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| **UČNI NAČRT PREDMETA / COURSE SYLLABUS** | | | | | | | | | | | | | | | | |
| **Predmet:** | | | Bioelektromagnetika | | | | | | | | | | | | | |
| **Course title:** | | | Bioelectromagnetics | | | | | | | | | | | | | |
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| **Študijski program in stopnja**  **Study programme and level** | | | | | **Študijska smer**  **Study field** | | | | | | | **Letnik**  **Academic year** | | **Semester**  **Semester** | | |
| Podiplomski magistrski študijski program druge stopnje Elektrotehnika | | | | | Biomedicinska tehnika | | | | | | | 2 | | 1 | | |
| 2nd cycle masters study programme in Electrical Engineering | | | | | Biomedical Engineering | | | | | | | 2 | | 1 | | |
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| **Vrsta predmeta / Course type** | | | | | | | | | | | Obvezni-strokovni / Compulsory professional | | | | | |
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| **Univerzitetna koda predmeta / University course code:** | | | | | | | | | | | 64281 | | | | | |
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| **Predavanja**  **Lectures** | **Seminar**  **Seminar** | | | **Vaje**  **Tutorial** | | | **Klinične vaje**  **work** | | | **Druge oblike študija** | | | **Samost. delo**  **Individ. work** | |  | **ECTS** |
| 45 |  | | | 30 | | |  | | |  | | | 75 | |  | 6 |
|  | | | | | | | | | | | | | | | | |
| **Nosilec predmeta / Lecturer:** | | | | | Tadej Kotnik, Peter Gajšek | | | | | | | | | | | |
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| **Jeziki /**  **Languages:** | | **Predavanja / Lectures:** | | | | slovenski / Slovenian | | | | | | | | | | |
| **Vaje / Tutorial:** | | | | slovenski / Slovenian | | | | | | | | | | |
| **Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:** | | | | | | | |  | **Prerequisites:** | | | | | | | |
| Vpis v letnik predmeta | | | | | | | |  | Enrolment in the year of the course | | | | | | | |

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| **Vsebina:** | |  | | **Content (Syllabus outline):** | |
| **Elektromagnetni spekter in kratek pregled bioloških učinkov:** neionizirna sevanja ter fizikalne osnove njihovih interakcij, termični učinki, netermič­ni učinki; ionizirna sevanja in njihovi biološki učinki  **Viri elektromagnetnih polj:** statično magnetno polje, nizkofrekvenčna elektromagnetna polja (0-100 kHz), visokofrekvenčna elektromag-netna polja in sevanja (100 kHz-300 GHz).  **Merjenje in dozimetrija:** pregled merilnih me-tod in standardov, eksperimentalna dozime-trija, nume­rična dozimetrija, mikrodozimetrija.  **Biološka snov v elektromagnetnem polju:** sta­tično električno in magnetno polje, nizkofrekvenčna polja (disociacija in elektrolitske raztopine, preva­janje, elektroliza in polarizacija, električne lastnosti celic in tkiv), visokofrekvenčna polja in sevanja (frekvenčna odvisnost električnih lastnosti celic in tkiv, bližnje in daljnje polje, vdorna globina, ab­sorpcija energije, segrevanje).  **Mehanizmi interakcij:** električne lastnosti celic in tkiv, interakcije s šibkimi polji (mikroelektroforeza, resonančni modeli), interakcije z močnimi polji (sila na nabite delce, interakcije z vzdražnimi tkivi, termične interakcije), elektroporacija.  **Pregled laboratorijskih in epidemioloških raz­iskav:** raziskave in vitro, raziskave na rastlinah in živalih in vivo, epidemiološke študije, pregled stanja raziskav v svetu.  **Ocena zdravstvenega tveganja, preventivni vidiki in strategija razvoja:** analiza tveganj zaradi prisotnosti elektromagnetnih polj, kontrola eksperi­mentalnih pogojev, ponovljivost eksperimentalnih polj, načelo previdnosti, zaščita pred polji in sevanji.  **Uporaba električnih tokov ter elektro-magnetnih polj in sevanj v medicini:** srčni spodbujevalniki in defibrilatorji, funkcionalna in protibolečinska elek­trična stimulacija, elek-troporacija, elektrokirurgija, elektrotermija.  **Standardi in mejne vrednosti:** izhodišča, medna­rodna priporočila, pravna ureditev. | |  | | **Electromagnetic spectrum and an overview of biological effects:** non-ionizing radiation and physics of their interactions, non-thermal effects, thermal effects; ionizing radiation and its biological effects  **Sources of electromagnetic fields (EMF):** static magnetic field, low-frequency EMF (0-100 kHz), high-frequency EMF and radiation (100 kHz-300 GHz).  **Measurements and dosimetry:** an overview of measuring methods and standards, experimental dosimetry, nume­rical dosimetry, microdosimetry.  **Biological matter in EMF:** static electric and magnetic fields, low-frequency fields (dissociation and solutions, electric conductivity, electrolysis and polarization, electrical properties of cells and tissues), high-frequency fields and radiation (frequency dependence of electrical properties of cells and tissues, near and far field, penetration depth, energy absorption, heating).  **Interaction mechanisms:** electric properties of cells and tissues, interactions with weak fields (microelectrophoresis, resonance models), interactions with strong fields (forces on charged particles, interactions with excitable cells and tissues, thermal effects, membrane electroporation).  **Overview of experimental and epidemiological studies:** research in vitro, research on plants and animals in vivo, epidemiological studies, current state of research and scientific position.  **Health risk assessment, prevention and development strategies:** analysis of risks due to EMF, control of experimental conditions, reproducibility of experimental fields, precautionary principle, protection from EMF.  **Use of electric currents and EMF in medicine:** pacemakers and defibrillators, functional and analgesic electrical stimulation, electroporation, electrosurgery, electrothermy.  **Standards and exposure limits:** fundamentals, international recommendations, regulations. | |
| **Temeljni literatura in viri / Readings:** | | | | | |
| 1. C. Furse, D. A. Christensen, C. H. Durney. *Basic Introduction to Bioelectromagnetics,* 2. *2nd ed*. CRC Press, 2009. 3. D. Miklavčič, P. Gajšek. *Vpliv neionizirnih elektromagnetnih sevanj na biološke sisteme*. Založba FE in FRI, 1999. 4. Bonner P, et al. *Establishing a dialogue on risks from electromagnetic fields*. WHO, 2002. 5. Adair RK. Biophysical limits on athermal effects of RF and microwave radiation. *Bioelectromagnetics* 24: 39-48, 2003. 6. Gajšek P (ur.). *Abstract book of the International conference on electromagnetic fields: From bioeffects to legislation*, INIS, Ljubljana, 2004. | | | | | |
| **Cilji in kompetence:** | |  | | **Objectives and competences:** | |
| Predstaviti znanstveno utemeljene mehanizme interakcij elektromagnetnih polj in sevanj z biološkimi sistemi, predstaviti vire polj in sevanj, merjenje in dozimetrijo, pomembnejše laboratorij­ske in epidemiološke raziskave ter znanstveno izoblikovane mejne vrednosti. | |  | | To describe the scientifically recognized interaction mechanisms of EMF with biological system, to present the sources of EMF, their measurements and dosimetry, the most important experimental and epidemiological studies, and scientifically based exposure limits. | |
| **Predvideni študijski rezultati:** | | |  | **Intended learning outcomes:** | |
| **Znanje in razumevanje:** Kombinacija teoretične obravnave znanstveno utemeljenih mehanizmov interakcij, meritev v laboratoriju in na terenu ter izračunov elektromagnetnih količin bo študentom nudila poglobljeno in večstransko razumevanje problematike interakcij elektromagnetnih polj in sevanj z živimi organizmi.  **Uporaba:** Razumevanje znanstveno utemeljenih mehanizmov interakcij, sposobnost uporabe sodobnih naprav in metod v eksperimentalni in numerični dozimetriji, poznavanje zdravstvenih tveganj, veljavnih standardov in mejnih vrednosti.  **Refleksija:** Študent bo sposoben kritično oceniti znanstveno utemeljenost posameznih trditev in hipotez o učinkih elektromagnetnih polj in sevanj, načrtovati in izvesti dozimetrične meritve in izračune. | | |  | **Knowledge and understanding:** Combination of theoretical assessment of scientifically recognized interaction mechanisms, lab and outdoor measurements, and numerical dosimetry of EMF will offer the students both broad and thorough understanding of EMF interactions with living organisms.  **Application:** Understanding the scientifically recognized interaction mechanisms, ability to use modern devices and methods in both experimental and numerical dosimetry, familiarity with health risks, standards and exposure limits.  **Reflection:** The student will acquire the ability to assess critically the existence (or lack) of scientific basis for claims and proposed hypotheses on effects of EMF, as well as to plan and perform dosimetric measurements and/or computations. | |
| **Prenosljive spretnosti:** Numerično modeliranje fizikalnih količin z metodama končnih diferenc v časovnem prostoru (FDTD) in končnih elementov (FE). Kritično vrednotenje rezultatov lastnega dela in dognanj drugih avtorjev. | | |  | **Transferrable skills:** Numerical modeling of physical quantities using the finite-difference time-domain (FDTD) and finite-element (FE) methods. Critical assessment of results of own, as well as other authors’ work and conclusions. | |
| **Metode poučevanja in učenja:** | | |  | **Learning and teaching methods:** | |
| Predavanja, laboratorijske vaje za pridobivanje samostojnih praktičnih izkušenj z metodami in napravami za eksperimentalno in numerično dozimetrijo in modeliranje ter določanje električnih lastnosti bioloških tkiv, individualne seminarske naloge za seznanitev z epidemiološkimi študijami in njihovo kritično ovrednotenje. | | |  | Lectures, laboratory work for acquisition of individual practical experience with methods and devices for experimental and numerical dosimetry and modeling, for measurements of electrical properties of biological tissues, individual seminars for improved familiarity with epidemiological studies and their critical scientific assessment. | |
| **Načini ocenjevanja:** | Delež (v %) /  Weight (in %) | | | | **Assessment:** |
| Pogoj za opravljanje izpita je pozitivna ocena laboratorijskih vaj (50 ≤ L ≤ 100), pisni izpit pa študent opravi, če zbere vsaj polovico točk (50 ≤ P ≤ 100). V tem primeru se določi izhodišče za končno oceno (I), I = (2P + L)/3, iz katerega sledi predlog končne ocene pri predmetu (K):  • 90 < I ≤ 100: K = 10  • 80 ≤ I ≤ 90: K = 9  • 70 ≤ I < 80: K = 8  • 60 ≤ I < 70: K = 7  • 50 ≤ I < 60: K = 6  Pri 50 ≤ P < 67 je obvezen ustni zagovor izpita, študent pa z uspešnim zagovorom potrdi oceno K. Pri 67 ≤ P ≤ 100 študent izbira med vpisom predlagane ocene K in ustnim zagovorom, s slednjim pa lahko končno oceno tako izboljša kot poslabša. | ocena vaj 33.33%;  ocena izpita 66.67%;  ustni zagovor lahko oceno potrdi, izboljša ali poslabša  /  lab work gra-de contributes 1/3, and exam grade 2/3 to the final grade; verbal exam can result in confirmation, reduction or increase of the grade | | | | The necessary condition for entering the written examination is a positive grade in lab work (50 ≤ L ≤ 100). Written exam is passed if at least half points are gained (50 ≤ P ≤ 100). If these requirements are met, a tentative basis for the final grade (K) is determined as follows:  I = (2P + L)/3,  • 90 < I ≤ 100: K = 10  • 80 ≤ I ≤ 90: K = 9  • 70 ≤ I < 80: K = 8  • 60 ≤ I < 70: K = 7  • 50 ≤ I < 60: K = 6  For 50 ≤ P < 67, the written exam is follo-wed by a verbal one, and with adequate understanding demonstrated, the stu-dent gets the grade K. For 67 ≤ P ≤ 100, the student chooses between accepting grade K and attending the verbal exam, where based on the adequacy of demonstrated understanding, grade K can be confirmed, reduced or increased. |
| **Reference nosilca / Lecturer's references:** | | | | | |
| 1. KOS, Bor, VALIČ, Blaž, KOTNIK, Tadej, GAJŠEK, Peter. Poklicna izpostavljenost elektromagnet-nim sevanjem. *Elektrotehniški vestnik*, 2010, letn. 77, št. 4, str. 200-207. 2. KOS, Bor, VALIČ, Blaž, MIKLAVČIČ, Damijan, KOTNIK, Tadej, GAJŠEK, Peter. Pre- and post-natal exposure of children to EMF generated by domestic induction cookers. *Physics in Medicine & Biology*, 2011, vol. 56, no. 19, str. 6149-6160. 3. KOS, Bor, VALIČ, Blaž, KOTNIK, Tadej, GAJŠEK, Peter. Exposure assessment in front of a multi-band base station antenna. *Bioelectromagnetics*, 2011, vol. 32, no. 3, str. 234-242. 4. KOS, Bor, VALIČ, Blaž, KOTNIK, Tadej, GAJŠEK, Peter. Occupational exposure assessment of magnetic fields generated by induction heating equipment - the role of spatial averaging. *Physics in Medicine & Biology*, 2012, vol. 57, no. 19, str. 5943-5953.   5. KOS, Bor, VALIČ, Blaž, KOTNIK, Tadej, GAJŠEK, Peter. Induced electric fields in workers near low-frequency induction heating machines. *Bioelectromagnetics*, 2014, vol. 35, no. 3, str. 222-226. | | | | | |