COURSE DESCRIPTION CARD - SYLLABUS

Course name
Metamaterials

Course

Field of study
Technical Physics

Year/Semester
1/2

Area of study (specialization)

Profile of study
general academic

Level of study
Second-cycle studies

Course offered in
Polish

Form of study
full-time

Requirements
elective

Number of hours

Lecture	Laboratory classes	Other (e.g. online)
30		
Tutorials	Projects/seminars	

Number of credit points

2

Lecturers

Responsible for the course/lecturer:
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Responsible for the course/lecturer:

Prerequisites

Knowledge of the basics of the classical theory of electromagnetism and the physics of dielectrics and magnetics in the scope of the curriculum content of the subjects at the 1st and 2nd degree of education in the field of Technical Physics. The ability to solve elementary problems in electromagnetism based on the acquired knowledge, the ability to obtain information from indicated sources.

Course objective

Acquainting students with selected issues related to electromagnetic properties of metamaterials and problems related to the propagation of electromagnetic waves in metamaterial media.

Course-related learning outcomes

Knowledge

1. Knows the physical models of electromagnetic phenomena in metamaterials, and knows the limitations in the use of these models. - [K2_W01, K2_W02]

2. Knows the basic methods of numerical simulations used for metamaterials. - [K2_W03]

3. Possesses up-to-date knowledge of the production and characterization of metamaterials and their potential applications. - [K2_W04, K2_W10, K2_W13]

Skills

1. Can formulate complex physical and technical problems concerning metamaterials and propose a strategy for their solution. - [K2_U05]

2. Can select dielectric and magnetic materials in terms of their applications in metamaterials technology. - [K2_U13]

Social competences

1. Perceives the possibilities and ways of continuous updating and supplementing knowledge in the field of modern technology using materials with different electromagnetic properties. - [K2_K04]

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Learning effect	Form of evaluation	Evaluation criteria	
W01, W02, W03,	written/oral exam	3	50.1%-70.0%
W04, W10, W13		4	70.1%-90.0%
		5	od 90.1%
U05, U013	written/oral exam	3	50.1%-70.0%
		4	70.1%-90.0%
		5	od 90.1%
K04	written/oral exam	3	50.1%-70.0%
		4	70.1%-90.0%
		5	od 90.1%

Programme content

1. Electromagnetic waves in metamaterial media

(Maxwell's equations, wave equation for media with zero densities of electric current and electric charge, relations between directions and arrows of electric and magnetic vectors and the wave vector, refractive index and wave impedance, Poynting's theorem, relations between wave vectors and Poynting vector for media with positive and negative electric and magnetic permeabilities)

2. Reflection and refraction of electromagnetic waves at the border of natural and metamaterial media

(boundary conditions for the electromagnetic field at the medium boundary, relationships between electric, magnetic and wave vectors for incident, reflected and refracted waves at the medium boundary, derivation of the laws of reflection and refraction, Fresnel formulas)

3. Complex electromagnetic parameters of materials

(complex refractive index for electrically non-conducting materials without free electric charges, complex refractive index as a consequence of atomic polarizability (Lorentz model), specific conductivity and complex electric permeability of electrically conductive materials)

4. Metamaterials with a negative real part of the refractive index

(complex permittivity of a network formed by mutually parallel wires of conductive materials (CW Pendry model), complex magnetic permeability of a network formed by double metal cylinders with a gap (Pendry SRR model))

5. The method of numerical simulations applied to the determination of electromagnetic parameters of metamaterials

(inverse problem - constitutive relationships, finite integration method, determination of electromagnetic parameters on the basis of transmission and reflection of an electromagnetic wave resulting from the scattering matrix)

6. Potential applications of metamaterials

Teaching methods

Lecture: detailed discussion of issues and derivation of formulas using chalk and blackboard, multimedia presentation of additional materials.

Bibliography

Basic

1. D.J. Griffith, Podstawy elektromagnetyzmu, wyd. 2, dodr. 3. Warszawa, 2011.

2. S.A. Ramakrishna, T.M. Grzegorczyk, Physics and Applications of Negative Refractive Index Metamaterials, CRC Press Taylor & Francis Group, Boca Raton, London, New York, 2009.

Additional

1. N. Engheta, R.W. Ziolkowski (ed.), Metamaterials: Physics and Engineering Explorations, John Wiley & Sons, Inc., 2006.

2. Tie Jun Cui, D. J. Smith, Ruopeng Liu, Metamaterials: Theory, Design, and Applications, Springer, New York, Dordrecht, Heidelberg, London.

Breakdown of average student's workload

	Hours	ECTS
Total workload	54	2,0
Classes requiring direct contact with the teacher	34	1,0
Student's own work (literature studies, preparation for laboratory classes/tutorials, preparation for tests/exam, project preparation) [1]	0	0,0

[1] delete or add other activities as appropriate