# Field theory - course description

## General information

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| Course name | Field theory |
| Course ID | 13.2-WF-FizD-FT-S17 |
| Faculty | Faculty of Physics and Astronomy |
| Field of study | Physics |
| Education profile | academic |
| Level of studies | Second-cycle studies leading to MS degree |
| Beginning semester | winter term 2020/2021 |

## Course information

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|---|---|
| Semester | 2 |
| ECTS credits to win | 6 |
| Available in specialities | Theoretical physics |
| Course type | obligatory |
| Teaching language | english |
| Author of syllabus | • dr hab. Maria Przybylska, prof. UZ |

## Classes forms

| The class form | Hours per semester (full-time) | Hours per week (full-time) | Hours per semester (part-time) | Hours per week (part-time) | Form of assignment |
|---|---|---|---|---|---|
| Lecture | 30 | 2 | - | - | Exam |
| Class | 30 | 2 | - | - | Credit with grade |

## Aim of the course

The aim of the course is to familiarize students with the formalism of special and general theories of relativity, the similarities and differences between them, and their applications to the description of certain physical and astronomical phenomena.

## Prerequisites

Mathematical Analysis I and II, mathematical physics, algebraic and geometric methods in physics

## Scope

- Spacetimes of Aristotle, Galileo, and Newton, the concept of the inertial system, absolute and relative character of the time and spatial distances between events, the geometry of the spacetime. Principles of relativity: Galileo's principle and Einstein's principle. Einstein's postulates.
- The Lorentz transformation, addition of velocities, constant velocity of light in various inertial frames, the time dilation and relativity of simultaneity, the contraction of distances.
- Space-time of the special theory of relativity: the event , the world line of a particle, thw cone of light , space-time interval , the classification of intervals, four vectors.
- Spacetime of general relativity , the relationship between spacetimes of general and special relativity , the local inertial frames.
- The principle of equivalence, relativity, minimal gravitational coupling and correspondence.
- Geodesic deviation and Einstein's equations in empty space. Newtonian limit of geodesic equations.
- Tensors of energy and momentum.
- Einstein's equations.
- The structure of Einstein's equations and their general properties.
- The Schwarzschild's solution.

## Teaching methods

Conventional lecture with applications of trained formalism to some physical and astronomical systems and phenomena.

## Learning outcomes and methods of theirs verification

| Outcome description | Outcome symbols | Methods of verification | The class form |
|---|---|---|---|
| The student knows examples of energy and momentum tensor. | • K2_U01 | • a quiz<br>• an exam - oral, descriptive, test and other | • Lecture<br>• Class |
| The student knows and understands the postulates of special and general theory of relativity. Students know and understand the theoretical results as well as experiments that led A. Einstein to his postulates. | • K2_W01<br>• K2_U01 | • a quiz<br>• an exam - oral, descriptive, test and other | • Lecture<br>• Class |
| The student knows and understands thought experiments with local and nonlocal lift and the relationship of this second experiment with Einstein's equations in empty space. | • K2_W02<br>• K2_U01 | • a quiz<br>• an exam - oral, descriptive, test and other | • Lecture<br>• Class |

| Outcome description | Outcome symbols | Methods of verification | The class form |
|---|---|---|---|
| The student can explain the form of the Schwarzschild metric and knows geodesics in this metric. | • K2_W02<br>• K2_U01 | • a discussion<br>• a quiz<br>• an exam - oral, descriptive, test and other | • Lecture<br>• Class |
| The student knows the steps of reasoning leading to the formulation of Einstein's equations. Students know the properties of these equations and manners of their usage. | • K2_W01<br>• K2_W02<br>• K2_U01 | • a discussion<br>• an exam - oral, descriptive, test and other | • Lecture<br>• Class |
| The student knows the physical and astronomical phenomena confirming the validity of the special and general theory of relativity. | • K2_W03 | • an exam - oral, descriptive, test and other | • Lecture<br>• Class |
| Student mastered the tensor calculus. They can calculate Christoffel symbols, curvature tensor, to determine equations of geodesics. | • K2_W02 | • a quiz<br>• an exam - oral, descriptive, test and other<br>• an oral response | • Lecture<br>• Class |
| The students gain on their own the knowledge about the special and general theories of relativity and develop their skills using a variety of sources in both Polish and English, as well as using modern techniques (internet, various databases). | • K2_U10 | • a quiz<br>• an exam - oral, descriptive, test and other | • Lecture<br>• Class |
| The student knows the geometry of space-time of Aristotle, Newton, special and general theory of relativity. Students can explain differences between them. | • K2_W02 | • a discussion<br>• an exam - oral, descriptive, test and other | • Lecture<br>• Class |
| The student can explain the phenomenon of time dilation and contraction of the distance from the point of view of both frames i.e. moving and resting coordinate frames. | • K2_W05<br>• K2_U01 | • a quiz<br>• an exam - oral, descriptive, test and other | • Lecture<br>• Class |

## Assignment conditions

**Lecture:**

The course credit is obtained by passing a final written exam containing tasks of varying degrees of difficulty.

**Class:**

A student is required to obtain at least the lowest passing grade from the test organized during class.

To be admitted to the test from the content of lecture a student must receive a credit for the class.

**Final grade:** weighted average of grades from the class (40%) and the written texam from the content of lecture (60%).

## Recommended reading

[1] W. A. Ugarow, *Special theory of relativity,* Mir Publisher, Moscow, 1979, Polish translation*: Szczególna teoria względności*, PWN, Warszawa 1985.

[2] J. Foster, J. D. Nightingale, *A short course in general relativity,* third edition, Springer, 2003, Polish translation*: Ogólna teoria wzgl*ędności, PWN, Warszawa 1985.

[3] J. B. Hartle, Gravity. *An introduction to Einstein's general relativity*, Addison Wesley, 2003, Polish translation*: Grawitacja, Wprowadzenie do ogólnej teorii względności Einsteina*, Wydawnictwo Uniwerystetu Warszawskiego, 2010.

[4] L. D. Landau, J. M Lifszyc, *The classical theory of fields,* fourth edition, Butterworth Heinemann, Polish translation*: Teoria pola*, Wydawnictwo Naukowe PWN, Warszawa 2009.

[5] R. D'Inverno, *Introducing Einstein's relativity*, Claredon Press, Oxford 1998.

[6] M. P. Hobson, G. Efstathiou, A. N. Lasenby, *General relativity: an introduction for physicists*, Cambridge University Press, Cambridge 2006.

## Further reading

[1] B. F. Schutz, *A first course in general relativity, second edition,* Cambridge University Press*, 2009,* Polish translation*: Wstęp do ogólnej teorii względności*, Wydawnictwo Naukowe PWN, Warszawa 2002.

## Notes

Modified by dr hab. Piotr Lubiński, prof. UZ (last modification: 09-06-2020 22:43)