FACULTY OF MECHANICAL AND POWER ENGINEERING

SUBJECT CARD

Name in Polish	Kriogenika
Name in English	**Cryogenics**
Main field of study	Power Engineering
Specialization	Refrigeration and Cryogenics
Profile	Academic
Level and form of studies	2nd level, full-time
Kind of subject	optional-specialization
Subject code	W09ENG-SM0072
Group of courses	NO

	Lecture	Classes	Laboratory	Project	Seminar
Number of hours of organized classes in university (ZZU)	30	30	30		
Number of hours of total student workload (CNPS)	60	60	60		
Form of crediting	Examination	crediting with grade	crediting with grade		
For group of courses mark (X) final course					
Number of ECTS points	2	2	2		
including number of ECTS points for practical (P) classes	0	2	2		
including number of ECTS points for direct teacher-student contact (BU) classes	1	1,5	1,5		

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

good knowledge of thermodynamics, heat transfer, fluid mechanics, background in physics, mechanical engineering and material engineering

SUBJECT OBJECTIVES

C1 – To familiarize the students with physical background of cryogenics.
C2 – To transfer knowledge concerning construction and operation of cryogenic devices
C3 – Practical training in safe handling of cryogenic liquids
C4 – Development of capabilities in low temperature measurements and data analysis
C5 – To train students in balancing of cryogenic devices
C6 – Training in calculation of cryogenic cycles

SUBJECT EDUCATIONAL EFFECTS

relating to knowledge:

PEU_W01 knows definition, terminology and applications of cryogenics
PEU_W02 knows the processes of obtaining low temperatures in fluids and solids
PEU_W03 knows the flow diagrams of cryogenic refrigerators and liquefiers
PEU_W04 knows basic methods of reaching the ultralow temperatures (below 1 K)
PEU_W05 knows the methods of gas mixtures separation (including air)

relating to skills:

PEU_U01 is able to define problem of cooling or cryostating of given object
PEU_U02 is able to calculate an energy balance of cryogenic refrigerators
PEU_U03 is able to choose a proper cryogenic refrigerator or liquefier for a given task
PEU_U04 is able to estimate temperature drop in cooling processes
PEU_U05 is able to depict processes of cryogenic refrigerators and liquefiers
PEU_U06 is able to handle the cryogenic liquids in a safe way
PEU_U07 is able to perform low temperature measurements

relating to social competences:

PEU_K01 is able to work and cooperate in heterogeneous groups
PEU_K02 is able to communicate effectively with others
PEU_K03 is able to active listening
PEU_K04 is able to leadership the group

PROGRAMME CONTENT

Lecture		Number of hours
Lec1	Introduction to cryogenics. Basic definitions. History of cryogenics. Applications of cryogenics and cryogenic technologies.	2
Lec2	Properties of cryogens,	2
Lec3	Safe handling of cryogenic liquids. Introduction to safety engineering in cryogenics.	2
Lec4	Materials in cryogenic engineering	2
Lec5	Cryogenic thermal insulations	2
Lec6	Gas temperature decrease processes. Isentropic expansion, isenthalpic throttling and free exhaustion. Comparison of the process's thermodynamics.	2
Lec7	Cryogenic liquefiers and refrigerators with recuperative heat exchangers – Joule-Thomson and Claude devices.	2
Lec8	Liquefaction of cryogenic gases. Minimal work of liquefaction. Thermodynamic optimization of the liquefier stage number.	2
Lec9	Gaseous cryogenic refrigerators with regenerative heat exchangers – part I (Stirling, Gifford-McMahon, pulse tubes).	2
Lec10	Gaseous cryogenic refrigerators with regenerative heat exchangers – part II (Vuilleumier-Taconis). Categorization of cryogenic liquefiers and refrigerators. .	2
Lec11	Temperature decrease in process of adiabatic demagnetization. Magnetic refrigerators.	2
Lec12	Basic properties of superfluid helium He II.	2
Lec13	Superfluid helium technology	2
Lec14	Methods of obtaining the temperatures below 1. Sorption refrigerators.	2
Lec15	Dilution of 3He in 4He II and solidification of 3He. Dilution and Pomeranchuk refrigerators. Laser cooling.	2
	Total hours	**30**

Classes		Number of hours
Cl 1	Introduction to tutorial classes. Laws of thermodynamics in cryogenics	2
Cl 2	Work of cryogenic systems: coolers and liquefactions systems	2
Cl 3	Joule-Thomson refrigerator and liquefier	2
Cl 4	Claude refrigerator and liquefier	2
Cl 5	Gifford-McMahon cooler	2
Cl 6	Minimal work of gas mixture separation process, phase equilibria	2
Cl 7	Introduction to failure analysis of cryogenic system	2
Cl 8	CoolProp, Refprop: cryogenic system calculations	2
Cl 9	CoolProp, Refprop: cryogenic system calculations (mixtures)	2
Cl 10	Introduction to DWSIM simulator	2
Cl 11	DWSIM: simulation of basic processes	2
Cl 12	DWSIM: modeling of simple cryogenic system 1	2
Cl 13	DWSIM: modeling of simple cryogenic system 2	2
Cl 14	Comparison of DWSIM and CoolProp models	2
Cl 15	Test	2
	Total hours	**30**
Laboratory		**Number of hours**
Lab 1	Introduction to laboratory	2
Lab 2	Physical properties of cryogenic liquids and materials in cryogenic temperatures	2
Lab 3	Risk analysis of using cryogens in confined space	2
Lab 4	Cryogenic thermal insulations – measurements of heat leaks	2
Lab 5	Joule-Thomson process of gas liquefaction	2
Lab 6	Measurements of working parameters of Joule-Thomson liquefier supplied with gas mixture	2
Lab 7	Measurements of cooling power of Gifford-McMahon cryocooler	2
Lab 8	Determination of the critical current for HTS superconducting tapes at different temperature levels	2
Lab 9	Determination of the critical current for HTS superconducting tapes at different magnetic field levels	2
Lab 10	Cryogenics in medicine	2
Lab 11	Cryogenic technologies in food industry	2
Lab 12	Performance of the liquid gas regasification heat exchanger	2
Lab 13	Gas leak detection methods	2
Lab 14	Cryogenics in mechanical engineering	2
Lab 15	Additional exercises and laboratory final grading	2
	Total hours	**30**

TEACHING TOOLS USED
N1. Traditional lecture with multimedia presentations N2. Traditional classes with “whiteboard” N3. Software and simulators supporting process calculations N4. Laboratory experiments aimed at process identification and parameters measurements N5. Individual consultancies N6. Student individual work

EVALUATION OF SUBJECT EDUCATIONAL EFFECTS ACHIEVEMENT- lecture

Evaluation (F– forming (during semester), C– concluding (at semester end)	Learning outcomes code	Way of evaluating educational effect achievement
C	PEU_W01 ÷PEU W05	Examination, written and oral

EVALUATION OF SUBJECT EDUCATIONAL EFFECTS ACHIEVEMENT- class

Evaluation (F– forming (during semester), C– concluding (at semester end)	Educational effect number	Way of evaluating educational effect achievement
F1	PEU_U01÷U05	Test
C Test grade		

EVALUATION OF SUBJECT EDUCATIONAL EFFECTS ACHIEVEMENT- laboratory

Evaluation (F– forming (during semester), C– concluding (at semester end)	Educational effect number	Way of evaluating educational effect achievement
F1	PEU U01-U07 PEU K01-K04	Written reports from performed laboratory tasks
C Average grade from the reports		

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE :

[1] M. Chorowski, *Cryogenics – fundamentals and applications*, MASTA 2007 (translation)
[2] Lecture scripts from www page
[3] Classes tutorials
[4] A.Piotrowska-Hajnus, J.Fydrych, J.Poliński, *Cryogenic Engineering Laboratory Handbook*, Wroclaw University of Technology 2010

SECONDARY LITERATURE:

[1] S. Van Sciver, *Helium Cryogenics 2nd ed*., Springer 2012, ISBN 1441999787
[2] A. Arkharov, I. Marfenina, Ye. Mikulin, *Cryogenic Systems*, Bauman Moscow, State Technical University Press, 2000
[3] J. G. Weisend II, *The Handbook of Cryogenic Engineering*, Taylor & Francis,1998, ISBN 1560323329
[4] K.D. Timmerhaus, T.M. Flynn, *Cryogenic Process Engineering*, Plenum Press, 1989
[5] C. Enss, S. Hunklinger, *Low-Temperature Physics*, Springer Berlin Heidelberg New York, ISBN 3-540-23164-1
[6] A. J. Croft, *Cryogenic Laboratory Equipment*, Springer Science+Business Media New York 1970, DOI 10.1007/978-1-4757-4893-2
[7] T. J. Peterson, J. G. Weisend II, *Cryogenic Safety*, Springer Nature Switzerland AG 2019, https://doi.org/10.1007/978-3-030-16508-6

SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)

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