TOMSK POLYTECHNIC UNIVERSITY
ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

APPROVED BY

Director of Nuclear Science & Engineering School

_____________ / Oleg Yu. Dolmatov

"25" 06 ________ 2020

Course Name: Reactor Physics

Field of Study: Nuclear Science and Technology

Programme name: Nuclear Science and Technology

Specialization: Nuclear Power Engineering

Level of Study: Master Degree Programme

Year of admission: 2019

Semester, year: semester 2, year 1

ECTS: 3

Total Hours: 108

Contact Hours: 48

- **Lectures:** 16
- **Labs:** 16
- **Practical experience:** 16

Self-study: 60

Assessment: Exam

Division: Nuclear Fuel Cycle

Director of Programme _____________ / Vera V. Verkhoturova

Instructors _____________ / Mikhail S. Kuznetsov

_____________ / Andrey O. Semenov

TOMSK POLYTECHNIC UNIVERSITY ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

Course name: Reactor Physics

Course Overview

Course Objectives	The objective of the course is to develop students' theoretical knowledge and practical skills, which will help determine and calculate neutron-physical parameters of the nuclear reactor.
Learning Outcomes	**Upon completion of the course a graduate will know**: – the basics of structuring a report and preparing presentations in a foreign language, accepted in the international environment; – the laws of the formation of the spatial and energy distribution of neutrons and the specific energy release in the core of a nuclear reactor; – the methods for calculating and modeling the neutron cycle in a nuclear reactor, the effective neutron multiplication factor, criticality conditions, the basics of lattice theory. **Upon completion of the course a graduate will be able to**: – perceive authentic audio and video materials related to training; – calculate the neutron distribution functions, the coefficient of uneven fluxes in a nuclear reactor; – calculate the basic neutron-physical characteristics of nuclear reactors; – calculate and model the neutron cycle in a nuclear reactor, the effective neutron multiplication factor, criticality conditions, the basics of lattice theory. **Upon completion of the course, a graduate will have experience in**: – application of knowledge of a foreign language at a sufficient level in his future professional activities; – calculating neutron distributions, specific energy release in nuclear reactors of various shapes and types, the effectiveness of control and protection rods; – conducting research studies of the optimal design of a nuclear reactor, taking into account its material and geometric features, purpose and operation.
Course Outline	The course consists of three parts. **Section 1. Interactions of neutrons with matter (2 hours - lectures, 4 hours - seminars, 10 hours self-study)** The properties of neutrons. Micro- and macroscopic cross sections for the interaction of neutrons with nuclei. Classification of nuclear reactions by neutrons. The interaction of fast, resonant, and thermal neutrons with nuclei. energy distribution of resonant and thermal neutrons. Doppler effect. **Section 2. Monoenergetic neutron diffusion (2 hours - lectures, 4 hours - seminars, 4 hours - Labs, 10 hours - self-study)** The concept of neutron diffusion. Neutron flux density. Speed of interaction. Typical neutron mean free paths. Neutron current density. Diffusion equation. Boundary conditions at the boundaries of two media and a medium with vacuum. Conditions for the applicability of the diffusion approximation. Integral equation

	for monoenergetic neutron flux. The interaction rate in the case of non-monoenergetic neutrons. Diffusion length. Neutron diffusion time in a medium. **Section 3. Slowing down neutrons in infinite media. (2 hours - lectures, 2 hours - seminars, 4 hours - labs, 10 hours - self-study)** Scattering in a laboratory coordinate system. Slowdown Step. The law of scattering. Average logarithmic energy loss in a single collision. The concept of lethargy. Energy distribution of decelerating neutrons in infinite homogeneous media. Slowing down on hydrogen without absorption and with absorption. Chance of avoiding absorption when slowing down. Slowing down on heavy diffusers without absorption and with absorption. Effective resonance absorption integral. **Section 4. Spatial energy distribution of neutrons (2 hours - lectures, 2 hours - seminars, 4 hours - labs, 10 hours - self-study)** Continuous Deceleration Model. Equation of age. The equation of deceleration in the age approximation. The age of neutrons. Neutron migration area. Multi-group approximation. Group diffusion equations. Thermalization of neutrons. The temperature of the neutron gas. **Section 5. Critical size theory (4 hours - lectures, 2 hours - seminars, 4 hours - labs, 10 hours - self-study)** Physical classification of nuclear reactors. Breeding rate. Possible representations of the neutron multiplication cycle. Effective breeding rate. Homogeneous reactor without reflector. The equation of the reactor in the diffusion-age approximation. Material parameter. The criticality condition of the reactor in the diffusion-age approximation. Single-group approximation. The geometric parameter and the distribution of the neutron flux throughout the reactor volume. Homogeneous reactor with a reflector in the single-group and two-group approximations. Effective supplement. Multi-zone reactor. The critical condition for a two-zone reactor with a reflector in the single-group approximation. **Section 6. Lattice theory (4 hours - lectures, 2 hours - seminars, 10 hours - self-study)** Physical features of a heterogeneous reactor. Classification of reactor gratings. Basic assumptions in lattice theory. Calculation of the coefficients of the formula of four factors in sparse and tight lattices. Calculation of diffusion and deceleration lengths in various gratings. The dependence of the material parameter on the ratio of the volumes of moderator and fuel. Choosing the best option for the grill. The undergraduate in accordance with the chosen option gives verbal answers to the questions posed in the ticket. The event takes 1.5 hours. Examination ticket includes 2 questions. Preparation time is 40 minutes. After preparation, the student verbally answers the teacher to the questions of the exam ticket. The teacher during the oral examination has the right to ask additional questions on the exam program, propose tasks for solving. The answer to each question is estimated at 10 points. The maximum number of points that a student can get in the exam is 20 points. Evaluation of each question of the exam ticket is carried out according to the following system:

	10 points - demonstrates a complete understanding of the problem and gives a detailed answer; 8 points - demonstrates a significant understanding of the problem and gives an answer with shortcomings, requiring clarifying questions. 6 points - demonstrates a partial understanding of the problem. 4 points - demonstrates a superficial understanding of the problem. 2 points - demonstrates a misunderstanding of the problem. 0 points - no answer. Upon successful completion of intermediate certification, students receive a rating of "excellent", "good", "satisfactory" depending on the total points scored for the current and intermediate certification in accordance with the TPU assessment system.
Prerequisites (if available)	1. Dosimetry and protection from ionizing radiation. 2. Nuclear Physics. 3. Special chapters of advanced mathematics. 4. Materials of Nuclear Installations.
Course Structure	Within the framework of the course, students study the following sections: 1. Interactions of neutrons with matter 2. Diffusion of monoenergetic neutrons 3. Slowing down neutrons in infinite media 4. Spatial energy distribution of neutrons 5. Theory of critical dimensions 6. Lattice Theory
Facilities and Equipment	1. Lecture hall with multimedia equipment: 634050, Tomsk, 2, Lenina ave., building 10, room 248, room 340. 2. Classroom for practical experience and labs: 634050, Tomsk, 2, Lenina ave., building 10, room 248Б.
Grading Policy	In accordance with TPU assessment system we use: - Current assessment, which is performed on a regular basis during the semester by scoring the quality of mastering of theoretical material and the results of practical activities (lab completing, problem solving). Max score for current assessment is 80 scores, min – 56 scores. - Course final assessment (credit test) is performed at the end of the semester. Max score for course final assessment is 20 scores, min – 12 scores. The final score is determined by summing the scores of the current assessment during the semester and credit test scores at the end of the semester. Maximum overall score corresponds to 100 scores, min pass score is 68.
Course Policy	Testing. Undergraduate in accordance with the option gives answers in writing to tasks with a choice of answer. The event takes 30 minutes. Testing includes 10 questions with a choice of answer. Full performance of the test is estimated at 10 points. Evaluation of the results of the test is as follows: 1 point - the answer is correct; 0 points, the answer is incorrect. Colloquium. Master student in accordance with the option gives written answers to the questions posed. 60 minutes are allotted for the event. The colloquium includes 2 questions. The full answer to the question of the colloquium is estimated at 10 points. The maximum score for a colloquium is 20 points. Evaluation of the results of the colloquium issue is carried out according to the following scheme:

	10 points - the answer to the question is given completely with all theoretical and mathematical justifications; 8 points - the answer is generally correct, but there are flaws; 6 points - the course of the answer is correct, but one or two errors were made that led to the wrong answer; 4 points - the answer is not presented in the work and incorrect theoretical calculations are given, but the formulas used and the course of the given part of the answer are correct; 2 points - an incorrect answer was received in the work related to a gross error reflecting a student's misunderstanding of the material read; 0 points - no answer. Problems solving. The undergraduate in accordance with the option gives written answers to the questions posed. The event takes 30 minutes. Examination includes 2 tasks. The complete solution of the control problem is estimated at 5 points. The maximum number of points for completing the test is 10 points. Evaluation of the results of the control work is carried out according to the following scheme: 5 points are set if the solution to the problem is correct and a rational solution is chosen; 4 points are set if the problem is solved basically correctly, but a slight mistake or a mistake is made; 3 points are given if the course of solving the problem is correct, but one or two errors were made that led to the wrong answer; 2 points are given if the answer is not received in the work and an incomplete solution of the problem is given, but the formulas used and the course of the given part of the solution are correct; 1 point is given if the work received an incorrect answer related to a gross error reflecting a student's misunderstanding of the material read; 0 points are set if there is no solution to the problem. Report of laboratory work To assess the development of practical skills, it is envisaged that the student conduct laboratory work and protect reports on each laboratory work performed. In total, 4 laboratory works are planned. The maximum number of points. Which a student can score for performing and defending a report on laboratory work is 5 points. Criteria for assessing the conduct and protection of reports on laboratory work: 5 points - the work is completed. The student owns theoretical material, there are no errors in the description of the theory, formulates his own, independent, reasonable, reasoned judgments, presents complete and detailed answers to additional questions. 4 points - the work is completed. The student owns theoretical material, there are no errors in the description of the theory, formulates his own, independent, substantiated, reasoned judgments, making minor errors on additional questions. 3 points - the work is completed. The student owns theoretical material at the minimum acceptable level, there are no errors in the description of the theory, he has difficulty in formulating his own justified and reasoned judgments, making minor errors on additional questions. 2 points - the work is completed. The student practically does not possess theoretical material, making mistakes on the nature of the issues being discussed (discussed), has difficulty in formulating his own justified and reasoned judgments, makes mistakes in answering additional questions.

	1 point - the work is completed. Work without protection.
Teaching Aids and Resources	**Compulsory reading**: 1. Marguet, S. The Physics of Nuclear Reactors / S. Marguet. — Cham : Springer International Publishing AG, 2017. — 1445 р. – Текст: электронный // SpringerLink. – URL: https://link.springer.com/book/10.1007/978-3-319-59560-3 (дата обращения: 20.09.2020). – Режим доступа: из корпоративной сети ТПУ. 2. Yoshiaki, O. Nuclear Reactor Design / O. Yoshiaki. - New York : Springer, 2014. - 337 p. - Текст: электронный // SpringerLink. – URL: https://link.springer.com/book/10.1007/978-4-431-54898-0 (дата обращения: 20.09.2020). – Режим доступа: из корпоративной сети ТПУ. 3. Oka Y. Nuclear Reactor Design / Y. Oka. – Tokyo : Springer, 2014. – 327 p. – Текст: электронный // SpringerLink. – URL: https://link.springer.com/book/10.1007/978-4-431-54898-0 (дата обращения: 20.09.2020). – Режим доступа: из корпоративной сети ТПУ. **Additional reading**: 1. Shimjith, S. R. Modeling and control of a large nuclear reactor / S. R. Shimjith, A. P. Tiwari, B. Bandyopadhyay. – New York : Springer, 2010. – 327 p. - Текст: электронный // SpringerLink. – URL: https://link.springer.com/book/10.1007/978-3-642-30589-4 (дата обращения: 20.09.2020). – Режим доступа: из корпоративной сети ТПУ.
Instructors	1. Mikhail S. Kuznetsov, associate professor, Nuclear Fuel Cycle Division, School of Nuclear Science & Engineering, TPU, Tel.: +7 (3822) 701-777 ext. 2330, e-mail: kms@tpu.ru, personal site: https://portal.tpu.ru/SHARED/k/KMS/eng 2. Andrey O. Semenov, senior lecturer, Nuclear Fuel Cycle Division, School of Nuclear Science & Engineering, TPU, Tel.: +7 (3822) 701-777 ext. 2330, e-mail: semenov_ao@tpu.ru, personal site: https://portal.tpu.ru/SHARED/s/SEMENOV_AO/eng