



Univerza v Mariboru

Fakulteta za naravoslovje
in matematiko

UČNI NAČRT PREDMETA / COURSE SYLLABUS

Predmet:	Termodinamika
Course title:	Thermodynamics

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
Predmetni učitelj The subject teacher		2	4

Vrsta predmeta / Course type

obvezni/ Compulsory

Univerzitetna koda predmeta / University course code:

Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Lab. vaje Laboratory work	Terenske vaje Field work	Samost. delo Individ. work	ECTS
20		20			50	3

Nosilec predmeta / Lecturer:

Milan Svetec

**Jeziki /
Languages:**

**Predavanja / Lectures:
Vaje / Tutorial:**

slovenski/Slovenian
slovenski/Slovenian

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

Pogojev ni. Priporočljivo je predznanje iz klasične mehanike.

Prerequisites:

None. Recommended preknowledge of classical mechanics.

Vsebina:

Temperatura - merjenje temperature, plinski termometer; ničti zakon termodinamike, temperaturno raztezanje
Toplota, specifična toplota in toplotne kapaciteta, fazni prehodi;
Prenos toplote: a) prevajanje, prevajanje skozi kompozitno ploščo, radialni toplotni tok v cevi; b) konvekcija, c) sevanje, črno telo, sevanje črnega telesa, Newtonov zakon hlajenja;
Idealni plin in kinetična teorija plinov: enačba stanja idealnega plina, kinetična teorija plinov,

Content (Syllabus outline):

Temperature - temperature measurement, gas thermometer; zeroth law of thermodynamics, temperature expansion
Heat, specific heat and heat capacity, phase transitions;
Heat transfer: a) conduction, conduction through a composite plate, radial heat transfer in the tube; b) convection, c) radiation, black body, black body radiation, Newton's law of cooling;
Ideal gas and kinetic theory of gases: equation of state of an ideal gas, kinetic theory of gases,



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povprečna prosta pot molekul, hitrostna porazdelitev molekul (Maxwell-Boltzmannova porazdelitev), tipične hitrosti molekul;
Prvi zakon termodinamike: notranja energija, krožna sprememba, kaj je adiabatni proces, sprememba pri konstantnem volumnu, izobarni proces, izotermni proces, specifična toplotna kapaciteta idealnega plina, adiabatni procesi in enačba adiabate, izotermna in adiabatna stisljivost, toplotna kapaciteta plinov, enakomerna porazdelitev energije;

Toplotni stroji in drugi zakon termodinamike: Carnotov toplotni stroj, hladilni stroj, entropija, drugi zakon termodinamike;

Termodinamski potenciali: izrek o recipročnosti in izrek o cikličnosti, toplotna kapaciteta, značilnosti funkcij stanja, Clausius-Clapeyronova enačba, Van der Waalsova enačba, termodinamski potenciali (Helmholtzova prosta energija, Gibbsova prosta energija, entalpija)

mean free path of molecules, velocity distribution of molecules (Maxwell-Boltzmann distribution), typical molecular velocity;

The first law of thermodynamics: internal energy, cyclical process, what is an adiabatic process, change in constant volume, isobaric process, isothermal process, specific thermal capacity of ideal gas, adiabatic processes and adiabatic equations, isothermal and adiabatic compressibility, thermal capacity of gases, uniform distribution of energy;

Heat engines and second law of thermodynamics: Carnot heat engine, cooling engine, entropy, second law of thermodynamics;

Thermodynamic potentials: theorem on reciprocity and the cyclicity theorem, the thermal capacity, the characteristics of the state functions, the Clausius-Clapeyron equation, Van der Waals equation, the thermodynamic potentials (Helmholtz free energy, Gibbs free energy, enthalpy)

Temeljni literatura in viri / Readings:

- D. Haliday, R. Resnick, J. Walker: Fundamentals of Physics, extended, with Modern Physics, John Wiley & Sons 1993.
- R. Resnick, D. Halliday, K.S. Krane: Physics, fourth edition, Wiley and Sons, 1992
- C. J. Adkins: Equilibrium Thermodynamics, Cambridge University Press, 2003
- M. W. Zemansky, R. H. Dittman: Heat and thermodynamics, McGraw-Hill, 1997
- E. Fermi: Thermodynamics, Dover publications, 1956
- V. Savelyev: Physics, A general course I, Mir publications Moscow, 1980
- J. Strnad: Fizika 1. del: Mehanika, Toplota, Društvo matematikov, fizikov in astronomov Slovenije 1995.

Cilji in kompetence:

Študenti usvojijo temeljna teoretična znanja s področja termodinamike in jih znajo uporabiti pri reševanju ustreznih problemov z rabo usvojenih konceptov in matematičnih orodij

Objectives and competences:

Students acquire basic theoretical knowledge in the field of thermodynamics and can use them to solve relevant problems using the adopted concepts and mathematical tools.

Predvideni študijski rezultati:

Intended learning outcomes:

**Znanje in razumevanje:**

Po uspešno zaključeni učni enoti bodo študenti sposobni:

- definirati fizikalni sistem, opredeliti dejavnike v okolici, ki vplivajo na stanje sistema, in kvalitativno ter kvantitativno napovedati spreminjanje stanja izbranega fizikalnega sistema v odvisnosti od parametrov in spremenljivk v sistemu in okolici;
- uporabiti zakonitosti termodinamike za analiziranje pojavov, povezanih s prenosom toplote, za analiziranje različnih stanj idealnega plina v odvisnosti od dejavnikov v okolici, za opis in razločevanje prehodov med različnimi stanji opazovanega sistema (predvsem idealnega plina) na pV diagramu, za matematični opis krožnih procesov in izračun izkoristka naprave, za opis sistema s primernim termodinamskim potencialom;
- obravnavati pV diagram poljubne tekočine in določiti kritično točko sistema ter napovedati tipično obnašanje sistema.

Prenesljive/ključne spretnosti in drugi atributi:

Po uspešno zaključeni učni enoti bodo študenti zmožni:

- uporabljati sodobno računalniško programsko opremo kot pomoč pri kvantitativnem računanju ter za izrisovanje odvisnosti med spremenljivkami v odvisnosti od vrednosti parametrov;
- pripravljati fizikalne skice in diagrame prehajanja stanj ter smiselno poročati o izbrani temi;

Knowledge and understanding:

After successful completion of the learning unit students will be able to:

- define the physical system, define the environmental factors that influence the state of the system, and predict qualitatively and quantitatively the change in the state of the selected physical system depending on the parameters and variables in the system and environment;
- apply the principles of thermodynamics to analyze the phenomena associated with heat transfer, to analyze the various states of ideal gas depending on the surrounding factors, to describe and distinguish the transitions between the various states of the observed system (especially the ideal gas) on the pV diagram, for the mathematical description of the cyclical processes and calculation of the efficiency of the engine, for describing the system with a suitable thermodynamic potential, for analyzing a system consisting of several components and an appropriate choice of the thermodynamic potential for the description;
- Consider the pV diagram of any liquid and determine the critical point of the system and predict the typical behavior of the system.

Transferable/Key Skills and other attributes:

After successful completion of the learning unit students will be able to:

- use modern computer software for quantitative calculations and for plotting dependencies among variables at different values of parameters;
- prepare physical sketches and diagrams of the state transitions and report in a meaningful manner on the chosen topic;



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Metode poučevanja in učenja:

eksperimentalna predavanja
teoretične vaje
razlaga
razgovor
demonstracija
delo s tekstom
metoda pisnih in grafičnih del
uporaba simulacij
elementi obrnjenega poučevanja

Poučevanje in učenje potekata z didaktično uporabo informacijsko-komunikacijske tehnologije.

Learning and teaching methods:

- lectures with experiments
- theoretical exercises
explanation
discussion
demonstration
work with text
work with graphic elements
use of simulations
elements of flipped learning

Teaching and learning are performed through the didactic use of ICT.

Delež (v %) /

Weight (in %)

Načini ocenjevanja:

Assessment:

Način (pisni izpit, ustno izpraševanje, naloge, projekt):

Pisni izpit (lahko se nadomesti z dvema vmesnima kolokvijema)

Ustni izpit

Za uspešno zaključeno učno enoto mora vsak del posebej biti pozitiven.

50

50

Type (examination, oral, coursework, project):

written exam (can be replaced by two written tests)

oral exam

For a successfully mastering this course, both oral and written exams have to be positive.

Reference nosilca / Lecturer's references:

1. TERNIK, Primož, ZADRAVEC, Matej, SVETEC, Milan, RUDOLF, Rebeka. Numerical analysis of the rapid solidification process of NiTi binary alloy. Acta physica Polonica. A, ISSN 0587-4246. [Print ed.], July 2015, vol. 128, no. 1, str. 43-47, doi: 10.12693/APhysPolA.128.43. [COBISS.SI-ID 18864150], [JCR, SNIP, WoS do 28. 5. 2017: št. citatov (TC): 2, čistih citatov (CI): 1, Scopus do 31. 8. 2017: št. citatov (TC): 2, čistih citatov (CI): 1]
2. ZADRAVEC, Matej, TERNIK, Primož, RUDOLF, Rebeka, SVETEC, Milan. Numerical analysis of rapid solidification of NiTi alloy : influence of boundary conditions = Numerična analiza hitrega strjevanja NiTi zlitine : vpliv robnih pogojev. Anali PAZU, ISSN 2232-416X, 2014, letn. 4, št. 2, str. 82-88, ilustr. <http://www.anali-pazu.si/sites/default/files/Numerical%20analysis....pdf>. [COBISS.SI-ID 19046166]
3. SVETEC, Milan, SLAVINEC, Mitja. Nematic liquid crystal locking menisci. Advances in condensed matter physics, ISSN 1687-8108, 2013, vol. 2013, art. ID 756902, str. 1-6.



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<http://dx.doi.org/10.1155/2013/756902>. [COBISS.SI-ID 19802888], [JCR, SNIP, WoS do 13. 5. 2013: št. citatov (TC): 0, čistih citatov (CI): 0, Scopus do 6. 5. 2013: št. citatov (TC): 0, čistih citatov (CI): 0]

4. SVETEC, Milan, KRALJ, Samo, POPA-NITA, Vlad. Disorder- driven gradual transition of the continuous symmetry- breaking phase transition = Z naključnim neredom spodbujen postopni fazni prehod sistema z zveznim faznim prehodom, ki zlomi simetrijo. Anali PAZU, ISSN 2232-416X, 2012, letn. 2, št. 1, str. 6-14, graf. prikazi. [COBISS.SI-ID 19545608]

5. KRALJ, Samo, KUTNJAK, Zdravko, LAHAJNAR, Gojmir, SVETEC, Milan. Phase behavior of perturbed liquid crystals. V: RZOSKA, Sylwester J. (ur.), DROZD-RZOSKA, Aleksandra (ur.), MAZUR, Victor A. (ur.). Metastable systems under pressure : proceedings of the NATO Advanced Research Workshop on Metastable Systems under Pressure: Platform for New Technologies and Environmental Applications, Odessa, Ukraine, 4-8 October 2008, (NATO science for peace and security series, ISSN 1874-6489, Series A, Chemistry and Biology). Dordrecht; London: Springer. 2010, str. 231-241. [COBISS.SI-ID 23197991], [SNIP]

tipologija 1.08 -> 1.01

6. SVETEC, Milan, SLAVINEC, Mitja. Structural transition of nematic liquid crystal in cylindrical capillary as a result of the annihilation of two point defects. The Journal of chemical physics, ISSN 0021-9606, 2008, vol. 128, no. 8, str. 084704-1-084704-6, ilustr., doi: 10.1063/1.2839301. [COBISS.SI-ID 15899400], [JCR, SNIP, WoS do 20. 1. 2019: št. citatov (TC): 4, čistih citatov (CI): 3, Scopus do 21. 12. 2018: št. citatov (TC): 5, čistih citatov (CI): 4]

7. SVETEC, Milan, KRALJ, Samo, BRADAČ, Zlatko, ŽUMER, Slobodan. Annihilation of nematic point defects : pre-collision and post-collision evolution. The European physical journal. E, Soft matter, ISSN 1292-8941, 2006, vol. 19, issue 5. [COBISS.SI-ID 14632712], [JCR, SNIP, WoS do 11. 6. 2017: št. citatov (TC): 24, čistih citatov (CI): 21, Scopus do 19. 2. 2019: št. citatov (TC): 28, čistih citatov (CI): 24]

8. SVETEC, Milan, BRADAČ, Zlatko, KRALJ, Samo, ŽUMER, Slobodan. Hedgehog annihilation in a confined nematic liquid crystal : [presented at 19th International Liquid Crystal Conference ILCC2002, Edinburgh]. V: 19th International Liquid Crystal Conference 2002 Edinburgh, UK 30 June - 5 July 2002, (Molecular crystals and liquid crystals, ISSN 1542-1406, Vol. 413, Issue 1). Philadelphia: Taylor & Francis. 2004, 413, str. 43/[2179]-51[2187]. [COBISS.SI-ID 1743460], [JCR, SNIP, WoS do 12. 2. 2017: št. citatov (TC): 4, čistih citatov (CI): 3, Scopus do 17. 6. 2017: št. citatov (TC): 6, čistih citatov (CI): 5]

tipologija 1.08 -> 1.01

9. REPNIK, Robert, MATHELITSCH, Leopold, SVETEC, Milan, KRALJ, Samo. Physics of defects in nematic liquid crystals. European journal of physics, ISSN 0143-0807, 2003, 24, str. 481-491, ilustr. [COBISS.SI-ID 12755208], [JCR, SNIP, WoS do 26. 5. 2019: št. citatov (TC): 25, čistih citatov (CI): 20, Scopus do 16. 5. 2019: št. citatov (TC): 26, čistih citatov (CI): 19]

10. BRADAČ, Zlatko, KRALJ, Samo, SVETEC, Milan, ŽUMER, Slobodan. Annihilation of nematic point defects : postcollision scenarios. Physical review. E, ISSN 1063-651X, 2003, 67, str. 050702-1-050702-4. [COBISS.SI-ID 1666404], [JCR, WoS do 10. 9. 2017: št. citatov (TC): 17, čistih citatov (CI): 10, Scopus do 16. 3. 2018: št. citatov (TC): 17, čistih citatov (CI): 10]