

## COURSE OUTLINE

### (1) GENERAL

|                                                                                                                                                                                                                                                                       |                                                                                         |                              |                |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|------------------------------|----------------|
| <b>SCHOOL</b>                                                                                                                                                                                                                                                         | School of Sciences                                                                      |                              |                |
| <b>ACADEMIC UNIT</b>                                                                                                                                                                                                                                                  | Department of Informatics and Telecommunications                                        |                              |                |
| <b>LEVEL OF STUDIES</b>                                                                                                                                                                                                                                               | Undergraduate                                                                           |                              |                |
| <b>COURSE CODE</b>                                                                                                                                                                                                                                                    | ΕΠ22στ                                                                                  | <b>SEMESTER</b>              | 7              |
| <b>COURSE TITLE</b>                                                                                                                                                                                                                                                   | Special Topics in Communications and Signal Processing: <b>Deep Learning</b>            |                              |                |
| <b>INDEPENDENT TEACHING ACTIVITIES</b><br><i>if credits are awarded for separate components of the course, e.g. lectures, laboratory exercises, etc. If the credits are awarded for the whole of the course, give the weekly teaching hours and the total credits</i> |                                                                                         | <b>WEEKLY TEACHING HOURS</b> | <b>CREDITS</b> |
| Lectures and Tutorials                                                                                                                                                                                                                                                |                                                                                         | 4                            | 4              |
|                                                                                                                                                                                                                                                                       |                                                                                         |                              |                |
|                                                                                                                                                                                                                                                                       |                                                                                         |                              |                |
| <i>Add rows if necessary. The organisation of teaching and the teaching methods used are described in detail at (4).</i>                                                                                                                                              |                                                                                         |                              |                |
| <b>COURSE TYPE</b><br><i>general background, special background, specialised general, knowledge, skills development</i>                                                                                                                                               | Special background                                                                      |                              |                |
| <b>PREREQUISITE COURSES:</b>                                                                                                                                                                                                                                          | Recommended prerequisite: Pattern Recognition -- Machine Learning (EP08)                |                              |                |
| <b>LANGUAGE OF INSTRUCTION and EXAMINATIONS:</b>                                                                                                                                                                                                                      | GREEK                                                                                   |                              |                |
| <b>IS THE COURSE OFFERED TO ERASMUS STUDENTS</b>                                                                                                                                                                                                                      | NO                                                                                      |                              |                |
| <b>COURSE WEBSITE (URL)</b>                                                                                                                                                                                                                                           | <a href="https://eclass.uoa.gr/courses/DI682/">https://eclass.uoa.gr/courses/DI682/</a> |                              |                |

### (2) LEARNING OUTCOMES

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| <p><b>Learning outcomes</b></p> <p><i>The course learning outcomes, specific knowledge, skills and competences of an appropriate level, which the students will acquire with the successful completion of the course are described.</i></p> <p><i>Consult Appendix A</i></p> <ul style="list-style-type: none"> <li>• <i>Description of the level of learning outcomes for each qualifications cycle, according to the Qualifications Framework of the European Higher Education Area</i></li> <li>• <i>Descriptors for Levels 6, 7 &amp; 8 of the European Qualifications Framework for Lifelong Learning and Appendix B</i></li> <li>• <i>Guidelines for writing Learning Outcomes</i></li> </ul> |
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| <p>Upon successful completion of the course, students will be able to:</p> <ul style="list-style-type: none"> <li>• Understand the theoretical and practical principles of deep neural networks, including architectures, optimization, and applications</li> <li>• Develop and train advanced deep learning models for real-world problems using modern tools and techniques</li> <li>• Understand and apply self-supervised learning methods for learning representations from unlabeled data</li> <li>• Design and implement generative AI systems</li> <li>• Reproduce research results in the field of deep learning</li> <li>• Recognize and address ethical challenges in developing artificial intelligence systems, applying principles of ethics and responsibility</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                 |                                                                                                             |                                        |                                   |                                                    |                        |                                            |                              |                                                                                                 |                  |                                     |                                                |                                                                  |                                                    |                  |                                         |  |
| <p><b>General Competences</b></p> <p><i>Taking into consideration the general competences that the degree-holder must acquire (as these appear in the Diploma Supplement and appear below), at which of the following does the course aim?</i></p> <table> <tr> <td><i>Search for, analysis and synthesis of data and information, with the use of the necessary technology</i></td><td><i>Project planning and management</i></td></tr> <tr> <td><i>Adapting to new situations</i></td><td><i>Respect for difference and multiculturalism</i></td></tr> <tr> <td><i>Decision-making</i></td><td><i>Respect for the natural environment</i></td></tr> <tr> <td><i>Working independently</i></td><td><i>Showing social, professional and ethical responsibility and sensitivity to gender issues</i></td></tr> <tr> <td><i>Team work</i></td><td><i>Criticism and self-criticism</i></td></tr> <tr> <td><i>Working in an international environment</i></td><td><i>Production of free, creative and inductive thinking .....</i></td></tr> <tr> <td><i>Working in an interdisciplinary environment</i></td><td><i>Others...</i></td></tr> <tr> <td><i>Production of new research ideas</i></td><td></td></tr> </table> |                                                                                                 | <i>Search for, analysis and synthesis of data and information, with the use of the necessary technology</i> | <i>Project planning and management</i> | <i>Adapting to new situations</i> | <i>Respect for difference and multiculturalism</i> | <i>Decision-making</i> | <i>Respect for the natural environment</i> | <i>Working independently</i> | <i>Showing social, professional and ethical responsibility and sensitivity to gender issues</i> | <i>Team work</i> | <i>Criticism and self-criticism</i> | <i>Working in an international environment</i> | <i>Production of free, creative and inductive thinking .....</i> | <i>Working in an interdisciplinary environment</i> | <i>Others...</i> | <i>Production of new research ideas</i> |  |
| <i>Search for, analysis and synthesis of data and information, with the use of the necessary technology</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <i>Project planning and management</i>                                                          |                                                                                                             |                                        |                                   |                                                    |                        |                                            |                              |                                                                                                 |                  |                                     |                                                |                                                                  |                                                    |                  |                                         |  |
| <i>Adapting to new situations</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | <i>Respect for difference and multiculturalism</i>                                              |                                                                                                             |                                        |                                   |                                                    |                        |                                            |                              |                                                                                                 |                  |                                     |                                                |                                                                  |                                                    |                  |                                         |  |
| <i>Decision-making</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <i>Respect for the natural environment</i>                                                      |                                                                                                             |                                        |                                   |                                                    |                        |                                            |                              |                                                                                                 |                  |                                     |                                                |                                                                  |                                                    |                  |                                         |  |
| <i>Working independently</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <i>Showing social, professional and ethical responsibility and sensitivity to gender issues</i> |                                                                                                             |                                        |                                   |                                                    |                        |                                            |                              |                                                                                                 |                  |                                     |                                                |                                                                  |                                                    |                  |                                         |  |
| <i>Team work</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <i>Criticism and self-criticism</i>                                                             |                                                                                                             |                                        |                                   |                                                    |                        |                                            |                              |                                                                                                 |                  |                                     |                                                |                                                                  |                                                    |                  |                                         |  |
| <i>Working in an international environment</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <i>Production of free, creative and inductive thinking .....</i>                                |                                                                                                             |                                        |                                   |                                                    |                        |                                            |                              |                                                                                                 |                  |                                     |                                                |                                                                  |                                                    |                  |                                         |  |
| <i>Working in an interdisciplinary environment</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <i>Others...</i>                                                                                |                                                                                                             |                                        |                                   |                                                    |                        |                                            |                              |                                                                                                 |                  |                                     |                                                |                                                                  |                                                    |                  |                                         |  |
| <i>Production of new research ideas</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                 |                                                                                                             |                                        |                                   |                                                    |                        |                                            |                              |                                                                                                 |                  |                                     |                                                |                                                                  |                                                    |                  |                                         |  |
| <p>Search for, analysis and synthesis of data and information, using necessary technologies, Working independently, Production of free, creative and inductive thinking, Decision making, Production of new research ideas, Showing social, professional and ethical responsibility.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                 |                                                                                                             |                                        |                                   |                                                    |                        |                                            |                              |                                                                                                 |                  |                                     |                                                |                                                                  |                                                    |                  |                                         |  |

### (3) SYLLABUS

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
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| <p>The "Deep Learning" course focuses on advanced deep learning technologies and architectures that shape the modern landscape of artificial intelligence. It aims at understanding theoretical foundations, practical implementation of advanced models, and ethical development of artificial intelligence systems.</p> <p>The course content includes fundamental principles such as computation graphs, activation functions, optimization algorithms, and regularization techniques. It covers classical deep neural network architectures (CNNs, RNNs, etc.), architectures for graph-structured data (GNNs), as well as modern architectures such as Transformers, Vision Transformers, and Foundation models.</p> <p>Additionally, self-supervised learning and contrastive learning techniques for representations from unlabeled data are introduced, as well as multimodal learning techniques. The course also includes generative models such as autoencoders (AEs, VAEs), generative adversarial networks (GANs), and diffusion models. Tensor methods for model interpretation and optimization are examined. Finally,</p> |
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ethical challenges and ethics issues in developing artificial intelligence systems are discussed.

#### (4) TEACHING and LEARNING METHODS - EVALUATION

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| <b>DELIVERY</b><br><i>Face-to-face, Distance learning, etc.</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Face-to-face                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                          |
| <b>USE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY</b><br><i>Use of ICT in teaching, laboratory education, communication with students</i>                                                                                                                                                                                                                                                                                                                                                                                             | <b>- Support of learning process through e-class platform</b><br><b>- Course description, provision of files/multimedia</b><br><b>- Announcements, Messages, Discussions</b><br><b>- Email communication</b>                                                                                                                                                                                                                                                                                          |                          |
| <b>TEACHING METHODS</b><br><i>The manner and methods of teaching are described in detail.</i><br><i>Lectures, seminars, laboratory practice, fieldwork, study and analysis of bibliography, tutorials, placements, clinical practice, art workshop, interactive teaching, educational visits, project, essay writing, artistic creativity, etc.</i><br><i>The student's study hours for each learning activity are given as well as the hours of non-directed study according to the principles of the ECTS</i>                         | <b>Activity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <b>Semester workload</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Lectures                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 39                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Tutorials                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 13                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Independent study & problem solving                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 48                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Course total                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <b>100</b>               |
| <b>STUDENT PERFORMANCE EVALUATION</b><br><i>Description of the evaluation procedure</i><br><i>Language of evaluation, methods of evaluation, summative or conclusive, multiple choice questionnaires, short-answer questions, open-ended questions, problem solving, written work, essay/report, oral examination, public presentation, laboratory work, clinical examination of patient, art interpretation, other</i><br><i>Specifically-defined evaluation criteria are given, and if and where they are accessible to students.</i> | The course evaluation is conducted through written examination that includes theoretical questions, analytical exercises and problems of designing advanced deep learning systems. Additionally, students complete assignments which include implementation of deep learning algorithms, experimental evaluation and presentation of results. The evaluation is based on understanding of basic concepts, ability to apply advanced techniques, quality of implementation and innovation of approach. |                          |

#### (5) ATTACHED BIBLIOGRAPHY

##### Recommended textbooks (Eudoxus):

- Ian Goodfellow, Yoshua Bengio, Aaron Courville "Deep Learning", Kleidarithmos Publications, 2024 (Eudoxus Code: 122075017)

##### Related academic journals and conferences:

- *IEEE Transactions on Pattern Analysis and Machine Intelligence*
- *Journal of Machine Learning Research (JMLR)*
- *International Conference on Machine Learning (ICML) Proceedings*
- *Neural Information Processing Systems (NeurIPS) Proceedings*
- *International Conference on Learning Representations (ICLR) Proceedings*

**Online Resources:**

- *arXiv.org* (cs.LG, cs.AI categories)
- *Papers With Code* (<https://paperswithcode.com/>)