2020/2021

General Relativity and Cosmology

Code: 103946
ECTS Credits: 6

Degree	Type	Year	Semester
2500097 Physics	OT	4	2

The proposed teaching and assessment methodology that appear in the guide may be subject to changes as a result of the restrictions to face-to-face class attendance imposed by the health authorities.

Contact

Name: Eduard Massó Soler

Email: Eduard.Masso@uab.cat

Use of Languages

Principal working language: english (eng)

Some groups entirely in English: Yes

Some groups entirely in Catalan: No

Some groups entirely in Spanish: No

External teachers

Vincenzo Vitagliano

Prerequisites

It is advisable to have taken Mecànica Teòrica i Sistemes no lineals, and Electrodinàmica i Radiació Sincrotró.

Objectives and Contextualisation

To learn the physical basis of General Relativity (GR) as well as the most important gravitational phenomena that are described with it.
This goal requires mastering tensorial calculus.
The classical tests of GR and the familiarization with the most important spacetimes are also included as part of the course.

Competences

- Apply fundamental principles to the qualitative and quantitative study of various specific areas in physics
- Be familiar with the bases of certain advanced topics, including current developments on the parameters of physics that one could subsequently develop more fully
- Carry out academic work independently using bibliography (especially in English), databases and through collaboration with other professionals
- Communicate complex information in an effective, clear and concise manner, either orally, in writing or through ICTs, and before both specialist and general publics
- Formulate and address physical problems identifying the most relevant principles and using approximations, if necessary, to reach a solution that must be presented, specifying assumptions and approximations
- Make changes to methods and processes in the area of knowledge in order to provide innovative responses to society's needs and demands.

- Take account of social, economic and environmental impacts when operating within one's own area of knowledge.
- Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
- Use mathematics to describe the physical world, selecting appropriate tools, building appropriate models, interpreting and comparing results critically with experimentation and observation
- Using appropriate methods, plan and carry out a study or theoretical research and interpret and present the results
- Work independently, have personal initiative and self-organisational skills in achieving results, in planning and in executing a project
- Working in groups, assume shared responsibilities and interact professionally and constructively with others, showing absolute respect for their rights.

Learning Outcomes

1. Calculate curvature tensor.
2. Calculate particle trajectories in gravitational fields solving the geodesic equation.
3. Calculate the effect of red shift and the deflection of light produced by a gravitational field.
4. Calculate the geodesics in a curved space.
5. Calculate the simple-distribution energy-momentum tensor for matter.
6. Communicate complex information in an effective, clear and concise manner, either orally, in writing or through ICTs, in front of both specialist and general publics.
7. Describe experimental evidence for the existence of gravitational waves.
8. Describe experimental evidence in favor of general relativity and the principle of equivalence in terrestrial and astrophysical observations.
9. Describe gravitational waves and their characteristic properties.
10. Describe observational evidence in favour of big bang cosmology.
11. Describe the basic concepts of current knowledge regarding the structure and evolution of the universe.
12. Describe the characteristics of the gravitational field generated by stars and black holes in addition to the effects they produce.
13. Establish the bases for describing the evaporation and thermodynamics of black holes.
14. Identify situations in which a change or improvement is needed.
15. Identify the social, economic and environmental implications of academic and professional activities within ones own area of knowledge.
16. Obtain physical magnitudes measured by different observers from pseudo-Riemannian metrics.
17. Obtain the Newtonian limit of Einsteins equations with weak non-relativistic sources.
18. Obtain tidal forces from the curvature tensor.
19. Relate general relativity and electromagnetism establishing their similarities and differences.
20. Use Einsteins equations in a linearized manner so as to describe weak gravitational fields, including the generation, propagation and detection of gravitational waves.
21. Use covariant equations and tensor calculus.
22. Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
23. Use differential geometry to implement the principle of equivalence.
24. Use space-time symmetries for solving problems of dynamics and relativistic kinematics.
25. Use the approach of homogeneity and isotropy to describe the structure and evolution of the universe on a large scale.
26. Use the approximation of spherical symmetry in the study of stars and black holes.
27. Work independently, take initiative itself, be able to organize to achieve results and to plan and execute a project.
28. Working in groups, assume shared responsibilities and interact professionally and constructively with others, showing absolute respect for their rights.
29. Carry out academic work independently using bibliography (especially in English), databases and through collaboration with other professionals

Content

Special Relativity

The Equivalence Principle

Tensors in curved space

Einstein's equations

Spherical symmetry. Black holes

Weak fields. Gravitational radiation

Cosmology

Methodology

This course will be given entirely in English. All the course material (problems, homework and exams) will be distributed in English

and students will be encouraged to do all the exercises/exams in English, although in Catalan or Spanish

will also be accepted and assesed with the same criteria.

This course will consist of theory and problem classes. There will be an equilibrium among work at class and at home.

Problem lists will be given to be solved individually or in groups. The solutions to the problelms will be discussed in the problem classes.

The students will solve individually and hand in after a limited time a selection of 'homework' problems that will count for the final course mark.

The students will have to prepare 2 written exams: a mid-term exam and a final exam, the latter of which can be re-taken once.

Activities

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Problem lectures and discussion	16	0.64	5, 1, 3, 4, 2, 6, 11, 12, 9, 13, 29, 17, 18, 16, 22, 19, 27, 28, 21, 25, 26, 23, 20, 24
Theory lectures	33	1.32	5, 1, 3, 4, 2, 6, 11, 7, 8, 10, 12, 9, 13, 17, 18, 16, 22, 19, 21, 25, 26, 23, 20, 24
Type: Autonomous			
Discussion and work in group	46	1.84	5, 1, 3, 4, 2, 6, 11, 7, 8, 10, 12, 9, 17, 18, 16, 22, 19, 28, 21, 25, 26, 23, 20, 24
Study of theoretical foundations	47	1.88	5, 1, 3, 4, 2, 6, 11, 7, 8, 10, 12, 9, 13, 29, 17, 18, 16, 22, 19, 27, 21, 25, 26, 23, 20, 24

Assessment

There will be a resit exam for students that: a) have done Exam 1 and Exam 2

and b) have failed the course with a mark of at least 3.5 (over 10).
Details on this exam will be announced in due course.
Students not attending Exam 2 will have the mark "Not presented - no avaluable"

Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Exam 1	30%	2	0.08	5, 1, 3, 4, 2, 6, 11, 7, 8, 10, 12, 9, 13, 15, 14, 17, 18, 16, 22, 19, 27, 21, 25, 26, 23, 20, 24
Exam 2 (Final)	50%	2	0.08	5, 1, 3, 4, 2, 6, 11, 7, 8, 10, 12, 9, 13, 15, 14, 17, 18, 16, 22, 19, 27, 21, 25, 26, 23, 20, 24
Homework	20%	2	0.08	5, 1, 3, 4, 2, 6, 13, 29, 17, 18, 16, 22, 19, 27, 28, 21, 25, 26, 23, 20, 24
Resit Exam	80%	2	0.08	5, 1, 3, 4, 2, 6, 11, 7, 8, 10, 12, 9, 13, 17, 18, 16, 22, 19, 27, 21, 25, 26, 23, 20, 24

Bibliography

Main: E. Massó, "Notes on GR" (Available in Campus Virtual)

Additional:

- S. Carroll, Spacetime and Geometry: an Introduction to General Relativity, Pearson Education, 2003.

- R.J.A. Lambourne, Relativity, Gravitation and Cosmology, Cambridge Univ Press, 2010.

- J.B. Hartle, Gravity: an Introduction to Einstein's General Relativity, Addison-Wesley, 2003.

- B.F. Schutz, A First Course in General Relativity, Cambridge Univ Press, 2009.

- S. Weinberg, Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity, J. Wiley & Sons, 1972.