UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Fizika materialov
Course title:	Physics of Materials

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
Nanoznanosti in nanotehnologije, 3. stopnja		1	1
Nanosciences and Nanotechnologies, 3rd cycle		1	1

Vrsta predmeta / Course type	Izbirni / Elective
Univerzitetna koda predmeta / University course code:	NANO3-798

Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Klinične vaje work	Druge oblike študija	Samost. delo Individ. work	ECTS
30	**30**			**30**	**210**	**10**

**Navedena porazdelitev ur velja, če je vpisanih vsaj 15 študentov. Drugače se obseg izvedbe kontaktnih ur sorazmerno zmanjša in prenese v samostojno delo. / This distribution of hours is valid if at least 15 students are enrolled. Otherwise the contact hours are linearly reduced and transfered to individual work.*

Nosilec predmeta / Lecturer:	Prof. dr. Zdravko Kutnjak Prof. dr. Boštjan Zalar
Jeziki / Languages: **Predavanja / Lectures:**	Slovenščina, angleščina / Slovenian, English
Vaje / Tutorial:	

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisits:**
Poznavanje pojmov iz fizike kondenzirane materije, pridobljenih na dodiplomskem kurzu fizike, kondenzirane snovi, fizike trdne snovi ali fizike mehke snovi.	Knowledge in condensed matter physics, acquired through an introductory course in condensed matter physics, solid state physics, or soft state physics at the undergraduate level.

Vsebina:	**Content (Syllabus outline):**
Struktura snovi: gradniki in interakcije, korelacijske funkcije, merilo reda v snoveh, kristali, kvazikristali, fraktali, invariantnost skale, stekla, mehke snovi, metamateriali; **Elektroni v kristalih**: prosti elektroni, energijski pasovi, Fermijeva površina, gostota stanj, plazemske oscilacije, transportne lastnosti v prevodnikih; **Polprevodniki**: čisti in dopirani, transportne lastnosti, p-n stik, laserska dioda, p-n-p transistor, supermreže; **Mrežna nihanja**: 1D veriga atomov, optične in akustične veje, 3D strukture, kvantnomehanska obravnava specifične toplote;	**Structure of matter**: building blocks and interactions, correlation functions, measure of order, crystals, quasicrystals, fractals, scale invariance, glasses, soft matter; metamaterials; **Electrons in crystals**: free electrons, energy bands, Fermi surface, density of states, plasma oscillations, transport properties of conductors; **Semiconductors**: pure and doped, transport properties, the p-n junction, laser diodes, the p-n-p transistor, superlattices; **Lattice oscillations**: 1D chain of atoms, optical and acoustical branch, 3D structures, quantum mechanical treatment of specific heat; **Diamagnetism and paramagnetism**: origin of

Diamagnetizem in paramagnetizem: izvor magnetnega momenta, Larmorjev diamagnetizem, paramagnetizem prostih magnetnih momentov in prevodniških elektronov, Hundova pravila; **Magnetne strukture**: izmenjalna interakcija, Weissova teorija, feromagnetizem antiferimagnetizem; **Superprevodnost**: termodinamika superprevodnega stanja, superprevodniki tipa I in II, Londonove enačbe, makroskopski kvantni pojavi, visokotemperaturni superprevodniki; **Nanosistemi**: 2D plin elektronov, mezoskopske elektronske strukture; **Mrežni defekti**: termodinamika točkastih defektov, električna prevodnost ionskih kristalov, barvni centri, polaroni in ekscitoni, dislokacije; **Površine**: struktura, fenomenološki opis omakanja; **Polimeri**: fenomenološki in statistični opis, elastičnost, viskoelastičnost, plastičnost; **Tekoči kristali**: faze, fenomenološki opis, elektrooptične lastnosti, defekti; **Amfifilni samoorganizirani sistemi**: struktura, red in fenomenologija; **Koloidi**: sile in DLVO teorija, koagulacija, strukture; **Geli**: termodinamski opis, stabilnost, kinetika.	magnetic moments, Larmor diamagnetism, paramagnetism of free magnetic moments and conduction electrons, Hund rules; **Magnetic structures**: exchange interaction, Weiss theory, ferromagnetism and antiferromagnetism; **Superconductivity**: thermodynamics of the SC state, phenomenological theory of type I and II superconductors, London equation, macroscopic quantum phenomena, high-Tc superconductors; **Nanosystems**: 2D electron gas, mesoscopic electronic structures; **Lattice defects**: thermodynamics of point defects, electric conductivity of ionic crystals, color centers, polarons and excitons, dislocations; **Surfaces**: structure, phenomenology of wetting; **Polymers**: phenomenological and statistical description, elasticity, viscoelasticity, plasticity; **Liquid crystals**: phases, phenomenological description, electrooptic properties, defects; **Amphiphilic self-organized systems**: structures, order and phenomenology; **Colloids**: forces and DLVO theory, coagulation, structures; **Gels**: thermodynamical description, stability, kinetics.

Temeljni literatura in viri / Readings:

- KUTNJAK, Zdravko. Physics of materials : selected problems. Ljubljana: Jožef Stefan International Postgraduate School, 2012. [11] str. [COBISS.SI-ID 25779495]
- KUTNJAK, Zdravko. Selected chapters from physics : supplemental materials and seminars. Ljubljana: Jožef Stefan International Postgraduate School, [2007]. 4, 21 str., ilustr., graf. prikazi. [COBISS.SI-ID 20737063]
- KUTNJAK, Zdravko. Selected chapters from physics of materials. Ljubljana: Jožef Stefan International Postgraduate School, [2006]. 61 str., ilustr. [COBISS.SI-ID 20225063]
- ZALAR, Boštjan. Physics of materials : selected chapters : fall semester 2010/2010. Ljubljana: Jozef Stefan International Postgraduate School, 2011. 55 str. COBISS.SI-ID 25579559]
- Solid State Physics, J. R. Hook in H. E. Hall, The Manchester Physics Series, John Wiley&Sons (1991);
- Solid state Physics, Gerald Burns, Academic Press, INC. (1990);
- Soft Matter Physics, M. Daud and C. E. Williams, Eds., Springer, Berlin (1999);
- Soft Matter Physics, An Introduction, M. Kleman, O. D. Lavrentovich, Springer, Berlin (2003);
- Physics of Materials, Yves Quere Gordon and Beach Science Publishers (1998)

Cilji in kompetence:

Študent razširi znanje iz fizike materialov, predvsem kondenzirane snovi, s ciljem pridobitve novega znanja na višjem nivoju, s pomočjo katerega bo lahko aktivno načrtoval nove napredne materiale ter funkcionalne mikro- in nanostrukture.

Splošne kompetence:

- obvladanje raziskovalnih metod, postopkov in procesov, razvoj kritične in samokritične presoje;
- razvoj sposobnosti uporabe znanja v praksi;
- razvoj komunikacijskih sposobnosti in spretnosti, posebej komunikacije v mednarodnem okolju;
- kooperativnost, delo v skupini (in v mednarodnem okolju).

Predmetnospecifične kompetence:

- kvalitativno in kvantitativno ovrednotenje pojavov v materialih z uporabo relevantnih parametrov in modernih teoretičnih in eksperimentalnih metod, ki opredeljujejo določen pojav;
- tekoče obvladovanje tujega jezika (angleščina) in angleške strokovne literature;
- pridobljena znanja se uporabljajo pri razvoju novih teoretičnih in eksperimentalnih metod v fiziki materialov.

Objectives and competences:

Students are expected to bring their knowledge in the physics of materials, in particular the condensed matter, to a higher level, with the goal of being able to actively engineer new advanced materials and functional micro- and nanostructures.

General competences:

- the student will master research methods, procedures and processes and develop skills to critically asses his activities;
- the student will develop skills to transfer the ideas from the basic knowledge pool into applications;
- the student will develop communications skills to present research achievements in the international environment;
- training for team work (in international environment).

Course specific competences:

- capability to qualitatively and quantitatively assess phenomena that take place in materials, by choosing the relevant parameters and modern theoretical and experimental methods that apply to a certain case;
- the students will be proficient in the use of non-native language (English) and literature;
- the acquired advanced knowledge will be used to develop new theoretical and experimental methods in the physics of materials.

Predvideni študijski rezultati:

Znanje in razumevanje:
Poznavanje in sposobnost razlage pojmov iz fizike materialov, predvsem kondenzirane snovi: klasifikacija materialov po različnih kriterijih, teoretično in eksperimentalno razumevanje povezave med mikroskopskimi lastnostmi snovi (električni naboj, električni in magnetni dipolni moment) in makroskopskim odzivom snovi v zunanjih poljih (električna prevodnost, dielektričnost, magnetni odziv, elastičnost); poznavanje modernih metod za izračun fizikalnih lastnosti kondenziranih snovi, tako klasičnih kot tudi kvantnomehanskih, ter njihovih omejitev.
Predmet pripravlja študente za uporabo znanja s področja fizike materialov.

Intended learning outcomes:

Knowledge and understanding:
Familiarity with and ability to explain phenomena in the physics of materials, particularly the condensed matter: classification of materials according to various criteria, understanding the relation between microscopic properties of matter (electrical charge, electric and magnetic dipole moment) and its macroscopic response to external fields (electric conductivity, dielectric properties, magnetic response, elasticity), both from the theoretical and experimental point of view; knowledge of advanced methods used to calculate physical properties of condensed systems, both classic and quantum-mechanical, as well as their limitations.
This course prepares students to apply knowledge of physics of materials.

Metode poučevanja in učenja:	Learning and teaching methods:
Predavanja in seminar, konzultacije	Lectures and seminar, consultations

Načini ocenjevanja:	Delež (v %) / Weight (in %)	Assessment:
Ustni izpit	50 %	Oral exam
Predstavitev seminarja	50 %	Presentation of seminar

Reference nosilca / Lecturer's references:

- KUTNJAK, Zdravko, PETZELT, Jan, BLINC, Robert. The giant electromechanical response in ferroelectric relaxors as a critical phenomenon. *Nature*, ISSN 0028-0836, 2006, vol. 441, str. 956-959.
- LEBAR, Andrija, CORDOYIANNIS, George, KUTNJAK, Zdravko, ZALAR, Boštjan. The isotropic-to-nematic conversion in liquid crystalline elastomers. *Advances in polymer science*, ISSN 0065-3195, 2012, vol. 250, str. 147-185, doi: 10.1007/12_2010_103.
- PIRC, Raša, ROŽIČ, Brigita, KORUZA, Jurij, MALIČ, Barbara, KUTNJAK, Zdravko. Negative electrocaloric effect in antiferroelectric PbZrO[sub]3. *Europhysics letters*, ISSN 0295-5075, 2014, vol. 107, no. 1, str. 17002-1-17002-5, doi: 10.1209/0295-5075/107/17002.
- PIRC, Raša, KUTNJAK, Zdravko. Electric-field dependent freezing in relaxor ferroelectrics = R. Pirc and Z. Kutnjak. *Physical review. B, Condensed matter and materials physics*, ISSN 1098-0121, 2014, vol. 89, no. 18, str. 184110-1-184110-7, doi: 10.1103/PhysRevB.89.184110.
- KUTNJAK, Zdravko, PIRC, Raša. Specific heat anomaly in relaxor ferroelectrics and dipolar glasses. *Journal of Applied Physics*, ISSN 0021-8979, 2017, vol. 121, no. 10, str. 105107-1-105107-7.