution of problems outside the classroom and/or Activity 7. Group test.

**Specific objectives:**
- Acquiring a methodology to estimate thermodynamic properties of pure substances.
- Applying the energy balance for closed systems to solve problems.

<table>
<thead>
<tr>
<th>Topic 2. Energy analysis of opened systems</th>
<th>Learning time: 21h 30m</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 3h 30m</td>
</tr>
<tr>
<td></td>
<td>Practical classes: 3h</td>
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<tr>
<td></td>
<td>Laboratory classes: 2h</td>
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<tr>
<td></td>
<td>Self study: 13h</td>
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</tbody>
</table>

**Description:**

**Related activities:**
- Activity 2. Practice 2. Compression of gases at low pressures.
- Activity 6. Individual test of continuous evaluation in the classroom.
- Activity 8. Resolution of problems outside the classroom and/or Activity 7. Group test.

**Specific objectives:**
- Applying mass and energy balances in opened systems to solve problems.
<table>
<thead>
<tr>
<th><strong>Topic 3. Entropy and exergy balances in opened systems</strong></th>
<th><strong>Learning time:</strong> 15h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 3h</td>
</tr>
<tr>
<td></td>
<td>Practical classes: 3h</td>
</tr>
<tr>
<td></td>
<td>Self study: 9h</td>
</tr>
</tbody>
</table>

**Description:**  

**Related activities:**  
Activity 8. Resolution of problems outside the classroom and/or Activity 7. Group test.

**Specific objectives:**  
Using entropy data to calculate isentropic performances. Applying the entropy and applying the entropy and exergy balance in the different formulations to solve the problems.

<table>
<thead>
<tr>
<th><strong>Topic 4. Power cycles of a vapour turbine</strong></th>
<th><strong>Learning time:</strong> 18h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 3h 30m</td>
</tr>
<tr>
<td></td>
<td>Practical classes: 4h</td>
</tr>
<tr>
<td></td>
<td>Self study: 11h</td>
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</tbody>
</table>

**Description:**  

**Related activities:**  
Activity 6. Individual test of continuous evaluation (in the classroom)  
Activity 8. Solving problems outside the classroom and/or Activity 7. Group test.

**Specific objectives:**  
Making schematic T-s diagrams and representations of vapour power cycles. Analysing energetically and exergetically Rankine’s power cycles.
### Topic 5. Gas power cycles
**Learning time:** 19h  
Theory classes: 3h 30m  
Practical classes: 2h 30m  
Laboratory classes: 2h  
Self study: 11h

**Description:**  

**Related activities:**  
Activity 3. Practice 3. Stirling's engine  
Activity 8. Solving problems outside the classroom and/or Activity 7. Group test.

**Specific objectives:**  
Analysing Otto, Diesel and Dual cycles.  
Analysing energetically and exergetically a gas turbine's cycles.

### Topic 6. Cooling cycles and heat pumps
**Learning time:** 15h  
Theory classes: 2h  
Practical classes: 2h  
Laboratory classes: 2h  
Self study: 9h

**Description:**  

**Related activities:**  
Activity 6. Individual test of continuous evaluation (in the classroom)  
Activity 8. Solving problems outside the classroom and/or Activity 7. Group test.

**Specific objectives:**  
Analysing refrigerating cycles by means of compressing vapour and by means of gas refrigeration.
# 240052 - Thermodynamics

## Topic 7. Non-reactive mixtures of ideal gases. Humid air

<table>
<thead>
<tr>
<th>Learning time: 15h 30m</th>
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<tbody>
<tr>
<td>Theory classes: 2h 30m</td>
</tr>
<tr>
<td>Practical classes: 2h</td>
</tr>
<tr>
<td>Laboratory classes: 2h</td>
</tr>
<tr>
<td>Self study: 9h</td>
</tr>
</tbody>
</table>

### Description:

### Related activities:
Activity 8. Solving problems outside the classroom and/or Activity 7. Group test.

### Specific objectives:
Applying principles of mass and energy conservation to analyse different processes of air conditioning. Using the psychometric diagram to analyse air conditioning processes.

## Topic 8. Reactive mixtures. Combustion

<table>
<thead>
<tr>
<th>Learning time: 11h 30m</th>
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<tbody>
<tr>
<td>Theory classes: 2h 30m</td>
</tr>
<tr>
<td>Practical classes: 2h</td>
</tr>
<tr>
<td>Self study: 7h</td>
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</tbody>
</table>

### Description:

### Related activities:
Activity 8. Solving problems outside the classroom and/or Activity 7. Group test.

### Specific objectives:
Applying mass and energy balances in reactive mixtures.
# Planning of activities

<table>
<thead>
<tr>
<th>Practice Number</th>
<th>Description</th>
<th>Support materials</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Practice 1. PVT properties of a pure substance</strong></td>
<td>Executing in groups of two students a laboratory practice about experimental determination of a pure substance's PVT properties.</td>
<td>Experimental assembling to determine pressure, volume and temperature of a pure substance confined in a closed system.</td>
</tr>
<tr>
<td><strong>Practice 2. Compression of low pressure gases</strong></td>
<td>Executing in groups of two students a laboratory practice on compressing low pressure gases.</td>
<td>Experimental assembly consisting in a cylinder-piston with three sensors that allow to measure in, real time, pressure, temperature and volume.</td>
</tr>
<tr>
<td><strong>Practice 3. Stirling's engine</strong></td>
<td>Executing in groups of two students a laboratory practice on an engine that uses air as a working fluid and alcohol as combustible and that operates according to a Stirling's cycle.</td>
<td>Experimental assembly consisting in a Stirling's engine with different sensors which allow to measure in real time pressure, volume and temperature of the gas inside the engine and the amount of rotations the engine executes.</td>
</tr>
</tbody>
</table>

**Specific objectives:**
- Interpreting the PVT surface of pure substances and their projections.
- Identifying different states of a fluid.
- Identifying different types of state equations.
- Identifying work and heat as trajectory functions.
- Distinguishing the concepts of isothermal, polytrophic and adiabatic processes.
- Relating, analytically and graphically, the polytrophic coefficient, work and heat.
- Understanding how a heat pump works and how a refrigerating cycle works.

**Hours:** 7h 30m
- Laboratory classes: 3h
- Self study: 4h 30m
### PRACTICE 4. REFRIGERATION CYCLE BY MEANS OF COMpressing VAPOUR WITH R-134A

**Description:**
Executing in groups of two students a laboratory practice on a refrigeration cycle by means of compression which works with R-134a as a refrigerant.

**Support materials:**
Experimental assembly consisting in a refrigeration cycle by means of vapour compression with R-134a. Manometers, thermometers, rotameters and wattmeter which allow to measure different experimental parameters.

**Specific objectives:**
- Analysing the Stirling’s cycle.
- Describing the working principle of engines and cycles refrigerated by means of gas.
- Determining the performance and the efficiency coefficient of real and ideal Stirling’s cycles.

**Hours:**
- Laboratory classes: 3h
- Self study: 4h 30m

### PRACTICE 5. COMBUSTION HEAT.

**CALORIMETRIC PUMP**

**Description:**
Refrigeration cycle by means of vapour compression on determining the calorific power of an organic solid substance.

**Support materials:**

**Specific objectives:**
- Applying mass and energy balances in reactive mixtures.
- Calculating internal combustion energies from combustion enthalpies.
- Using concepts such as: oxygen excess, adiabatic temperature, combustion enthalpy.

**Hours:**
- Laboratory classes: 3h
- Self study: 4h 30m
INDIVIDUAL TESTS OF CONTINUOUS EVALUATION IN THE CLASSROOM

Description:
Individual test in the classroom consisting in the execution of an exercise to evaluate if the student has achieved the minimal necessary contents of all topics (up to the date of the test).

Support materials:
Test's wording, calculator and thermodynamic charts.

Descriptions of the assignments due and their relation to the assessment:
Delivering the solved test with the corresponding teaching staff feedback.

Specific objectives:
Achieving specific objectives of the topic on which the test is about.

GROUP TESTS

Description:
Puzzle sessions with base groups of three students. Numerical problems will be distributed with, a single solution, to the group members this way each problem partially covers the learning objectives which are intended to achieve. After the problems resolution by each member of the group, in the final part of the session the group agrees to a definitive solution and delivers it to the professor.

Support materials:
Test's wording, calculator and thermodynamic charts.

Descriptions of the assignments due and their relation to the assessment:
Delivering solved problems, with the corresponding teaching staff feedback, in the following session and group thinking on the most remarkable errors if necessary. Alternatively the solution of the problem could be delivered in ATENEA.

Specific objectives:
Achieving the topic's specific objectives of the workshop.

RESOLUTION OF PROBLEMS OUTSIDE THE CLASSROOM

Description:
Solving problems individually outside the classroom. This way the student will progressively achieve the main teaching objectives.

Support materials:
Test's wording, calculator and thermodynamic charts, books and class notes.

Descriptions of the assignments due and their relation to the assessment:
Delivery of solved problems with the corresponding teaching staff feedback.

Specific objectives:
Achieving specific objectives of the topic on which the activity is about.
Evaluation will consist of four marks:

1) Final exam mark (Nef). Nef is the mark of the test that will take place in a date decided by the School and will consist in a collection of numerical exercises. During the final exam students will be allowed to use a sheet (DIN A4) with formulas, a book with graphs and charts and the calculator.

2) Partial test mark (Npp). Npp is the mark of the partial test that takes place in mid-semester in a date fixed by the School and will consists in a collection of numerical exercises. Nothing else but the chart and graph handbook and the calculator are allowed to be used during this test.

3) Laboratory mark (Nlab). This mark corresponds to the laboratory practices mark and will be obtained from the pre-laboratory work, the post-laboratory report and the professor's evaluation on the student's performance in the laboratory.

4) Continuous evaluation mark (Nac). 40% of this mark will be obtained from individual tests of continuous evaluation (previously determined date) which will take place along the course. 60% of the mark will be fixed by the professor's evaluation on the student's performance throughout the course using parameters such as: solved exercises (outside the classroom) delivery and group tests.

The final mark is calculated as the maximum of the the following formulas:

\[ N_{\text{final}} = 0.55 \times N_{\text{ef}} + 0.1 \times N_{\text{pp}} + 0.1 \times N_{\text{lab}} + 0.25 \times N_{\text{ac}} \]

\[ N_{\text{final}} = 0.65 \times N_{\text{ef}} + 0.1 \times N_{\text{lab}} + 0.25 \times N_{\text{ac}} \]

The final mark of re-evaluation is calculated with the following formula:

\[ N_{\text{final, re}} = 0.9 \times N_{\text{ef, re}} + 0.1 \times N_{\text{lab}} \]

where \( N_{\text{ef, re}} \) is the re-evaluation exam mark.
240052 - Thermodynamics

Bibliography

Basic:

Complementary:

Others resources:
- Charts and graphics of thermodynamic properties.
- Thermodynamics. Test and problems.
- In the ATENEA platform academic material will be uploaded, such as: laboratory practice guidelines, problem wordings and multiple choice sample tests with their resolution. In addition each professor will upload their own audiovisual and software material.