<table>
<tr><td>Add. 3</td><td colspan="5">Course program for the second level (second cycle - postgraduate) of studies</td></tr>
<tr><td>1.</td><td>Course title</td><td colspan="4">Advanced thermodynamics - selected chapters</td></tr>
<tr><td>2.</td><td>Code</td><td colspan="4">1M5SEE02</td></tr>
<tr><td>3.</td><td>Study group(s)</td><td colspan="4">SEE</td></tr>
<tr><td>4.</td><td>The organizer of the study program (unit, institute, department)</td><td colspan="4">“Ss. Cyril and Methodius” University in Skopje, Faculty of Mechanical Engineering - Skopje</td></tr>
<tr><td>5.</td><td>Level (first, second, third degree)</td><td colspan="4">Second</td></tr>
<tr><td>6.</td><td>Academic year / semester</td><td>V / winter</td><td>7.</td><td>ECTS credits</td><td>6</td></tr>
<tr><td>8.</td><td>Professor</td><td colspan="4">Assoc. prof. Risto Filkoski</td></tr>
<tr><td>9.</td><td>Prerequisites for enrolling the course</td><td colspan="4">None</td></tr>
<tr><td>10.</td><td colspan="5">Course objectives (competences):<br><br>To obtain knowledge of the advanced topics in applied thermodynamics and heat transfer related to mechanical engineering, with emphasize to thermal power engineering and environmental protection. The course includes additional thermodynamics relations, including advanced thermodynamic cycles, two- and three-component systems and their applications. The course also covers advanced topics in conduction, convection and radiation heat transfer and related industrial applications.<br><br>Advanced methods of modelling techniques of fluid flow, turbulence, combustion and heat transfer in engineering applications, with emphasize on numerical modelling. Engineering and scientific approach to the advanced techniques of modelling and simulation of thermal processes. Ability to create and use software applications for design, energy efficiency analysis and operating problems solution of steady-state and dynamic systems in the field of thermal and power engineering.</td></tr>
<tr><td>11.</td><td colspan="5">Course content:<br>Thermodynamics of irreversible processes. Second law of the classical thermodynamics and irreversible processes. Entropy. Thermodynamic potentials, Helmholtz energy, Gibbs energy, chemical potential, Maxwell relations. Multi-phase systems, phase changes. Chemical equilibrium. Energy and exergy analysis of thermal engineering systems<br>Real gases, Van der Waals equation of state of real gases, equation of corresponding states and other equations. Liquid state. Internal pressure, surface stress and capillary phenomenon.<br>Third law of classical thermodynamics, extensivity, entropy.Flow of compressible fluids.<br>Mixtures and mixing. Binary solutions. Thermodynamics of two- and three component systems.<br>Thermo-mechanical transformations. Thermodynamic processes in thermal machines, facilities and plants. Advanced thermodynamic cycles.<br>Thermodynamic efficiency of the processes, maximal work, maximal technical work - exergy, exergy balance, energy analysis, Grassmann diagram for exergy flow<br>Mass and energy balance of combustion process. Kinetics and dynamics of the combustion process of solid, liquid and gaseous fuels. Heat transfer topics and efficiency. Theory of similarity. Heat transfer in different applications in power engineering and process industry.<br>Selected chapters on fluid flow, turbulence, combustion and heat transfer processes.<br>Computational fluid dynamics (CFD) and computational thermal analysis (CTA). The finite volume method. Discretisation of the governing equations and numerical solution. Numerical domain, object geometry, numerical grid and its evaluation. Modelling of flow processes with chemical reactions. Modelling of combustion. Modelling of heat transfer with CFD/CTA.<br>Convection. Radiation energy transfer. Equation for radiation energy transfer. Modelling of</td></tr>
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| | thermal radiation heat transfer by different methods. Time-dependant flow modelling, modelling of transitional processes.<br>CFD technique as a tool for modelling operation of burners, combustors, combustion chambers, boiler plants, industrial furnaces (ovens), other industrial facilities and devices. Modelling of the formation and reduction of air pollutants (CO, $NO_x$, $SO_2$, etc.). | | | | |
| 12. | Study methods: Interactive lectures, auditory and/or laboratory practice, selfrunning and/or team work on project assignments, selfrunning assignments | | | | |
| 13. | Total hours | | 6 ECTS x 30 hours = 180 hours | | |
| 14. | Hours allocation per activity: | | 30+30+35+15+60 = 180 hours | | |
| 15. | Lectures/Lab | 15.1. | Lectures (15 week x 2) | 30 hours | |
| | | 15.2. | Lab (student work) | 30 hours | |
| 16. | Project Work/Assignments | 16.1. | Project assignments | 35 hours | |
| | | 16.2. | Individual assignments | 15 hours | |
| | | 16.3. | Self-study | 60 hours | |
| 17. | Points/Marks: | | | | |
| | 17.1. | Exams | | 50 points | |
| | 17.2. | Projects | | 45 points | |
| | 17.3. | Attendance | | 5 points | |
| 18. | Grading scale | Under 50 | 5 (five) (F) | | |
| | | 51 - 60 points | 6 (six) (E) | | |
| | | 61 - 70 points | 7 (seven) (D) | | |
| | | 71 - 80 points | 8 (eight) (C) | | |
| | | 81 - 90 points | 9 (nine) (B) | | |
| | | 91 - 100 points | 10 (ten) (A) | | |
| 19. | Prerequisites for taking the final exam | Activities 15.2 and 16.1 | | | |
| 20. | Language | English | | | |
| 21. | Course evaluation | Student questionnaire | | | |
| 22. | Textbooks | | | | |
| | 22.1 | Instruction materials | | | |

| No. | Author | Title | Publisher | Year |
|---|---|---|---|---|
| 1. | K. Annamalai, I. K. Puri, M. A. Jog, | Advanced Thermodynamics Engineering | CRC Press, 2nd edition | 2011 |
| 2. | I. D. Holclajtner Antunovic | General course of physical chemistry | ZUNS, University in Belgrade | 2000 |
| 3. | Baukal C.E. et al. | CFD in Industrial Combustion | CRC Press | 2001 |

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| 22.2 | Supplemental Instruction Materials | | | |

| | | No. | Author | Title | Publisher | Year |
|---|---|---|---|---|---|---|
| | | 1. | Baukal C.E. et al. | Heat Transfer in Industrial Combustion | CRC Press | 2000 |
| | | 2. | Filkoski R. | Modelling of energy conversion processes | Faculty of Mechanical Eng., Skopje | 2011 |
| | | 3. | Petrovski K. | Termodinamics, 3rd edition | | 1999 |