UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Kozmos v kapljici tekočega kristala
Course title:	Universe in a Droplet of Liquid Crystal

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: NANO3-884

Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Klinične vaje work	Druge oblike študija	Samost. delo Individ. work	ECTS
15	15			15	105	5

**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. Samo Kralj

Jeziki / Languages:	
Predavanja / Lectures:	slovenščina, angleščina / Slovenian, English
Vaje / Tutorial:	slovenščina, angleščina / Slovenian, English

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:

Opravljeni izpiti iz mehanike, elektromagnetizma, moderne fizike (FNM, Univerza v Mariboru, oz. temu ekvivalentni kurzi fizike).

Prerequisits:

Passed exams in Mechanics, Electromagnetism, and Modern Physics (FNM, University of Maribor, or in equivalent courses).

Vsebina:

1) Predstavitev poglavitnih tekoče-kristalnih (TK) faz.
2) Zlom simetrije in umeritveno polje.
3) Topološki defekti (TD):
   - TD v TK v orientacijski in translacijski urejenosti,
   - topološki naboj: univerzalna definicija,
   - analogije med TD v TK in drugih področjih fizike (magnetni monopol, kozmične strune, vorteksi v superprevodnikih in supertekočinah, skyrmioni v fiziki delcev in magnetizmu, robne in zvite dislokacije v trdni snovi….).
4) Vpliv geometrije "prostora" na TD:
   - univerzalni pomen Gaussove ukrivljenosti (Gauss-Bonnetov in Poincarejev teorem),

Content (Syllabus outline):

1) Introduction of key liquid crystalline (LC) phases.
2) Symmetry breaking and gauge fields.
3) Topological defects (TD):
   - TD in LCs in orientational and translational degree of ordering,
   - topological charge: universal definition,
   - analogy between TDs in LCs and other fields of physics (Dirac monopole, cosmic strings, vortices in superconductors and superfluids, skyrmions in particle physics and magnetism, edge and screw dislocations in condensed matter…).
4) Impact of curvature of "space" on TDs:
   - universal role of Gaussian curvature (Gauss-Bonnet and Poincare theorem),

- vpliv ukrivljenosti “prostora” na lego TD,
- krivinsko inducirana tvorba parov defekt-antidefekt,
- koncept “paralenega transporta” in analogija s splošno teorijo relativnosti,
- stabilizacija mrež TD.

5) Anihilacija topoloških defektov:
   - anihilacija TD v orientacijski in translacijski urejenosti TK,
   - analogija z anihilacijo matematično sorodnih TD v kondenzirani materiji in delcev v fiziki osnovnih delcev.
6) Domenska struktura in zlom zvezne simetrije:
   - anihilacija TD in rast domen,
   - vpliv TD na sedanjo strukturo vesolja: Kibble-Zurkov mehanizem,
   - univerzalni vpliv naključnega nereda na domensko strukturo: teorem Imry-Ma.
7) Univerzalni delčni opis narave z lokaliziranimi rešitvami pripadajočih ureditvenih polj.

- impact of curvature on position of TDs,
- curvature driven unbinding of pairs defect-antidefect,
- concept of “parallel transport” and analogy with theory of general realativity,
- stabilisation of lattices of TDs.

5) Annihilation of TDs:
   - annihilation of TDs in orientational and translational ordering in LCs,
   - annihilation of mathematically analogous TDs in condensed matter physics and particle physics,
6) Domain structure and symmetry breaking:
   - annihilation of TDs and domain growth,
   - impact of TDs on structure of Universe: Kibble-Zurek mechanism.
   - universal impact of random-type disorder on domain patterns: Imry-Ma theorem.
7) Universal “particle” description of nature in terms of localized solutions in relevant gauge fields.

Temeljni literatura in viri / Readings:

1. P.G. de Gennes, J. Prost, The Physics of Liquid Crystals, Clarendon press, Oxford, 1998.
2. M. Kleman, O.D. Lavrentovich, Soft Matter Physics, Springer-Verlag, New York, 2003.
3. P. M. Chaikin, T. C. Lubensky, Principles of Condensed Matter Physics, Cambridge University Press, Cambridge, England, 1995.
4. W.H. Zurek, Cosmological experiments in condensed matter, *Nature* **317**, 505-508, 1985.

Cilji in kompetence:

Študentje se seznanijo s fiziko tekočih kristalov in preko njih spoznajo številne univerzalne pojave v naravi, ki so skupni tako fiziki osnovnih delcev, fiziki kondenzirane materije in kozmologiji.

Objectives and competences:

Students get acquainted with physics of liquid crystals. Phenomena observed in liquid crystals are exploited as testing grounds for several universal phenomena in nature, spanning particle physics, condensed matter and cosmology.

Predvideni študijski rezultati:

Študenti se seznanijo s številnimi univerzalnimi pojavi v tekočih kristalih, preko katerih dobijo vpogled v bazične zakonitosti narave.
Predmet pripravlja študente za uporabo znanja s področja fizike tekočih kristalov.

Intended learning outcomes:

Students acquire knowledge on diverse universal phenomena in liquid crystals. Via them they get basic understanding of several fundamental concepts in nature and ability to integrate this understanding in their research work.
This course prepares students to apply knowledge of physics of liquid crystals.

Metode poučevanja in učenja:

- Predavanja
- Seminarji
- Konzultacije

Learning and teaching methods:

- Lectures
- Seminar work
- Consultations

Načini ocenjevanja:	Delež (v %) / Weight (in %)	Assessment:
Ustni izpit	50 %	Oral examination
Naloge ali projekt	50 %	Coursework or project

Reference nosilca / Lecturer's references:

- KURIOZ, Pavlo, KRALJ, Marko, MURRAY, Bryce S., ROSENBLATT, Charles, KRALJ, Samo. Nematic topological defects positionally controlled by geometry and external fields. Beilstein journal of nanotechnology, 2018, vol. 9, str. 109-118, https://www.beilstein-journals.org/bjnano/content/pdf/2190-4286-9-13.pdf, doi: 10.3762/bjnano.9.13.
- KRALJ, Samo, MESAREC, Luka, KURIOZ, Pavlo, RZOSKA, Sylwester, IGLIČ, Aleš. Topological defects : from simplicity to complexity. Global journal of science frontier research, 2017, vol. 17, no. 3-A, str. 23-43. https://journalofscience.org/index.php/GJSFR/article/view/2052/1913.
- HARKAI, Saša, AMBROŽIČ, Milan, KRALJ, Samo. Impact of diffusion limited aggregates of impurities on nematic ordering. Physica. A, Statistical mechanics and its applications, 2017, vol. 467, str. 249-256, doi: 10.1016/j.physa.2016.10.001.
- KRALJ, Samo, MURRAY, Bryce S., ROSENBLATT, Charles. Decomposition of strongly charged topological defects. Physical review. E, 2017, vol. 95, iss. 4, str. 042702-1-042702-9, doi: 10.1103/PhysRevE.95.042702.
- MESAREC, Luka, GÓŹDŹ, Wojciech, IGLIČ, Aleš, KRALJ, Samo. Effective topological charge cancelation mechanism. Scientific reports, ISSN 2045-2322, 2016, vol. 6, art. no. 27117, str. 1-9, http://www.nature.com/articles/srep27117, doi: 10.1038/srep27117.