TOMSK POLYTECHNIC UNIVERSITY | ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

APPROVED BY

Director of Nuclear Science & Engineering School
_______________ / Oleg Yu. Dolmatov
"25" 06 2020

Course Name: Safeguards Techniques and Equipment

Field of Study: 14.04.02 Nuclear Physics and Technology

Programme name: Nuclear Science and Technology

Academic profile: Nuclear Safety, Security and Non-Proliferation of Nuclear Materials

Level of Study: Master Degree Programme

Year of admission: 2020

Semester, year: semester 3, year 2

ECTS: 5

Total Hours: 180

Contact Hours: 64
- **Lectures:** 24
- **Labs:** 40

Self-study: 116

Assessment: Exam, term paper

Division: Nuclear Fuel Cycle

Director of Programme _______________ / Vera V. Verkhoturova

Instructor _______________ / Mikhail S. Kuznetsov

Course name: Safeguards Techniques and Equipment

Course Overview

Course Objectives	The course aims to develop knowledge and skills, which are necessary to conduct destructive and non-destructive analysis of nuclear materials in order to prevent their diversion from peaceful to military purposes. Having mastered the training course, graduates are expected to acquire knowledge and skills which will enable the graduates to achieve competences required to perform research, design, production and technological, organizational and managerial activities in the nuclear field.
Learning Outcomes	**Upon completion of the course, a graduate will obtain the knowledge of:** – modern methods of research, evaluation and presentation of the results of work performed; – measurement programs for nuclear materials and radioactive substances at the enterprises of the nuclear industry for the purpose of their accounting and control; **Upon completion of the course, graduates are expected to develop the following skills:** – to apply modern research methods, evaluate and present the results of work performed; – to verify the correctness and completeness of statements on the availability of nuclear materials declared by the state; **Upon completion of the course, graduates should acquire the practical experience in:** – applying modern methods of research, evaluation and presentation of the results of work performed; – to apply destructive and non-destructive analysis of nuclear materials and radioactive substances;
Course Outline	The training course is delivered through the following teaching modes: – 12 lectures; – 12 labs; – 1 term project paper. The course consists of 6 sections, which are given below. **Section 1. Spectrometry of nuclear materials** **Section 2. Counting neutrons** **Section 3. Spent Fuel Measurement** **Section 4. Alternative methods of NDA** **Section 5. Elemental Analysis** **Section 6. Isotope Analysis** Each section includes several lectures and laboratory experiences. Laboratory work involves introducing students to most of the widely used methods for analyzing nuclear materials and radioactive substances. During laboratory works, measurements will be made using various types of detectors (scintillation, semiconductor, gas-filled). The methods of gamma spectrometric, alpha spectrometric and X-ray fluorescence analyzes will be considered.

	In the course of the term project performance, students are invited to design and equip a system for measuring and controlling the amount of nuclear materials and radioactive substances at a nuclear energy facility. The term project shall contain the following sections: – An analytical review of the proposed facility containing a description of the main facilities with consideration of the amount of nuclear material, by its movement, potential ways of changing the number of nuclear materials and explosives. – Selection of the instrument base for the NM and RS measurements at the facility, including a comparative analogue of domestic and foreign analogues. A justified choice shall be confirmed by calculations to analyze a specific NM and RS. – Analytical control of materials at the facility in case of impossibility of direct confirmatory measurements. – The economic feasibility of the system.
Course Structure	The content of the course covers 6 topics. Each topic is studied through lectures and labs. **Section 1. Spectrometry of nuclear materials** Objectives of the course. Problems of gamma spectrometric analysis. Main errors in the gamma-spectrometric analysis of NM and RS. Methods for processing NM and RS spectra. Spectrum analysis, determination of the radionuclide composition of emitters and their activity (quantity). **Section 2. Counting neutrons** Interaction of neutrons with matter. Sources of neutrons. The main types of detectors for measuring neutron fluxes. Determination of the total neutron flux. Neutron coincidence method for monitoring the parameters of nuclear materials. **Section 3. Spent Fuel Measurement** Spent fuel parameters for various types of nuclear reactors. SNF neutron, gamma and Cherenkov radiation. Methods for calculating and measuring SNF parameters. Peculiarities of using detectors of various types for measuring SNF parameters. **Section 4. Alternative methods of NDA** Measurement of radiation characteristics of nuclear material. Assessment of residual quantities of nuclear materials. Measurement of physical properties of objects containing nuclear materials **Section 5. Elemental Analysis** Accuracy and correctness of destructive analysis methods. Chemical reactions to determine the availability of nuclear materials. Methods of titration, sedimentation and gravimetry when measuring solutions of nuclear materials. **Section 6. Isotope Analysis** Isotopes of uranium and plutonium. Features of isotopic radiation of nuclear materials. Techniques for gamma spectrometric analysis of nuclear materials. Software for analysis of material beneficiation. Methods for determining the content of uranium and plutonium in solids and solutions.
Facilities and Equipment	1. Lecture Hall with multimedia equipment: 634050, Tomsk, Lenin ave. 2, building 10, room 248. 2. Physical modelling laboratory, which includes laboratory scales VLTE-5000 g with a calibration weight of 2 kg, Barcode ID Training Kit, sealing devices Training kit: 634050, Tomsk, Lenin ave. 2, building 10, room 318.

Grading Policy	In accordance with TPU rating 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 (performance tests, perform tasks, problem solving). Max score for current assessment is 80 points, min – 44 points. – Course final assessment (exam/ credit test) is performed at the end of the semester. Max score for course final assessment is 20 points, min – 11 points. The final rating is determined by summing the points of the current assessment during the semester and protection of the course project at the end of the semester. Maximum overall rating corresponds to 100 points, min pass score is 55.
Course Policy	Attendance is strictly controlled. All classes are obligatory for attendance.
Teaching Aids and Resources	**Compulsory reading:** 1. Cerrito, L. Radiation and Detectors. Introduction to the Physics of Radiation and Detection Devices / L. Cerrito. - Cham : Springer International Publishing, 2017. — XIV, 210 p. — Текст: электронный // SpringerLink. – URL: https://link.springer.com/book/10.1007/978-3-319-53181-6 (дата обращения: 20.09.2020). – Режим доступа : по подписке. 2. D'Auria S. In Introduction to Nuclear and Particle Physics / S. D'Auria. - Cham : Springer, 2018. — XIII, 192 p. — Текст: электронный // SpringerLink. – URL: https://link.springer.com/book/10.1007/978-3-319-93855-4 (дата обращения: 20.09.2020). – Режим доступа : по подписке. 3. Tavernier, S. Experimental Techniques in Nuclear and Particle Physics / S. Tavernier. - New York : Springer, 2010. – IX, 306 p. - Текст: электронный // SpringerLink. – URL: https://link.springer.com/book/10.1007/978-3-642-00829-0 (дата обращения: 20.09.2020). – Режим доступа : по подписке. **Additional reading** 1. Morse, E. C. Analytical Methods for Nonproliferation / E. C. Morse. — Cham : Springer International Publishing, 2016. — XIII, 250 p. — Текст : электронный // SpringerLink. – URL: https://link.springer.com/book/10.1007/978-3-319-29731-6 (дата обращения: 20.09.2020). – Режим доступа : по подписке.
Instructor	Mikhail S. Kuznetsov, Associate Professor, Nuclear Fuel Cycle Division, School of Nuclear Science and Engineering, Tomsk Polytechnic University, e-mail: kms@tpu.ru, tel.: +7 (3822) 701-777 ext. 2330, personal site: https://portal.tpu.ru/SHARED/k/KMS/eng