FACULTY OF ELECTRICAL ENGINEERING

SUBJECT CARD

Name in Polish:	**Modelowanie obwodowo-polowe maszyn i urządzeń elektrycznych**
Name in English:	**Field-circuit modelling of electrical machines and apparatus**
Main field of study (if applicable):	**Electrical Engineering**
Specialization (if applicable):	**Industrial Electrical Engineering**
Level and form of studies:	**2nd level, full-time**
Kind of subject:	**optional**
Subject code:	**ELR043106**
Group of courses:	**NO**

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in University (ZZU):	30		15		
Number of hours of total student workload (CNPS):	60		30		
Form of crediting:	examination		crediting with grade		
For group of courses mark (X) final course:					
Number of ECTS points:	2		1		
including number of ECTS points for practical (P) classes :			1		
including number of ECTS points for direct teacher-student contact (BK) classes:	1.40		0.70		

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Has a basic knowledge of ordinary differential equations and differential equations with partial derivatives.
2. Has a basic knowledge of classical electrodynamics (electrostatics, electric current, magnetostatics, electromagnetic induction, electromagnetic waves).
3. He knows the fundamental laws and properties of the electromagnetic field.
4. Is able to correctly and effectively apply the knowledge of differential and integral calculus of several variables for qualitative and quantitative analysis of mathematical problems related to engineering discipline of study.
5. Is able to apply the learned theory of the electromagnetic field for the qualitative and quantitative assessment of the physical quantities of an engineering.
6. Is able to work together in a group and present the results of this cooperation.

SUBJECT OBJECTIVES

C1. Presentation for students the physical description of electromagnetic phenomena which constitute the principle of operation of electrical machines and apparatus.

C2. Raising students' awareness due to the relationship between induced electromagnetic fields in machines and apparatus and characteristics of their operations.

C3. Acquaint students with the universal method of fields calculation (finite element method) as a tool for calculating the induction parameters, forces and power losses.

C4. Acquaint students with the field-circuit method for analysis and design of electrical machines and apparatus.

C5. Acquaint with work as a team on the calculation project.

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:	
PEK_W01	Know the basic laws of electrodynamics described by Maxwell's equations.
PEK_W02	Is able to describe the construction of a field model and a field-circuit model of electrical machines and apparatus.
PEK_W03	Is able to explain the methods for calculating the induction parameters of windings, electromagnetic forces and power losses.
relating to skills:	
PEK_U01	Is able to use commercial applications to field and field-circuit electromagnetic calculation.
PEK_U02	Is able to design two-dimensional field and field-circuit models of electrical machines and apparatus and is able to assess the results of numerical calculations of electromagnetic field distribution.
PEK_U03	Is able to calculate the inductance of windings, electrodynamic forces and torques, and the power losses in construction elements.
relating to social competences:	
PEK_K01	He knows the rules of group work and managing a small team taking responsibility for the results of his work.

PROGRAMME CONTENT		
Form of classes - lecture		**Number of hours:**
Lec 1	A general description of the course. Historical outline. Indication and discussion of literature. Presentation of requirements and way to complete the course.	2
Lec 2	Fundamental laws of electrodynamics. Maxwell's equations, constitutive relations.	2
Lec 3	Differential and integral equations. Scalar and vector potentials.	2
Lec 4	Energy and power. Energetic relations.	2
Lec 5	Poynting's theorem. Eddy current power losses.	2
Lec 6	Electromagnetic properties of materials used in electrical machines and apparatus. Hard and soft magnetic materials.	2
Lec 7	Fundamentals of numerical finite element method.	2
Lec 8	Construction of field calculation model, mesh generation.	2
Lec 9	Field and field-circuit models.	2
Lec 10	Coupling the field-circuit model with the equation of motion. Dynamic calculations.	2
Lec 11	Calculations for the steady state. Harmonics fields. Complex magnetic vector potential.	2
Lec 12	The calculation of transients. Solution "transient".	2
Lec 13	Calculation of self and mutual multi-phase winding inductance using power and magnetic coupling methods.	2
Lec 14	Power losses in windings, magnetic cores and in construction elements.	2
Lec 15	Electrodynamic forces and electromagnetic torque.	2
	Total hours:	**30**

Form of classes - laboratory		**Number of hours:**
Lab 1	Instruction manual of computer software for field calculation.	2
Lab 2	Development of the two-dimensional, flat-parallel field model of the electromagnetic device (e.g. electromagnet contactor).	2
Lab 3	Calculations of the flat-parallel magnetic field in the electromagnetic device. Analysis of the field distribution.	2
Lab 4	Development of the two-dimensional, axisymmetric field model of the electromagnetic device (e.g. electromagnetic valve).	2
Lab 5	Calculations of axisymmetric magnetic field in the electromagnetic device. Analysis of the field distribution and calculation of the electrodynamics force.	2
Lab 6	Development of the PM (permanent magnets) electrical machine field model.	2
Lab 7	Calculation of the magnetic field distribution in the electrical motor with permanent magnets. Calculation of the winding inductance and torque.	2
Lab 8	Presentation to assessment of reports of performed classes.	1
	Total hours:	**15**

TEACHING TOOLS USED
N1. Lecture with audio-visual technology, multimedia presentations.
N2. Computing laboratory conducted on individual workstations.

EVALUATION OF SUBJECT EDUCATIONAL EFFECTS ACHIEVEMENT		
Evaluation *F – forming (during semester)* *P – concluding (at semester end)*	**Educational effect number**	**Way of evaluating educational effect achievement**
F1(W)	PEK_W01 PEK_W02 PEK_W03	Examination
P(W)	P=F1	
F1(L)	PEK_U01 PEK_U02 PEK_U03 PEK_K01	Reports on performed calculations
P(L)	P=F1	

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE:

[1] Turowski J., Obliczenia elektromagnetyczne elementów maszyn i urządzeń elektrycznych, WNT, Warszawa 1982
[2] Turowski J., Elektrodynamika techniczna, WNT, Warszawa 1993
[3] Demenko A., Symulacja dynamicznych stanów pracy maszyn elektrycznych w ujęciu polowym, Wydawnictwo Politechniki Poznańskiej, 1997

SECONDARY LITERATURE:

[1] Sadiku M. N. O., Numerical Techniques in Electromagnetics, CRC PRESS LLC, 2001
[2] Bianchi N., Electrical machine analysis using finite elements, CRC Taylor&Francis, Boca Raton, 2005

SUBJECT SUPERVISOR

Paweł Zalas, pawel.zalas@pwr.edu.pl

MATRIX OF CORRELATION BETWEEN EDUCATIONAL EFFECTS FOR SUBJECT
ELR043106 - Field-circuit modelling of electrical machines and apparatus
AND EDUCATIONAL EFFECTS FOR MAIN FIELD OF STUDY **Electrical Engineering**
AND SPECIALIZATION **Industrial Electrical Engineering**

Subject educational effect	Correlation between subject educational effect and educational effects defined for main field of study and specialization (if applicable)	Subject objectives	Programme content	Teaching tool number
PEK_W01	S2ETP_W11	C.1 C.2	Lec1 Lec2 Lec3 Lec4 Lec5 Lec6	N.1
PEK_W02	S2ETP_W11	C.2 C.3	Lec7 Lec8 Lec9 Lec10	N.1
PEK_W03	S2ETP_W11	C.4	Lec11 Lec12 Lec13 Lec14 Lec15	N.1
PEK_U01	S2ETP_U09	C.3	Lab1	N.2
PEK_U02	S2ETP_U09	C.3 C.4	Lab2 Lab3 Lab4 Lab5 Lab6 Lab7	N.2
PEK_U03	S2ETP_U09	C.3 C.4	Lab3 Lab5 Lab7	N.2
PEK_K01	K2ETK_K07	C.5	Lab1 Lab2 Lab3 Lab4 Lab5 Lab6 Lab7 Lab8	N.2