# CONTENT

## COURSE INFORMATION LETTER

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|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ AJF1/08 | **Course name:** Applied Nuclear Physics |
| **Course type, scope and the method:**<br>**Course type:** Lecture<br>**Recommended course-load (hours):**<br>**Per week:** 2 **Per study period:** 28<br>**Course method:** present | |
| **Number of ECTS credits:** 4 | |
| **Recommended semester/trimester of the course:** 3. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>Semestral project, its presentation, 2x elaboration of tasks, test, exam.<br>Credit evaluation of the course: direct teaching and consultations (1credit), self-study (1credit), practical activities - project, tasks (1credit), evaluation (1credit), total 4credits. Minimum limit for completion of the course is to obtain at least 51% of the total evaluation. | |
| **Learning outcomes:**<br>Overview of applications of nuclear radiation. | |
| **Brief outline of the course:**<br>1. -2. Properties of radioactive radiation. Artificial radioactivity. Interaction of radiation with matter. Production of radionuclides. Methods of using nuclear radiation and radioactivity.<br>3.-4. Influence of ionizing radiation on humans. Effects of ionizing radiation on the cell. Factors influencing the radiobiological effect of radiation. Irradiation disease.<br>5.-6. Dosimetry and radiation protection. System of dosimetric quantities. Methods of measuring dosimetric quantities. Radiation protection, limits and standards.<br>7. Activation analysis, principles of the method. Absolute and relative method. Determining the quantity of an element. Preparation of samples and standards. Interfering processes. Applications.<br>8. Radioactive indicators, basic characteristics. principles of the method. Selection and properties of isotope indicators. Requirements for radioactive indicators. Examples of applications. Overview of the most important radionuclides.<br>9.-10. Radioactive dating methods. Radiocarbon and tritium dating. Applications. Other methods.<br>11.-12. Radiobiological effects of ionizing radiation, new trends, hadron therapy. | |
| **Recommended literature:**<br>1. Cooper J.R, Randle K., Sokhi R.S.: Radioactive releases in the environment, J.Wiley &Sons, Ltd. 2003<br>2. R. L. Murray, Nuclear Energy, An Introduction to th Concepts, Systems, and Applications of Nuclear Processes, 6th edition,Elsevier, 2009<br>3. Ahmed S.N., Physics & Engineering of Radiation Detection, Elsevier, 2015<br>4. Dosanjh M.: From Particle Physics to Medical Applications, IOP Publishing, 2017<br>5. Powsner R.A.: Essential Nuclear Medicine Physics, Blackwell Publishing, 2006 | |

**Course language:**
slovak and english

**Notes:**

**Course assessment**
Total number of assessed students: 13

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 69.23 | 23.08 | 7.69 | 0.0 | 0.0 | 0.0 |

**Provides:** doc. RNDr. Janka Vrláková, PhD.

**Date of last modification:** 19.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

**COURSE INFORMATION LETTER**

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|---|
| **University:** P. J. Šafárik University in Košice |
| **Faculty:** Faculty of Science |
| **Course ID:** ÚFV/APR/17 — **Course name:** Astronomical instrumetation |
| **Course type, scope and the method:**<br>**Course type:** Lecture / Practice<br>**Recommended course-load (hours):**<br>**Per week:** 3 / 1 **Per study period:** 42 / 14<br>**Course method:** present |
| **Number of ECTS credits:** 6 |
| **Recommended semester/trimester of the course:** 1. |
| **Course level:** II. |
| **Prerequisities:** |
| **Conditions for course completion:**<br>To successfully complete the course, the student must demonstrate a sufficient understanding of the physical principles of operation of astronomical instruments and light detectors. Must master the principles of photometry and spectroscopy. In addition to direct participation in teaching, the student's independent work is also required within the self-study of professional topics assigned by the teacher. In order to obtain an evaluation and thus also credits, the student must meet the requirements of a continuous written test (with a weight of 30% of the total evaluation) and pass a written final exam (with a weight of 70% of the total evaluation). Credit evaluation of the course takes into account the following student workload: direct teaching (2 credits), self-study (2 credits), individual consultations (1 credit), and exam (1 credit). Rating scale: A (90-100%), B (80-89%), C (70-79%), D (60-69%), E (50-59%), F (0-49%). |
| **Learning outcomes:**<br>After completing the lectures and exercises and on the basis of the final evaluation, the student will demonstrate adequate mastery of the content standard of the course, which is defined by a brief syllabus of the course and recommended literature. Mastering the content of the subject allows him to acquire knowledge about the construction of astronomical telescopes, light detectors, will master the principles of obtaining astronomical data by methods such as photometry and spectroscopy, and will be able to perform the basic reduction of this data. They will understand the physical principles of the operation of instruments and light detectors in various spectral regions. |
| **Brief outline of the course:**<br>The time schedule of the course content is updated in the electronic bulletin board of the course.<br>1. Principle of geometric optics, optical errors and their correction,<br>2. Types of telescopes and their construction<br>3. Telescope mounts<br>4. Radio telescopes, UV and X-telescopes,<br>5. Lght detectors - eye, photographic plate, photomultiplier<br>6. Light detectors - CCD, CMOS, EMCCD<br>7. Introduction to photometry - basic concepts, photometric filters<br>8. Principle of photometry - differential, all-sky,<br>9. Aperture and PSF psf photometry |

10. Photometry cabibration - transformation into a standard system
11. Introduction to spectroscopy - types of spectroscopes
12. Spectrum processing and calibration

**Recommended literature:**

1. Howell : 2000, Handbook of CCD Astronomy, Cambridge University Press.
2. Cheng, J.: 2009, The Principles of Astronomical Telescope Design, Springer-Verlag
3. Kitchin, C.R., 2013, Telescopes and Techniques, Springer, 3rd edition
4. Lena et al.: 1996, Observational Astrophysics, Springer-Verlag
5. Martinez a Klotz: 1998, A practical giude to CCD Astronomy, Cambridge University Press.
6. Romano: 2009, Geometric Optics: Theory and Design of Astronomical Optical Systems Using Mathematica 7. Schroeder: 1999, Astronomical Optics, Academic Press

**Course language:**
Slovak, English

**Notes:**

**Course assessment**
Total number of assessed students: 10

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 60.0 | 0.0 | 30.0 | 10.0 | 0.0 | 0.0 |

**Provides:** doc. Mgr. Štefan Parimucha, PhD.

**Date of last modification:** 22.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

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|---|---|
| **Course ID:** ÚFV/ MSSAA/14 | **Course name:** Astronomy and Astrophysics |

**Course type, scope and the method:**
**Course type:**
**Recommended course-load (hours):**
**Per week: Per study period:**
**Course method:** present

**Number of ECTS credits:** 4

**Recommended semester/trimester of the course:**

**Course level:** II.

**Prerequisities:** ÚFV/PHD/17 and ÚFV/MPH1/13 and ÚFV/FSL1/13

**Conditions for course completion:**

**Learning outcomes:**

**Brief outline of the course:**

**Recommended literature:**

**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 11

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 81.82 | 0.0 | 9.09 | 0.0 | 9.09 | 0.0 |

**Provides:**

**Date of last modification:** 19.12.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ APMM/19 | **Course name:** Atomistic Computer MOdeling of Materials |
| **Course type, scope and the method:**<br>**Course type:** Lecture / Practice<br>**Recommended course-load (hours):**<br>**Per week:** 2 / 2 **Per study period:** 28 / 28<br>**Course method:** present | |
| **Number of ECTS credits:** 5 | |
| **Recommended semester/trimester of the course:** 2., 4. | |
| **Course level:** II. | |
| **Prerequisities:** ÚFV/TKL1/99 | |
| **Conditions for course completion:** | |
| **Learning outcomes:** | |
| **Brief outline of the course:**<br>1. Many-body Schrödinger Equation. Born–Oppenheimer, independent electron approximation, and mean-field approximation. Hartree-Fock equations.<br>2. Introduction to Density Functional Theory.<br>3. Hohenberg-Kohn variational principle. Local density approximation.<br>4. Kohn-Sham equations. Self-consistent field calculations.<br>5. Pseudopotentional theory. Norm-conserving pseudopotentials. PAW method.<br>6. Equilibrium structures of materials. Adiabatic approximation. Atomic forces. Verlet's algorithm.<br>7. Calculation of elastic material properties.<br>8. Quantum molecular dynamics. Car-Parrinello algorithm.<br>9. Phonons calculations. Frozen phonon method. Density functional perturbation theory.<br>10. Calculation of optical properties and excitation spectra. Time-dependent density functional theory.<br>11. Wannier functions and maximally localized Wannier functions.<br>12. Density functional theory for magnetic materials. | |
| **Recommended literature:**<br>Giustino, F. Materials Modelling using Density Functional Theory. Oxford University Press, 2014.<br>Kohanoff, J. Electronic Structure Calculations for Solids and Molecules. Cambridge University Press, 2006.<br>Martin, R. M. Electronic Structure, Basic Theory and Practical Methods. Cambridge University Press, 2004.<br>Bluegel, S. et al. Computing Solids. Lecture Notes of the 45th IFF Spring School, 2014.<br>Springborg, M. Methods of Electronic-Structure Calculations: From Molecules to Solids. Wiley, 2000. | |
| **Course language:** | |
| **Notes:** | |

**Course assessment**
Total number of assessed students: 16

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 56.25 | 12.5 | 25.0 | 6.25 | 0.0 | 0.0 |

**Provides:** RNDr. Martin Gmitra, PhD.

**Date of last modification:** 29.11.2022

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚINF/ PSDU/24 | **Course name:** Case studies in data mining |
| **Course type, scope and the method:**<br>**Course type:** Practice<br>**Recommended course-load (hours):**<br>**Per week:** 2 **Per study period:** 28<br>**Course method:** present | |
| **Number of ECTS credits:** 3 | |
| **Recommended semester/trimester of the course:** 1. | |
| **Course level:** II., N | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>The realization of a project focused on case studies in data mining.<br>Successful completion of the written and oral part of the exam focused on case studies in data mining. | |
| **Learning outcomes:**<br>Solving practical tasks in the field of data mining. Basic concepts of data mining. Knowledge of data mining methods. | |
| **Brief outline of the course:**<br>1. Basic notions in data mining<br>2. Data preparation in data mining<br>3. Methods and algorithms of data mining<br>4. Methods and algorithms of data mining II<br>5. Extraction of knowledge from large data volumes<br>6. Case study analysis using data mining methods in different application areas<br>7. Case study analysis using data mining methods in different application areas II<br>8. Application of methods for automated analysis of large data volumes<br>9. Solving practical tasks using appropriate software tools<br>10. Solving practical tasks using appropriate software tools II<br>11. Solving practical tasks using appropriate software tools III<br>12. Testing data mining algorithms<br>13. Testing data mining algorithms II | |
| **Recommended literature:**<br>[1] Watt, J., Borhani, R., Katsaggelos, A.K.: Machine learning refined: foundations, algorithms, and applications. Cambridge: Cambridge University Press, 2016.<br>[2] Zhao, Y., Cen, Y.: Data Mining Applications with R. Elsevier Inc. 2014.<br>[3] Han, J. and Kamber, M.: Data Mining Concepts and Techniques. 3rd Edition, Morgan Kaufmann, Burlington, 2011.<br>[4] Witten, I.E., Frank, E.: Data Mining: Practical Machine Learning Tools and Techniques, Elsevier, 2005. | |

**Course language:**
Slovak or English

**Notes:**

**Course assessment**
Total number of assessed students: 65

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 96.92 | 3.08 | 0.0 | 0.0 | 0.0 | 0.0 |

**Provides:** doc. RNDr. Ľubomír Antoni, PhD.

**Date of last modification:** 19.03.2024

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ NME/17 | **Course name:** Celestial mechanics |
|---|---|

**Course type, scope and the method:**
**Course type:** Lecture / Practice
**Recommended course-load (hours):**
**Per week:** 3 / 1 **Per study period:** 42 / 14
**Course method:** present

**Number of ECTS credits:** 6

**Recommended semester/trimester of the course:** 1.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**

To successfully complete the course, the student must demonstrate sufficient knowledges of the mathematical apparatus necessary to calculate and run simple numerical simulations using available software packages. In addition to direct participation in teaching, the student's independent work is also required within the self-study of professional topics assigned by the teacher. Active participation in the exercises and passing the oral final exam is required to obtain the evaluation and thus also the credits. Credit evaluation of the course takes into account the following student workload: direct teaching (2 credits), self-study (3 credits), individual consultations (1 credit), and exam (1 credit), Rating scale: A (90-100%), B (80-89%), C (70-79%), D (60-69%), E (50-59%), F (0-49%) .

**Learning outcomes:**

After completing lectures and exercises and on the basis of the final evaluation, the student will prove
adequate mastery of the content standard of the subject, which is defined by a brief syllabus
subject and recommended literature. He will be able to solve the problem of 2 bodies, he will understand the mathematical apparatus necessary for calculations in celestial mechanics and he will be able to apply these in numerical simulations of the problem of n-bodies

**Brief outline of the course:**

The time schedule of the course content is updated in the electronic bulletin board of the course.
1.Equations of motion for "n" material bodies,
2. Restricted three-body problem, equations in the non-rotating frame, equations in the rotating coordinate frame,
3. Jacobi integral, surfaces and curves of zero velocity (Hill surfaces),
4. Lagrange libration points,
5. Tisserand criterion.
6. Numerical integration of orbits, perturbation function.
7. Practical use of numerical integrators. Method of variation of constants,
8.Elements of orbit as a function of time
9. Langrange brackets,
10. Whittaker method of the detemination of Lagrange brackets,

11. Lagrange equations, Lagrange equations for canonical elements,
12. Gauss form of the Lagrange equations.

**Recommended literature:**


1. Andrle P., 1971, Základy nebeské mechaniky. Academia, Praha
2. Brouwer D., Clemence G. M., 1961, Methods of Celestial Mechanics, Academia Press, New York and London,
3. Roy A. E., 1978, Orbital Motion, Adam Hilger Ltd., Bristol
4. Everhart E., 1985, An efficient integrator that uses Gauss-Radau spacings, in: Dynamics of Comets: Their Origin and Evolution, eds. A. Carusi and G. B. Valsecchi, Reidel, Dordrecht, s, 185-202
5. Boccaletti D., Pucacco G., 2001, Theory of Orbits. 1. Integrable Systems and Non-perturbative Methods, Springer, Berlin - Heidelberg
6. Boccaletti D., Pucacco G., 2002, Theory of Orbits. 2. Perturbative and Geometrical Methods, Springer, Berlin - Heidelberg - New York,
7. Neslušan, L., 2017, 2017, Elementárny úvod do nebeskej mechaniky, VEDA, SAV, Bratislava


**Course language:**
slovak, english

**Notes:**

**Course assessment**
Total number of assessed students: 12

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 66.67 | 0.0 | 8.33 | 0.0 | 25.0 | 0.0 |

**Provides:** Mgr. Marián Jakubík, PhD.

**Date of last modification:** 22.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

# COURSE INFORMATION LETTER

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|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** KPPaPZ/KK/07 | **Course name:** Communication and Cooperation |
| **Course type, scope and the method:**<br>**Course type:** Practice<br>**Recommended course-load (hours):**<br>**Per week:** 2 **Per study period:** 28<br>**Course method:** present | |
| **Number of ECTS credits:** 2 | |
| **Recommended semester/trimester of the course:** 3. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>Evaluation:<br>A condition for student evaluation is his active participation in the seminar. It is expected that the student will actively participate in the discussions and will express their positions and possible solutions.<br>The output for evaluation will be the development of a project in the form of a Power Point presentation or a video on a selected communication topic. | |
| **Learning outcomes:**<br>The goal of the subject Communication, cooperation is the formation and development of students' language and communication skills through experiential activities.<br>The student can demonstrate an understanding of individual behavior in various communication contexts.<br>The student can describe, explain and evaluate communication techniques (cooperation, assertiveness, empathy, negotiation, persuasion) in practical contexts.<br>The student can apply these techniques in common communication schemes. | |
| **Brief outline of the course:**<br>Communication<br>Communication theory<br>Non-verbal communication and its means<br>Verbal communication (basic components of communication, language means of communication) about active listening<br>Empathy<br>Short conversation and effective communication (principles and principles of effective communication)<br>Cooperation<br>About the basics of cooperation<br>About types, signs, types and factors of cooperation<br>Characteristics of the team (positions in the team)<br>Small social group (structure, development, characteristics of a small social group, position of the individual in the group) | |

About leadership (characteristics of the leader, management, leadership styles)

**Recommended literature:**

**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 281

| abs | n | z |
|---|---|---|
| 98.22 | 1.78 | 0.0 |

**Provides:** Mgr. Ondrej Kalina, PhD., Mgr. Lucia Barbierik, PhD.

**Date of last modification:** 12.09.2024

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ POF1b/99 | **Course name:** Computational Physics II |
| **Course type, scope and the method:**<br>**Course type:** Lecture / Practice<br>**Recommended course-load (hours):**<br>**Per week:** 2 / 1 **Per study period:** 28 / 14<br>**Course method:** present | |
| **Number of ECTS credits:** 4 | |
| **Recommended semester/trimester of the course:** 1. | |
| **Course level:** I., II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>To successfully complete the course, the student must demonstrate a sufficient understanding of the basic methods of computer simulations of multiparticle systems. The basis of continuous assessment is participation and activity in exercises and work on assignments. The course ends with a final oral exam, the completion of which is conditional on the submission of all four assignments (projects) electronically and with the attached computer program. Credit rating of the course takes into account the following student workload: direct teaching (2 credits) and individual work on projects (2 credits). The minimum threshold for completing the course is to obtain at least 50% of the total score, using the following rating scale: A (90-100%), B (80-89%), C (70-79%), D (60-69%), E (50-59%), F (0-49%). | |
| **Learning outcomes:**<br>To teach students to create simulation projects to help to solve various physical problems. To acquaint students with basic simulation methods of multiparticle systems by Monte Carlo and molecular dynamics and verify their practical implementation by preparing a computer program and analyzing the obtained results. | |
| **Brief outline of the course:**<br>1. Methods of Monte Carlo (MC) simulations of lattice spin systems.<br>2. Local and cluster perturbation algorithms.<br>3. Errors and histogram analysis of MC data.<br>4. Reweighting by simple and histogram methods.<br>5. Universality and finite-size scaling.<br>6. Determination of order of phase transitions and calculation of critical exponents.<br>7. Basics of quantum MC simulations.<br>8. MC simulations of stochastic processes.<br>9. Diffusion equation.<br>10. Stochastic processes in financial analysis.<br>11.Basics of molecular dynamics method.<br>12. Discretization schemes of molecular dynamics. | |
| **Recommended literature:**<br>Basic study literature: | |

LANDAU, D.P., BINDER, K.: A Guide to Monte Carlo Simulations in Statistical Physics, Cambridge Univ. Press, 5-th edition, 2021.
BOTTCHER, L., HERRMANN, H.J., Computational Statistical Physics, Cambridge Univ. Press, 2021.
Other study literature:
BERG, B.A.: Introduction to Markov Chain Monte Carlo Simulations and Their Statistical Analysis (http://www.worldscibooks.com/etextbook/5904/5904_intro.pdf)
JANKE, W.: Monte Carlo Simulations of Spin Systems (http://www.physik.uni-leipzig.de/~janke/Paper/spinmc.pdf)

**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 60

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 50.0 | 20.0 | 16.67 | 10.0 | 1.67 | 1.67 |

**Provides:** prof. RNDr. Milan Žukovič, PhD.

**Date of last modification:** 14.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ PAST/17 | **Course name:** Computer astrophysics |
|---|---|

**Course type, scope and the method:**
**Course type:** Lecture / Practice
**Recommended course-load (hours):**
**Per week:** 2 / 2 **Per study period:** 28 / 28
**Course method:** present

**Number of ECTS credits:** 5

**Recommended semester/trimester of the course:** 2.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
To successfully complete the course, the student must demonstrate a sufficient understanding of the various numerical methods used in astrophysics, the principles of machine learning, and the processing of large amounts of data. Must be able to work with astronomical software packages as well as the astropy library. In addition to direct participation in teaching, independent student work is also required within the self-study of special topics. To obtain the evaluation and thus the credits, the student must develop a software project on a topic assigned by the teacher and present it at the exercise (with a weight of 70% of the total evaluation) and pass a written final exam (with a weight of 30% of the total evaluation). The credit evaluation of the course takes into account the following student workload: direct teaching (1 credit), self-study (3 credits) and exam (1 credit).
Rating scale: A (90-100%), B (80-89%), C (70-79%), D (60-69%), E (50-59%), F (0-49%) .

**Learning outcomes:**
After completing lectures and exercises and on the basis of the final evaluation, the student will demonstrate adequate mastery of the content standard of the course, which is defined by a brief syllabus of the course and recommended literature. Mastering the content of the subject allows him to control various packages of astronomical software and work with a package of astropy. They will get acquainted with the concept of a virtual observatory for access to different data. They will be able to independently create software for processing and analysis of observations, and processing large amounts of data using machine learning.

**Brief outline of the course:**
The time schedule of the course content is updated in the electronic bulletin board of the course.
1. Sources of professional astronomical information on the Internet: VIZIER database, NASA ADS Abstract Service, arXiv, astronomical journals
2. Virtual observatory - concept and basic means of VO
3. Virtual observatory - use of VO in astronomy, VO and big data in astronomy
4. FITS file format for storing astronomical data
5. Working with MIDAS, IRAF and IDL packages
6. Basics of Python language
7. Astropy library, creating graphs, working with tables and figures,
8. Astropy Library - works with time data and coordinates

9. Working with FITS files in the astropy library
10. Introduction to machine learning
11 .ML in astrophysics - identification of galaxies
12. ML in astrophysics - detection of variable stars

**Recommended literature:**

1. Ghedini: 1982, Software for Photometric astronomy
2. Press et al., 1992, Numerical Recipes in C, The art of scientific Computing, CUP
3. Schmith, W.,, Völschow, M., 2021, Numerical Python in Astronomy and Astrophysics, Springer
4. manuals of software packages

**Course language:**
Slovak, English

**Notes:**

**Course assessment**
Total number of assessed students: 9

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 88.89 | 0.0 | 11.11 | 0.0 | 0.0 | 0.0 |

**Provides:** doc. Mgr. Štefan Parimucha, PhD.

**Date of last modification:** 22.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ KZI1/03 | **Course name:** Cosmic Rays |
| **Course type, scope and the method:**<br>**Course type:** Lecture<br>**Recommended course-load (hours):**<br>**Per week:** 2 **Per study period:** 28<br>**Course method:** present | |
| **Number of ECTS credits:** 4 | |
| **Recommended semester/trimester of the course:** 3. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>1. Participation in course in accordance with the study regulations and instructions of the teacher.<br>2. Elaboration of a recherche work according to a selected article from the field of cosmic ray particle physics.<br>Final written or oral exam<br>Conditions for course succesfull completion:<br>1. Participation in course in accordance with the study regulations and according to the instructions of the teacher;<br>2. Mastering the conditions of the interim and final evaluation in the overall expression at the level of at least 80%.<br>The credit evaluation of the course takes into account the following student workload: direct teaching (2 credits), self-study (1 credit) and evaluation (1 credit). | |
| **Learning outcomes:**<br>During the continuous and final evaluation, the student will demonstrate adequate mastery and understanding of the content of the subject. Understands the ways and techniques of numerical solution of two basic physical problems from lectures, the motion of cosmic ray particles in the Earth's magnetosphere (Lorentz equation) and modulation of cosmic rays in the heliosphere (Fokker-Planck equation). They will learn how to determine the shape of the diffusion tensor for different shapes of the magnetic field. Gain a basic overview of the acceleration of cosmic radiation on shock waves, the geomagnetic field and the characteristics of cosmic radiation. | |
| **Brief outline of the course:**<br>1. Overview of the history of cosmic ray research.<br>2. Basic characteristics of cosmic rays. Energy spectrum and chemical composition.<br>3. Possible sources of cosmic rays. Changes in composition and energies from source to detector.<br>4. Overview of significant experiments. Space, atmospheric-balloon, ground, underground experiments.<br>5. Production of secondary cosmic radiation in the atmosphere. Hard, soft and electromagnetic component. Change in flux in the atmosphere with altitude.<br>6. Geomagnetic field of the Earth. Internal and exterbnal current systems. | |

7. Motion of cosmic rays in the Earth's magnetosphere. Cut-off rigidity and magnetospheric optics. Backward solution of the Lorenz equation.
8. Distribution of cosmic rays in the heliosphere. Fokker-Planck equation and ways to solve it.
9. Parker field, diffusion tensor derived for Parker field
10. Solution of Fokker-Planck equation for supernova explosion. Basic characteristics of a supernova explosion.
11. Acceleration of cosmic rays on shock waves.

**Recommended literature:**

1. Marius S. Potgieter, Solar Modulation of Cosmic Rays, Living Reviews in Solar Physics volume 10, Article number: 3 (2013)
2. A Smart, D. F.; Shea, M. A.; Flückiger, E. O., Magnetospheric Models and Trajectory Computation, Space Science Reviews, 93, 2000
3. T. K. Gaisser. Cosmic Rays and Particle Physics. Cambridge, 1990.
4. L.I. Dorman: Cosmic Rays in the Earth's Atmosphere and Underground, Springer, 2004.
5. K. Kudela: On energetic particles in space, acta physica slovaca vol. 59 No. 5, 537 – 652, oct. 2009.
6. Precision Measurement of the Proton Flux in Primary Cosmic Rays from Rigidity 1 GV to 1.8 TV with the Alpha Magnetic Spectrometer on the International Space Station, Physical Review Letters, 114, 17, id.171103, 2015

**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 47

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 93.62 | 6.38 | 0.0 | 0.0 | 0.0 | 0.0 |

**Provides:** RNDr. Pavol Bobík, PhD.

**Date of last modification:** 19.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

# COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ KOZM/13 | **Course name:** Cosmology |
|---|---|

**Course type, scope and the method:**
**Course type:** Lecture
**Recommended course-load (hours):**
**Per week:** 2 **Per study period:** 28
**Course method:** present

**Number of ECTS credits:** 4

**Recommended semester/trimester of the course:** 3.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
To successfully complete the course, the student must demonstrate sufficient understanding of the basic knowledge of the structure and evolution of the universe. Knowledge of the distribution of matter in the universe, expansion and other properties of the universe, application of the equations of the General Theory of Relativity in the construction of cosmological models, the origin and evolution of the universe are required. The condition for obtaining credits is passing a written or oral exam, preparation, and presentation of a semester essay. The credit evaluation of the course considers the following student workload: direct teaching (1 credit), self-study (2 credit) and assessment (1 credits). The minimum threshold for completing the course is to obtain at least 50% of the total score, using the following rating scale: A (90-100%), B (80-89%), C (70-79%), D (60-69%), E (50-59%), Fx (0-49%).

**Learning outcomes:**
After completing the lectures, the student will master the basic knowledge about the distribution of matter in the universe, expansion and other properties of the universe, the origin and evolution of the universe. He will also be able to apply the equations of the General Theory of Relativity in the construction of cosmological models and will have sufficient physical knowledge and mathematical apparatus to independently solve a wide range of tasks related to cosmological research.

**Brief outline of the course:**
1. Introduction to cosmology: historical development of views on the universe, Olbers' paradox, gravitational paradox, cosmological principle.
2. Distribution of matter in the universe: Milky Way, its structure, dynamics and evolution, types of galaxies, quasars, intergalactic matter.
3. Groups, clusters and superclusters of galaxies, large-scale structure of the universe, dark matter, and dark energy.
4. Properties of the universe: isotropy and homogeneity of the universe, cosmic background radiation, expansion of the universe.
5. General theory of relativity: Einstein's gravitational equations.
6. Experimental tests of General theory of relativity, black holes, gravitational waves.
7. Relativistic cosmology: static solutions of Einstein's equations for homogeneous and isotropic universes, cosmological constant.

8. Dynamic solutions of Einstein's equations for homogeneous and isotropic universes, FLWR metric.
9. Fridman's equations, models of the universe and their properties.
10. Standard cosmological model: the theory of the expanding universe, the Big Bang, the age of the universe.
11. The origin of the universe: the initial stages of the expansion of the universe, inflationary expansion, nucleogenesis, the formation of galaxies and galaxy clusters.
12. Physics of the universe, cosmological problems: the steady state theory and other cosmological theories, arrow of time, future of the universe, anthropic principle.

**Recommended literature:**
1. Narlikar, J.V., An Introduction to Cosmology, Cambridge University Press, Cambridge, 2002;
2. Contopoulos, D. Kotsakis, Cosmology, the structure and evolution of the Universe, Springer, 1984;
3. Weinberg, S., Gravitation and Cosmology, Wiley, New York, 1971;
4. Horský, J., Novotný, J., Štefánik, M., Úvod do fyzikální kosmologie, Academia, Praha, 2004;
5. Ullman, V., Gravitace, černé díry a fyzika prostoročasu, Československá astronomická společnost ČSAV, Ostrava, 1986;

**Course language:**
Slovak, English

**Notes:**

**Course assessment**
Total number of assessed students: 34

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 73.53 | 20.59 | 5.88 | 0.0 | 0.0 | 0.0 |

**Provides:** doc. RNDr. Rudolf Gális, PhD.

**Date of last modification:** 20.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ DAD/21 | **Course name:** Detection and dosimetry of cosmic rays at Earth |
| --- | --- |

**Course type, scope and the method:**
**Course type:** Lecture
**Recommended course-load (hours):**
**Per week:** 2 **Per study period:** 28
**Course method:** present

**Number of ECTS credits:** 4

**Recommended semester/trimester of the course:** 2.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
Final written or oral exam.
The credit evaluation of the course takes into account the following student workload: direct teaching (2 credits), self-study (1 credit) and evaluation (1 credit).

**Learning outcomes:**
Students will acquire basic knowledge in the field of dosimetry of ionizing radiation and radiation protection. Course is focused on application of obtained knowledge in the field of dosimetry of mixed radiation fields including the cosmic radiation fields. The course describes, which methods are used to measure cosmic rays at Earth, how is the radiation situation at low Earth orbit, at the International Space Station and how to protect a man in an environment with increased levels of ionizing radiation including the cosmic radiation. Course attendees will obtain not only basic knowledge about the radiation protection from cosmic rays but also in the radiation protection in general. Hence, acquired knowledge can be used also in other branches of human activities where ionizing radiation is used like e.g. in medicine or industry.

**Brief outline of the course:**
1. Introductory lecture: Revision of basic terms and quantities from experimental and nuclear physics: radioactivity, ionizing radiation, survey of elementary particles, sources of ionizing radiation, interactions of ionizing radiation with matter, directly and non-directly ionizing radiation. (PB)
2. Basics of ionizing radiation dosimetry: Definition of basic ionizing radiation dosimetry quantities - exposition, kerma and absorbed dose. Electron equilibrium. A Theory of Cavity Ionization. Conversion of quantities. (JK)
3. Biologic effects of ionizing radiation and radiation protection: Linear energy transfer, dose equivalent, personal dose equivalent, equivalent dose, effective dose, cumulative effective dose. (PB)
4. Metrology of dosimetric quantities: Detection of photon radiation. Measurement of exposition, kerma and absorbed dose in photon radiation field. (JK)
5. Metrology of dosimetric quantities: Detection of charged particles. Measurement of linear energy transfer in electron and proton radiation field. (JK)

6. Metrology of dosimetric quantities: Detection of neutron radiation. Measurement of kerma and absorbed dose in the neutron radiation field. (JK)
7. Dosimetry of mixed ionizing radiation fields: Measurement of dosimetric quantitites in mixed radiation fields. Multiple detectors systems. (PB)
8. Shielding of ionizing radiation: Designing the radiation shielding. Equation for determination of thickness of shielding materials. Monte Carlo calculations. Multi-layer shielding of mixed radiation fields. Examples of shielding for common ionizing radiation sources. (JK)
9. Cosmic radiation sources at the Earth and in its vicinity: Galactic cosmic rays. Van Allen radiation belts. Secondary cosmic radiation. (PB)
10. Monitoring of cosmic radiation at the Earth: Basic methods and principles. Multiple detectors systems for cosmic rays showers detection. Neutron monitors. (PB)
11. Cosmic radiation detectors at the Lomnický štít observatory: NM64 type neutron monitor and the SEVAN instrument. Description of construction. Electronics. Detection units. (PB)
12. NM64 neutron monitor and SEVAN instrument at the Lomnický štít observatory: Visit of the workplace. Presentation of instruments on site. Data evaluation and processing. (PB)
13. Cosmic radiation and spaceflights: Risks that possess cosmic radiation for spaceflights. Shielding and radiation protection from cosmic rays. Radiation exposure of International Space Station (ISS) crew. Survey of experiments focused on radiation protection of ISS crew. (PB)

**Recommended literature:**
1. Jacob Shapiro - Radiation protection: a guide for scientists, regulators and physicians, Harvard University Press, 2002, ISBN: 0-674-00740-9
2. Glenn F. Knoll - Radiation Detection and Measurement, John Wiley & Sons, Inc., 2010, ISBN: 978-0-470-13148-0
3. P.K.F. Grieder - Cosmic Rays at Earth, Elsevier, 2001, ISBN: 978-0-444-50710-5

**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 3

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Provides:** RNDr. Pavol Bobík, PhD., Ing. Ján Kubančák, PhD.

**Date of last modification:** 19.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ DPO/14 | **Course name:** Diploma Thesis and its Defence |
|---|---|

**Course type, scope and the method:**
**Course type:**
**Recommended course-load (hours):**
**Per week:** **Per study period:**
**Course method:** present

**Number of ECTS credits:** 16

**Recommended semester/trimester of the course:**

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**

**Learning outcomes:**

**Brief outline of the course:**

**Recommended literature:**

**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 77

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 72.73 | 18.18 | 5.19 | 1.3 | 2.6 | 0.0 |

**Provides:**

**Date of last modification:** 07.12.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ EKF/04 | **Course name:** Econophysics |

**Course type, scope and the method:**
**Course type:** Lecture / Practice
**Recommended course-load (hours):**
**Per week:** 2 / 1 **Per study period:** 28 / 14
**Course method:** present

**Number of ECTS credits:** 4

**Recommended semester/trimester of the course:** 3.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
To successfully complete the course, the student must demonstrate a sufficient understanding of the ways of applying several statistical physics concepts in the field of economics and finance. The basis of continuous assessment is participation and activity in exercises and work on assignments. The course ends with a final oral exam, the completion of which is conditional on the submission of all four assignments (projects) electronically and with the attached computer program. The credit evaluation of the course takes into account the following student workload: direct teaching (2 credits) and individual work on projects (2 credits). The minimum threshold for completing the course is to obtain at least 50% of the total score, using the following rating scale: A (90-100%), B (80-89%), C (70-79%), D (60- 69%), E (50-59%), F (0-49%).

**Learning outcomes:**
To teach student to employ the aquired knowledge from physics in different disciplines such as economy, finantial analysis and sociology. Student will learn how statistical physics concepts such as stochastic dynamics, short- and long-range correlations, self-similarity and scaling permit an understanding of the global behavior of economic systems.

**Brief outline of the course:**
1. Introduction. Pareto and Bachelier approach.
2. The physical "philosophy" in the formulation of models of social and economic models.
3. The system of measurable quantities in economy, the logarithmic price, the uints of time and price in economy.
4. The stochastic models, random processess and distribution functions, stability of distributions, infinitely divisible process.
5. Scaling of distribution functions, Gauss and Lévy distribution, the simulation of random processes via computer.
6. Selected parallels between economy and fluid turbulence, market volatility and intermittence.
7. Correlations of markets, the markets in mutual correlations and anticorrelations.
8. Autocorrelations and analysis of time series.
9. Portfolio taxonomy and the strategy of the joining of enterprises and formation of corporations.
10. Computer modeling of GARCH and ARCH random processes with variable dispersion of volatility.

11. Models based on the stochastic diferential equations, Black-Scholes model of the rational option price.
12. Internet as a source of current economic information, M&P 500 indices, DJIA.

**Recommended literature:**
Basic literature:
MANTEGNA, R.N., STANLEY, H.E., An Introduction to Econophysics: Correlations and Complexity in Finance, Cambridge University Press 2000.
Other literature:
VOIT, J., The Statistical Mechanics of Financial Markets, Springer 2003.
SINHA, S. a kol., Econophysics: An Introduction, Wiley VCH 2011.

**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 16

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 75.0 | 18.75 | 6.25 | 0.0 | 0.0 | 0.0 |

**Provides:** prof. RNDr. Milan Žukovič, PhD.

**Date of last modification:** 14.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

**COURSE INFORMATION LETTER**

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ FEC1/04 | **Course name:** Elementary Particle Physics |
| **Course type, scope and the method:**<br>**Course type:** Lecture / Practice<br>**Recommended course-load (hours):**<br>**Per week:** 4 / 2 **Per study period:** 56 / 28<br>**Course method:** present | |
| **Number of ECTS credits:** 8 | |
| **Recommended semester/trimester of the course:** 1. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>Conditions for a successful course completion:<br>1. condition: successful passing of the written test with selected exercises from relativistic kinematics, dynamical conservation laws, Feynman diagrams and spin and isospin formalism<br>2. condition follows after successful 1. one: written or oral exam from the whole subject<br>Credit distribution:<br>lectures+exercises: 72 hours - 3 credits<br>preparation for exercises + study: 50 hours - 2 credits<br>preparation for final test with exercises: 25 hours - 1 credit<br>preparation for the final exam: 50 hours - 2 credits | |
| **Learning outcomes:**<br>Successful candidate will know how to solve standard exercises from relativistic kinematics connected with accelerator and detector, he/she will judge if the decay or interaction is allowed and to draw them using Feynman diagrams, he/she will know how to solve problems involving (iso)spin formalism.<br>Successful candidate will have knowledge about basic discoveries in elementary particle physics, about kinematic and dynamic conservation laws and abut Standard Model of particle physics in general. | |
| **Brief outline of the course:**<br>I. part: Introduction (1. week):<br>Elementary particles - definition and properties, sources of elementary particles, detection of elementary particles, units in elementary particle physics<br>II. part: Relativistic kinematics (2. week):<br>Lorentz transformations - Four-vectors - Energy and momentum - Classical and relativistic collisions - Lifetime - Cross section<br>III. part: Historical introduction (3.-7. week):<br>The classical era (1897-1932): discovery of electron, proton and neutron - Photon (1900-1924): photoelectric effect, Compton scattering - Leptons and mesons (1934-1947): Yukawa meson, discovery of muon and pion in cosmic rays - Antiparticles (1930-1956): discovery of positron in cosmic rays, discovery of antiproton – experiment at Bevatron in Berkeley - Neutrinos (1930-1962): | |

neutrino discovery, Reines-Cowan experiment, - Strange particles (1947-1960): discovery of K-mesons a Lambda hyperons in cosmic rays, strangeness - a new quantum number - Eightfold way (1961-1964): baryon and meson multiplets, discovery of Omega- in BNL - Quark model (1964): flavour and colour, isospin, resonances - November revolution revolution and its aftermath (1974-1983,1995): discovery of c quark in BNL and in SLAC, discoveries of b and t quarks in Fermilab, tau lepton discovery - Intermediate bosons (1983): discovery of W+- and Z0 at CERN, Higgs boson (2012) - Standard model (1978-?)
IV. part: Particle dynamics (8.-9. week):
The four forces - Quantum electrodynamics: examples of processes - Quantum chromodynamics: asymptotic freedom, examples of processes - Weak interactions: neutral and charged currents, interactions a decays of leptons and quarks, CKM matrix - Decays and conservation laws: charge, colour, lepton and baryon number, flavour - Unification scheme: electroweak theory, GUT theory
V. part: Symmetries (10.-11. week):
Symmetries and conservation laws - Spin, Isospin - Parity: parity violation in weak interactions, madam Wu experiment, Goldhaber experiment - Combined parity: neutral K-mesons, violation of combined parity, Cronin-Fitch experiment - CPT theorem
VI. part: Beyond Standard Model Physics (12. week):
Neutrino oscillations - Grand Unified Theories - Supersymmetry

**Recommended literature:**

1. D. Griffiths: Introduction to Elementary Particles, Wiley-VCH, 2008, ISBN 978-3-527-40601-2
2. A. Bettini: Introduction to Elementary Particle Physics, Cambridge University Press, 2008, ISBN 978-0-521-88021-3
3. B. Martin and G. Shaw: Particle Physcis, Wiley, 2008, ISBN 978-0-470-03293-0
4. D. Perkins: Introduction to High Energy Physics, Cambridge University Press, 2000, ISBN 978-0521621960


**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 37

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 45.95 | 32.43 | 10.81 | 5.41 | 5.41 | 0.0 |

**Provides:** doc. RNDr. Marek Bombara, PhD., Mgr. Lucia Anna Tarasovičová, Dr. rer. nat.

**Date of last modification:** 28.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

**COURSE INFORMATION LETTER**

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ EJF1a/04 | **Course name:** Experimental Methods of Nuclear Physics |
|---|---|

**Course type, scope and the method:**
**Course type:** Lecture / Practice
**Recommended course-load (hours):**
**Per week:** 4 / 2 **Per study period:** 56 / 28
**Course method:** present

**Number of ECTS credits:** 8

**Recommended semester/trimester of the course:** 3.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
1. Active participation in lectures and excersises
2. Elaboration of a written report
3. Passing the oral exam

Detailed conditions are updated annually on the electronic notice board of the subject in AiS2 or within the repository for digital support materials (LMS UPJŠ, MS Teams UPJŠ, etc.)
Credit evaluation of the course takes into account the following student workload: direct teaching (3 credits), individual consultations (1 credit), self-study (2 credits), rating (2 credits). The minimum threshold for completing the course is to obtain at least 51% of the total score, using the following rating scale: A (91-100%), B (81-90%), C (71-80%), D (61- 70%), E (51-60%), F (0-50%).

**Learning outcomes:**
Acquire basic knowledges of the principles of particle detectors, construction of large detectors complex and basis of electronics in subnuclear physics.

**Brief outline of the course:**
1. week: Charged particle accelerators and their types. A brief history of accelerators and their use. Movement of charged particles in electric and magnetic fields, physical principles of acceleration, basic parts of accelerators, classification of accelerators.
2. week: Linear accelerators - electrostatic linear accelerators, cascade and Van de Graff generator, resonant linear accelerators, phase stability principle, beam focusing. Cyclic accelerators - the principle of operation of a cyclic accelerator, cyclotron and relativistic effect, stability of circular orbits, microtron and betatron, phasotron, electron synchrotron, synchrophasotron, colliding beams.
3. Principles and construction of particle detectors: quantities characterizing detectors.
4. Interaction of particles with matter.
5. Gaseous detectors: operation and construction - electrons and ions in gases: gas amplification, ion mobility, diffusion of ions in gas, recombination and capture of electrons, drift of electrons in an electric and magnetic field, diffusion of electrons in an electric and magnetic field.
6. Special types of gas detectors: Proportional chambers, MWPC. Drift chambers, TPC.
7. Silicon detectors (pixels/strips).
8. Scintilators and photodetectors.

9. Methods of physical quantities measurement: Vertex detectors. Track detectors (measurement of coordinates, paths, angles, momenta). Charged particle identification (ionisation losses, time of flight ...).
10. Calorimetry, electromagnetic and hadron calorimeters.
11. Large detector systems, fixed target and collider experiments.
12. Basis of electronics used in subnuclear physics (fundamental concepts, principles, requirements, specialness).

**Recommended literature:**

Fernow R.: Introduction to experimental particle physics, Cambridge, 1986.
Kleinknecht K.: Detectors for particle radiation, Cambridge, 1986.
Leo W.R., Techniques for Nuclear and Particle Physics Experiments, Springer Verlag, New York Berlin Heidelberg, 1994.
Bartke J.: Introduction to Relativistic Heavy Ion Physics, World Scientific Publishing, Singapore, 2009.
Grupen C.: Particle detectors, Cambridge, 2011.
Ahmed S. N.: Physics & Engineering of Radiation Detection, Elsevier, Amsterdam, 2015.

**Course language:**
slovak and english

**Notes:**

**Course assessment**
Total number of assessed students: 26

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 65.38 | 26.92 | 3.85 | 3.85 | 0.0 | 0.0 |

**Provides:** doc. RNDr. Adela Kravčáková, PhD., Mgr. Lucia Anna Tarasovičová, Dr. rer. nat.

**Date of last modification:** 23.08.2022

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ ESP1/13 | **Course name:** Extrasolar Planets |
| **Course type, scope and the method:**<br>**Course type:** Lecture<br>**Recommended course-load (hours):**<br>**Per week:** 2 **Per study period:** 28<br>**Course method:** present | |
| **Number of ECTS credits:** 3 | |
| **Recommended semester/trimester of the course:** 3. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>To successfully complete the course, the student must demonstrate a sufficient understanding of the methods of searching for exoplanets, their basic properties and their origin and evolution. In addition to direct participation in teaching, the student's independent work is also required within the self-study of professional topics assigned by the teacher. In order to obtain an evaluation and thus also credits, the student must meet the requirements of a continuous written test (with a weight of 40% of the total evaluation) and pass a written final exam (with a weight of 60% of the total evaluation). The credit evaluation of the course considers the following student workload: direct teaching (1 credit), self-study (1 credits) and exam (1 credit).<br>Rating scale: A (90-100%), B (80-89%), C (70-79%), D (60-69%), E (50-59%), F (0-49%) . | |
| **Learning outcomes:**<br>After completing the lectures and on the basis of the final evaluation, the student will demonstrate adequate mastery of the content standard of the course, which is defined by a brief syllabus of the course and recommended literature. Mastering the content of the subject allows him to master the various methods of searching for exoplanets, to orientate in their properties and to understand the laws of their origin and development. | |
| **Brief outline of the course:**<br>The time schedule of the course content is updated in the electronic bulletin board of the course.<br>1. History of solar system research and search for extrasolar planets<br>2. Overview of methods for searching for exoplanets and their limits<br>3. Radial velocity method - basic principles<br>4. Radial velocity method - surveys and instruments and their results<br>5. Transit method - basic principles<br>6. Transit method - surveys and results - satellite observations CoRoT, Kepler, TESS<br>7. Other methods - direct imaging, astrometry, microlensing, TTV<br>8. Basic properties of exoplanets and their determination using various observational methods<br>9. Origin and evolution of exoplanets - prostellar disks and planet formation<br>10. The origin of giant planets, their dynamics in systems<br>11. Earth-like planets - habitable zone<br>12. Statistical properties of exoplanets | |

**Recommended literature:**

1. Barnes, R.:2010, Formation and Evolution of Exoplanets, Wiley-VCH
2. Cassen et al:2006, Extrasolar planets, Springer
3. Haswell C. A.: 2010, Transiting exoplanets, Cambridge University Press
4. Lena et al.: 2011, Observational Astrophysics, Springer-Verlag
5. Mason, J.: 2008, Exoplanets: Detection, Formation, Properties, Habitability, Springer
6. Perryman, M.: 2011, The Exoplanet Handbook, Cambridge University Press

**Course language:**
Slovak, English

**Notes:**

**Course assessment**
Total number of assessed students: 17

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 76.47 | 23.53 | 0.0 | 0.0 | 0.0 | 0.0 |

**Provides:** doc. Mgr. Štefan Parimucha, PhD.

**Date of last modification:** 22.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| | |
|---|---|
| **Course ID:** ÚFV/ GEA1/13 | **Course name:** Galactic and Extragalactic Astronomy |

**Course type, scope and the method:**
**Course type:** Lecture
**Recommended course-load (hours):**
**Per week:** 3 **Per study period:** 42
**Course method:** present

**Number of ECTS credits:** 5

**Recommended semester/trimester of the course:** 2.

**Course level:** II.

**Prerequisities:** ÚFV/TAF1/13

**Conditions for course completion:**
To successfully complete the course, the student must demonstrate a sufficient understanding of the structure of our Galaxy, its individual parts and their relationship, as well as the origin and evolution of different types of galaxies. In addition to direct participation in teaching, the student's independent work is also required within the self-study of professional topics assigned by the teacher. In order to obtain an evaluation and thus also credits, the student must meet the requirements of a continuous written test (with a weight of 40% of the total evaluation) and pass a written final exam (with a weight of 60% of the total evaluation). The credit evaluation of the course considers the following student workload: direct teaching (1 credit), self-study (2 credits), individual consultations (1 credit) and exam (1 credit). Rating scale: A (90-100%), B (80-89%), C (70-79%), D (60-69%), E (50-59%), F (0-49%) .

**Learning outcomes:**
After completing the lectures and on the basis of the final evaluation, the student will demonstrate adequate mastery of the content standard of the course, which is defined by a brief syllabus of the course and recommended literature. Mastering the content of the subject allows him to master the various methods of distance determination in the Universe, will be able to identify different types of galaxies, and gain sufficient knowledge about the structure of our Galaxy, the motion of stars, and its position in space.

**Brief outline of the course:**
The time schedule of the course content is updated in the electronic bulletin board of the course.
1. The Milky Way as a galaxy
2. Instruments of Galatic astronomy - GAIA satellite
3. Determination of he distances in space.
4. Stars motion in the Galaxy and around the Sun.
5. The motion of the Sun in space - Oort constants
6. Stellar statistics.
7. The structure of the Galaxy - the core
8. Subsystems, population and spiral structure of the Galaxy
9. Galaxies in space, their classification.
10. Local group of galaxies,

11. Clusters and superclusters of galaxies.
12. Evolution of galaxies and large-scale structure of the universe.

**Recommended literature:**


1. Bertin a Lin: 1996, Spiral Structure in Galaxies, The MIT Press.
2. Ciotti, L., 2021, Introduction to Stellar Dynamics, Cambridge university Press
3. Combes et al.: 2003, Galaxies and Cosmology, Springer, Berlin
4. Harwitt: 1998, Astrophysical Concepts, Springer, Berlin
5. Mihalas: 1968, Galactic Astronomy, Freeman Publishing
6. Schneider, P. 2016, Extragalactic Astronomy and Cosmology, Springer


**Course language:**
Slovak, English

**Notes:**

**Course assessment**
Total number of assessed students: 16

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 75.0 | 12.5 | 6.25 | 6.25 | 0.0 | 0.0 |

**Provides:** doc. Mgr. Štefan Parimucha, PhD.

**Date of last modification:** 22.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| | |
|---|---|
| **Course ID:** ÚFV/ TRV1/00 | **Course name:** General Theory of Relativity |

**Course type, scope and the method:**
**Course type:** Lecture
**Recommended course-load (hours):**
**Per week:** 2 **Per study period:** 28
**Course method:** present

**Number of ECTS credits:** 3

**Recommended semester/trimester of the course:** 2.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**

**Learning outcomes:**

**Brief outline of the course:**

**Recommended literature:**

**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 99

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 84.85 | 6.06 | 8.08 | 0.0 | 1.01 | 0.0 |

**Provides:** RNDr. Tomáš Lučivjanský, PhD., univerzitný docent

**Date of last modification:** 16.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

# COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ DEJ1/99 | **Course name:** History of Physics |
| **Course type, scope and the method:**<br>**Course type:** Lecture<br>**Recommended course-load (hours):**<br>**Per week:** 2 **Per study period:** 28<br>**Course method:** present | |
| **Number of ECTS credits:** 2 | |
| **Recommended semester/trimester of the course:** 2., 4. | |
| **Course level:** I., II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>Term project and its defense (60b), exam (40b).<br>Credit evaluation of the subject: direct teaching and consultations (1credit), self-study, practical activities - project and evaluation (1credit). The minimum for completing the course is to obtain at least 51% of the total evaluation. | |
| **Learning outcomes:**<br>Basic facts in the history of physics. | |
| **Brief outline of the course:**<br>1.-2. Evolution of knowledge before Galileo.<br>3.-4. Evolution of physics within the mechanical picture of the world.<br>5.-6. Evolution and limits of classical physics, phase of breakthrough in physics.<br>7.-8. Origin and evolution of the theory of relativity. Quantum physics and prospects of further evolution of physics and their application.<br>9.-10. Atomic and nuclear physics.<br>11.-12. Subnuclear physics. Contemporary state of physical research and its application in technology, natural sciences and philosophy. Position of physics in our society. | |
| **Recommended literature:**<br>1. R.Zajac, J.Chrapan: Dejiny fyziky, skriptá, MFF UK, Bratislava, 1982.<br>2. V.Malíšek: Co víte o dějinách fyziky, Horizont, Praha, 1986.<br>3. I.Kraus, Fyzika v kulturních dějinách Evropy, Starověk a středověk, Nakladatelství ČVUT, Praha, 2006.<br>4. A.I.Abramov: Istoria jadernoj fiziky, KomKniga, Moskva, 2006.<br>5. L.I.Ponomarev: Pod znakom kvanta, Fizmatlit, Moskva, 2006.<br>6. I.Kraus, Fyzika v kulturních dějinách Evropy, Od Leonarda ke Goethovi, Nakladatelství ČVUT, Praha, 2007.<br>7. I.Kraus, Fyzika od Thaléta k Newtonovi, Academia, Praha, 2007.<br>8. I.Štoll, Dějiny fyziky, Prometheus, Praha, 2009.<br>9. www-pages.<br>10.Brandt S., The harvest of a century, Discoveries of modern physics in 100 episodes, Oxford, 2009. | |

**Course language:**
slovak and english

**Notes:**
The course is realized in the form of attendance, if necessary by distance learning in the environment of MS Teams or bbb.science.upjs.sk.

**Course assessment**
Total number of assessed students: 40

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 85.0 | 7.5 | 7.5 | 0.0 | 0.0 | 0.0 |

**Provides:** doc. RNDr. Janka Vrláková, PhD.

**Date of last modification:** 19.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ MPH1/13 | **Course name:** Interpalnetary Matter |

**Course type, scope and the method:**
**Course type:** Lecture
**Recommended course-load (hours):**
**Per week:** 4 **Per study period:** 56
**Course method:** present

**Number of ECTS credits:** 6

**Recommended semester/trimester of the course:** 3.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
To successfully complete the course, the student must demonstrate sufficient understanding of the process of origin, mutual interaction and development of various components of interplanetary matter. In addition to direct participation in teaching, the student's independent work is also required within the self-study of professional topics assigned by the teacher. In order to obtain an assessment and thus also credits, the student must meet the requirements of a continuous written test (with a weight of 50% of the total assessment)
and pass the oral final exam (weighing 50% of the total assessment). Credit evaluation of the course takes into account the following student workload: direct teaching (2 credits), self-study (2 credits), individual consultations (1 credit), and exam (1 credit) ,
Rating scale: A (90-100%), B (80-89%), C (70-79%), D (60-69%), E (50-59%), F (0-49%) .

**Learning outcomes:**
After completing the lectures and on the basis of the final evaluation, the student will prove adequate mastery of the content standard of the subject, which is defined by a brief syllabus subject and recommended literature. They will understand nature of individual components of interplanetary matter, their mutual interaction and development and physical and dynamic properties.

**Brief outline of the course:**
1. Discoveries and naming of asteroids
2. Astrometry and photometry of asteroids
3. Physical properties of asteroids - masses, rotation, dimensions
4. Composition of asteroids
5. Observational methods of meteoric astronomy
6. Time variations of observed frequencies of sporadic meteors
7. Radiants of meteor swarms
8. Meteorites
9. Origin and evolution of comets
10. Characteristics of the cometary spectrum, cometary emissions and their mother molecules 11. Chemical composition, structure, and physical properties of the cometary nucleus
12. Cometary tails and their dynamics

**Recommended literature:**
J.S. Lewis: Physics and Chemistry of the Solar System, London, Academic Press, 1997 (kapitoly VI, VII, VIII).
Michel, P., Demeo, F.E., Bottke, W.F.: Asteroids IV, Tucson, University of Arizona Press, 2015.
Brandt, J.C., Chapman, D.: Introduction to comets, Cambridge, Cambridge University Press, 2004.
Murad, E., Williams I.P.: Meteors in the Earth`s Atmosphere, Cambridge, Cambridge University Press, 2002.

**Course language:**
Slovak, English

**Notes:**

**Course assessment**
Total number of assessed students: 18

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 72.22 | 11.11 | 16.67 | 0.0 | 0.0 | 0.0 |

**Provides:** Mgr. Zuzana Kaňuchová, Mgr. Marek Husárik, PhD.

**Date of last modification:** 22.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| | |
|---|---|
| **Course ID:** ÚFV/UEM/17 | **Course name:** Introduction to Exactly Solvable Models in Statistical Mechanics |

**Course type, scope and the method:**
**Course type:** Lecture / Practice
**Recommended course-load (hours):**
**Per week:** 2 / 1 **Per study period:** 28 / 14
**Course method:** present

**Number of ECTS credits:** 5

**Recommended semester/trimester of the course:** 4.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
To successfully complete the course, the student must demonstrate sufficient understanding of the basics terms, concepts and applications of statistical physics. Knowledge of basic concepts of statistical physics is required at the level of their mathematical definition as well as their physical content and concrete applications. During the semester, the student must continuously master the content of the curriculum in order to gain the acquired knowledge that he actively and creatively uses in solving specific tasks during the exercises and written test taken into account in the overall evaluation of the subject. The condition for obtaining credits is passing 1 continuous written test in exercises and an oral exam, which consists of one more complex computational task and theoretical questions. The credit evaluation of the course takes into account the following student workload: direct teaching (2 credits), self-study (1 credit), individual consultations (1 credit) and assessment (1 credit). Minimum threshold for passing the subject is to obtain at least 50% of the total score, while the following rating scale is used: A (90-100%), B (80-89%), C (70-79%), D (60-69%), E (50-59%), F (0-49%).

**Learning outcomes:**
After completing lectures and exercises, the student will have sufficient physical skills, knowledge and mathematical apparatus enabling the exact solution of a wide range traditional and current scientific problems in statistical physics. The student also gets an overview of applications of statistical physics in various fields of physics such as atomic and molecular physics, magnetism, condensed matter physics.

**Brief outline of the course:**
1. Exact solution of one-dimensional Ising models in zero and non-zero external magnetic field: combinatorial approach and transition-matrix method.
2. Spontaneous dimerization as a consequence of magneto-elastic interaction of one-dimensional Ising models, spin-Peierls instability.
3. Exact solution of one-dimensional Ising models with interactions between more distant spins, Dobson's method.
4. Rigorous solution of the Ising model on Bethe lattices using the method of exact recursive relations.

5. Exact solution of one-dimensional classical Heisenberg model in zero external magnetic field. Violation of the validity of the 3rd law of thermodynamics.
6. Exact solution of geometrically frustrated quantum Heisenberg models using lattice-gas models, theory of localized magnons.
7. Exact solution for a one-dimensional six-vertex model as an ice model. Non-zero residual entropy of ice.
8. Exact solution for a one-dimensional six-vertex model as a model of KDP ferroelectrics. The first-order phase transitions and latent heat.
9: Exact solution for a one-dimensional sixteen-vertex model. Absence of phase transitions in Takagi's model.
10. Exact solution for the one-dimensional eight-vertex model and Suzuki's hypothesis of weak universality. Continuously changing critical indices with a weak-universal critical behavior.
11. Eight-vertex model as the Ising model with two-spin and four-spin interactions.

**Recommended literature:**

1. R. J. Baxter, Exactly Solved Models in Statistical Mechanics (Academic, New York, 1982).
2. F. Y. Wu, Exactly Solvable Models: A Journey in Statistical Mechanics
(World Scientific, Singapore, 2008).
3. J. Strečka, Exactly Solvable Models in Statistical Physics, supportive textbook,
(ESF 2005/NP1-051 11230100466, Košice, 2008).

**Course language:**
1. Slovak; 2. English

**Notes:**

**Course assessment**
Total number of assessed students: 12

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 41.67 | 50.0 | 0.0 | 0.0 | 0.0 | 8.33 |

**Provides:** doc. RNDr. Jozef Strečka, PhD.

**Date of last modification:** 19.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| | |
|---|---|
| **Course ID:** ÚFV/ZMSE/07 | **Course name:** Introduction to Simulations and Modeling of Experiments |

**Course type, scope and the method:**
**Course type:** Lecture / Practice
**Recommended course-load (hours):**
**Per week:** 2 / 1 **Per study period:** 28 / 14
**Course method:** present

**Number of ECTS credits:** 4

**Recommended semester/trimester of the course:** 2.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
exam - analysis of given task with algorithm

**Learning outcomes:**
Introduce the basics of Monte-Carlo methods and the applications in the simulation of high energy physics processes.

**Brief outline of the course:**
Mathematical foundations of Monte-Carlo methods. Buffon`s needle and basic MC methods. Comparisons of Monte-Carlo integrations with numerical quadrature. Random number generators (random numbers, random numbers generation, tests of random number generators). Monte-Carlo simulations of high energy physics processes.

**Recommended literature:**
James F.: Monte-Carlo theory and practice, Rep. Prog. Phys. 43, 1980, s. 1145-1189; Cern preprint DD/80/6, February 1980.
http://placzek.home.cern.ch/placzek/lectures,
http://en.wikipedia.org/wiki/Monte_Carlo_method

**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 12

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 66.67 | 8.33 | 8.33 | 0.0 | 16.67 | 0.0 |

**Provides:** RNDr. Martin Vaľa, PhD.

**Date of last modification:** 18.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

**Course ID:** ÚFV/PSD/14 | **Course name:** Introduction to distributed data processing

**Course type, scope and the method:**
**Course type:** Lecture
**Recommended course-load (hours):**
**Per week:** 2 **Per study period:** 28
**Course method:** present

**Number of ECTS credits:** 4

**Recommended semester/trimester of the course:** 2.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
semestral project, presentation, evaluation

**Learning outcomes:**
Introductory lectures to basics of parallel data processing on analysis farms.

**Brief outline of the course:**
Basics of scripting languages under various operating systems.
Scripting in Unix/Linux.
Simple parametrization of jobs on analyses farms.
Basic principles of batch farm organizations.
Basic principles of interactive farm organizations.
Implementation and realization of job paralelization.

**Recommended literature:**
https://www.gnu.org/software/bash/
http://www.adaptivecomputing.com/products/open-source/torque/
http://root.cern.ch/drupal/
http://xrootd.org/
https://eos.readthedocs.org/en/latest/

**Course language:**
English

**Notes:**

**Course assessment**
Total number of assessed students: 6

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Provides:** RNDr. Martin Vaľa, PhD.

**Date of last modification:** 18.11.2021

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| **Approved:** prof. RNDr. Michal Jaščur, CSc. |

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ ZDC/14 | **Course name:** Introduction to particle detection by calorimetric methods |
|---|---|

**Course type, scope and the method:**
**Course type:** Lecture
**Recommended course-load (hours):**
**Per week:** 2 **Per study period:** 28
**Course method:** present

**Number of ECTS credits:** 4

**Recommended semester/trimester of the course:** 2.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
Knowledge of the issue at a sufficient level, exam.
The credit evaluation of the course takes into account the following student workload: direct teaching (2k), self-study (1k) and assessment (1k). The minimum limit for completing the course is to obtain at least 51% of the total score.

**Learning outcomes:**
Special lectures as intoduction to partcle calorimetry.

**Brief outline of the course:**
PASSAGE OF PARTICLES THROUGH MATTER:
Electronic energy loss by heavy particles, momenta and cross sections, maximum energy transfer in a single collision.
Stopping power at intermediate energies. Mean excitation energy, density effect, energy loss at low energies.
Energetic knock-on electrons (δ rays). Restricted energy loss rates for relativistic ionizing particles.
Fluctuations in energy loss, energy loss in mixtures and compounds, ionization yields.
Multiple scattering through small angles.
Photon and electron interactions in matter.
Collision energy losses by e±, Radiation length, Bremsstrahlung energy loss by e±.
Critical energy, energy loss by photons, bremsstrahlung and pair production at very high energies.
Photonuclear and electronuclear interactions at still higher energies , muon energy loss at high energy.
Cherenkov and transition radiation.
Optical Cherenkov radiation.
Coherent Cherenkov radiation.
CALORIMETERS:
Principles of Calorimetry.
Electromagnetic and Hadronic Showers.
Shower Profiles and Containment .
Electromagnetic calorimeters.
Hadronic calorimeters.

Signal Detection.
Energy and position resolution in calorimetry.

**Recommended literature:**
J. Beringer et al. (Particle Data Group), Phys. Rev. D86, 010001 (2012)
and 2013 partial update for the 2014 edition.
http://indico.cern.ch/getFile.py/access?contribId=24&resId=0&materialId=slides&confId=44587
http://www.slidefinder.net/c/
calorimetry_energy_measurements_prof_robin/252b_lecture8/27257380
http://www-ppd.fnal.gov/EPPOffice-w/Academic_Lectures/DGreen.pd
phttp://www-group.slac.stanford.edu/sluo/lectures/detector_lecture_files/detectorlectures_13.pd
http://indico.cern.ch/getFile.py/access?contribId=24&resId=0&materialId=slides&confId=44587
http://www.kip.uni-heidelberg.de/atlas/seminars/WS2009_JC/compensation1
R.Wigmans, Calorimetry, Energy measurement in Particle Physics,Oxford Univ.Press, 2017

**Course language:**
English

**Notes:**

**Course assessment**
Total number of assessed students: 4

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 75.0 | 0.0 | 0.0 | 0.0 | 25.0 | 0.0 |

**Provides:** RNDr. Pavol Stríženec, CSc.

**Date of last modification:** 18.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

# COURSE INFORMATION LETTER

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|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ UKF/22 | **Course name:** Introductory Medical Physics |
| **Course type, scope and the method:**<br>**Course type:** Lecture<br>**Recommended course-load (hours):**<br>**Per week:** 2 **Per study period:** 28<br>**Course method:** present | |
| **Number of ECTS credits:** 4 | |
| **Recommended semester/trimester of the course:** 1. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>1. Attendance at seminars (also applies to the online form of Teaching). A student's excused absence for a maximum of two seminars will be excused without the need for an alternative term. In the case of long-term justified absence (e.g. due to sick leave), the teacher will assign the student a substitute form of mastering the missed content.<br>2. Successful completion of the exam. | |
| **Learning outcomes:**<br>The course provides students with the theoretical basis for the work of a medical physicist. The student should know the physical principles of application of ionizing radiation in medicine - in radiodiagnostics, nuclear medicine, radiotherapy and the principles of radiation protection. | |
| **Brief outline of the course:**<br>1. Competencies of medical physicists in radiation oncology, nuclear medicine and radiodiagnostics.<br>2. Ionizing radiation sources used in medicine - radionuclides and generators.<br>3. Interactions of photon, electron, proton and heavy ions with matter. Interaction of ionizing radiation with organisms.<br>4. Ionizing radiation detection and measurement of the absorbed dose in medicine. Quantities and units used in medical dosimetry.<br>5. Radiofrequency linear accelerators. Proton accelerators and heavy ion accelerators for radiotherapy.<br>6. Overview of radiation treatment techniques (3D CRT, IMRT, SRS, SABR, TBI, RMM, gating). Imaging methods in radiotherapy.<br>7. Linear accelerator quality control systems.<br>8. Physical principles of brachytherapy application.<br>9. Treatment planning systems for radiotherapy. Information and verification systems in radiation oncology.<br>10. Imaging methods in radiodiagnostics and nuclear medicine.<br>11. Radiobiological models for predicting the effect of ionizing radiation.<br>12. Principles of radiation protection and current legislation. | |
| **Recommended literature:** | |

1. Podorsak E.B..et al.: Radiation Oncology Physics , IAEA, 2005
2. Khan F. M.: The Physics of Radiation Therapy, Lippincott Williams & Wilkins, 2009
3. Šlampa P., Petera J.: Radiační onkológie, Galen Karolinum Praha 2007
4. Hirohiko T., et al.: Carbon-Ion Radiotherapy, Springer, 2014
5. Bushberg J. T., et al.: The Essential Physics of Medical Imaging, Wolters Kluwer, 2020
6. Lancaster J.L., Hasegawa B.1: Fundamental Mathematics And Physics Of Medical Imaging, CRC Press, 2016
7. Platná legislatíva SR (Zák.č. 87/2018 Z.z., vyhláška MZ SR č. 99/2018 Z.z., vyhláška MZ SR č. 101/2018 Z.z.)

**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 3

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 0.0 | 33.33 | 66.67 | 0.0 | 0.0 | 0.0 |

**Provides:** RNDr. Martin Jasenčak, PhD.

**Date of last modification:** 18.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

# COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ FNT1/03 | **Course name:** Low Temperature Physics |
|---|---|

**Course type, scope and the method:**
**Course type:** Lecture
**Recommended course-load (hours):**
**Per week:** 4 **Per study period:** 56
**Course method:** present

**Number of ECTS credits:** 6

**Recommended semester/trimester of the course:** 1., 3.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
To successfully complete the course, the student must demonstrate sufficient understanding of the basics concepts, applications and applications in low temperature physics with emphasis on experimental examples. Knowledge of basic concepts about superfluidity, superconductivity, electrical and thermal conductivity, heat capacity of matter at low temperatures is required.
The credit evaluation of the course takes into account the following student workload: direct teaching (2 credits), self-study (2 credits) and assessment (2 credits). During the semester, the student must continuously master the content of the curriculum and pass two written tests. The final evaluation consists of the averaged results of two tests, each with a minimum success rate of 50%, evaluation scale: A (90-100%), B (80-89%), C (70-79%), D (60-69%), E (50-59%), F (0-49%).

**Learning outcomes:**
The cours gives knowledge of methods and techniques used in low-temperature physics and information on basic physical properties of condensed matter at low temperatures.

**Brief outline of the course:**
1. The concept of temperature. Thermodynamic absolute temperature. International Practical Scale ITS - 90. Overview of the properties of cryogenic liquids. Phase diagram of 4He. Thermal properties of 4He. Transport properties of 4He.
2. Superfluidity of 4He - Two-component theory, Bose condensation, Landau's theory of He-II, criterion of superfluidity. Thermodynamic functions of He-II. Wave propagation in helium. Quantum vortices. Motion of charged particles in He.
3. Properties of 3He - phase diagram of 3He. Manifestation of Fermi-Dirac statistics on the properties of liquid 3He. Landau's theory of Fermi fluid. Zero sound in Fermi fluid. Superfluid phases of 3He and their properties. Topology of superfluid phases 3He. Description of 3He superfluidity using an order parameter.
4. Properties of liquid solutions of 3He-4He. Elementary excitations in 3He-4He solutions. Properties of solid 4He. Properties of solid 3He. Phase transition in solid 3He. Solid solutions of 3He-4He. Quantum crystals. Quantum diffusion. Kapitza resistance.
5. Basic properties of superconductors, penetration depth, coherence length. Classification of superconductors.

6. Phenomenological theory of superconductivity and basics of BCS theory. High temperature superconductivity.
7. Tunneling phenomena in superconductors. Quantum interference and SQUID.
8. Electrical conductivity of metals at low temperatures. Classical and quantum size effects. Mesoscopic objects (Quantum Hall effect, ballistic transport, properties of 2D electron gas).
9. Heat capacity at low temperatures. Lattice and electron specific heat. Schottky's contribution. Heat capacity of superconductors and semiconductors. Thermal conductivity of metals. Electron and phonon component and their separation. Thermal conductivity of semiconductors, insulators and superconductors.
10. Methods of measuring low and very low temperatures. Gas thermometer. Condensation thermometers. Resistance thermometers. Thermocouples. Paramagnetic thermometers. Nuclear orientation thermometer. NMR thermometry. Noise thermometer.
11. 4He cryostats, 3He refrigerator. 3He-4He refrigerator. Pomeranchuk refrigerator. Adiabatic demagnetization of paramagnetic salts. Cryocoolers - pulsed-tube refrigerator.
12. Nuclear demagnetization. Hyperfine nuclear cooling. Nuclear magnetism in metals. Nanokelvin and negative temperatures.

**Recommended literature:**

Skrbek L. a kol.: Fyzika nízkych teplôt, Matfyzpress, MFF KU Praha, 2011.
C. Enss, S. Hucklinger, Low-Temperature Physics, Springer, 2005.
Jánoš Š.: Fyzika nízkych teplôt, ALFA Bratislava, 1980.
A. Kent: Experimental low-temperature physics. Mac Millan Press Ltd., 1993.
D.S. Betts: An introduction to Milikelvin Technology. Cambridge University Press, 1989.
P.V.E. McClintok et al.: Low-Temperature Physics. Blackie, Galsgow and London 1992.
F. Pöbell: Matter an Methods at Low Temperatures. Springer - Verlag, Berlin, 1992.

**Course language:**

slovak

**Notes:**

Teaching is carried out in person or remotely using the MS Teams tool. The form of teaching is specified by the teacher, updated continuously.

**Course assessment**

Total number of assessed students: 79

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 84.81 | 10.13 | 5.06 | 0.0 | 0.0 | 0.0 |

**Provides:** doc. RNDr. Erik Čižmár, PhD.

**Date of last modification:** 18.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ MKL/03 | **Course name:** Magnetic Properties of Solids |
|---|---|

**Course type, scope and the method:**
**Course type:** Lecture
**Recommended course-load (hours):**
**Per week:** 4 **Per study period:** 56
**Course method:** present

**Number of ECTS credits:** 6

**Recommended semester/trimester of the course:** 2.

**Course level:** II., III.

**Prerequisities:**

**Conditions for course completion:**
To successfully complete the course (presence, if necessary distance) the student must demonstrate sufficient understanding of the concepts, phenomena and laws of magnetism of condensed matter, so that his knowledge of the physics of condensed matter is holistic. Knowledge of intrinsic magnetic properties of solids, types of energy, behavior of solids in a magnetic field and, in the case of ferromagnets and ferromagnets, also their domain structure is required. Knowledge of the basic use of magnetic materials in practice is also required.
Credit evaluation takes into account the scope of teaching (4 hours of lectures), evaluation (2 credits) and the fact that it is a profile subject that is part of the master's state exam. If the subject is included in the doctoral study of Progressive Materials, the fact that the subject is highly demanding for graduates of non-physical education is taken into account.
The minimum limit for successful completion of the course is to obtain 50 points in the oral exam from the subsequent point evaluation
Rating scale
A 100-91
B 90-81
C 80-71
D 70-61
E 60-50
Fx 49-0

**Learning outcomes:**
After completing the lectures and taking the exam, the student will have a deep knowledge of the magnetism of condensed matter and will have the ability to enter into a systematic theoretical and experimental solution of the problems of magnetism of condensed matter. He will also gain basic knowledge about the possibilities of using magnetic materials in technical practice.

**Brief outline of the course:**
1. week:
The classification of solids according to their magnetic properties. Classical diamagnetic, paramagnetic and ferromagnetic materials.
Magnetic quantities.

Magnetic moment. Orbital and spin momentum, orbital and spin magnetic moment.
2. week:
Atom with one electron and with more electrons. Hund's rules. Gyromagnetic experiments, resonance experiments.
The sources of magnetic fields (solenoid, toroid, Helmholtz coil, superconducting solenoid, electromagnet).
3. week:
The methods of measuring of the magnetic field. (Induction methods, fluxmeter method, magnetooptical effects, magnetoresistance, Hall effect, flux-gate method, SQUID method)
Diamagnetism. The classsical and Landau's diamagnetism. De Haas - van Alphen effect. Diamagnetism of superconductors.
4. week:
Paramagnetism.. The classical and quantum theory of paramagnetism. Pauli paramagnetism.
The methods of measuring the magnetic susceptibility of diamagnetics and paramagnetics. (Weiss method, torsion scales, Goy - Pascal scales).
5. week:
Ferromagnetism. Magnetization, Weiss theory of ferromagnetism. Exchange interactions. Curie temperature. Ferromagnetism of metals, alloys, rare earths and compounds.
6. week:
Thermal properties, thermal capacity, magnetocaloric effect and phase transitions.
Antiferromagnetism (structure, magnetization, susceptibility and Curie temperature).
7. week:
Ferrimagnetism (structure, spontaneous magnetization susceptibility to Curie and Neel temperature).
Study of spontaneous magnetic arrangement by neutron diffraction.
8. week:
Temperature dependence of spontaneous magnetic polarization, determination of Curie temperature (Extrapolation methods, line method of equal polarization, measurement of thermodynamic coefficients).
Energy of ferromagnets energy. (exchange, crystallographic magnetic anisotropy, magnetostriction, magnetoelastic, magnetostatic)
9. week:
Magnetic anisotropy.
Methods for measuring anisotropy constants (by measuring magnetization work, torsional anisometer).
Electrical resistance, Hall effect and magnetoresistance of ferromagnets.
10. week:
Domain structure of ferromagnets. Geometry and energy of domain walls. Primary and secondary domain structure.
Methods of domain structure monitoring (powder pattern method, magneto-optical phenomena, electron microscopy, X-ray method, ferromagnetic probe method).
11. week:
Magnetostriction, Villary effect.
Spontaneous magnetostriction. Magnetostriction of a monodomain particle, single crystals and polycrystalline substances.
Methods of measuring magnetostriction constants (strain gauge measurement, mechanical - optical, interference methods).
12. week:
Magnetization curves.

Demagnetizing effect of the sample. Magnetic circuit, yoke.
Basic ideas for the magnetization process. Elementary magnetization processes. Barkhausen phenomenon.
Methods for investigating the Barkhausen effect.
Mechanism of magnetic reversal, magnetic hysteresis, remanence and coercivity.
13. week:
Methods of recording the primary magnetization curve and the hysteresis loop (static and dynamic).
Premagnetization losses and methods of their measurement (wattmer, phase shift method, calorimetric, hysteresis loop area measurement).
Types of susceptibility of ferromagnetic substances (initial, maximum, reversible, irreversible, differential).
Measurement of susceptibility of ferromagnetic substances (Maxwell - Wien bridge, Owen bridge).

**Recommended literature:**

1. S. Chikazumi: Physics of Magnetism, J.Willey and Sons, Inc. New York, London, Sydney, 1997.
2. J. M. D. Coey: Magnetism and Magnetic Materials, Cambridge University Press, 2009
3. H. Kronmüller, S. Parkin - Handbook of Magnetism and Advanced Magnetic Materials, Wiley 2007
4. F. Fiorillo, Measurement and Characterization of Magnetic Materials, _Elsevier 2004
5. S. Tumanski, Handbook of Magnetic Measurements, CRC Press, 2011

**Course language:**
english

**Notes:**
Presence form represents a standart form for the course, if a need arises, the course is performed using MS Teams.

**Course assessment**
Total number of assessed students: 129

| A | B | C | D | E | FX | N | P |
|---|---|---|---|---|---|---|---|
| 37.21 | 13.95 | 10.85 | 3.88 | 2.33 | 3.88 | 2.33 | 25.58 |

**Provides:** prof. RNDr. Peter Kollár, DrSc.

**Date of last modification:** 22.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

# COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** KF/ FMPV/22 | **Course name:** Methodology of Science 1 |
| **Course type, scope and the method:**<br>**Course type:** Lecture / Practice<br>**Recommended course-load (hours):**<br>**Per week:** 1 / 1 **Per study period:** 14 / 14<br>**Course method:** present | |
| **Number of ECTS credits:** 2 | |
| **Recommended semester/trimester of the course:** | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>Attendance: A student may have one unexcused absence in seminar at the most. Absence in more than one seminar must be reasoned and substituted by consultations. Conditions of continuous and final control: during the semester a student is continuously checked and assessed according to his/her activity. To be awarded the credits, a student must pass a test from knowledge obtained in the lectures and seminars. Results of the test will make up the final grade. | |
| **Learning outcomes:**<br>The course is aimed at getting familiar with the basic issues of methodology and philosophy of science. Significant part will be devoted to presenting the main concepts of the philosophy of science in the 20th century and this aim will be achieved by reading the source and interpretive texts. | |
| **Brief outline of the course:**<br>• Falsificationism and critical realism by K. R. Popper.<br>• Development and critique of the Popper's concept.<br>• Understanding the science development in the work by T. S. Kuhn.<br>• Methodology of scientific research programmes of I. Lakatos.<br>• Methodological anarchism of P. Feyerabend.<br>• W.V.O. Quine – the issue of relation between theory and empiricism. | |
| **Recommended literature:**<br>BILASOVÁ, V. – ANDREANSKÝ, E.: Epistemológia a metodológia vedy. Prešov: FF PU 2007.<br>FAJKUS, B.: Filosofie a metodologie vědy. Praha: Academia 2005.<br>BEDNÁRIKOVÁ, M. Úvod do metodológie vied. Trnavská univerzita: Trnava 2013.<br>DÉMUTH, A. Filozofické aspekty dejín vedy. Trnavská univerzita: Trnava 2013.<br>FEYERABEND, P.: Proti metodě. Prel. J. Fiala. Praha: Aurora 2001.<br>KUHN, T. S.: Štruktúra vedeckých revolúcií. Prel. Ľ. Valentová. Bratislava 1982. | |
| **Course language:**<br>Slovak | |
| **Notes:** | |

**Course assessment**
Total number of assessed students: 6

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Provides:** prof. PhDr. Eugen Andreanský, PhD.

**Date of last modification:** 01.02.2022

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ KDO1/22 | **Course name:** Methods of Clinical Dosimetry |
|---|---|

**Course type, scope and the method:**
**Course type:** Lecture
**Recommended course-load (hours):**
**Per week:** 2 **Per study period:** 28
**Course method:** present

**Number of ECTS credits:** 4

**Recommended semester/trimester of the course:** 2.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
1. Attendance at seminars (also applies to the online form of Teaching). A student's excused absence for a maximum of two seminars will be excused without the need for an alternative term. In the case of long-term justified absence (e.g. due to sick leave), the teacher will assign the student a substitute form of mastering the missed content.
2. Successful completion of the exam.

**Learning outcomes:**
The course provides students with the theoretical basis for the work of a medical physicist. The student should know the methods of detection of ionizing radiation used in medicine, know the basic characteristics of detectors and dosimeters, be able to independently select the correct type of detector, and perform dosimetric measurements. The student should know the principles of radiation protection.

**Brief outline of the course:**
1. Physical characteristics and types of detectors and dosimeters in radiotherapy.
2. System of Standard Dosimetry Laboratories and calibration of dosimeters. Standards for measuring absorbed dose to water. Correction factors.
3. Standard of measurement of absorbed dose to water for photon beams. Measurements under reference conditions in the user beam. Uncertainty estimation.
4. Standard of measurement of absorbed dose to water for electron beams. Measurements under reference conditions in the user beam. Uncertainty estimation.
5. Acceptance tests and commissioning of the linear accelerator.
6. Daily and monthly stability checks and long-term stability tests of linear accelerators in radiotherapy.
7. Phantoms in dosimetry - anthropomorphic, geometric, tissue-equivalent, and dynamic.
8. Dosimetry methods in brachytherapy.
9. Dosimetry audits for treatment planning systems. Dose Calculation Algorithms
10. Verification of treatment plans - dosimetry "in vitro" and "in vivo".
11. Dosimetry of low- and intermediate-energy photon beams in radiotherapy and radiodiagnostics (X-ray therapy, CT, mammography)
12. Dosimetry and radiation protection in the nuclear medicine facility.

**Recommended literature:**
1. Podorsak E.B..et al.: Radiation Oncology Physics , IAEA, 2005
2. Khan F. M.: The Physics of Radiation Therapy, Lippincott Williams & Wilkins, 2009
3. Platná legislatíva SR (Zák.č. 87/2018 Z.z., vyhláška MZ SR č. 99/2018 Z.z., vyhláška MZ SR č. 101/2018 Z.z.)
4. Andreo, P. et al.: Absorbed Dose Determination in External Beam Radiotherapy: An International Code of Practice for Dosimetry based on Standards of Absorbed Dose to Water, IAEA TRS-398, 2006

**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 3

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Provides:** RNDr. Martin Jasenčak, PhD.

**Date of last modification:** 18.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

# COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚINF/NEU/24 | **Course name:** Neural networks |
| **Course type, scope and the method:**<br>**Course type:** Lecture / Practice<br>**Recommended course-load (hours):**<br>**Per week:** 2 / 2 **Per study period:** 28 / 28<br>**Course method:** present | |
| **Number of ECTS credits:** 5 | |
| **Recommended semester/trimester of the course:** 3. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>Successful realization of a project focused on the applications of neural networks. Successful completion of two written tests at 60% which are focused on various architectures of neural networks and the connections with other areas of computer science - automata, fuzzy logic. Demonstration of knowledge focused on neural network methods and their application in the exam. | |
| **Learning outcomes:**<br>Knowledge of basic paradigms of neural networks. Knowledge about applications of neural networks in various fields. Ability to assess the applicability of neural networks in solving algorithmic problems. | |
| **Brief outline of the course:**<br>1. Motivational examples. Mathematical model of neuron and neural network. Perceptrons. Linear separable objects, adaptation process (learning), perceptron convergence, multiple perceptrons.<br>2. Computational power of single input neural networks, neuromata. Simulation of automata using neural networks.<br>3. Classical layer neural networks, hidden neurons, adaptation process (learning), feedback method backpropagation and its variants.<br>4. Recurrent neural networks, algorithm for training recurrent networks. Examples of use.<br>5. Self-organization of neural networks and Kohonen neural networks, learning algorithm, use.<br>6. Networks with local neurons, RBF networks, networks with semi - local units. RBF approximations<br>networks.<br>7. Written test I. Neuromat for regular language. neural network to deterministic finite state automaton, recurrent backpropagation algorithm and its applications, Kohonen ane RBF neural networks.<br>8. Convolutional neural networks. Basic knowledge of convolution. Convolutional neural networks for image processing.<br>9. Deep neural networks and their use.<br>10. Graph neural networks, structure, learning and applications.<br>11. Deductive systems of fuzzy logic. Fuzzy neural networks and their use. Fuzzy controller. | |

12. Universal approximation using neural networks, Kolmogorov theorem. Approximation properties layered neural networks.
13. Solving practical problems using neural networks.
14. Written test II. Convolution and convolutional neural networks, deep neural networks, graph neural networks, constructtion of fuzzy regulator, Kolmogorov theorem and idea of its proof.

**Recommended literature:**


1. Y. Bengio: Learning Deep Architectures for AI, Foundations and Trends in ML, Vol. 2, No. 1 , 2009, pp. 1-127 ##
2. I. Goodfellow, Y. Bengio and A. Courville: Deep Learning, MIT Press book, 2016, ISBN-13: 978-0262035613
https://www.deeplearningbook.org/ ##
3. M. H. Hassoun: Fundamentals of artificial neural networks. MIT Press, Cambridge, 1995. ##
4. J. Hertz, A. Krogh, R.G. Palmer: Introduction to the theory of neural computation, Addison-Wesley, 1991. ##
5. V. Kvasnička a kol.: Úvod do teórie neurónových sietí, IRIS, Bratislava, 1997. ##
6. P. Sinčák, G. Andrejková: Neurónové siete. I. diel: Dopredné siete, II. diel: Rekurentné a modulárne siete, Košice, 1997. ##
7. J. Šíma, R. Neruda: Teoretické otázky neuronových sití, Matfyzpress, MFF UK, Praha, 1996. ##
8. F. Scarselli, M. Gori, Ah Ch. Tsoi, M. Hagenbuchner, and G. Monfardini: The Graph Neural Network Model. IEEE TRANSACTIONS ON NEURAL NETWORKS, VOL. 20, NO. 1, JANUARY 2009 ##


**Course language:**
Slovak or English

**Notes:**
For ERASMUS students:
It is necessary to know a model of artificial neurons, its computation and its setting, layered neural networks and backpropagation training algorithm.

**Course assessment**
Total number of assessed students: 107

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 32.71 | 19.63 | 20.56 | 12.15 | 13.08 | 1.87 |

**Provides:** doc. RNDr. Ľubomír Antoni, PhD., doc. RNDr. Gabriela Andrejková, CSc.

**Date of last modification:** 19.03.2024

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ NSF/10 | **Course name:** Non-Equilibrium Statistical Physics |
| **Course type, scope and the method:**<br>**Course type:** Lecture / Practice<br>**Recommended course-load (hours):**<br>**Per week:** 2 / 1 **Per study period:** 28 / 14<br>**Course method:** present | |
| **Number of ECTS credits:** 5 | |
| **Recommended semester/trimester of the course:** 3. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:** | |
| **Learning outcomes:**<br>To give basic knowledges about modern trends and theoretical methods in description of non-equlibrium phenomena in physics. | |
| **Brief outline of the course:**<br>Problems of kinetic theory - formulations of basic tasks. Distribution function. Liouville theorem. Liouville operator. Kinetic Boltzman equation. H-theorem. Maxwell distribution. Transport phenomena. Conservation laws. Derivation of the macroscopic eduqtions in leading and next-to-leading approximation. Hydrodynamic approximation. Set of equations for density, mean velocity and temperature. Derivation of continuity equation, Navier-Stokes equation, heat conductivity equation. Derivation of vicosity and diffusivity coefficients from microscopic description. Stokes laws. Reynolds number. Dynamical derivation of kinetic equation. Liouville (master) equation for N-particle distribution function. Bogolyubov set of equations for distribution functions.<br>Principle of weakening of statistical correlations. Equation for one-particle distribution function. Brown motion. Langevin equation. Fokker-Planck equation and specific tasks. | |
| **Recommended literature:**<br>1. Landau L.D., Lifshitz E.M.: Teoreticheskaja fizika X: Lifshitz E.M., Pitaevskij L.P.: Fizicheskaja<br>kinetika, Moskva, Fizmatlit 2002<br>2. K. Huang: Statistical mechanics, John Wiley and Sons, Inc., New York-London, 1963.<br>D.N.Zubarev: Neravnovesnaja statisticheskaja termodinamika, Moskva, Nauka, 1971.<br>A.N.Vasiliev Kvantovopolevaja renormgruppa v teorii kriticeskogo povedenija i stochasticeskoj dinamike, Sankt-Peterburg, Izd. Peters. Inst. Of. Nuclear physics (1998) 773 (The Field Theoretic Renormalization Group in Critical Behavior Theory and Stochastic Dynamics, Chapman & Hall CRS Press Company New York, 2004) | |
| **Course language:**<br>slovak and english | |
| **Notes:** | |

**Course assessment**
Total number of assessed students: 28

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 64.29 | 7.14 | 17.86 | 10.71 | 0.0 | 0.0 |

**Provides:** prof. RNDr. Michal Hnatič, DrSc., RNDr. Tomáš Lučivjanský, PhD., univerzitný docent

**Date of last modification:** 18.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ NOT1a/03 | **Course name:** Nontraditional Optimization Techniques I |
|---|---|

**Course type, scope and the method:**
**Course type:** Lecture / Practice
**Recommended course-load (hours):**
**Per week:** 2 / 2 **Per study period:** 28 / 28
**Course method:** present

**Number of ECTS credits:** 5

**Recommended semester/trimester of the course:** 1.

**Course level:** I., II.

**Prerequisities:**

**Conditions for course completion:**
Oral examination (50%), results and quality of the
personal presentation of the projects (50%).
Monitoring progress in solving applied projects. From given set of problems, the student must pick 1 to 3 projects and develop functioning implementation of the solution in form of computer program. In case of more challenging problems, collaborative work of students is acceptable, but each student must be able to present her/his individual contribution.

**Learning outcomes:**
To familiarize students with biologically and physically inspired optimization, simulation and prediction techniques. To expand students' creativity and programming skills by applying heuristic techniques in solving applied problems.
Upon successful completion of course, student shall possess knowledge about most typical non-traditional optimization techniques, as well as practical experience of solving concrete problems.

**Brief outline of the course:**
1. Fundamentals terms and definitions of optimization theory. Physical laws as optimization tasks. Variational principle.
2. Model optimization problems. Basic types of objective functions. Classification of optimization methods. Computational scaling of optimization methods. Big O notation. Parallelization, Metcalf's law, Amdahl's bottleneck.
3. Exhaustive search, Gradient-based optimization techniques.
4. Evolutionary algorithms. Canonical Genetic algorithm. Genetic algorithms as Markov processes. Statistical Mechanics description of Genetic Algorithms.
5. Monte Carlo simulation and simulated annealing. Metropolis algorithm and statistics of sampling in solution space.
6. Swarm optimization. Ant algorithms.
7. Cellular Automata and their applications in simulations of complex systems.
8. data structures and representation of solution space and optimization problems. Compression of information and symmetry. Manifolds.
9. Generators. grammars and languages. Genetic programming. AST and operations on AST representation of programs.

10. Fractals. Lindenmayer systems. Life-like and agent-based models.
11. Evolutionary games. Evolution of cooperation.
12. Fundamentals of Neural Networks. Stochastic gradient optimization.

**Recommended literature:**

Hartmann, A. K., Rieger, H., Optimization Algorithms in Physics, Wiley, 2002
Reeves, C. R., Rowe, J. E., Genetic Algorithms: Principles and perspectives, Kluwer, 2003
Mitchell, M., Complexity. A Guided Tour, Oxford University Press, 2009
Solé, R. V., Phase Transitions, Princeton University Press, 2011
Ilachinski, A., Cellular Automata. A Discrete universe, World Scientific, 2002
Haykin, S., Neural Networks. A Comprehensive Foundation, Prentice-Hall, 1999
Actual literature and data related to problem sets

**Course language:**

English language is essential for students as "lingua franca" for the latest advancements and applications of optimization techniques.

**Notes:**

The subject is taught using direct contact form. Should the epidemiological situation (or other relevant circumstances) mandate, the distant form will be used, preferentially using MS Teams learning environment.

**Course assessment**

Total number of assessed students: 108

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 71.3 | 17.59 | 6.48 | 1.85 | 2.78 | 0.0 |

**Provides:** doc. RNDr. Jozef Uličný, CSc.

**Date of last modification:** 22.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

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|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ NOT1b/03 | **Course name:** Nontraditional Optimization Techniques II |
| **Course type, scope and the method:**<br>**Course type:** Lecture / Practice<br>**Recommended course-load (hours):**<br>**Per week:** 2 / 2 **Per study period:** 28 / 28<br>**Course method:** present | |
| **Number of ECTS credits:** 5 | |
| **Recommended semester/trimester of the course:** 2. | |
| **Course level:** I., II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>Presentation of the project in written form. Oral exam and discussion of the presented project. Should corona-virus quarantine persist, written report and answer to posed questions suffice. | |
| **Learning outcomes:**<br>By using examples from the biology to learn applications of optimization techniques on study and interpretation of complex systems. Introduction to new paradigms in the area of systems biology, including parasite/host coevolution. | |
| **Brief outline of the course:**<br>Complex systems, emergent behavior. Evolutionary theory and memetics. Application of optimization techniques on complex systems. Application of methods /genetic algorithms, simulated annealing, taboo search/ on selected problems of biomolecular simulations. Molecular dynamics, protein folding. Population dynamics, metabolic networks and complexity in bioinformatics. | |
| **Recommended literature:**<br>The actual scientific papers. | |
| **Course language:** | |
| **Notes:** | |
| **Course assessment**<br>Total number of assessed students: 64 | |

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 87.5 | 6.25 | 4.69 | 1.56 | 0.0 | 0.0 |

| | |
|---|---|
| **Provides:** doc. RNDr. Jozef Uličný, CSc. | |
| **Date of last modification:** 08.09.2021 | |
| **Approved:** prof. RNDr. Michal Jaščur, CSc. | |

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/JADF/14 | **Course name:** Nuclear Physics |
| **Course type, scope and the method:**<br>**Course type:**<br>**Recommended course-load (hours):**<br>**Per week: Per study period:**<br>**Course method:** present | |
| **Number of ECTS credits:** 4 | |
| **Recommended semester/trimester of the course:** | |
| **Course level:** II. | |
| **Prerequisities:** ÚFV/FEC1/04 and ÚFV/EJF1a/04 and ÚFV/FJA1/14 and ÚFV/KTP1a/03 and ÚFV/KTP1b/03 | |
| **Conditions for course completion:** | |
| **Learning outcomes:** | |
| **Brief outline of the course:** | |
| **Recommended literature:** | |
| **Course language:** | |
| **Notes:** | |

**Course assessment**
Total number of assessed students: 12

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 75.0 | 8.33 | 8.33 | 8.33 | 0.0 | 0.0 |

| | |
|---|---|
| **Provides:** | |
| **Date of last modification:** 19.11.2021 | |
| **Approved:** prof. RNDr. Michal Jaščur, CSc. | |

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ JRE1/14 | **Course name:** Nuclear Reactions |
| **Course type, scope and the method:**<br>**Course type:** Lecture<br>**Recommended course-load (hours):**<br>**Per week:** 2 **Per study period:** 28<br>**Course method:** present | |
| **Number of ECTS credits:** 4 | |
| **Recommended semester/trimester of the course:** 2. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>Semestral project, its presentation, 2x elaboration of tasks, test, exam.<br>Credit evaluation of the course: direct teaching and consultations (1credit), self-study (1credit), practical activities - project, tasks (1credit), evaluation (1credit), total 4credits. Minimum limit for completion of the course is to obtain at least 51% of the total evaluation. | |
| **Learning outcomes:**<br>Introduction to nuclear reactions. | |
| **Brief outline of the course:**<br>1.-2. Introduction to nuclear reactions. Conservation laws, kinematics, cross section, scattering theory.<br>3.-5. Mechanism of nuclear reactions. Direct nuclear reactions. Resonance reactions. Bohr model of nuclear reactions, compound nucleus. Plane wave Born approximation. Distorted wave Born approximation. Pre-compound model of nuclear reactions: cassade model, exciton model, fireball.<br>6.-8.Neutron physics. Neutron induced reactions.<br>9. Heavy ion reactions.<br>10.Gamma reactions.<br>11. Nuclear synthesis. Fusion in the Sun and Stars, carbon cycle, proton cycle.<br>12. Application - nuclear medicine physics. | |
| **Recommended literature:**<br>1. Bertulani C.A., Danielewicz P.: Introduction to nuclear reaction, IOP Publish. Ltd., 2004.<br>2. G. McCracken, P. Stott: Fusion, The Energy of the Universe, Elsevier 2005<br>3. P.A.Tipler, R.A.Llewellyn: Modern Physics, 6th Edition,W.H.Freeman and Company, 2012<br>4. Cahn R., Goldhaber G., The experimental Foundations of Particle Physics, Cambridge Univ. Press, 2011<br>5. Iliadis Ch., Nuclear Physics of Stars, Wiley -VCH Verlag, 2015<br>6. Heyde K., Basic Ideas and Concepts in Nuclear Physics, IoP Publ., 2004 | |
| **Course language:**<br>slovak and english | |
| **Notes:** | |

**Course assessment**
Total number of assessed students: 19

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 73.68 | 21.05 | 0.0 | 5.26 | 0.0 | 0.0 |

**Provides:** doc. RNDr. Janka Vrláková, PhD.

**Date of last modification:** 22.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| | |
|---|---|
| **Course ID:** ÚFV/ FPK1/07 | **Course name:** Phase Transitions and Critical Phenomena |

**Course type, scope and the method:**
**Course type:** Lecture
**Recommended course-load (hours):**
**Per week:** 3 **Per study period:** 42
**Course method:** present

**Number of ECTS credits:** 4

**Recommended semester/trimester of the course:** 2.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
To successfully complete the course, the student is required to understand the concept of phase transitions and critical phenomena based on thermodynamics and statistical physics. The successful graduate will be able to apply this apparatus to simpler models of magnetic systems using exact or approximate methods. The condition for obtaining credits is successful completion of the final oral exam. The credit evaluation of the course takes into account the following student workload: direct teaching (2 credits), self-study (1 credit), and assessment (1 credit). The minimum limit for completing the course is to obtain at least 50% of the total score, using the following rating scale: A (90-100%), B (80-89%), C (70-79%), D (60- 69%), E (50-59%), F (0-49%).

**Learning outcomes:**
To acquaint students with the basic problems of the theory of phase transitions and critical phenomena and their solutions using the methods of thermodynamics and statistical physics. Emphasis is placed on the study of phase transitions in magnetic systems, through several theoretical models, but the course also covers other areas such as phase transitions in nuclear matter.

**Brief outline of the course:**
1. Thermodynamics and phase transitions.
2. Conditions of stability of the equilibrium state of the magnetic system.
3. Phase equilibrium, phase transitions. Clausius-Clapeyron equation.
4. Classical (Ehrenfest) classification of phase transitions: phase transitions of the first and second kind.
5. Landau's description of phase transitions of the second kind.
6. Critical indices, universality. Definition of critical indices for the magnetic system. Thermodynamic relations between critical indices.
7. Basic microscopic models of magnetic phase transitions. Heisenberg and Ising model.
8. Exact solutions of microscopic models: one-dimensional and two-dimensional Ising model.
9. Thermodynamic functions for a one-dimensional Ising model.
10. Some approximate methods of solving the Ising model.
11. Landau's theory of phase transitions.
12. Phases of nuclear matter.

**Recommended literature:**

Basic literature:
BOBÁK, A., Phase Transitions and Critical Phenomena, Project 2005/NP1-051 11230100466, European Social Fund, Košice 2007.
STANLEY, H.G.: Introduction to Phase Transitions and Critical Phenomena, Clarendon Press Oxford, 1971.
Other literature:
REICHL, L.E.: A Modern Course in Statistical Physics, University of Texas Press, Austin, 1980.
PLISCHKE, M., BERGERSEN, B.: Equilibrium Statistical Physics, World Scientific, 1994.
KADANOFF, L.P.: Statistical Physics, Statistics, Dynamics and Renormalization, World Scientific, 2000.

**Course language:**
1. Slovak,
2. English

**Notes:**
The course is realized in the presence form, if necessary remotely in the MS Teams environment.

**Course assessment**
Total number of assessed students: 142

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 53.52 | 11.97 | 11.97 | 15.49 | 7.04 | 0.0 |

**Provides:** prof. RNDr. Milan Žukovič, PhD.

**Date of last modification:** 19.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

**COURSE INFORMATION LETTER**

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** KF/ FILA/22 | **Course name:** Philosophical Antropology |
| **Course type, scope and the method:**<br>**Course type:** Practice<br>**Recommended course-load (hours):**<br>**Per week:** 2 **Per study period:** 28<br>**Course method:** present | |
| **Number of ECTS credits:** 2 | |
| **Recommended semester/trimester of the course:** | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:** | |
| **Learning outcomes:** | |
| **Brief outline of the course:** | |
| **Recommended literature:** | |
| **Course language:** | |
| **Notes:** | |

**Course assessment**
Total number of assessed students: 0

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| | |
|---|---|
| **Provides:** doc. PhDr. Kristína Bosáková, PhD. | |
| **Date of last modification:** 01.02.2022 | |
| **Approved:** prof. RNDr. Michal Jaščur, CSc. | |

**COURSE INFORMATION LETTER**

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ LEK1/02 | **Course name:** Physical Principles of Medical Diagnostics and Therapy |
| **Course type, scope and the method:**<br>**Course type:** Lecture<br>**Recommended course-load (hours):**<br>**Per week:** 2 **Per study period:** 28<br>**Course method:** present | |
| **Number of ECTS credits:** 2 | |
| **Recommended semester/trimester of the course:** 1., 3. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>To complete successfully the course, the student has to demonstrate the understanding of the basic notions and the physical principles of medical technology, especially of the diagnostic (imaging). In addition to attending classes, it is necessary for the student to study some specifics (details) of the discussed issues within self-study. The conditions for obtaining credits is, in addition to participation in teaching and passing the final exam, a successful completion of a written test. The minimum limit for passing the exam is to obtain 51% of the total score, which takes into account all required activities. The credit evaluation takes into account the following student workload: direct teaching - 1 credit, self-study of recommended literature - 1 credit, continuous study for the test and evaluation - 1 credit.<br>Rating scales: A - 91% -100% points, B - 81% -90% points, C - 71% -80% points, D - 61% -70% points, E - 51% -60% points. | |
| **Learning outcomes:**<br>After completing the lectures, the student will have the knowledge to understand the principles and operation of modern medical devices, such as e.g. ultrasound diagnostics, computed transmission tomography, computed emission (positron) tomography, magnetic (resonance) tomography, radiotherapy and lasers, and to be able to explain the principles and use of the facilities to others. The acquired knowledge should also be a good prerequisite for a possible employment of the student in companies producing or operating modern medical technology. | |
| **Brief outline of the course:**<br>1. Division of medical technology into diagnostic and therapeutic. A brief history of medical technology.<br>2. Ultrasound diagnostics (USG). Basic terms - used frequencies, wave intensities, acoustic impedance, ultrasound generation, absorption of ultrasonic waves, reflection and refraction of waves, space resolution, focusing of waves. Types of ultrasound imaging: type A and B imaging, creation of a dynamic (real time) image, time imaging (time motion). Some methods of signal processing: digitization, time-dependent signal balancing, etc.<br>3. Ultrasound diagnostics based on Doppler effect. Systems with unmodulated and modulated carrier waves, examination of blood flow in the organism. Possibilities of ultrasound diagnostics and | |

its advantages. Interaction of ultrasound with tissues (active and passive), principles of ultrasound therapy.
4. Transmission computed tomography (CT). Absorption of X-rays in tissues, evaluation of relationships between the intensity of incident and the intensity of penetrated radiation, image constructions.
5. Construction of a CT equipment, X-ray source, detection system, evaluation and processing of results. Types (generations) of CT devices. Implementation of CT examination and image evaluation. 6. Emission computed tomography (ET). Single-photon emission tomography - selection of suitable radionuclides and evaluation of the distribution of radionuclides in the body.
7. Construction of emission tomograph, benefits and use of emission tomography. Positron emission tomography (PET). Positron emitters, positron - electron annihilation, coincident photon detection. Construction of PET equipment, benefits and use of PET.
8. Thermography - basic concepts. Contact thermography - properties of liquid crystals, detection of changes in surface temperature of an organism. Contactless thermography. Radiation of bodies, detection of infrared radiation, distribution and properties of detectors. Thermograph design, use of thermography in medicine and other areas.
9. Magnetic (resonance) tomography (MR/MT). Principles of nuclear magnetic resonance - magnetic moment of the nucleus, movement (precession) of magnetic moments in magnetic field. Longitudinal and transverse relaxation times, causes of their change. Methods of measuring relaxation times.
10. Acquisition of image information - use of magnetic field gradients, methods of their creation. Design of magnetic tomographs - basic magnet, high frequency coils, shielded rooms, evaluation systems. Possibilities and use of MT, the use of contrast agents.
11. Lasers in medical technology. Principle of laser operation, spontaneous and induced emission, three-level lasers (solid, gas), construction of lasers. Properties of laser radiation and the effect of laser beam on biological objects (tissues). Use of lasers in various fields of medicine.
12. Principles of radiotherapy. Interaction of various ionizing particles (photons, electrons, neutrons, protons) with the environment. Biological effects of ionizing radiation, applied doses, survival curves. New methods of irradiation, the use of Bragg maximum in hadron irradiation therapy, neutron capture therapy. Possibilities of ionizing radiation beam modification.

**Recommended literature:**

- Režňák I. et al., Modern imaging methods in medical diagnostics, Vyd. Osveta, Martin, 1992.
- Jurga Ľ. et al., Basics of Medical Radiology, Script of LF UPJŠ, Košice, 1990.
- Mc Ainsh T.F., Physics in Medicine and Biology, Pergamon Press, Oxford, 1987.
- Huda W., Slone R.M., Review of Radiologic Physics, Lippincot, London, 1995
- Bushberg J.T, et al., The essential physics of imaging, Lippincott Williams, Philadelphia, 2002.

**Course language:**

Slovak, English

**Notes:**

Recommended range of lessons (in hours): Weekly: 2/0
For the period of study: 26/0
Method of study: Teaching is carried out in person, if necessary remotely, in the environment of MS Teams.
Number of ECTS credits: 3
Degree of studz: I. resp. II.
Prerequisites: none

**Course assessment**
Total number of assessed students: 44

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 88.64 | 9.09 | 2.27 | 0.0 | 0.0 | 0.0 |

**Provides:** doc. RNDr. Karol Flachbart, DrSc.

**Date of last modification:** 06.10.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ FJA1/14 | **Course name:** Physics of the Nucleus |
|---|---|

**Course type, scope and the method:**
**Course type:** Lecture
**Recommended course-load (hours):**
**Per week:** 2 **Per study period:** 28
**Course method:** present

**Number of ECTS credits:** 4

**Recommended semester/trimester of the course:** 1.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
Active participation in lectures.
Passing the oral exam.
Detailed conditions are updated annually on the electronic notice board of the subject in AiS2 or within the repository for digital support materials (LMS UPJŠ, MS Teams UPJŠ, etc.)
The teacher excuses the justified absence of the student (incapacity for work, family reasons, etc.) for a maximum of two lectures during the semester without the need for substitute performance.
In the case of a longer-term justified absence (for example due to incapacity for work), the student will be assigned an alternative form of mastering the missed study matter.
Credit evaluation of the course takes into account the following student workload: direct teaching and individual consultations (2 credits), self-study (1 credit), rating (1 credit). The minimum threshold for completing the course is to obtain at least 51% of the total score, using the following rating scale: A (91-100%), B (81-90%), C (71-80%), D (61- 70%), E (51-60%), F (0-50%).

**Learning outcomes:**
Extension of basic knowledge of nuclear physics on a better theoretical basis:
Theory of scattering.
Properties of nucleus. Nuclear masses, binding energy. Nuclear radius, density distribution of nuclear matter.
Nuclear momentum and parity. Spin and magnetic momentum of nuclei. Quadrupole electric momentum.
Theory of deuteron. Nuclear spin and isospin.
Nuclear forces. Models of atomic nucleus.
Alpha, beta, gamma radioactive decay.

**Brief outline of the course:**
1. Introduction. Theoretical and experimental methods.
2. Sources of particles, accelerators and accumulation rings, colliding beams,
3. Particle scattering problem.
4. Properties of stable atomic nuclei: basic elements of atom, antiparticles.
5. Nuclear composition, isotopes, isobars, nuclides, mass and binding energy, spin and parity.
6. Nuclear moments and nucleus shape: dipole moment, magnetic moment, quadrupole moment,

7. Magnetic moments, measurement of nuclear moments.
8. Shape, dimensions and structure of atomic nuclei.
9. Models of atomic nuclei and nuclear forces: one-particle, droplet, layer and generalized model.
10. Properties of nuclear forces, meson and field theory of nuclear forces.
11. Decay of unstable nuclei, radioactivity and its laws.
12. Decays of α, β, γ and their applications.

**Recommended literature:**
Preston M.A. , Physics of the Nucleus, Addison-Wesley Publishing Company, 1962.
Bertulani C., Danielewicz P., Introduction to Nuclear Reactions, IoP, 2004.
Suhonen J., From Nucleons to Nucleus, Springer, 2007.

**Course language:**
slovak and english

**Notes:**

**Course assessment**
Total number of assessed students: 52

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 65.38 | 13.46 | 9.62 | 7.69 | 3.85 | 0.0 |

**Provides:** doc. RNDr. Adela Kravčáková, PhD.

**Date of last modification:** 16.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/PSP/19 | **Course name:** Practical Guide to Scientific Routine for Students |
|---|---|

**Course type, scope and the method:**
**Course type:** Practice
**Recommended course-load (hours):**
**Per week:** 2 **Per study period:** 28
**Course method:** present

**Number of ECTS credits:** 2

**Recommended semester/trimester of the course:** 2.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
During the continuous and final evaluation, the student should demonstrate adequate mastery of the course content standard. The basis of continuous assessment is active participation in teaching and demonstration of the ability to work independently. The condition for successful completion of the course is the elaboration of homework and final evaluation. The final evaluation consists of submitting a written project proposal for financing own virtual or real research according to the provided form and oral presentation of the research within a short 15 minutes talk. The final evaluation takes into account all required activities with relevant weight.
To obtain 2 ECTS credits the following should be fulfilled: participation in direct teaching, self-study and individual homework (1 ECTS credit) and submission of a semester project and final presentation (1 ECTS credit). Final rating scale: A 100% - 90%, B 89% - 75%, C 74% - 60%, D 59% - 40%, E 39% - 20%, FX 19% - 0.

**Learning outcomes:**
Selected topics of current interest in physics used as a source material for gaining practical experience in reading, writing and preparing a scientific visual and oral presentation utilized not only for further career growth in the academic environment. The student will learn how to work with online academic libraries, acquire the basics of writing in LaTeX, processing of scientific data and their graphical visualization. The aim of the exercises is to apply the acquired practical skills to improve the level of independence in reading and writing of scientific texts, research papers and skills in oral presentation. The choice of working material can be agreed according to individual needs. Students can work on their own project, diploma or dissertation thesis.

**Brief outline of the course:**
1. Work with academic citation databases (Web of Science, Scopus, Google Scholar). Personal Publication Manager (Zotero).
2. Research funding, grant schemes (at University, local and European), European Commission portal (https://ec.europa.eu). Curriculum Vitae - EUROPASS.
3. Basics of writing in LaTeX, collaborative cloud-based editor (www.overleaf.com). Formulation of goals and tasks of academic writing.
4. Guide to a scientific research proposal writing.
5. Processing of scientific data and their graphical representation (matplotlib, gnuplot).

6. Data visualization and 3D modeling (inkscape, Mayavi, Povray, Blender).
7. Guide to scientific poster preparation and presentation.
8. Research dissemination and social research networks (www.researchgate.net).
9. Scientific conferences. Guide to talk preparation. Communication soft skills and small talks.
10. High-performance computing, Supercomputing Centers, Portable Batch System for job scheduling. The PRACE mission (http://www.prace-ri.eu).

**Recommended literature:**
M. Aliotta, Mastering Academic Writing in the Sciences : A Step-by-Step Guide, CRC Press 2018.
B. Gastel, R. A. Day, How to Write and Publish a Scientific Paper, GreenWood 2016.
J. Schimel, Writing Science, Oxford University Press 2012.
B. Gustavii, How to Write and Illustrate Scientific Papers, Cambridge University Press 2008.
S. Bailey, Academic Writing: A Practical Guide for Students, Routledge 2004.
P. Dunleavy, Authoring a PhD Thesis: How to Plan, Draft, Write and Finish a Doctoral Dissertation, Palgrave Macmillan 2003.
R. S. Brause, Writing Your Doctoral Dissertation: Invisible Rules for Success, Routledge 1999.
Selected articles from high impact factor journals or other scientific peer-reviewed publications.

**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 12

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Provides:** RNDr. Martin Gmitra, PhD.

**Date of last modification:** 14.02.2022

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ PRA/13 | **Course name:** Practice in Astronomy |
| **Course type, scope and the method:**<br>**Course type:** Practice<br>**Recommended course-load (hours):**<br>**Per week:** 3 **Per study period:** 42<br>**Course method:** present | |
| **Number of ECTS credits:** 3 | |
| **Recommended semester/trimester of the course:** 1. | |
| **Course level:** II. | |
| **Prerequisities:** ÚFV/APR/17 | |
| **Conditions for course completion:**<br>To successfully complete the course, the student must demonstrate an understanding of basic astronomical observations, be able to work with online tools for preparing observations and programs to control telescopes. In order to obtain an evaluation and thus also credits, the student must prepare a semester work according to the assignment of the teacher and present the obtained results. The credit evaluation of the course takes into account the following student workload: direct teaching (1 credit), self-study (2 credits). The minimum limit for completing the course is to obtain at least 50% of the total score. | |
| **Learning outcomes:**<br>After completing the practise, the student will be able to work with astronomical telescopes, will be able to work with programs to control instruments and telescopes and will be able to use online tools to prepare observations. | |
| **Brief outline of the course:**<br>1. Working with telescopes<br>2. Software for controlling of telescopes and CCD cameras<br>3. Overview of online tools<br>4. Preparation of astronomical observations<br>5. Practical observation | |
| **Recommended literature:**<br>1. Budding E., Demircan O.: Introduction to Astronomical Photometry (Second Edition). Cambridge University Press, New York, 2007<br>2. Howell S. B.: Handbook of CCD Astronomy (Second Edition). Cambridge University Press, New York, 2006<br>3. Roth G. D.: Handbook of Practical Astronomy, Springer-Verlag, Heidelberg, 2009<br>4. Warner B. D. : A Practical Guide to Lightcurve Photometry and Analysis, Springer, New York, 2006<br>5. URL: http://www.minorplanetcenter.net/<br>6. URL: http://ssd.jpl.nasa.gov/?horizons<br>7. niektoré vybrané kapitoly z Asteroids III a IV | |

**Course language:**
Slovak, English

**Notes:**

**Course assessment**
Total number of assessed students: 16

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Provides:** Mgr. Marek Husárik, PhD.

**Date of last modification:** 21.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ PRAF/13 | **Course name:** Practice in Astrophysics |

**Course type, scope and the method:**
**Course type:** Practice
**Recommended course-load (hours):**
**Per week:** 4 **Per study period:** 56
**Course method:** present

**Number of ECTS credits:** 4

**Recommended semester/trimester of the course:** 2.

**Course level:** II.

**Prerequisities:** ÚFV/TAF1/13

**Conditions for course completion:**
To successfully complete the course, the student must demonstrate an understanding of the basics of spectroscopic observations, and be able to process and calibrate astronomical spectra. In order to obtain an evaluation and thus also credits, the student must prepare a semester esay according to the assignment of the teacher and present the obtained results. Credit evaluation of the course takes into account the following student workload: direct teaching (1 credit), self-study (2 credits), individual consultations (1 credit). The minimum limit for completing the course is to obtain at least 50% of the total score.

**Learning outcomes:**
After completing of the practice, the student will master the basics of spectroscopy, will be able to distinguish the manifestations of various physical processes in the spectrum of stars. he gains the skills necessary to process, reduce and calibrate spectra.

**Brief outline of the course:**
1. Introduction to spectroscopy
2. Acquaintance with instrumentation
3. Acquisition of spectra,
4. Basic reduction
5. Spectrum calibration
6. Measurement of radial velocities and line intensities,
7. Determination of the chemical composition of the atmosphere of the Sun and stars
8. Determination of the radial velocity curve

**Recommended literature:**

1. Appenzeller, I., Introduction to Astronomical Spectroscopy, Cambridge University Press, 2012
2. Gray, R,O., Corbally, C,J., Stellar Spectral Clasification, Princeton University Press, 2009
3. Kitchin, C.R., Optical Astronomical Spectroscopy, IoP Publishing, 1995
4. Kitchin, C.R., Telescopes and Techniques, Springer, 3rd edition, 2013


**Course language:**
Slovak, English

**Notes:**

**Course assessment**
Total number of assessed students: 14

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Provides:** doc. Mgr. Štefan Parimucha, PhD.

**Date of last modification:** 22.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

**COURSE INFORMATION LETTER**

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ PFJ1/13 | **Course name:** Programming and Data Processing in Nuclear Physics I |
|---|---|

**Course type, scope and the method:**
**Course type:** Lecture / Practice
**Recommended course-load (hours):**
**Per week:** 2 / 2 **Per study period:** 28 / 28
**Course method:** present

**Number of ECTS credits:** 5

**Recommended semester/trimester of the course:** 1.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
semestral project, presentation, evaluation

**Learning outcomes:**
To teach the students python language and how to analyse data using the ROOT framework and help them to gain practical skills.

**Brief outline of the course:**
Introduction to Python. Implementation of own histogram object and display it via tcl library.Basic description of ROOT environment, work with the basic tools for data processing: histograms and graphs, their creation and fitting, data storing into the structure suitable for analysis in ROOT - trees, working with trees.

**Recommended literature:**
1. https://www.python.org/
2. https://docs.python.org/3/tutorial/
3. https://root.cern.ch/

**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 17

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 88.24 | 0.0 | 11.76 | 0.0 | 0.0 | 0.0 |

**Provides:** RNDr. Martin Vaľa, PhD.

**Date of last modification:** 19.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ PJF2/13 | **Course name:** Programming and Data Processing in Nuclear Physics II |
|---|---|

**Course type, scope and the method:**
**Course type:** Lecture / Practice
**Recommended course-load (hours):**
**Per week:** 2 / 2 **Per study period:** 28 / 28
**Course method:** present

**Number of ECTS credits:** 5

**Recommended semester/trimester of the course:** 2.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
semestral project, presentation, evaluation

**Learning outcomes:**
To provide practical cookbook of the object oriented programming in C++

**Brief outline of the course:**
Introduction to C++.
Create own project using cmake and configure it using ROOT libraries.
Basic description of ROOT environment, work with the basic tools for data processing: histograms and graphs, creation and fitting.
Data storing into the structure suitable for analysis in ROOT - trees, working with trees.

**Recommended literature:**

1. J.J. Barton, L.R. Nackman, Scientific and Engineering C++, Addison Wesley, 1994
2. B. Kernigham, D. Ritchie, ANSI C 3. Stephen Prata, Mistrovství v C++ (3. aktualizované vydání), Computer Press, 2007
4. http://www.cplusplus.com/doc/tutorial/
5. http://www-root.fnal.gov/root/CPlusPlus/index.html
6. B. Eckel: Thinking in C++, 2d ed,, 2000


**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 14

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 92.86 | 0.0 | 0.0 | 0.0 | 7.14 | 0.0 |

**Provides:** RNDr. Martin Vaľa, PhD.

**Date of last modification:** 18.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ KTP1a/03 | **Course name:** Quantum Field Theory I |
| **Course type, scope and the method:**<br>**Course type:** Lecture / Practice<br>**Recommended course-load (hours):**<br>**Per week:** 3 / 1 **Per study period:** 42 / 14<br>**Course method:** present | |
| **Number of ECTS credits:** 6 | |
| **Recommended semester/trimester of the course:** 1. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:** | |
| **Learning outcomes:** | |
| **Brief outline of the course:** | |
| **Recommended literature:** | |
| **Course language:** | |
| **Notes:** | |
| **Course assessment**<br>Total number of assessed students: 83 | |

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 42.17 | 16.87 | 9.64 | 9.64 | 19.28 | 2.41 |

| | |
|---|---|
| **Provides:** RNDr. Tomáš Lučivjanský, PhD., univerzitný docent | |
| **Date of last modification:** 16.11.2021 | |
| **Approved:** prof. RNDr. Michal Jaščur, CSc. | |

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ KTP1b/03 | **Course name:** Quantum Field Theory II |
| **Course type, scope and the method:**<br>**Course type:** Lecture / Practice<br>**Recommended course-load (hours):**<br>**Per week:** 3 / 1 **Per study period:** 42 / 14<br>**Course method:** present | |
| **Number of ECTS credits:** 6 | |
| **Recommended semester/trimester of the course:** 2. | |
| **Course level:** II. | |
| **Prerequisities:** ÚFV/KTP1a/03 | |
| **Conditions for course completion:**<br>Assignment processing; their presentation at exercises, joint analysis of the issue;<br>an exam.<br>Conditions for successful completion of the course - demonstration of knowledge of the issue at sufficient level, active participation in teaching through the presentation of assignment solutions.<br>Course credit evaluation: direct teaching (3 credits), self-study (1credit), practical activities - assignments (1credit) and evaluation (1 credit). The minimum threshold for completing the course is to obtain at least<br>51% of the total score. | |
| **Learning outcomes:**<br>To offer basic knowledges about modern trends and theoretical methods in description of microword and phenomena in physical systems with infinite degrees of freedom. | |
| **Brief outline of the course:**<br>Interacting fields. The principle of symmetry and the form of interactions of quantum fields. Lagrange operator in QED. S – matrix. Wick theorems and Feynman diagrams. Perturbative calculation of S - matrix. S - matrix and cross section of the processes. Compton scattering of the proton on electron cross section calculation in QCD frame. Radiation corrections and the divergences of the Feynman graphs. Running coupling constant. | |
| **Recommended literature:**<br>Bogoljubov N.N., Širkov D.V.: Vvedenie v teoriu kvantovannych polej, Moskva, 1957 (prvé vydanie); Moskva, Nauka 1984 (4. Vydanie)<br>Itzykon C., Zuber J.B.: Quantum field theory,McGraw-Hill, New York, 1986; ruský preklad: Icikon K., Zjuber Z.B.: Kvantovaja teoria polja,<br>Mir, Moskva, 1984.<br>Ryder L.H.: Quantum field theory, Cambridge University Press, 1985; ruský<br>preklad: Rajder L.: Kvantovaja teoria polja, Mir, Moskva, 1987. | |
| **Course language:**<br>slovak and english | |
| **Notes:** | |

**Course assessment**
Total number of assessed students: 67

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 52.24 | 28.36 | 10.45 | 4.48 | 4.48 | 0.0 |

**Provides:** prof. RNDr. Michal Hnatič, DrSc., RNDr. Tomáš Lučivjanský, PhD., univerzitný docent

**Date of last modification:** 15.12.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ KTM/14 | **Course name:** Quantum Theory of Magnetism |
| **Course type, scope and the method:**<br>**Course type:** Lecture<br>**Recommended course-load (hours):**<br>**Per week:** 3 **Per study period:** 42<br>**Course method:** present | |
| **Number of ECTS credits:** 5 | |
| **Recommended semester/trimester of the course:** 3. | |
| **Course level:** II., III. | |
| **Prerequisities:** | |

**Conditions for course completion:**

To successfully complete the course, the student must demonstrate sufficient understanding of the basics terms, concepts, and applications of quantum theory of magnetism. Knowledge of basic concepts of quantum physics at the level of their mathematical definition is required, as well as understanding of their physical content and specific applications in the field of magnetism. During the semester, the student must continuously master the content of the curriculum, so that he can actively and creatively use the acquired knowledge in solving specific tasks assigned to independent solutions at home. The condition for obtaining credits is passing an oral exam, which consists of one more demanding computational task and theoretical questions covering the entire scope of the course. The credit evaluation of the course takes into account the following student workload: direct teaching (2 credits), self-study (1 credit), individual consultations (1 credit) and assessment (1 credit). The minimum threshold for completing the course is to obtain at least 50% of the total score, using the following rating scale: A (90-100%), B (80-89%), C (70-79%), D (60- 69%), E (50-59%), F (0-49%).

**Learning outcomes:**

After completing lectures, the student will have sufficient physical skills, knowledge and mathematical apparatus enabling independent solution of a wide range traditional and current scientific problems in quantum theory of magnetism. At the same time, he will gain an
overview of the applications of quantum theory of magnetism for a description of insulating magnetic materials.

**Brief outline of the course:**

1. Introduction to quantum theory of magnetism, definition of basic lattice-statistical models in magnetism: Ising model, Heisenberg model, Hubbard model, t-J model.
2. Exchange interaction and its quantum-mechanical origin. Formalism of the second quantization and basic commutation relations between ladder spin operators.
3. Elementary quantum theory of a pair of interacting magnetic particles: Heisenberg dimer.
4. Elementary quantum theory of a pair of interacting magnetic particles: Hubbard dimer.
5. One-dimensional quantum Heisenberg model, spin waves as collective excitations of ferromagnetic spin chain, one-magnon spectrum.

6. One-dimensional quantum Heisenberg model with ferromagnetic interaction, two-magnon spectrum, free and bound spin waves, basics of Bethe-ansatz method.
7. Crystal of singlet dimers as a basic state of frustrated quantum Heisenberg models (Majumdar-Ghosh model and Gelfand ladder).
8. Fermionization of one-dimensional quantum XX model in transverse magnetic field: Jordan-Wigner and Fourier transform. Quantum critical point and thermodynamic behavior.
9. Fermionization of one-dimensional quantum Ising model in transverse magnetic field: Jordan-Wigner, Fourier and Bogoliubov transformation.
10. Variational description of quantum phase transitions in dimerized quantum Heisenberg spin models.
11. Theory of localized magnons as a tool for a simple description of the thermodynamic behavior of frustrated quantum Heisenberg models at nonzero temperatures.
12. Spin-wave theory for a generalized quantum Heisenberg model of arbitrary spatial dimension and spin size. Bosonization through the Holstein-Primakoff transformation.

**Recommended literature:**

1. J. B. Parkinson, D. J. J. Farnell, An Introduction to Quantum Spin Systems, Lecture Notes in Physics 816 (Springer, Berlin Heidelberg, 2010).
2. U. Schollwock, J. Richter, D. J. J. Farnell, R. F. Bishop, Quantum Magnetism, Lecture Notes in Physics 645 (Springer, Berlin Heidelberg, 2004).
3. N. Majlis, The Quantum Theory of Magnetism (World Scientific, Singapore, 2000).

**Course language:**

EN - english

**Notes:**

The subject is realized in presence form, in case of need in distance form in MS Teams enviroment.

**Course assessment**

Total number of assessed students: 32

| A | B | C | D | E | FX | N | P |
|---|---|---|---|---|---|---|---|
| 12.5 | 34.38 | 12.5 | 3.13 | 12.5 | 3.13 | 6.25 | 15.63 |

**Provides:** doc. RNDr. Jozef Strečka, PhD.

**Date of last modification:** 19.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

**COURSE INFORMATION LETTER**

| **University:** P. J. Šafárik University in Košice | |
|---|---|
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ KSF/22 | **Course name:** Quantum statistical physics |
| **Course type, scope and the method:**<br>**Course type:** Lecture / Practice<br>**Recommended course-load (hours):**<br>**Per week:** 2 / 2 **Per study period:** 28 / 28<br>**Course method:** present | |
| **Number of ECTS credits:** 5 | |
| **Recommended semester/trimester of the course:** 1. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>To successfully complete the course, the student must demonstrate sufficient understanding of all basic cconcepts and applications of quantum statistical physics. Knowledge of basic concepts of quantum statistical physics at the level of their mathematical definition is required, as well as their physical content and fundamental applications. The student must be able to actively master the content of the curriculum continuously during the semester, so that he can actively and creatively use the acquired knowledge in solving specific problems during exercises and for independent homework. In addition to direct participation in lectures, the student is obliged to study within the self-study professional topics assigned by the teacher and also to develop and present two homework assignments. The condition for obtaining credits is, in addition to participation in lectures, also the successful completion of three written tests from exercises and lectures and the elaboration of home assignments. The minimum limit for passing the exam is to obtain 51% of the total score, which takes into account all required activities with relevant weight.<br>Rating scale: A - 91% -100% points, B - 81% -90% points, C - 71% -80% points,<br>D - 61% -70% points, E - 51% -60% points. | |
| **Learning outcomes:**<br>After completing lectures and exercises, the student will have sufficient physical knowledge and mathematical apparatus to independently solve a wide range of current scientific problems in various fields of physics, especially in the field of condensed matter physics and materials research. In addition to solving traditional physical problems, the student will be able to creatively apply the methods of quantum statistical physics in solving various practical problems. These are mainly practical applications in the field of quantum algorithms and calculations, in the field of life sciences (spread of dangerous infectious diseases), but also in the field of big data processing, in the social and political sciences (election results prediction). The graduate will also be able to solve specific application tasks in the field of informatics, including the creation of various software products. | |
| **Brief outline of the course:**<br>1. Basic concepts of quantum statistical physics. Pure and mixed quantum statistical ensembles. Definition of statistical density matrix. Liouville's theorem for the density matrix. Equilibrium / mean values in quantum statistical physics. | |

2. Quantum microcanonical statistical ensemble. Density matrix in a microcanonical ensemble. Quantum theory of independent lattice harmonic vibrations in the microcanonical ensemble. Entropy, internal energy, free energy and heat capacity of the crystal lattice within microcanonical ensemble.
3. Quantum canonical set. Density matrix for the canonical ensemble. Partition function, von Neuman entropy, internal and free energy in a canonical ensemble. Quantum theory of independent lattice harmonic vibrations in the ensemble set. Entropy, internal energy, free energy and heat capacity of the crystal within canonical ensemlbe. Relationship between microcanonical and canonical ensemble.
4. Quantum theory of paramagnetism in the canonical ensemble. Magnetization, susceptibility, entropy, internal energy, enthalpy and heat capacity of a paramagnetic crystal.
5. Interacting systems. Bogoľubov inequality and mean field theory for the ferromagnetic transverse Ising model on an arbitrary crystal lattice.
6. Quantum grand-canonical ensemble. Density matrix and grand-canonical partition function, entropy and grand-canonical potential
7. Ideal gases in quantum statistical physics. Density of quantum states and quasiclassical approximation. Fermi-Dirac and Bose-Einstein statistics. Classical limit of quantum statistics - Boltzmann statistics. Quantum statistics of relativistic ideal gases.
8. Applications of the Fermi-Dirac distribution. Completely and partially degenerate fermion gas.
9. Stability of degenerate stars. Radius of white dwarfs. Chandrasekhar's criterion. Radius of neutron stars. Oppenhaimer-Volkov criterion.
10. Applications of the Bose-Einstein distribution. Radiation of an absolutely black body. Rayleigh-Jeans law, Planck's law, Wien's shift law and Stefan-Boltzmann's law.
11. Bose-Einstein condensate. Formation of the Bose-Einstein condensate and its heat capacity. Helium superfluidity. Superconductivity. Green's functions. Solving the Bloch equation using Green 's functions.
12. Integral equations for the density operator. Einstein's theory of fluctuations. Correlation of fluctuations. Onsager reciprocity relations.

**Recommended literature:**

1. F. Čulík, M. Noga: Úvod do štatistickej fyziky a termodynamiky, Alfa, Bratislava 1992.
2. J. Kvasnica: Statisticka fyzika, Academia, Praha, 1998.
3. W. Greiner, L. Neise, H. Stöcker: Thermodynamics and Statistical Physics, Springer, New York 1994.
4. L. E. Reichel: A Modern Course in Statistical Physics, University of Texax Press, Austin 1980.

**Course language:**
slovak, english

**Notes:**

**Course assessment**
Total number of assessed students: 16

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 75.0 | 6.25 | 18.75 | 0.0 | 0.0 | 0.0 |

**Provides:** prof. RNDr. Michal Jaščur, CSc.

**Date of last modification:** 19.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| | |
|---|---|
| **Course ID:** ÚFV/ RJF1/14 | **Course name:** Relativistic Nuclear Physics |

**Course type, scope and the method:**
**Course type:** Lecture
**Recommended course-load (hours):**
**Per week:** 2 **Per study period:** 28
**Course method:** present

**Number of ECTS credits:** 4

**Recommended semester/trimester of the course:** 2.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
exam + elaboration of one of the key publications in relativistic heavy ions in a form of a paper draft
Credit distributiuon:
lectures: 28 hours - 1 credit
home study: 25 hours - 1 credit
paper draaft study: 25 hours - 1 credit
preparation for the final exam: 25 hours - 1 credit

**Learning outcomes:**
Students will obtain basic information about physics of relativistic nuclear collisions and they will have a knowledge of experimental methods used for these collisions as well as experimental signatures of quark-gluon plasma which is created in these collisions. At the end of the course, the student should be able to understand a baseline in publications in corresponding physics area.

**Brief outline of the course:**
1. week: relativistic kinematics for nuclear collisions, transverse momentum, rapidity and pseudorapidity, measurement results: transverse momentum spectrum and integrated yield
2. week: introduction to quark-gluon plasma physics, Bjorken collision evolution, nuclear matter phase diagram, quark-gluon plasma in early Universe and in neutron stars
3. week: experimental methods of studying the quark-gluon plasma: accelerators with heavy ions (AGS, SPS, RHIC and LHC) and experiments (NA57, STAR and ALICE), overview of experimental signatures of quark-gluon plasma
4. week: particle production in heavy ion collisions, production scaling with number of participants and with number of binary collisions, Glauber model, centrality and multiplicity, Lund model for particle production
5. week: strange particle production in heavy ion collisions and in proton-proton collisions, statistical model, production of deuterons and lighter nuclei
6. week: J/Psi production suppression, production of states with heavy quark as a function of environment temperature
7. week: high momentum transfer processes, jets, nuclear modification factor R_AA, jet quenching in central nucleus-nucleus collisions, dead cone effect

8. week: angular two-particle correlations of particles with high transverse momentum, angular correlations with strange particles, I_AA variable
9. week: collective flow of partons and hadrons in nucleus-nucleus collision, spatial and momentum anisotropy of the collision system, elliptic and triangular flow
10. week: HBT correlations, femtoscopy of like and not like particle pairs, source size and interaction intensity
11. week: hadron resonances and possible changes of their properties in quark-gluon plasma environment, regeneration and rescattering in hadron phase
12. week: baryon production to meson prouction ratio as a signature of the quark-gluon plasma, production of direct photons and dileptons in quark-gluon plasma environment
13. week: indications of quark-gluon plasma production in small collisional systems, e.g. proton-proton or proton-lead collisions
14. week: summary of the experimental signatures of the quark-gluon plasma, outlook to the future - new accelerators and experiments

**Recommended literature:**

Chenk-Yin Wong: Introduction to High-Energy Heavy Ion Collisions, World Scientific, 1994.
Jerzy Bartke: Introduction to Relativistic Heavy Ion Physics, World Scientific, 2008
Sarkar, Sourav, Satz, Helmut, Sinha, Bikash (Eds.): The Physics of the Quark-Gluon Plasma, Lecture notes in Physics, Springer, 2010
Recent publications

**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 29

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 62.07 | 13.79 | 13.79 | 0.0 | 10.34 | 0.0 |

**Provides:** doc. RNDr. Marek Bombara, PhD.

**Date of last modification:** 28.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

# COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| | |
|---|---|
| **Course ID:** ÚFV/ REHY/24 | **Course name:** Relativistická hydrodynamika |

**Course type, scope and the method:**
**Course type:** Lecture / Practice
**Recommended course-load (hours):**
**Per week:** 2 / 1 **Per study period:** 28 / 14
**Course method:** present

**Number of ECTS credits:** 5

**Recommended semester/trimester of the course:** 1., 3.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**

**Learning outcomes:**

**Brief outline of the course:**

**Recommended literature:**

**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 0

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Provides:** RNDr. Zuzana Paulínyová, PhD.

**Date of last modification:**

**Approved:** prof. RNDr. Michal Jaščur, CSc.

**COURSE INFORMATION LETTER**

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚTVŠ/ CM/13 | **Course name:** Seaside Aerobic Exercise |
| **Course type, scope and the method:**<br>**Course type:** Practice<br>**Recommended course-load (hours):**<br>**Per week:** 2 **Per study period:** 28<br>**Course method:** present | |
| **Number of ECTS credits:** 2 | |
| **Recommended semester/trimester of the course:** | |
| **Course level:** I., II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>Completion: passed<br>Condition for successful course completion:<br>- active participation in line with the study rule of procedure and course guidelines<br>- effective performance of all tasks- aerobics, water exercise, yoga, Pilates and others | |
| **Learning outcomes:**<br>Content standard:<br>The student demonstrates relevant knowledge and skills in the field, which content is defined in the course syllabus and recommended literature.<br>Performance standard:<br>Upon completion of the course students are able to meet the performance standard and:<br>- perform basic aerobics steps and basics of health exercises,<br>- conduct verbal and non-verbal communication with clients during exercise,<br>- organise and manage the process of physical recreation in leisure time | |
| **Brief outline of the course:**<br>Brief outline of the course:<br>1. Basic aerobics – low impact aerobics, high impact aerobics, basic steps and cuing<br>2. Basics of aqua fitness<br>3. Basics of Pilates<br>4. Health exercises<br>5. Bodyweight exercises<br>6. Swimming<br>7. Relaxing yoga exercises<br>8. Power yoga<br>9. Yoga relaxation<br>10. Final assessment<br>Students can engage in different sport activities offered by the sea resort – swimming, rafting, volleyball, football, table tennis, tennis and other water sports in particular. | |
| **Recommended literature:**<br>1. BUZKOVÁ, K. 2006. Fitness jóga. Praha: Grada. 167 s. | |

2. ČECHOVSKÁ, I., MILEROVÁ, H., NOVOTNÁ, V. Aqua-fitness. Praha: Grada. 136 s.
3. EVANS, M ., HUDSON, J., TUCKER, P. 2001. Umění harmonie: meditace, jóga, tai-či, strečink. 192 s.
4. JARKOVSKÁ, H., JARKOVSKÁ, M. 2005. Posilováni s vlastním tělem 417 krát jinak. Praha: Grada. 209 s.
5. KOVAŘÍKOVÁ, K. 2017. Aerobik a fitness. Karolium, 130 s.

**Course language:**
Slovak language

**Notes:**

**Course assessment**
Total number of assessed students: 62

| abs | n |
|---|---|
| 9.68 | 90.32 |

**Provides:** Mgr. Agata Dorota Horbacz, PhD.

**Date of last modification:** 29.03.2022

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ PFC1/03 | **Course name:** Selected Topics from Elementary Particle Physics |
|---|---|

**Course type, scope and the method:**
**Course type:** Lecture
**Recommended course-load (hours):**
**Per week:** 2 **Per study period:** 28
**Course method:** present

**Number of ECTS credits:** 4

**Recommended semester/trimester of the course:** 3.

**Course level:** II.

**Prerequisities:** ÚFV/FEC1/04

**Conditions for course completion:**
Active participation in lectures and seminars
2. Elaboration of a written report
3. Passing the oral exam
Detailed conditions are updated annually on the electronic notice board of the subject in AiS2 or within the repository for digital support materials (LMS UPJŠ, MS Teams UPJŠ, etc.)
The teacher excuses the justified absence of the student (incapacity for work, family reasons, etc.) for a maximum of two lectures during the semester without the need for substitute performance. In the case of a longer-term justified absence (for example due to incapacity for work), the student will be assigned an alternative form of mastering the missed study matter.
Credit evaluation of the course takes into account the following student workload: direct teaching and individual consultations (2 credit), self-study (1 credits), rating (1 credits). The minimum threshold for completing the course is to obtain at least 51% of the total score, using the following rating scale: A (91-100%), B (81-90%), C (71-80%), D (61- 70%), E (51-60%), F (0-50%).

**Learning outcomes:**
Unified description of processes in nuclear and particle physics and selected experiments that lead to nuclear and nucleon substructures - to the quarks.

**Brief outline of the course:**
1. Basic building blocks of matter, interactions, symmetries and conservation laws, experiments and units.
2. Scattering processes: elastic and inelastic scattering, Cross section, Fermis „Golden Rule“, Feynman diagrams.
3. Geometric shapes of nuclei: Kinematics of electron scattering, The Rutherford cross section.
4. Mott cross section, Nuclear form factors.
5. Elastic scattering off nucleons: form factor of the nucleons.
6. Quasi-elastic scattering.
7. Deep-inelastic scattering: excited states of nucleons, structure functions, Callan-Gross relation, scale invariance.
8. Parton model, interpretation of structure functions in the Parton model.

9. Quarks, gluons and strong interaction: the quark structure of nucleons, quarks in hadrons, quark-gluon interaction, Scaling violation of the structure functions.
10. Particle production in electron - positron collisions: production of lepton pairs, resonances, non-resonant hadron production, gluon emission.
11. The Mesons: mesonic multiplets, meson masses, decay channels, neutral kaon decay.
12. The Baryons: Production and detection of baryons, baryon multiplets, masses, magnetic moments, decay channels.

**Recommended literature:**
Perkins D.H.: Introduction to high energy physics, Cambridge, 2000.
Martin B., Shaw G.: Particle Physics, Wiley, 2008.
Martin B.R.: Nuclear and Particle Physics, Wiley, 2006.
Povh, Rith, Scholz, Zetsche: Particles and Nuclei, An Introduction to the Physical Concepts, Berlin, 1993.
Ryder L.H.: Elementary particles and symmetries, Routledge, 1975.

**Course language:**
slovak and english

**Notes:**

**Course assessment**
Total number of assessed students: 21

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 61.9 | 19.05 | 9.52 | 4.76 | 4.76 | 0.0 |

**Provides:** doc. RNDr. Adela Kravčáková, PhD.

**Date of last modification:** 16.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

# COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| | |
|---|---|
| **Course ID:** KF/ FIVYC/22 | **Course name:** Selected Topics in Philosophy of Education (General Introduction) |

**Course type, scope and the method:**
**Course type:** Lecture / Practice
**Recommended course-load (hours):**
**Per week:** 1 / 1 **Per study period:** 14 / 14
**Course method:** present

**Number of ECTS credits:** 2

**Recommended semester/trimester of the course:**

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**

**Learning outcomes:**

**Brief outline of the course:**

**Recommended literature:**

**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 2

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Provides:** PhDr. Dušan Hruška, PhD.

**Date of last modification:** 27.04.2022

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ VTFTL/20 | **Course name:** Selected Topics in Solid State Physics: Computational Physics Applications |
| **Course type, scope and the method:**<br>**Course type:** Lecture / Practice<br>**Recommended course-load (hours):**<br>**Per week:** 2 / 1 **Per study period:** 28 / 14<br>**Course method:** present | |
| **Number of ECTS credits:** 5 | |
| **Recommended semester/trimester of the course:** 1., 3. | |
| **Course level:** II. | |
| **Prerequisities:** ÚFV/TKL1/99 | |
| **Conditions for course completion:** | |
| **Learning outcomes:** | |
| **Brief outline of the course:** | |
| **Recommended literature:** | |
| **Course language:** | |
| **Notes:** | |
| **Course assessment**<br>Total number of assessed students: 8 | |

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 50.0 | 25.0 | 12.5 | 12.5 | 0.0 | 0.0 |

| | |
|---|---|
| **Provides:** RNDr. Martin Gmitra, PhD. | |
| **Date of last modification:** 03.10.2021 | |
| **Approved:** prof. RNDr. Michal Jaščur, CSc. | |

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ SPTFAa/14 | **Course name:** Semestral Work I |
| **Course type, scope and the method:**<br>**Course type:**<br>**Recommended course-load (hours):**<br>**Per week: Per study period:**<br>**Course method:** present | |
| **Number of ECTS credits:** 2 | |
| **Recommended semester/trimester of the course:** 1. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>To successfully complete the course, the student must demonstrate mastery of the assigned tasks set by the project leader at the beginning of the semester to the required extent and level. Specific study and research assignments are formulated at the beginning of the semester by the project leader, who is usually the supervisor of the final thesis. Tasks include, for example, studying literature in a selected field of theoretical physics, astrophysics or astronomy, mastering the theoretical, computer and experimental methods and procedures needed to solve specific research problems, mastering the operation of experimental equipment, obtaining original scientific data and their processing, interpretation and eventual presentation within a joint seminar. Credit evaluation reflects the student's workload when working on a semester project in the range of 50 hours per semester. Individual activities of the student are evaluated by the project leader and the overall work of the student is evaluated on a scale of 0-100 points. The minimum limit for obtaining the evaluation is 50% of the evaluation scale, which is determined as follows: A 100-91% B 90-81% C 80-71% D 70-61% E 60-50% Fx 49-0% . | |
| **Learning outcomes:**<br>By completing the course the student will master the experimental and theoretical methods necessary for the study of scientific research issues according to the assignment of the final thesis. The student will gain skills and experience with independent acquisition and processing of original scientific results necessary for the final thesis. | |
| **Brief outline of the course:**<br>The program for the semester project is prepared for each student individually by the project leader at the beginning of each semester. The program can be focused on the study of literature for the field of research, preparation and implementation of experimental measurements, study of the necessary mathematical apparatus and methods of theoretical physics, creation of software for collection, processing, evaluation and interpretation of scientific data and presentation of results at the department seminar. The specific content of the project for each semester is determined by the project leader. | |
| **Recommended literature:**<br>Scientific articles and other literary sources according to the assignment of the final master's thesis. | |

**Course language:**
slovak, english

**Notes:**

**Course assessment**
Total number of assessed students: 42

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 85.71 | 9.52 | 0.0 | 0.0 | 4.76 | 0.0 |

**Provides:**

**Date of last modification:** 26.12.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ SPTFAb/14 | **Course name:** Semestral Work II |
| **Course type, scope and the method:**<br>**Course type:**<br>**Recommended course-load (hours):**<br>**Per week: Per study period:**<br>**Course method:** present | |
| **Number of ECTS credits:** 4 | |
| **Recommended semester/trimester of the course:** 2. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>To successfully complete the course, the student must demonstrate mastery of the assigned tasks set by the project leader at the beginning of the semester to the required extent and level. Specific study and research assignments are formulated at the beginning of the semester by the project leader, who is usually the supervisor of the final thesis. Tasks include, for example, studying literature in a selected field of theoretical physics, astrophysics or astronomy, mastering the theoretical, computer and experimental methods and procedures needed to solve specific research problems, mastering the operation of experimental equipment, obtaining original scientific data and their processing, interpretation and eventual presentation within a joint seminar. Credit evaluation reflects the student's workload when working on a semester project in the range of 100 hours per semester. Individual activities of the student are evaluated by the project leader and the overall work of the student is evaluated on a scale of 0-100 points. The minimum limit for obtaining the evaluation is 50% of the evaluation scale, which is determined as follows: A 100-91% B 90-81% C 80-71% D 70-61% E 60-50% Fx 49-0%. | |
| **Learning outcomes:**<br>By completing the course the student will master the experimental and theoretical methods necessary for the study of scientific research issues according to the assignment of the final thesis. The student will gain skills and experience with independent acquisition and processing of original scientific results necessary for the final thesis. | |
| **Brief outline of the course:**<br>The program for the semester project is prepared for each student individually by the project leader at the beginning of each semester. The program can be focused on the study of literature for the field of research, preparation and implementation of experimental measurements, study of the necessary mathematical apparatus and methods of theoretical physics, creation of software for collection, processing, evaluation and interpretation of scientific data and presentation of results at the department seminar. The specific content of the project for each semester is determined by the project leader. | |
| **Recommended literature:**<br>Scientific articles and other literary sources according to the assignment of the final master's thesis. | |

**Course language:**
slovak, english

**Notes:**

**Course assessment**
Total number of assessed students: 40

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 85.0 | 10.0 | 0.0 | 0.0 | 5.0 | 0.0 |

**Provides:**

**Date of last modification:** 26.12.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ SPTFAc/14 | **Course name:** Semestral Work III |
|---|---|

**Course type, scope and the method:**
**Course type:**
**Recommended course-load (hours):**
**Per week:** **Per study period:**
**Course method:** present

**Number of ECTS credits:** 4

**Recommended semester/trimester of the course:** 3.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
To successfully complete the course, the student must demonstrate mastery of the assigned tasks set by the project leader at the beginning of the semester to the required extent and level. Specific study and research assignments are formulated at the beginning of the semester by the project leader, who is usually the supervisor of the final thesis. Tasks include, for example, studying literature in a selected field of theoretical physics, astrophysics or astronomy, mastering the theoretical, computer and experimental methods and procedures needed to solve specific research problems, mastering the operation of experimental equipment, obtaining original scientific data and their processing, interpretation and eventual presentation within a joint seminar. Credit evaluation reflects the student's workload when working on a semester project in the range of 100 hours per semester. Individual activities of the student are evaluated by the project leader and the overall work of the student is evaluated on a scale of 0-100 points. The minimum limit for obtaining the evaluation is 50% of the evaluation scale, which is determined as follows: A 100-91% B 90-81% C 80-71% D 70-61% E 60-50% Fx 49-0%.

**Learning outcomes:**
By completing the course the student will master the experimental and theoretical methods necessary for the study of scientific research issues according to the assignment of the final thesis. The student will gain skills and experience with independent acquisition and processing of original scientific results necessary for the final thesis.

**Brief outline of the course:**
The program for the semester project is prepared for each student individually by the project leader at the beginning of each semester. The program can be focused on the study of literature for the field of research, preparation and implementation of experimental measurements, study of the necessary mathematical apparatus and methods of theoretical physics, creation of software for collection, processing, evaluation and interpretation of scientific data and presentation of results at the department seminar. The specific content of the project for each semester is determined by the project leader.

**Recommended literature:**
Scientific articles and other literary sources according to the assignment of the final master's thesis.

**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 34

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 82.35 | 5.88 | 11.76 | 0.0 | 0.0 | 0.0 |

**Provides:**

**Date of last modification:** 26.12.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/SPJFa/14 | **Course name:** Semestral project I |
|---|---|

**Course type, scope and the method:**
**Course type:**
**Recommended course-load (hours):**
**Per week:** **Per study period:**
**Course method:** present

**Number of ECTS credits:** 2

**Recommended semester/trimester of the course:** 1.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
Successful solution of tasks given by the supervisor and presentation of the achieved results orally or in written form.

**Learning outcomes:**
Diploma thesis serves as a confirmation of theory and terminology understanding, application of standard scientific methods and the gained knowledge and skills level. It is a proof of independent work in the field.

**Brief outline of the course:**
The subject is usually realised via individual consultations of student with his/her supervisor. The contents of the consultations depends on the diploma thesis subject.

**Recommended literature:**
KATUŠČÁK, Dušan: Ako písať vysokoškolské a kvalifikačné práce : Ako písať seminárne a ročníkové práce, práce študentskej vedeckej a odbornej činnosti, diplomové, záverečné a atestačné práce a dizertácie. 2. doplnené vyd. Bratislava: Stimul, 1998.
ČMEJRKOVÁ, Světla - DANEŠ, František - SVĚTLÁ, Jindra: Jak napsat odborný text. Praha : Leda, 1999.
BARTOŠ, Josef: Metodika diplomové práce. Olomouc : FF Univerzity Palackého, 1991.
MEŠKO, Dušan - KATUŠČÁK, Dušan a kol.: Akademická príručka. Martin : Osveta, 2004.
ŠANDEROVÁ, Jadwiga: Jak číst a psát odborný text ve společenských vědách : Několik zásad pro začátečníky. Praha : Slon, 2005.

**Course language:**
slovak and english

**Notes:**

**Course assessment**
Total number of assessed students: 14

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 85.71 | 7.14 | 0.0 | 0.0 | 7.14 | 0.0 |

| |
|---|
| **Provides:** |
| **Date of last modification:** 15.12.2021 |
| **Approved:** prof. RNDr. Michal Jaščur, CSc. |

# COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/SPJFb/14 | **Course name:** Semestral project II |
| **Course type, scope and the method:**<br>**Course type:**<br>**Recommended course-load (hours):**<br>**Per week: Per study period:**<br>**Course method:** present | |
| **Number of ECTS credits:** 6 | |
| **Recommended semester/trimester of the course:** 2. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>Successful solution of tasks given by the supervisor and presentation of the achieved results orally or in written form. | |
| **Learning outcomes:**<br>Diploma thesis serves as a confirmation of theory and terminology understanding, application of standard scientific methods and the gained knowledge and skills level. It is a proof of independent work in the field. | |
| **Brief outline of the course:**<br>The subject is usually realised via individual consultations of student with his/her supervisor. The contents of the consultations depends on the diploma thesis subject. | |
| **Recommended literature:**<br>KATUŠČÁK, Dušan: Ako písať vysokoškolské a kvalifikačné práce : Ako písať seminárne a ročníkové práce, práce študentskej vedeckej a odbornej činnosti, diplomové, záverečné a atestačné práce a dizertácie. 2. doplnené vyd. Bratislava: Stimul, 1998. ČMEJRKOVÁ, Světla - DANEŠ, František - SVĚTLÁ, Jindra: Jak napsat odborný text. Praha : Leda, 1999. BARTOŠ, Josef: Metodika diplomové práce. Olomouc : FF Univerzity Palackého, 1991. MEŠKO, Dušan - KATUŠČÁK, Dušan a kol.: Akademická príručka. Martin : Osveta, 2004. ŠANDEROVÁ, Jadwiga: Jak číst a psát odborný text ve společenských vědách : Několik zásad pro začátečníky. Praha : Slon, 2005. | |
| **Course language:**<br>slovak and english | |
| **Notes:** | |
| **Course assessment**<br>Total number of assessed students: 13 | |

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 84.62 | 0.0 | 7.69 | 0.0 | 7.69 | 0.0 |

**Provides:**

| |
|---|
| **Date of last modification:** 15.12.2021 |
| **Approved:** prof. RNDr. Michal Jaščur, CSc. |

# COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| | |
|---|---|
| **Course ID:** ÚFV/ SPJFc/14 | **Course name:** Semestral project III |

**Course type, scope and the method:**
**Course type:**
**Recommended course-load (hours):**
**Per week: Per study period:**
**Course method:** present

**Number of ECTS credits:** 6

**Recommended semester/trimester of the course:** 3.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
Successful solution of tasks given by the supervisor and presentation of the achieved results orally or in written form.

**Learning outcomes:**
To learn the basic problems and methods of data processing and data analysis in the nuclear and subnuclear physics.

**Brief outline of the course:**
To solve selected problems from nuclear and subnuclear physics.

**Recommended literature:**
As recommended by the supervisor.

**Course language:**
slovak and english

**Notes:**

**Course assessment**
Total number of assessed students: 13

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 69.23 | 15.38 | 7.69 | 0.0 | 7.69 | 0.0 |

**Provides:**

**Date of last modification:** 03.05.2015

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ SPTFAd/22 | **Course name:** Semestrálna práca IV |
| **Course type, scope and the method:**<br>**Course type:**<br>**Recommended course-load (hours):**<br>**Per week: Per study period:**<br>**Course method:** present | |
| **Number of ECTS credits:** 6 | |
| **Recommended semester/trimester of the course:** 4. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>The conditions for completing the course are as follows:<br>Independent study of recommended literature from a selected field of theoretical physics, astrophysics or astronomy. Content and methodical mastery of the studied issues. Independent creative scientific work on the assigned issue and synthesis of scientific results achieved throughout the study. Writing the final master's thesis. Credit evaluation reflects the student's workload when working on a semester project in the range of 150 hours per semester. Individual activities of the student are evaluated by the project leader and the overall work of the student is evaluated on a scale of 0-100 points. The minimum threshold for obtaining a rating is 50% of the rating scale, which is determined as follows: A 100-91% B 90-81% C 80-71% D 70-61% E 60-50% Fx 49-0%. | |
| **Learning outcomes:**<br>By completing the course the student will master the experimental and theoretical methods necessary for the study of scientific research issues according to the assignment of the final thesis. The student obtains the original scientific results, which he is obliged to present at the student scientific conference or at the seminar of the training workplace. The student must also master the relevant computer programs and applications necessary for writing and graphic processing of the master's thesis. | |
| **Brief outline of the course:**<br>Independent study of scientific literature and consultation of selected problems with the supervisor of the master's thesis. Research work focused on further creative elaboration of the results of the master's thesis achieved by the students of the previous semesters of study. Processing the achieved results and writing the work in the required scope and quality. | |
| **Recommended literature:**<br>Scientific publications and other literary and electronic resources according to the assignment of the final master's thesis. | |
| **Course language:**<br>slovak, english | |
| **Notes:** | |

**Course assessment**
Total number of assessed students: 4

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Provides:**

**Date of last modification:** 26.12.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

# COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ SEB1/04 | **Course name:** Seminar from Nuclear Physics |
| **Course type, scope and the method:**<br>**Course type:** Practice<br>**Recommended course-load (hours):**<br>**Per week:** 1 **Per study period:** 14<br>**Course method:** present | |
| **Number of ECTS credits:** 1 | |
| **Recommended semester/trimester of the course:** 1. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:** | |
| **Learning outcomes:**<br>To bring the topical problems, methodics and tools of high energy physics to the students. | |
| **Brief outline of the course:**<br>Department seminar - selected topical problems of the nuclear and subnuclear physics. | |
| **Recommended literature:** | |
| **Course language:**<br>Slovak and English | |
| **Notes:** | |
| **Course assessment**<br>Total number of assessed students: 21 | |

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| | |
|---|---|
| **Provides:** doc. RNDr. Janka Vrláková, PhD. | |
| **Date of last modification:** 22.11.2021 | |
| **Approved:** prof. RNDr. Michal Jaščur, CSc. | |

## COURSE INFORMATION LETTER

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|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ SEC1/04 | **Course name:** Seminar from Nuclear Physics |
| **Course type, scope and the method:**<br>**Course type:** Practice<br>**Recommended course-load (hours):**<br>**Per week:** 1 **Per study period:** 14<br>**Course method:** present | |
| **Number of ECTS credits:** 1 | |
| **Recommended semester/trimester of the course:** 2. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>Active participation in seminars, presentation at a seminar. The credit evaluation of the course takes into account the following student workload: practical activity - preparation of the contribution and its presentation in English (1credit). | |
| **Learning outcomes:**<br>To bring the topical problems, methodics and tools of high energy physics to the students. | |
| **Brief outline of the course:**<br>Department seminar - selected topical problems of the nuclear and subnuclear physics. | |
| **Recommended literature:** | |
| **Course language:**<br>Slovak and English | |
| **Notes:** | |
| **Course assessment**<br>Total number of assessed students: 18 | |

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| | |
|---|---|
| **Provides:** doc. RNDr. Janka Vrláková, PhD. | |
| **Date of last modification:** 22.11.2021 | |
| **Approved:** prof. RNDr. Michal Jaščur, CSc. | |

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ SED1/04 | **Course name:** Seminar from Nuclear Physics |
|---|---|

**Course type, scope and the method:**
**Course type:** Practice
**Recommended course-load (hours):**
**Per week:** 1 **Per study period:** 14
**Course method:** present

**Number of ECTS credits:** 1

**Recommended semester/trimester of the course:** 3.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**

**Learning outcomes:**
To bring the topical problems, methodics and tools of high energy physics to the students.

**Brief outline of the course:**
Department seminar - selected topical problems of the nuclear and subnuclear physics.

**Recommended literature:**

**Course language:**
Slovak and English

**Notes:**

**Course assessment**
Total number of assessed students: 17

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 88.24 | 5.88 | 5.88 | 0.0 | 0.0 | 0.0 |

**Provides:** doc. RNDr. Janka Vrláková, PhD.

**Date of last modification:** 22.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ FSL1/13 | **Course name:** Solar Physics |
|---|---|

**Course type, scope and the method:**
**Course type:** Lecture
**Recommended course-load (hours):**
**Per week:** 4 **Per study period:** 56
**Course method:** present

**Number of ECTS credits:** 6

**Recommended semester/trimester of the course:** 2.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
To successfully complete the course, the student must demonstrate sufficient understanding of the physical processes that take place in the Sun, from its core to its surface. In addition to direct participation in teaching, the student's independent work is also required within the self-study of professional topics assigned by the teacher. In order to obtain an evaluation and thus also credits, they must pass an oral final exam. Credit evaluation of the course takes into account the following student workload: direct teaching (2 credits), self-study (2 credits), individual consultations (1 credit), and exam (1 credit).
Rating scale: A (90-100%), B (80-89%), C (70-79%), D (60-69%), E (50-59%), F (0-49%) .

**Learning outcomes:**
After completing the lectures and on the basis of the final evaluation, the student will prove adequate mastery of the content standard of the subject, which is defined by a brief syllabus subject and recommended literature. Mastering the content of the subject allows him to understand the physical processes taking place in the Sun, from its deepest central regions to the visible surface and solar atmosphere. The student will get acquainted with the cycle of solar activity, its manifestations in the interplanetary environment, and influences on the Earth (so-called solar-earth relations).

**Brief outline of the course:**
The time schedule of the course content is updated in the electronic bulletin board of the course.
1 Introductory definitions and assumptions, basic physical facts about the Sun,
2. Internal structure of the Sun, energy production, the problem of solar neutrinos,
3. Energy transfer by radiation and convection,
4. Helioseismology,
5. Solar atmosphere, photosphere radiation and structures in the photosphere,
6. Chromosphere, transition region and corona,
7. Optically thin radiation, solar flares, coronal mass ejections,
8. Magnetic fields in the atmosphere of the Sun, measuring the magnitude of magnetic induction, Stokes parameters,
9. Basic magneto-hydrodynamic equations,
10. Dynamics of the Sun, differential rotation and its description,

11. Standard model of the Sun, solar activity and its cycle,
12. Solar wind, solar-earth relations, space weather.

**Recommended literature:**

H. Zirin: Astrophysics of the Sun, Cambridge Univ. Press, Cambridge, 1988.
M. Stix: The Sun, An Introduction, Springer, 2nd edition, 2002.
E. R. Priest: Solar Magnetohydrodynamics, Reidel, 1982.
K. R. Lang: The Sun from Space, Springer, 2000.
Physics of the Sun I. II. III. Geophysics and Astrophysics Monorgaphs, eds: P.A. Sturrock, T. E. Holzer, D.M. Mihalas, R.K. Ulrich, Riedel Publ. Dodrecht 1968.

**Course language:**
Slovak, basic English

**Notes:**

**Course assessment**
Total number of assessed students: 16

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 62.5 | 6.25 | 31.25 | 0.0 | 0.0 | 0.0 |

**Provides:** Mgr. Peter Gömöry, PhD.

**Date of last modification:** 22.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

**COURSE INFORMATION LETTER**

| **University:** P. J. Šafárik University in Košice | |
|---|---|
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ SPJ1/99 | **Course name:** Special Practice from Nuclear Physics |
| **Course type, scope and the method:**<br>**Course type:** Practice<br>**Recommended course-load (hours):**<br>**Per week:** 3 **Per study period:** 42<br>**Course method:** present | |
| **Number of ECTS credits:** 3 | |
| **Recommended semester/trimester of the course:** 2. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>Written tests, measurements of experimental tasks, written reports of tasks.<br>Credit evaluation of the course: practical activities - measurements of experimental task, reports (2credits), evaluation (1credit), total 3credits. Minimum limit for completion of the course is to obtain at least 51% of the total evaluation. | |
| **Learning outcomes:**<br>Practice in nuclear physics – quantitative and qualitative analysis, selected detector methods and tasks. | |
| **Brief outline of the course:**<br>1. Introduction to practice.<br>2. MEDIPIX - study of alpha and beta particles.<br>3. MEDIPIX - visualization of particle tracks.<br>4. MEDIPIX - detection of cosmic ray muons.<br>5. MEDIPIX - radiography.<br>6. Identification of an unknown gamma emitter, determination of activity.<br>7. Identification of an unknown beta emitter.<br>8. Short-lived radioisiotopes.<br>9.-10. Atom structure, atomic spectra, Frank-Hertz experiment.<br>11. Study of gamma radiation.<br>12. Study of beta radiation.<br>13. Study of alpha spectra. | |
| **Recommended literature:**<br>1. J.Vrláková, S.Vokál: Základné fyzikálne praktikum, skriptá PF UPJŠ, Košice, 2012, dostupné na : http://www.upjs.sk/public/media/5596/Zakladne-fyzikalne-praktikum-III.pdf<br>2. W.R.Leo: Techniques for Nuclear and Particles Physics Experiments, Springer-Verlag,1994<br>3. V.Vícha: Experimenty s pixelovým detektorem pro výuku jaderné a částicové fyziky, ČVUT, Praha, 2016 | |
| **Course language:**<br>slovak | |

**Notes:**

**Course assessment**
Total number of assessed students: 17

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 88.24 | 11.76 | 0.0 | 0.0 | 0.0 | 0.0 |

**Provides:** doc. RNDr. Janka Vrláková, PhD., RNDr. Zuzana Paulínyová, PhD.

**Date of last modification:** 22.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ SSA/13 | **Course name:** Special Seminar in Astronomy |
| **Course type, scope and the method:**<br>**Course type:** Practice<br>**Recommended course-load (hours):**<br>**Per week:** 3 **Per study period:** 42<br>**Course method:** present | |
| **Number of ECTS credits:** 3 | |
| **Recommended semester/trimester of the course:** 2. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>To successfully complete the course, the student must demonstrate an overview of the latest results of astrophysical research in fields such as extrasolar planets, cataclysmic variable stars, quasars, dark matter and more. The condition for obtaining credits is the preparation and presentation of the semester essay. The credit evaluation of the course considers the following student workload: direct teaching (1 credit), self-study (1 credits) and exam (1 credit). The minimum limit for completing the course is to obtain at least 50% of the total score. | |
| **Learning outcomes:**<br>After completing the course, the student will have an overview of the latest results of astrophysical research in areas such as extrasolar planets, cataclysmic variable stars, quasars, dark matter and more. He will also have sufficient physical knowledge and mathematical apparatus to enable independent solution of a wide range of astrophysical problems. | |
| **Brief outline of the course:**<br>1. Extrasolar planets: history of exoplanet discoveries, definitions of planets, exoplanets, dwarf planets, small bodies of the Solar system.<br>2. Methods of exoplanet detection: radial velocities, planetary transits.<br>3. Other methods of exoplanet detection: timing, microlensing, imaging, astrometry.<br>4. Properties of exoplanets, equations of internal structure, atmosphere of exoplanets, classification of exoplanets.<br>5. Brown dwarfs: history of brown dwarf discoveries, spectral classification (M, L, T, Y), definitions.<br>6. Observations, properties, interior and atmosphere of brown dwarfs, formation, and evolution of brown dwarfs.<br>7. Cataclysmic variable stars: mass transfer in binary systems, accretion disks.<br>8. Polars and intermediate polars, novae and supernovae.<br>9. High energy astrophysics: physical processes leading to the production of X-rays and gamma rays.<br>10. X-ray binary stars, active galactic nuclei, quasars and blazars, X-rays of the cosmic background.<br>11. Structure and distribution of matter in the universe, the origin of elements in the universe.<br>12. Dark matter, dark energy, antimatter, WIMP particles. | |

**Recommended literature:**
Current articles in astronomical and astrophysical journals, internet.

**Course language:**
Slovak, English

**Notes:**

**Course assessment**
Total number of assessed students: 14

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Provides:** doc. RNDr. Rudolf Gális, PhD., doc. Mgr. Štefan Parimucha, PhD.

**Date of last modification:** 22.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| | |
|---|---|
| **Course ID:** ÚFV/ TRS/03 | **Course name:** Special Theory of Relativity |

**Course type, scope and the method:**
**Course type:** Lecture / Practice
**Recommended course-load (hours):**
**Per week:** 2 / 1 **Per study period:** 28 / 14
**Course method:** present

**Number of ECTS credits:** 4

**Recommended semester/trimester of the course:** 1.

**Course level:** I., II.

**Prerequisities:** ÚFV/TEP1/03

**Conditions for course completion:**

**Learning outcomes:**

**Brief outline of the course:**

**Recommended literature:**

**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 187

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 49.73 | 20.86 | 15.51 | 8.02 | 5.88 | 0.0 |

**Provides:** RNDr. Tomáš Lučivjanský, PhD., univerzitný docent

**Date of last modification:** 06.03.2025

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚTVŠ/ TVa/11 | **Course name:** Sports Activities I. |
| **Course type, scope and the method:**<br>**Course type:** Practice<br>**Recommended course-load (hours):**<br>**Per week:** 2 **Per study period:** 28<br>**Course method:** present | |
| **Number of ECTS credits:** 2 | |
| **Recommended semester/trimester of the course:** 1. | |
| **Course level:** I., II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>Min. 80% of active participation in classes. | |
| **Learning outcomes:**<br>Sports activities in all their forms prepare university students for their professional and personal life. They have a great impact on physical fitness and performance. Specialization in sports activities enables students to strengthen their relationship towards the selected sport in which they also improve. | |
| **Brief outline of the course:**<br>Brief outline of the course:<br>The Institute of physical education and sport at the Pavol Jozef Šafárik University offers 20 sports activities aerobics; aikido, basketball, badminton, body-balance, body form, bouldering, floorball, yoga, power yoga, pilates, swimming, fitness, indoor football, SM system, step aerobics, table tennis, chess, volleyball, tabata, cycling.<br>Additionally, the Institute of physical education and sport at the Pavol Jozef Šafárik University offers winter courses (ski course, survival) and summer courses (aerobics by the sea, rafting on the Tisza River) with an attractive programme, sports competitions with national and international participation. | |
| **Recommended literature:**<br>BENCE, M. et al. 2005. Plávanie. Banská Bystrica: FHV UMB. 198s. ISBN 80-8083-140-8. [online] Dostupné na: https://www.ff.umb.sk/app/cmsFile.php?disposition=a&ID=571<br>BUZKOVÁ, K. 2006. Fitness jóga, harmonické cvičení těla I duše. Praha: Grada. ISBN 8024715252.<br>JARKOVSKÁ, H, JARKOVSKÁ, M. 2005. Posilování s vlastním tělem 417 krát jinak. Praha: Grada. ISBN 9788024757308.<br>KAČÁNI, L. 2002. Futbal:Tréning hrou. Bratislava: Peter Mačura – PEEM. 278s. ISBN 8089197027.<br>KRESTA, J. 2009. Futsal.Praha: Grada Publishing, a.s. 112s. ISBN 9788024725345.<br>LAWRENCE, G. 2019. Power jóga nejen pro sportovce. Brno: CPress. ISBN 9788026427902.<br>SNER, Wolfgang. 2004. Posilování ve fitness. České Budějovice: Kopp. ISBN 8072322141. | |

STACKEOVÁ, D. 2014. Fitness programy z pohledu kinantropologie. Praha: Galén. ISBN 9788074921155.
VOMÁČKO, S. BOŠTÍKOVÁ, S. 2003. Lezení na umělých stěnách. Praha: Grada. 129s. ISBN 8024721743.

**Course language:**
Slovak language

**Notes:**

**Course assessment**
Total number of assessed students: 15781

| abs | abs-A | abs-B | abs-C | abs-D | abs-E | n | neabs |
|---|---|---|---|---|---|---|---|
| 85.74 | 0.06 | 0.0 | 0.0 | 0.0 | 0.04 | 9.0 | 5.15 |

**Provides:** Mgr. Patrik Berta, Mgr. Agata Dorota Horbacz, PhD., Mgr. Dávid Kaško, PhD., Mgr. Ladislav Kručanica, PhD., Mgr. Richard Melichar, Mgr. Petra Tomková, PhD., Mgr. Marcel Čurgali, Mgr. Alena Buková, PhD., univerzitná docentka, doc. PaedDr. Ivan Uher, MPH, PhD., prof. RNDr. Stanislav Vokál, DrSc., Mgr. Zuzana Küchelová, PhD., Mgr. Ferdinand Salonna, PhD.

**Date of last modification:** 07.02.2024

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚTVŠ/TVb/11 | **Course name:** Sports Activities II. |
|---|---|

**Course type, scope and the method:**
**Course type:** Practice
**Recommended course-load (hours):**
**Per week:** 2 **Per study period:** 28
**Course method:** present

**Number of ECTS credits:** 2

**Recommended semester/trimester of the course:** 2.

**Course level:** I., II.

**Prerequisities:**

**Conditions for course completion:**
active participation in classes - min. 80%.

**Learning outcomes:**
Sports activities in all their forms prepare university students for their professional and personal life. They have a great impact on physical fitness and performance. Specialization in sports activities enables students to strengthen their relationship towards the selected sport in which they also improve.

**Brief outline of the course:**
Brief outline of the course:
The Institute of physical education and sport at the Pavol Jozef Šafárik University offers 20 sports activities aerobics; aikido, basketball, badminton, body-balance, body form, bouldering, floorball, yoga, power yoga, pilates, swimming, fitness, indoor football, SM system, step aerobics, table tennis, chess, volleyball, tabata, cycling.
Additionally, the Institute of physical education and sport at the Pavol Jozef Šafárik University offers winter courses (ski course, survival) and summer courses (aerobics by the sea, rafting on the Tisza River) with an attractive programme, sports competitions with national and international participation.

**Recommended literature:**

BENCE, M. et al. 2005. Plávanie. Banská Bystrica: FHV UMB. 198s. ISBN 80-8083-140-8. [online] Dostupné na: https://www.ff.umb.sk/app/cmsFile.php?disposition=a&ID=571
BUZKOVÁ, K. 2006. Fitness jóga, harmonické cvičení těla I duše. Praha: Grada. ISBN 8024715252.
JARKOVSKÁ, H, JARKOVSKÁ, M. 2005. Posilování s vlastním tělem 417 krát jinak. Praha: Grada. ISBN 9788024757308.
KAČÁNI, L. 2002. Futbal:Tréning hrou. Bratislava: Peter Mačura – PEEM. 278s. ISBN 8089197027.
KRESTA, J. 2009. Futsal.Praha: Grada Publishing, a.s. 112s. ISBN 9788024725345.
LAWRENCE, G. 2019. Power jóga nejen pro sportovce. Brno: CPress. ISBN 9788026427902.
SNER, Wolfgang. 2004. Posilování ve fitness. České Budějovice: Kopp. ISBN 8072322141.

STACKEOVÁ, D. 2014. Fitness programy z pohledu kinantropologie. Praha: Galén. ISBN 9788074921155.
VOMÁČKO, S. BOŠTÍKOVÁ, S. 2003. Lezení na umělých stěnách. Praha: Grada. 129s. ISBN 8024721743.

**Course language:**
Slovak language

**Notes:**

**Course assessment**
Total number of assessed students: 13799

| abs | abs-A | abs-B | abs-C | abs-D | abs-E | n | neabs |
|---|---|---|---|---|---|---|---|
| 83.85 | 0.49 | 0.01 | 0.0 | 0.0 | 0.04 | 11.17 | 4.43 |

**Provides:** Mgr. Agata Dorota Horbacz, PhD., Mgr. Dávid Kaško, PhD., Mgr. Marcel Čurgali, Mgr. Patrik Berta, Mgr. Ladislav Kručanica, PhD., Mgr. Richard Melichar, Mgr. Petra Tomková, PhD., Mgr. Alena Buková, PhD., univerzitná docentka, doc. PaedDr. Ivan Uher, MPH, PhD., prof. RNDr. Stanislav Vokál, DrSc., Mgr. Zuzana Küchelová, PhD., Mgr. Ferdinand Salonna, PhD.

**Date of last modification:** 07.02.2024

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| | |
|---|---|
| **Course ID:** ÚTVŠ/ TVc/11 | **Course name:** Sports Activities III. |

**Course type, scope and the method:**
**Course type:** Practice
**Recommended course-load (hours):**
**Per week:** 2 **Per study period:** 28
**Course method:** present

**Number of ECTS credits:** 2

**Recommended semester/trimester of the course:** 3.

**Course level:** I., II.

**Prerequisities:**

**Conditions for course completion:**
min. 80% of active participation in classes

**Learning outcomes:**
Sports activities in all their forms prepare university students for their professional and personal life. They have a great impact on physical fitness and performance. Specialization in sports activities enables students to strengthen their relationship towards the selected sport in which they also improve.

**Brief outline of the course:**
Brief outline of the course:
The Institute of physical education and sport at the Pavol Jozef Šafárik University offers 20 sports activities aerobics; aikido, basketball, badminton, body-balance, body form, bouldering, floorball, yoga, power yoga, pilates, swimming, fitness, indoor football, SM system, step aerobics, table tennis, chess, volleyball, tabata, cycling.
Additionally, the Institute of physical education and sport at the Pavol Jozef Šafárik University offers winter courses (ski course, survival) and summer courses (aerobics by the sea, rafting on the Tisza River) with an attractive programme, sports competitions with national and international participation.

**Recommended literature:**
BENCE, M. et al. 2005. Plávanie. Banská Bystrica: FHV UMB. 198s. ISBN 80-8083-140-8. [online] Dostupné na: https://www.ff.umb.sk/app/cmsFile.php?disposition=a&ID=571
BUZKOVÁ, K. 2006. Fitness jóga, harmonické cvičení těla I duše. Praha: Grada. ISBN 8024715252.
JARKOVSKÁ, H, JARKOVSKÁ, M. 2005. Posilování s vlastním tělem 417 krát jinak. Praha: Grada. ISBN 9788024757308.
KAČÁNI, L. 2002. Futbal:Tréning hrou. Bratislava: Peter Mačura – PEEM. 278s. ISBN 8089197027.
KRESTA, J. 2009. Futsal.Praha: Grada Publishing, a.s. 112s. ISBN 9788024725345.
LAWRENCE, G. 2019. Power jóga nejen pro sportovce. Brno: CPress. ISBN 9788026427902.
SNER, Wolfgang. 2004. Posilování ve fitness. České Budějovice: Kopp. ISBN 8072322141.

STACKEOVÁ, D. 2014. Fitness programy z pohledu kinantropologie. Praha: Galén. ISBN 9788074921155.
VOMÁČKO, S. BOŠTÍKOVÁ, S. 2003. Lezení na umělých stěnách. Praha: Grada. 129s. ISBN 8024721743.

**Course language:**
Slovak language

**Notes:**

**Course assessment**
Total number of assessed students: 9334

| abs | abs-A | abs-B | abs-C | abs-D | abs-E | n | neabs |
|---|---|---|---|---|---|---|---|
| 87.96 | 0.06 | 0.01 | 0.0 | 0.0 | 0.02 | 4.92 | 7.03 |

**Provides:** Mgr. Marcel Čurgali, Mgr. Agata Dorota Horbacz, PhD., Mgr. Dávid Kaško, PhD., Mgr. Patrik Berta, Mgr. Ladislav Kručanica, PhD., Mgr. Richard Melichar, Mgr. Petra Tomková, PhD., Mgr. Alena Buková, PhD., univerzitná docentka, doc. PaedDr. Ivan Uher, MPH, PhD., prof. RNDr. Stanislav Vokál, DrSc., Mgr. Zuzana Küchelová, PhD., Mgr. Ferdinand Salonna, PhD.

**Date of last modification:** 07.02.2024

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚTVŠ/ TVd/11 | **Course name:** Sports Activities IV. |
|---|---|

**Course type, scope and the method:**
**Course type:** Practice
**Recommended course-load (hours):**
**Per week:** 2 **Per study period:** 28
**Course method:** present

**Number of ECTS credits:** 2

**Recommended semester/trimester of the course:** 4.

**Course level:** I., II.

**Prerequisities:**

**Conditions for course completion:**
min. 80% of active participation in classes

**Learning outcomes:**
Sports activities in all their forms prepare university students for their professional and personal life. They have a great impact on physical fitness and performance. Specialization in sports activities enables students to strengthen their relationship towards the selected sport in which they also improve.

**Brief outline of the course:**
Brief outline of the course:
The Institute of physical education and sport at the Pavol Jozef Šafárik University offers 20 sports activities aerobics; aikido, basketball, badminton, body-balance, body form, bouldering, floorball, yoga, power yoga, pilates, swimming, fitness, indoor football, SM system, step aerobics, table tennis, chess, volleyball, tabata, cycling.
Additionally, the Institute of physical education and sport at the Pavol Jozef Šafárik University offers winter courses (ski course, survival) and summer courses (aerobics by the sea, rafting on the Tisza River) with an attractive programme, sports competitions with national and international participation.

**Recommended literature:**

BENCE, M. et al. 2005. Plávanie. Banská Bystrica: FHV UMB. 198s. ISBN 80-8083-140-8. [online] Dostupné na: https://www.ff.umb.sk/app/cmsFile.php?disposition=a&ID=571
BUZKOVÁ, K. 2006. Fitness jóga, harmonické cvičení těla I duše. Praha: Grada. ISBN 8024715252.
JARKOVSKÁ, H, JARKOVSKÁ, M. 2005. Posilování s vlastním tělem 417 krát jinak. Praha: Grada. ISBN 9788024757308.
KAČÁNI, L. 2002. Futbal:Tréning hrou. Bratislava: Peter Mačura – PEEM. 278s. ISBN 8089197027.
KRESTA, J. 2009. Futsal.Praha: Grada Publishing, a.s. 112s. ISBN 9788024725345.
LAWRENCE, G. 2019. Power jóga nejen pro sportovce. Brno: CPress. ISBN 9788026427902.
SNER, Wolfgang. 2004. Posilování ve fitness. České Budějovice: Kopp. ISBN 8072322141.

STACKEOVÁ, D. 2014. Fitness programy z pohledu kinantropologie. Praha: Galén. ISBN 9788074921155.
VOMÁČKO, S. BOŠTÍKOVÁ, S. 2003. Lezení na umělých stěnách. Praha: Grada. 129s. ISBN 8024721743.

**Course language:**
Slovak language

**Notes:**

**Course assessment**
Total number of assessed students: 5845

| abs | abs-A | abs-B | abs-C | abs-D | abs-E | n | neabs |
|---|---|---|---|---|---|---|---|
| 82.53 | 0.27 | 0.03 | 0.0 | 0.0 | 0.0 | 8.25 | 8.91 |

**Provides:** Mgr. Marcel Čurgali, Mgr. Agata Dorota Horbacz, PhD., Mgr. Dávid Kaško, PhD., Mgr. Patrik Berta, Mgr. Ladislav Kručanica, PhD., Mgr. Richard Melichar, Mgr. Petra Tomková, PhD., Mgr. Alena Buková, PhD., univerzitná docentka, doc. PaedDr. Ivan Uher, MPH, PhD., prof. RNDr. Stanislav Vokál, DrSc., Mgr. Zuzana Küchelová, PhD., Mgr. Ferdinand Salonna, PhD.

**Date of last modification:** 07.02.2024

**Approved:** prof. RNDr. Michal Jaščur, CSc.

# COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚMV/ NPR/19 | **Course name:** Stochastic processes |
| **Course type, scope and the method:**<br>**Course type:** Lecture / Practice<br>**Recommended course-load (hours):**<br>**Per week:** 3 / 2 **Per study period:** 42 / 28<br>**Course method:** present | |
| **Number of ECTS credits:** 6 | |
| **Recommended semester/trimester of the course:** 2., 4. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>Total evaluation based on a written test (30p) + individual project work (30p) and oral exam (40p). At least 50% must be obtained from each part.<br>Final evaluation: ≥90% A; ≥80% B; ≥70% C; ≥60% D; ≥50% E; <50% FX. | |
| **Learning outcomes:**<br>To obtain knowledge of the stationary stochastic processes analysis in time domain and spectral domain.<br>To study properties of random processes with discrete time (time series) and continuous time and their application in finance.<br>To obtain skills in time series analysis with software R. | |
| **Brief outline of the course:**<br>1.-2. Stationary precess, linear process.<br>3. Causal and invertible process.<br>4. Time domain analysis (autocovariance, autocorrelation and partial autocorrelation function).<br>5. Sample characteristic of time series and their properties.<br>6.-7. Frequency domain analysis (spectral density and distribution function, periodogram).<br>8. Prediction of time series.<br>9. Random processes with continuous time (fundamental concepts).<br>10. Brownian motion, Itô's process, Itô's lemma and its application.<br>11.-12. The Black-Scholes formula. | |
| **Recommended literature:**<br>1. Brockwell P., Davis R.: Introduction to Time Series and Forecasting, 3rd ed., Springer, New York, 2016<br>2. Prášková Z.: Základy náhodných procesů II, Karolinum, Praha, 2016 (in Czech)<br>3. Tsay R.: Analysis of Financial Time Series, 3rd ed., Wiley Interscience, New Jersey, 2010<br>4. Shumway R., Stoffer D.: Time Series Analysis and Its Applications with R Examples, 5th ed., Springer, New York, 2024<br>5. Melicherčík I., Olšarová L., Úradníček V.: Kapitoly z finančnej matematiky, Epos, Bratislava, 2005 (in Slovak)<br>6. Oksendal B.K.: Stochastic Differential Equations, 6th ed., Springer, 2014 | |

**Course language:**
Slovak

**Notes:**
The students are required to have basic knowledge about random vectors and their characteristics, conditional distribution, estimation theory and hypothesis testing.

**Course assessment**
Total number of assessed students: 92

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 41.3 | 20.65 | 20.65 | 8.7 | 5.43 | 3.26 |

**Provides:** doc. RNDr. Martina Hančová, PhD.

**Date of last modification:** 21.11.2024

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ SVK/13 | **Course name:** Student Scientific Conference |
| **Course type, scope and the method:**<br>**Course type:**<br>**Recommended course-load (hours):**<br>**Per week: Per study period:**<br>**Course method:** present | |
| **Number of ECTS credits:** 4 | |
| **Recommended semester/trimester of the course:** | |
| **Course level:** I., II. | |
| **Prerequisities:** | |
| **Conditions for course completion:** | |
| **Learning outcomes:** | |
| **Brief outline of the course:** | |
| **Recommended literature:** | |
| **Course language:** | |
| **Notes:** | |
| **Course assessment**<br>Total number of assessed students: 26 | |
| abs | n |
| 100.0 | 0.0 |
| **Provides:** | |
| **Date of last modification:** 30.11.2021 | |
| **Approved:** prof. RNDr. Michal Jaščur, CSc. | |

# COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚTVŠ/ LKSp/13 | **Course name:** Summer Course-Rafting of TISA River |
| **Course type, scope and the method:**<br>**Course type:** Practice<br>**Recommended course-load (hours):**<br>**Per week:** 2 **Per study period:** 28<br>**Course method:** present | |
| **Number of ECTS credits:** 2 | |
| **Recommended semester/trimester of the course:** | |
| **Course level:** I., II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>Completion: passed<br>Condition for successful course completion:<br>- active participation in line with the study rule of procedure and course guidelines<br>- effective performance of all tasks: carrying a canoe, entering and exiting a canoe, righting a canoe, paddling | |
| **Learning outcomes:**<br>Content standard:<br>The student demonstrates relevant knowledge and skills in the field, which content is defined in the course syllabus and recommended literature.<br>Performance standard:<br>Upon completion of the course students are able to meet the performance standard and:<br>- implement the acquired knowledge in different situations and practice,<br>- implement basic skills to manipulate a canoe on a waterway,<br>- determine the right spot for camping,<br>- prepare a suitable material and equipment for camping. | |
| **Brief outline of the course:**<br>Brief outline of the course:<br>1. Assessment of difficulty of waterways<br>2. Safety rules for rafting<br>3. Setting up a crew<br>4. Practical skills training using an empty canoe<br>5. Canoe lifting and carrying<br>6. Putting the canoe in the water without a shore contact<br>7. Getting in the canoe<br>8. Exiting the canoe<br>9. Taking the canoe out of the water<br>10. Steering<br>a) The pry stroke (on fast waterways)<br>b) The draw stroke | |

11. Capsizing
12. Commands

**Recommended literature:**
1. JUNGER, J. et al. Turistika a športy v prírode. Prešov: FHPV PU v Prešove. 2002. ISBN 8080680973.
Internetové zdroje:
1. STEJSKAL, T. Vodná turistika. Prešov: PU v Prešove. 1999.
Dostupné na: https://ulozto.sk/tamhle/UkyxQ2lYF8qh/name/Nahrane-7-5-2021-v-14-46-39#!ZGDjBGR2AQtkAzVkAzLkLJWuLwWxZ2ukBRLjnGqSomICMmOyZN==

**Course language:**
Slovak language

**Notes:**

**Course assessment**
Total number of assessed students: 232

| abs | n |
|---|---|
| 36.64 | 63.36 |

**Provides:** Mgr. Dávid Kaško, PhD.

**Date of last modification:** 29.03.2022

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ PAF/13 | **Course name:** Summer Practice in Astrophysics |
|---|---|

**Course type, scope and the method:**
**Course type:** Practice
**Recommended course-load (hours):**
**Per week:** **Per study period:** 7d
**Course method:** present

**Number of ECTS credits:** 5

**Recommended semester/trimester of the course:** 2.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
To successfully complete the course, the student must create his/her own observation project in the field of study of exoplanets, variable stars or interplanetary matter, for which they will use observational instruments of UPJŠ and possibly cooperating organizations (AI SAS, Viholtat Observatory in Humenné). In order to obtain an evaluation and thus also credits, the student must evaluate the basic physical properties of the examined objects and present the obtained results. The credit evaluation of the course takes into account the following student workload: direct teaching (1 credit), self-study (2 credits), individual consultations (2 credits). The minimum limit for completing the course is to obtain at least 50% of the total score.

**Learning outcomes:**
After completing the course, the student will have the knowledge with which he/she will be able to prepare an observation proposal for different types of observations and for different observational instruments. He/she will gain practical experience with photometric and spectroscopic observation and processing of observed data, which he/she will be able to apply in his/her further research.

**Brief outline of the course:**
1. Introduction to astronomical observations.
2. Preparation of the observational proposal.
3. Preparation for observation.
4. Practical photometric and spectroscopic observations of variable stars using telescopes and detectors at the Astronomical Observatory UPJŠ Kolonické sedlo.
5. Reduction and analysis of obtained observations and their basic interpretation.
6. Presentation of results.

**Recommended literature:**
1. Howell, S. B., Handbook of CCD Astronomy, Cambridge University Press, Cambridge, 2000;
2. Léna, P., Rouan, D., Lebrun, F., Mignard, F., Pelat, D., Observational Astrophysics, Springer-Verlag, Berlin, 1996;
3. Martinez P., Klotz A., A practical guide to CCD Astronomy, Cambridge University Press, Cambridge, 1998;

**Course language:**

Slovak, English

**Notes:**

**Course assessment**
Total number of assessed students: 14

| abs | n | z |
|---|---|---|
| 100.0 | 0.0 | 0.0 |

**Provides:** doc. RNDr. Rudolf Gális, PhD., doc. Mgr. Štefan Parimucha, PhD.

**Date of last modification:** 22.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ TAF1/13 | **Course name:** Theoretical Astrophysics I |
| **Course type, scope and the method:**<br>**Course type:** Lecture / Practice<br>**Recommended course-load (hours):**<br>**Per week:** 3 / 1 **Per study period:** 42 / 14<br>**Course method:** present | |
| **Number of ECTS credits:** 6 | |
| **Recommended semester/trimester of the course:** 1. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>To successfully complete the course, the student must demonstrate sufficient understanding of the astronomical knowledge related to the structure and evolution of stars. Knowledge of stellar structure equations, models of stars, energy sources in stars, formation, evolution, and final stages of stellar evolution is required. During the semester, the student must continuously master the content of the curriculum so that he can use the acquired knowledge in solving computational tasks during the exercises and pass written tests taken into account in the overall evaluation of the subject. The condition for obtaining credits is passing 2 written tests during exercises and an oral exam, which consists of three theoretical questions in the scope of the lectured subject matter. The credit evaluation of the course considers the following student workload: direct teaching (2 credits), self-study (2 credit) and assessment (2 credits). The minimum threshold for completing the course is to obtain at least 50% of the total score, using the following rating scale: A (90-100%), B (80-89%), C (70-79%), D (60- 69%), E (50-59%), Fx (0-49%). | |
| **Learning outcomes:**<br>After completing lectures and exercises, the student will master the basic equations of stellar structure, models of stars, energy sources in stars, knowledge about the origin, evolution, and final stages of stellar evolution. It will also have sufficient physical knowledge and mathematical apparatus to enable independent solving of a wide range of astronomical problems related to the structure and evolution of stars. | |
| **Brief outline of the course:**<br>1. Stellar matter: state equation, polytrophic process, a mixture of gas and radiation.<br>2. Excitation, Boltzmann equation, ionization, Saha equation.<br>3. Distribution functions, state equation of degenerate gas, temperature of degeneration.<br>4. Stellar structure: hydrostatic equilibrium, estimation of state quantities in the stellar center, radiative equilibrium.<br>5. Energy transfer by radiation, opacity, energy transfer by conduction and convection, condition of convective instability.<br>6. Basic equations of stellar structures, Lane–Emden equation and its solution.<br>7. Models of main sequence stars, model of the outer layers of stars. | |

8. Sources of energy in stars: virial theorem, gravitational energy, nuclear reactions, the rate of energy production.
9. Stellar and explosive nucleosynthesis, proton-proton cycle, CNO cycle, 3-alpha process.
10. Origin of stars: Jeans' criterion, adiabatic and non-adiabatic contraction, fragmentation, rotation, influence of magnetic field.
11. Evolution of stars: collapse of interstellar cloud, evolution of protostars.
12. Evolution of stars on the main sequence, post main sequence evolution, red giants, shell source.
13. The final stages of stellar evolution: model of degenerate stars, white dwarfs, neutron stars, pulsars, black holes.

**Recommended literature:**

1. Böhm-Vittense, E., Introduction to Stellar Astrophysics, III, Cambridge University Press, Cambridge, 1989;
2. Kipenhahn, R., Weigert, A., Stellar Structure and evolution, Springer-Verlag, Berlin, 1990;
3. Hansen, C.J., Kawaler, S.D., Stellar Interiors – Physical Principles, Structure and Evolution, Springer-Verlag, New York, 1994;
4. Vanýsek, V., Základy astronómie a astrofyziky, Academia, Praha, 1980;

**Course language:**
Slovak, English

**Notes:**

**Course assessment**
Total number of assessed students: 18

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 50.0 | 22.22 | 5.56 | 22.22 | 0.0 | 0.0 |

**Provides:** doc. RNDr. Rudolf Gális, PhD.

**Date of last modification:** 16.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

# COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ TAF2/13 | **Course name:** Theoretical Astrophysics II |
| **Course type, scope and the method:**<br>**Course type:** Lecture / Practice<br>**Recommended course-load (hours):**<br>**Per week:** 3 / 1 **Per study period:** 42 / 14<br>**Course method:** present | |
| **Number of ECTS credits:** 6 | |
| **Recommended semester/trimester of the course:** 2. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>To successfully complete the course, the student must demonstrate sufficient understanding of the basis of the formation of spectra in stellar atmospheres and their properties. Knowledge of basic concepts of stellar atmosphere physics, radiation and convection energy transfer, continuous and line absorption coefficients, photosphere model and spectral line properties is required. During the semester, the student must continuously master the content of the curriculum so that he can use the acquired knowledge in solving computational tasks during the exercises and pass written tests taken into account in the overall evaluation of the subject. The condition for obtaining credits is passing 2 written tests during exercises and an oral exam, which consists of three theoretical questions in the scope of the lectured subject matter. The credit evaluation of the course considers the following student workload: direct teaching (2 credits), self-study (2 credit) and assessment (2 credits). The minimum threshold for completing the course is to obtain at least 50% of the total score, using the following rating scale: A (90-100%), B (80-89%), C (70-79%), D (60- 69%), E (50-59%), Fx (0-49%). | |
| **Learning outcomes:**<br>After completing lectures and exercises, the student will master the basic concepts of the physics of stellar atmospheres, knowledge related to energy transfer by radiation and convection, continuous and line absorption coefficients, photosphere model and the properties of spectral lines. It will also have sufficient physical knowledge and mathematical apparatus to enable the independent solution of a wide range of astronomical problems related to the analysis of stellar spectra. | |
| **Brief outline of the course:**<br>1. Basic concepts and definitions: radiation flux, intensity, K-integral and radiation pressure.<br>2. Optical depth, absorption and emission coefficient, source function, scattering and absorption, Einstein coefficients.<br>3. Energy transfer in the stellar atmosphere: equation of radiative transfer and its formal solution, spherical geometry, exponential integrals.<br>4. Radiative equilibrium, gray atmosphere, Milne equations, convection in the stellar atmospheres.<br>5. Continuous absorption coefficient: origin of continuous absorption, individual absorbers: neutral hydrogen. | |

6. Individual absorbers: negative hydrogen ion, negative helium ion and metals, electron scattering, the total absorption coefficient.
7. Model photosphere: hydrostatic equilibrium, temperature distribution in the solar photosphere and in other stars.
8. Pg-Pe-T relation, completion of the model, geometrical depth, computation of the spectrum.
9. Properties of models, effect of chemical composition, changes with temperature and pressure.
10. Line absorption coefficient: natural atomic absorption, damping constant.
11. Broadening of spectral lines due to collisions and thermal motion, combining absorption coefficients, the equivalent width of spectral lines.
12. Behaviour of spectral lines: line transfer equation and source function in a spectral line, depth of formation of a spectral line, contribution function.
13. Calculation of spectral line profile in LTE, the dependence on temperature, pressure, abundance.

**Recommended literature:**
1. Tennyson, J., Astronomical spectroscopy, Imperial College Press, London, 2005
2. Gray, D.F., The observation and analysis of stellar photospheres, Cambridge University Press, Cambridge, 1992;
3. Böhm-Vitense, E., Introduction to stellar astrophysics II, Stellar atmospheres, Cambridge University Press, Cambridge,1997;

**Course language:**
Slovak, English

**Notes:**

**Course assessment**
Total number of assessed students: 12

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 66.67 | 33.33 | 0.0 | 0.0 | 0.0 | 0.0 |

**Provides:** doc. RNDr. Rudolf Gális, PhD.

**Date of last modification:** 16.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ MSSTF/14 | **Course name:** Theoretical Physics |
| **Course type, scope and the method:**<br>**Course type:**<br>**Recommended course-load (hours):**<br>**Per week: Per study period:**<br>**Course method:** present | |
| **Number of ECTS credits:** 4 | |
| **Recommended semester/trimester of the course:** | |
| **Course level:** II. | |
| **Prerequisities:** ÚFV/KTP1b/03 | |
| **Conditions for course completion:**<br>The condition for passing the course is to demonstrate sufficient knowledge of key subjects of theoretical physics at the master's degree level. Successful completion of the oral exam is a necessary condition for completing a master's degree. | |
| **Learning outcomes:** | |
| **Brief outline of the course:**<br>A) Condensed matter theory:<br>Electrons in a periodic crystal potential. Bloch theorem. Born-van Kárman boundary conditions. Brillouin zone. Mean electron velocity in a crystal. Effective mass. Density of states. Approximation of nearly free electrons. Tight-binding method. Band structure. Electrons in a magnetic field. Landau levels. Lattice vibrations in harmonic approximation. Acoustic and optical modes in a linear chain with one and two atoms in a unit cell. Lattice vibrations of three dimensional lattice. Phonons. Specific heat of crystals. Optical properties of solids. Dielectric function. Optical conductivity. Superconductivity and effect on<br>physical properties of solids. Electron-phonon attractive interaction. Cooper pairs. Ground state and excited state of a superconductor. Itinerant and localized magnetism in solids. Magnons and spin waves in insulators.<br>B) Phase transitions and critical phenomena:<br>Phase equilibrium and phase transitions. Classical (Ehrenfest) and modern classification of phase transitions. Landau description of phase transitions: order parameter and symmetry breaking at continuous phase transitions. Critical indices and universality. Basic microscopic models of magnetic phase transitions: Heisenberg and Ising model. Exact solution of a one-dimensional Ising model in an external magnetic field. Mean (molecular) field approximation for Ising model. Phenomenological Landau theory of phase transitions. Tricritical point.<br>C) Quantum field theory:<br>Classical and quantum fields - general definition. Lagrange formalism for classical fields. Euler equations for fields. Symmetry and conservation laws. General dynamic invariants. Energy-momentum tensor. Free classical scalar (real and complex) field, Klein-Gordon equation. Dynamic invariants for scalar fields. Free classical electromagnetic field, Maxwell equations in covariant form. Dynamic invariants for electromagnetic fields. Free spinor field, Dirac equation. Dynamic | |

invariants for a spinor field. Quantization of classical free fields, heuristic approach and general rules. Scalar field quantization. Spinor field quantization. Electromagnetic field quantization as an example of quantization of fields with constrains. Interacting fields, basic rules for introducing coupling members into Lagrangians. Local calibration invariance, minimal interaction of spinor and electromagnetic fields. Lagrangian of quantum electrodynamics. The concept of N -, S - and T - products of quantum-field operators. Wick theorem for the N-product. Wick theorem for T-product. Evolution operator, S-operator and S-matrix. Green functions as vacuum means of T products of free and interacting quantum fields. Generating functional of Green functions. Feynman diagram technique, general rules for graph construction. General rules for calculation of Green functions using perturbation theory. Compton scattering: calculation of the S matrix and the effective cross section for non-polarized particles in the leading order approximation.

**Recommended literature:**

**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 17

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 64.71 | 11.76 | 17.65 | 5.88 | 0.0 | 0.0 |

**Provides:**

**Date of last modification:** 21.12.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ TKL1/99 | **Course name:** Theory of Condensed Matter |
|---|---|

**Course type, scope and the method:**
**Course type:** Lecture / Practice
**Recommended course-load (hours):**
**Per week:** 4 / 2 **Per study period:** 56 / 28
**Course method:** present

**Number of ECTS credits:** 8

**Recommended semester/trimester of the course:** 1.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
1. Attendance at lessons in accordance with the study rules and the teacher's instructions.
2. Activity at exercises.
3. Self-study and submission of independently solved homework.
Conditions for the final evaluation:
1. Final written exam, solving of problems.
2. Final oral exam or multiple choice test.
Conditions for successful completion of the course and obtaining 8 ECTS credits:
1. Participation at lessons in accordance with the study regulations and according to the instructions of the teacher (40% share of ECTS credits).
2. Mastering conditions of continuous assessment of self-study and homeworks at the level in the assessment scale of at least 60% in total (50% share of ECTS credits).
3. Mastering conditions of the final evaluation in the overall expression at the level of at least 20% from solving of problems and an oral exam or test (10% share of ECTS credits).
4. Rating scale: A 100% - 90%, B 89% - 75%, C 74% - 60%, D 59% - 40%, E 39% - 20%, FX 19% - 0.

**Learning outcomes:**
The graduate of the course will master basic concepts of the condensed matter structure and acquire knowledge of derivation their properties from the quantum nature of electrons, phonons, photons, magnons and their mutual interactions, which are modulated by the periodic arrangement of atoms. The graduate will learn the quasiparticle formalism in order to the describe electrical properties, optical properties, superconductivity, and will be able to calculate dispersions of quasiparticles and deduce basic properties of the condensed matter. The graduate will acquire sufficient physical and mathematical knowledge to independently solve current scientific problems in the physics of condensed matter and in the study of material properties.

**Brief outline of the course:**
1. Theoretical description of solid state structure. Electrons in periodic lattice, Bloch's theorem, reciprocal lattice and Brillouin zone, Born-von Karmán periodic boundary conditions.
2. Velocity of Bloch states, density of states, approximation of nearly-free electrons.
3. Band structure. Tight-binding method.

4. k.p method and Wannier functions.
5. Electrons in magnetic field. Properties of materials, heat capacity and susceptibility.
6. Lattice vibrations in harmonic approximation, thermodynamics of crystal solids.
7. Quantum theory of lattice vibration in solids, phonons.
8. Optical properties of solids, dielectric function, optical conductivity, excitons.
9. Superconductivity, electron-phonon effective attractive interaction.
10. Cooper pairs, BCS theory. Ground and excited state of superconductor.
11. Magnetism in solids, itinerant and localized ferromagnetism, Laudau diamagnetism.
12. Magnons and spin waves in insulators, thermodynamics of magnons. Spin dynamics.

**Recommended literature:**

Simon, S. H. The Oxford Solid State Basics. Oxford University Press, 2013.
Girvin, S. M., Yang, K. Modern Condensed Matter Physics. Cambridge University Press, 2019.
Cohen, M. L., Louie, S. G. Fundamentals of Condensed Matter Physics. Cambridge University Press, 2016.
Ketterson, J. B. The Physics of Solids. Oxford University Press, 2016.
Kaxiras, E. Atomic and Electronic Struture of Solids, Cambridge University Press, 2003.
Ashcroft, N. W., Mermin, N. D. Solid State Physics. Harcourt College Publishers, 1976.

**Course language:**

**Notes:**
The course is implemented in a full-time form, if necessary remotely in the MS Teams environment.

**Course assessment**
Total number of assessed students: 117

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 48.72 | 13.68 | 17.09 | 8.55 | 11.97 | 0.0 |

**Provides:** RNDr. Martin Gmitra, PhD.

**Date of last modification:** 18.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ TRANS/18 | **Course name:** Transport properties of solids |
| **Course type, scope and the method:**<br>**Course type:** Lecture / Practice<br>**Recommended course-load (hours):**<br>**Per week:** 2 / 1 **Per study period:** 28 / 14<br>**Course method:** present | |
| **Number of ECTS credits:** 4 | |
| **Recommended semester/trimester of the course:** 2., 4. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>During the continuous and final assessment, the student will demonstrate adequate mastery of the course content standard and a sufficient level of understanding of the topics covered in the course outline. The basis of the mid-term evaluation is active participation in the class and submission of independently solved homework assignments at the overall level of 50% correct solutions for the entire semester. A condition for successful completion of the course is the final assessment, which consists of a written part - problem solutions and their oral presentation, and a test on theory. The final assessment takes into account all the required activities with the relevant weighting. The 4 ECTS credit assessment takes into account the following: participation in direct teaching (2 ECTS credits), self-study and individual homework solution (1 ECTS credit), and passing the final examination (1 ECTS credit).<br>Final grade scale: A 100% - 85%, B 84% - 70%, C 69% - 55%, D 54% - 40%, E 39% - 20%, FX 19% - 0. | |
| **Learning outcomes:**<br>The student will learn the basics of electron and thermal transport in the classical and quantum regime. The student will master Boltzmann and quantum Landauer-Büttiker formalisms to solve standard transport problems and to apply the knowledge independently to similar physics problems. The knowledge gained will help the student to interpret experimental measurements or determine relevant transport physical mechanisms. | |
| **Brief outline of the course:** | |
| **Recommended literature:**<br>1. K. Hirose, N. Kobayashi, Quantum Transport Calculations for Nanosystems, Pan Standford Publishing, 2014.<br>2. D. K. Ferry, An Introduction to Quantum Transport in Semiconductors, Pan Standford Publishing, 2018.<br>3. M. Galperin, Quantum Transport, Lecture Notes, 1998.<br>4. S. Datta, Electronic Transport in Mesoscopic Systems, Cambridge University Press, 1995.<br>5. M. Di Ventra, Electrical Transport in Nanoscale Systems, Cambridge University Press, 2009.<br>6. T. Ihn, Electronic Quantum Transport in Mesoscopic Semiconductor Structures, Springer Tracts in Modern Physics, Volume 192, 2004. | |

7. T. Heinzel, Mesoscopic Electronics in Solid State Nanostructures, Wiley-VCH, 2003.
8. N. W. Ashcroft, N. D. Mermin, Solid State Physics, Harcourt College Publisher, 1976.
7. M. P. Marder, Condensed Matter Physics, Wiley, 2010.
9. J. B. Ketterson, The Physics of Solids, Oxford University Press, 2016.
10. J. Sólyom, Fundamentals of the Physics of Solids, Volume 2 – Electronic Properties, Springer, 2009.

**Course language:**

**Notes:**
The course is implemented in a full-time form, if necessary remotely in the MS Teams environment.

**Course assessment**
Total number of assessed students: 19

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 26.32 | 10.53 | 36.84 | 10.53 | 15.79 | 0.0 |

**Provides:** RNDr. Martin Gmitra, PhD.

**Date of last modification:** 31.01.2022

**Approved:** prof. RNDr. Michal Jaščur, CSc.

**COURSE INFORMATION LETTER**

| | |
|---|---|
| **University:** P. J. Šafárik University in Košice | |
| **Faculty:** Faculty of Science | |
| **Course ID:** ÚFV/ CUVE/13 | **Course name:** Ultra High Energy Particles |
| **Course type, scope and the method:**<br>**Course type:** Lecture<br>**Recommended course-load (hours):**<br>**Per week:** 2 **Per study period:** 28<br>**Course method:** present | |
| **Number of ECTS credits:** 3 | |
| **Recommended semester/trimester of the course:** 1. | |
| **Course level:** II. | |
| **Prerequisities:** | |
| **Conditions for course completion:**<br>1. Participation in course in accordance with the study regulations and instructions of the teacher.<br>2. Elaboration of a recherche work according to a selected article from the field of ultra high energy cosmic ray particle physics.<br>Final written or oral exam.<br>Conditions for course succesful completion:<br>1. Participation in course in accordance with the study regulations and according to the instructions of the teacher;<br>2. Mastering the conditions of the interim and final evaluation in the overall expression at the level of at least 80%. | |
| **Learning outcomes:**<br>During the continuous and final evaluation, the student will demonstrate adequate understanding of the content of the subject. He will gain a basic overview of the properties of cosmic rays of ultra-high energies and showers of secondary cosmic rays in the Earth's atmosphere. Understand the principles of current and future experiments to observe ultra-high energy particles, specifically the JEM-EUSO experiment. Student will understand the basics of numerical solution of the motion of cosmic rays in the Galaxy and in interstellar space. They will learn the basics of working with software tools to simulate atmospheric showers. | |
| **Brief outline of the course:**<br>1) MAin characteristics of cosmic rays of ultra high energies (UHECR). Discovery of UHECR particles, composition and energy spectrum.<br>2) Experimental basics, principles of UHECR particle registration<br>3) Extenxive Air Showers (EAS) - shower development, basic characteristics, EAS components, reconstruction, Monte-Carlo simulation of EAS cascades.<br>4) Overview of experiments - history, current experiments. History of UHECR particle measurements - experiments HiRes, AGASA. Current experiments to monitor UHECR - Pierre Auger Observatory, Telescope Array.<br>5) Measurement of UHECR from space, reasons / motivation. JEM-EUSO experiment (I) - observation principle, basic technical description, mission pathfinders. | |

6) JEM-EUSO experiment (II) - case selection - trigger, simulation, reconstruction, analysis, pattern recognition.
7) Acceleration mechanisms, acceleration of particles in the cosmos, Hillas plot
8) Propagation of UHECR through galaxy and intergalactic space. Galactic and intergalactic magnetic field, Fokker-Planck equation (FPE).
9) FPE solution, general form of diffusion tensor.
10) Greisen – Zatsepin – Kuzmin effect.
11) Possible sources of UHECR.
12) Software tools for simulation of atmospheric showers of secondary cosmic rays.

**Recommended literature:**
Cosmic rays at Earth, P.K.F. Grieder, Elsevier Science B.V. 2001
Extensive Air Showers, P.K.F. Grieder, Springer-Verlag Berlin Heidelberg 2010
The JEM-EUSO mission, New Journal of Physics, Volume 11, Issue 6, pp. 065009, 2009
Web: http://jemeuso.riken.jp
Ultra High Energy Cosmic Rays: origin and propagation, Todor Stanev, ICRC'07 Merida
Origin and Propagation of Extremely High Energy Cosmic Rays, P.Bhattacharjee, arXiv:astroph/9811011
Features of the Energy Spectrum of Cosmic Rays above 2.5×10^18 eV Using the Pierre Auger Observatory, Phys. Rev. Lett. 125, 121106 – Published 16 September 2020

**Course language:**

**Notes:**

**Course assessment**
Total number of assessed students: 7

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Provides:** RNDr. Pavol Bobík, PhD., RNDr. Blahoslav Pastirčák, CSc.

**Date of last modification:** 18.11.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.

## COURSE INFORMATION LETTER

**University:** P. J. Šafárik University in Košice

**Faculty:** Faculty of Science

| **Course ID:** ÚFV/ PHD/17 | **Course name:** Variable and binary stars |
|---|---|

**Course type, scope and the method:**
**Course type:** Lecture / Practice
**Recommended course-load (hours):**
**Per week:** 3 / 1 **Per study period:** 42 / 14
**Course method:** present

**Number of ECTS credits:** 6

**Recommended semester/trimester of the course:** 1.

**Course level:** II.

**Prerequisities:**

**Conditions for course completion:**
To successfully complete the course, the student must demonstrate a sufficient understanding of the physical properties of different types of variable stars, their origin, and evolution, as well as methods of their search and detection. In addition to direct participation in teaching, the student's independent work is also required within the self-study of professional topics assigned by the teacher. In order to obtain an evaluation and thus also credits, the student must meet the requirements of a continuous written test (with a weight of 50% of the total evaluation) and pass a written final exam (with a weight of 50% of the total evaluation).Credit evaluation of the course takes into account the following student workload: direct teaching (2 credits), self-study (2 credits), individual consultations (1 credit), and exam (1 credit) . Rating scale: A (90-100%), B (80-89%), C (70-79%), D (60-69%), E (50-59%), F (0-49%).

**Learning outcomes:**
After completing the lectures and exercises and on the basis of the final evaluation, the student will demonstrate adequate mastery of the content standard of the course, which is defined by a brief syllabus of the course and recommended literature. Mastering the content of the subject allows him to acquire knowledge about different types of variable stars and binaries, they will be able to determine the period of their changes and their basic properties from the light curve. They will be able to identify different types of variability such as the presence of other bodies in the systems.

**Brief outline of the course:**
The time schedule of the course content is updated in the electronic bulletin board of the course.
1. Definition of variable stars and historical overview of their research
2. Basic concepts necessary for the study of variable stars
3. Methods of finding variability and its periodicity.
4. Classification of variable stars and basic properties.
5. Eclipsing binaries
6. Rotating variable stars
7. Pulsating variable stars
8. Eruptive variable stars
9. Two-body problem and orbital parameters
10. Roche potential and model of close binary stars

11. Mass transfer and change of system period
12. Multiple systems and their detection

**Recommended literature:**
1. Egglecton: 2006: Evolutionary Processes in Binary and Multiple Stars, Cambridge University Press
2. Hilditch: 2001, Close binaries, Cambridge University Press
3. Kallrath J., Milone E.F.: 2009, Eclipsing Binary Stars - Modeling and Analysis, Springer
4. Lena et al.: 1996, Observational Astrophysics, Springer-Verlag
5. Roth G.: 1994, Compendium of Practical Astronomy, Springer-Verlag
6. Sterken a Jashek, 1996, Light Curves of variable Stars, Cambridge University Press
7. Warner: 1995, Cataclysmic Variables, Cambridge University Press

**Course language:**
Slovak, English

**Notes:**

**Course assessment**
Total number of assessed students: 11

| A | B | C | D | E | FX |
|---|---|---|---|---|---|
| 54.55 | 36.36 | 0.0 | 9.09 | 0.0 | 0.0 |

**Provides:** doc. Mgr. Štefan Parimucha, PhD.

**Date of last modification:** 22.09.2021

**Approved:** prof. RNDr. Michal Jaščur, CSc.