Univerza v Mariboru

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Fakulteta za naravoslovje in matematiko

UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Fizika koloidov in makromolekul
Course title:	Physics of colloids and macromolecules

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
Fizika 2. st.		2	3
Physics 2nd degree		2	3

Vrsta predmeta / Course type	izbirni/ optional
Univerzitetna koda predmeta / University course code:	

Predavanja Lectures	Seminar Seminar	Sem. vaje Tutorial	Lab. vaje Laboratory work	Teren. vaje Field work	Samost. delo Individ. work	ECTS
30	15	0	0	0	105	5

Nosilec predmeta / Lecturer:	Jure Dobnikar

Jeziki / Languages:	**Predavanja / Lectures:**	Slovenski/Slovenian in/and angleški/English
	Vaje / Tutorial:	Slovenski/Slovenian in/and angleški/English

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisits:**
Priporočljivo je predznanje s področij fizike materialov, fizike tekočin, mehke snovi, statistične termodinamike in elektromagnetnega polja.	Preknowledge from the following fields of physics is recommended: Physics of materials, Physics of liquids, Soft matter physics, Statistical thermodynamics, Electromagnetic field.

Vsebina:	**Content (Syllabus outline):**
Koloidi so delci veliki med nekaj nanometri in nekaj mikrometri; veliko večji od atomov, a še ne makroskopski. Ponavadi jih najdemo ali uporabljamo v raztopinah, kjer je poleg koloidov še topilo ter razne vrste mikroionov. Fizikalni opis takšnih sistemov je zaradi različnih velikostnih in časovnih razredov sestavnih delcev precej zapleten, zato pa tudi zanimiv. Poskusi s koloidi se relativno enostavni, zato so koloidne raztopine zelo dober modelski sistem, s katerim lahko preizkušamo splošne fizikalne zakonitosti. Koloidi so sestavni del žive snovi, zato je fizika koloidov nepogrešljiva v biologiji in medicini. Nenazadnje so koloidi tudi industrijsko zelo uporabne snovi, najdemo	Colloids are particles ranging in size between a few nm and a few microns. They usually exist in suspensions, surrounded by the solvent and a huge number of other microions. The physics of such a system is – due to the very different length and time scales of the particles – quite complicated but therefore also quite interesting. Experiments with colloids are relatively easy to do, making the colloids an exceptionally good model system to study general physical laws. Colloids are building blocks of the living matter, therefore the physics of colloids is essential to biology, medicine,... Industrially the colloids are very widely used, e.g.: food, drugs, emulsions, paints, fotonic crystals and many more.

jih praktično povsod: hrana, zdravila, emulzije, barve, fotonski kristali ...

Pri predmetu Fizika koloidov se bomo posvetili interakcijam v koloidnih raztopinah, kot so:

- sterična,
- elektrostatska,
- hidrodinamska,
- termična in
- disperzijska interakcija.

Posebej podrobno bomo obravnavali elektrostatske interakcije med električno nabitimi makroioni v raztopini, ki so v ravnovesnih strukturah najpomembnejše. Ogledali si bomo naravo elektrostatskih interakcij med koloidi, ki se prenašajo preko velikega števila mikroionov v raztopino, ter različne teoretične pristope k opisu teh interakcij:

- Poisson-Boltzmann-ova enačba,
- teorija DLVO
- efektivne parske interakcije,
- mnogodelčne interakcije,
- celični model.

Opisali bomo eksperimentalne metode za preučevanje koloidov, kot so:

- rentgensko sipanje,
- laserska pinceta,
- videomikroskopija,
- merjenje efektivnega naboja.

Spoznali bomo tudi, kako pristopimo k opisu koloidnih raztopin s pomočjo numeričnih simulacij.

V drugem delu si bomo podrebneje ogledali lastnosti makromolekul, ki so osnovni gradniki koloidnih sistemov:

- Polimeri: fizikalni opis (preprosti modeli, lastnosti: persistenčna dolžina, elastičnost), pomembnost in uporaba
- Polielektroliti: vpliv elektrosatike
- Molekula DNK: zgradba in lastnosti, kromosom, funkcija v biologiji, fazni diagram, pakiranje DNK v virus/celico, experimentalne metode, električna prevodnost DNK, genom, mutacije in statistika fluktuacij
- Proteini: zgradba, funkcija, interakcije, eksperimentalno preučevanje, problem kristalizacije
- Numerične simulacije makromolekul in eksperimentalne metode za njihovo preučevanje

At *Physics of colloids* we will learn about the interactions that are present among colloids:

- steric,
- electrostatic,
- hydrodynamic,
- thermic,
- dispersion.

The emphasis will be on electrostatics, which is the most important interaction in equilibrium. We will learn how the electrostatic interactions are mediated via a large number of microions and how can we theoretically describe them:

- Poisson-Boltzmann equation,
- DLVO theory,
- effective pair interactions,
- many-body interactions,
- cell model, and other approximations.

The experimental methods like

- light scatgtering,
- laser tweezers,
- videomicroscopy,
- effective charge measurements,...

will be presented. Finally, the numerical simulations of colloidal suspensions will be presented.

Next, we will more closely inspect the properties of macromolecules, which are basic building blocks of colloidal systems:

- Polymers: physical description (simple models, properties: persistent length, elasticity), applications
- Polyelectrolytes: role of electrostatics
- DNA molecule: structure and properties, biological function, chromosome, phase diagram, packing into viruses/cells, experimental methods, electrical conductivity along the chain, genome, mutations and fluctuation statistics
- Proteins: structure, function, interactions, experimental study, problem of crystalization

Numerical simulation of macromolecules and experimental methods for their investigation

Temeljni literatura in viri / Readings:

1. W.B. Russel, D.A. Saville and W.R. Scholwater, Colloidal Dispersions, Cambridge University Press, 1989
2. D.F. Evans and H. Wennerström, The Colloidal Domain: where Physics, Chemistry, Biology and Technology meet, VCH, 1994
3. Alexander Yu Grosberg, A. R. Khokhlov, Giant Molecules: Here, There, and Everywhere..., Academic Press, 1997
4. D. Frenkel, B.J.Smit, Understanding Molecular Simulation,Elsevier, 2002
5. M.P. Allen, D.J. Tildesley, Computer Simulation of Liquids,Oxford, 1989
6. J.P. Hansen, I.R. McDonald, Theory of Simple Liquids, Academic Press, 1990
7. Članki v znanstvenih revijah / Papers in scientific publications

Cilji in kompetence:

- Pridobiti vpogled v fiziko koloidov
- Pridobiti pregledno znanje o eksperimentalnih metodah, teoretičnih modelih in moderni uporabi koloidov
- Razumeti komlpeksnost elektrostatskih interakcij v raztopinah
- Podati pregled lastnosti in funkcij biološko pomembnih makromolekul
- Podrobno se seznaniti z aktualnimi raziskavami in odprtimi vprašanji v zvezi s proteini in molekulo DNK
- Obdelati osnovne metode za numerične simulacije makromolekul
- Zmožnost samostojne izvedbe: preprostih numeričnih simulacij, predstavitve seminarja…

Objectives and competences:

- Overview: physics of colloids
- Overview: experimental methods, theoretical models, applications
- Understanding of complexity of electrostatics in media
- Learn about basic theoretical description of macromolecules
- DNA and proteins: find out about the state of the art research and open problems
- Learn the basic numerical methods to simulate macromolecules
- Capability of independent conduction of: simple numerical work, presenting a seminar

Predvideni študijski rezultati:

Znanje in razumevanje:

- Interakcije med koloidnimi delci,
- elektrostatika v raztopinah,
- mnogodelčne interakcije,
- numerične simulacije koloidnih raztopin
- Fizika polimerov in polielektrolitov,
- pregledno znanje o molekuli DNK in o proteinih

Prenesljive/ključne spretnosti in drugi atributi:

- Teoretični opis mnogodelčnih sistemov,
- numerično reševanje parcialnih diferencialnih enačb,
- Računske metode za opis polimerov in polielektrolitov,
- poznavanje numeričnih metod (Monte Carlo) in njihova uporaba za simulacije polimerov ter polielektrolitov,
- znanje o eksperimentalnih metodah
- samostojno pregledovanje znanstvene literature in predstavitev seminarja

Intended learning outcomes:

Knowledge and Understanding:

- Interactions among colloids,
- electrostatics in suspension,
- many-body interactions,
- numerical simulations of colloidal suspensions
- Polymer and polyelectrolyte physics,
- overview of DNA molecule and proteins

Transferable/Key Skills and other attributes:

- Theoretical description of many-body systems,
- numerical methods for solving partial differential equations,
- Computational methods for polymers and polyelectrolytes,
- Numerical methods (Monte Carlo) to study polymers and polyelectrolytes
- knowledge about experimental methods
- Independent literature search and presentation of seminars

Metode poučevanja in učenja:

Learning and teaching methods:

Predavanja	Lectures
Seminarji	Seminars
Projektne naloge	Project work
Vaje	Excersises

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
Ustni izpit	30	Oral exam
Seminar	30	Seminar
Domače naloge	40	Home works

Reference nosilca / Lecturer's references:

KANDUČ, Matej, DOBNIKAR, Jure, PODGORNIK, Rudolf. Counterion-mediated electrostatic interactions between helical molecules. *Soft matter*, 2009, issue 5, vol. 5, str. 868-877, doi: 10.1039/b811795k. [COBISS.SI-ID 2149988]

TRIZAC, Emmanuel, EL SHAWISH, Samir, DOBNIKAR, Jure. Dimeric and dipolar ground state orders in colloidal molecular crystals. *An. Acad. Bras. Cienc.*, 2010, vol. 82, no. 1, str. 87-94. [COBISS.SI-ID23483687]

EL SHAWISH, Samir, DOBNIKAR, Jure, TRIZAC, Emmanuel. Colloidal ionic complexes on periodic substrates : ground-state configurations and pattern switching. *Phys. rev., E Stat. nonlinear soft matter phys. (Print)*, 2011, vol. 83, no. 4, str. 041403-1-041403-10. [COBISS.SI-ID 24653095]

MATTHÄUS, Franziska, MOMMER, Mario S., CURK, Tine, DOBNIKAR, Jure. On the origin and characteristics of noise-induced Lévy Walks of E. Coli. *PLoS one*, 2011, vol. 6, no. 4, str. e18623-1-e18623-8.http://www.plosone.org/article/info:doi/10.1371/journal.pone.0018623. [COBISS.SI-ID 25045031]

CURK, Tine, HOOGH, Anouk de, MARTINEZ-VERACOECHEA, Francisco J., EISER, Erika, FRENKEL, Daan, DOBNIKAR, Jure, LEUNISSEN, Mirjam E. Layering, freezing, and re-entrant melting of hard spheres in soft confinement. *Phys. rev., E Stat. nonlinear soft matter phys. (Online)*. [Online ed.], 2012, vol. 85, iss. 2, str. 021502-1-021502-5. http://link.aps.org/doi/10.1103/PhysRevE.85.021502, doi:10.1103/PhysRevE.85.021502. [COBISS.SI-ID 518221081]