# COURSE OUTLINE

## (1) GENERAL

| | | | |
|---|---|---|---|
| **SCHOOL** | NATURAL SCIENCES | | |
| **ACADEMIC UNIT** | DEPT. OF PHYSICS | | |
| **LEVEL OF STUDIES** | Graduate | | |
| **COURSE CODE** | **M122** | **SEMESTER** | **2** |
| **COURSE TITLE** | Gravity and Cosmology | | |

| **INDEPENDENT TEACHING ACTIVITIES**<br>*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* | **WEEKLY TEACHING HOURS** | **CREDITS** |
|---|---|---|
| | 5 | 7 |
| | | |
| | | |
| *Add rows if necessary. The organisation of teaching and the teaching methods used are described in detail at (d).* | | |

| | |
|---|---|
| **COURSE TYPE**<br>*general background, special background, specialised general knowledge, skills development* | Special Background |
| **PREREQUISITE COURSES:** | Cosmology undergraduate course, computer programming basics (Fortran, Mathematica) |
| **LANGUAGE OF INSTRUCTION and EXAMINATIONS:** | English and Greek |
| **IS THE COURSE OFFERED TO ERASMUS STUDENTS** | Yes also available through Distance Learning |
| **COURSE WEBSITE (URL)** | http://ecourse.uoi.gr/course/view.php?id=47 |

## (2) LEARNING OUTCOMES

**Learning outcomes**

*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.*

*Consult Appendix A*

- *Description of the level of learning outcomes for each qualifications cycle, according to the Qualifications Framework of the European Higher Education Area*
- *Descriptors for Levels 6, 7 & 8 of the European Qualifications Framework for Lifelong Learning and Appendix B*
- *Guidelines for writing Learning Outcomes*

**The course provides advanced knowledge required in order to understand the principles and the phenomena of cosmology and the theory of general relativity. It also provides the mathematical techniques needed to solve relevant problems.**

**After the successful completion of the course the student will be in a position to**

1. **Derive the Einstein Equations and solve them for simple symmetric spacetimes (homogeneous-isotropic, spherically symmetric etc)**
2. **Describe spacetimes with black holes including the cases of charged and rotating black holes.**
3. **Interpret and draw qualitative conclusions for describing the structure and evolution of the universe based on a small number of laws and concepts (Einstein equations)**
4. **Use mathematical techniques to analytically calculate the expansion rate of the Universe for given ideal fluid (defined by equation of state) contained in a homogeneous and isotropic universe.**
5. **Formulate cosmology problems within dark energy and dark matter models, and use appropriate analytical and numerical methods to test these models by comparing with observational data.**
6. **Calculate approximately the predicted values of cosmological parameters under various cosmological models of early (inflationary) and late Universe.**

**General Competences**

*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?*

| | |
|---|---|
| *Search for, analysis and synthesis of data and information, with the use of the necessary technology* | *Project planning and management* |
| *Adapting to new situations* | *Respect for difference and multiculturalism* |
| *Decision-making* | *Respect for the natural environment* |
| *Working independently* | *Showing social, professional and ethical responsibility and sensitivity to gender issues* |
| *Team work* | *Criticism and self-criticism* |
| *Working in an international environment* | *Production of free, creative and inductive thinking* |
| *Working in an interdisciplinary environment* | *……* |
| *Production of new research ideas* | *Others…* |
| | *…….* |

Search, analysis and synthesis of data and information, using appropriate analytical and numerical techniques.
Autonomous work.
Promotion of free, creative and inductive thinking.

**(3) SYLLABUS**

A. General Relativity

1. Metric, Energy Momentum Tensor, Geodesics
2. Derivation of Einstein Equations from Action Principle
3. Simple symmetric metrics (FRW, Schwarzschild, Kerr etc)
4. Weak Fields – Gravitational Waves
5. Scalar-Tensor Theories (action, cosmological equations)

B. Homogeneous and Isotropic Universe:
1. Geometry and Dynamics of the Universe.
2. Inflationary Universe.
3. Thermal History of the Universe

C. Perturbations in Homogeneous Background.
1. Cosmological Theory of Perturbations
2. Formation of Structures in the Universe.
3. Initial Conditions in the Inflationary Universe

## (4) TEACHING and LEARNING METHODS - EVALUATION

| | |
|---|---|
| **DELIVERY**<br>*Face-to-face, Distance learning, etc.* | Face to face teaching and distance learning methods |
| **USE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY**<br>*Use of ICT in teaching, laboratory education, communication with students* | Use of asynchronous system Moodle for placing educational material online including videolectures, notes, homework and solutions. Use of synchronous education tools for distance learning including teleconferencing (Skype, Team Viewer etc) and lecture recording tools. Use of computer algebra software. |
| **TEACHING METHODS**<br>*The manner and methods of teaching are described in detail.*<br>*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.*<br><br>*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* | see table below |

| ***Activity*** | ***Semester workload*** |
|---|---|
| Lectures | 39 |
| Tutorial | 13 |
| Bibliography and Study | 90 |
| Free Study | 30 |
| Exams | 3 |
| | |
| | |
| | |
| | |
| Course total | 175 |

| | |
|---|---|
| **STUDENT PERFORMANCE EVALUATION**<br>*Description of the evaluation procedure*<br><br>*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*<br><br>*Specifically-defined evaluation criteria are given, and if and where they are accessible to students.* | Written exams at the end and during the course and/or written essays/reports with solved problems and in class presentations. |

## (5) ATTACHED BIBLIOGRAPHY

*- Suggested bibliography:*


- Amendola L. & Tsujikawa S.: Dark Energy Theory and Observations

(Cambridge 2010)
- Dodelson, S.: Modern Cosmology (Academic Press 2003)
- Peacock, J.: Physical Cosmology (Cambridge University Press 1999)
- Padmanabhan, T.: Theoretical Astrophysics III (Cambridge University Press 2002)
- Kolb, E. & Turner, M.: The Early Universe (Addison Wesley 1990)
- Peebles, J.: Principles of Physical Cosmology (Princeton 1993)
- Liddle, A. R. & Lyth, D.H.: Cosmological Inflation and Large Scale Structure
- Weinberg, S.: Gravitation and Cosmology (Wiley 1972)
- Schneider, P: Introduction to Extragalactic Astronomy and Cosmology (Springer 2006)
- Padmanabhan, T.: Cosmology and Astrophysics through Problems (Cambridge University Press 1996)
- Padmanabhan, T.: Structure Formation in the Universe (Cambridge University Press 1993)
- Cambridge Part III Cosmology Notes: http://www.damtp.cam.ac.uk/user/db275/Cosmology.pdf

*- Related academic journals:*

- Physical Review D
- Journal of Cosmology and Astroparticle Physics
- General Relativity and Gravitation
- Classical and Quantum Gravity