TOMSK POLYTECHNIC UNIVERSITY | ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

APPROVED BY

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

**Course Name:**
**Methods and Instruments for Nuclear and Other Radioactive Materials Measurements**

**Field of Study:** Nuclear Science 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, graded credit-test

**Division:** Nuclear Fuel Cycle

**Director of Programme** _______________ / Vera V. Verkhoturova

**Instructor** _______________ / Mikhail S. Kuznetsov

TOMSK POLYTECHNIC UNIVERSITY ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

**Course name:**
**Methods and Instruments for Nuclear and Other Radioactive Materials Measurements**

## Course Overview

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| **Course Objectives** | The course aims to develop knowledge and skills, which are necessary to conduct practical activities related to the analysis of nuclear and radioactive materials at any nuclear or radiation hazardous facility.<br>As a result of mastering the training course, graduates obtain knowledge and skills that ensure the achievement of the goals assigned for the academic program 14.04.02 "Nuclear Science and Technology" (Nuclear Safety, Security and Non-Proliferation of Nuclear Materials) and which are required to perform research, design, production and technological and organizational and managerial activities of graduates. |
| **Learning Outcomes** | **Upon completion of the course, a graduate will obtain the knowledge of:**<br>– modern methods of research, evaluation and presentation of the results of work performed;<br>– measurement programs for nuclear materials and radioactive substances at the enterprises of the nuclear industry for the purpose of their accounting and control;<br>**Upon completion of the course, graduates are expected to develop the following skills:**<br>– to apply modern research methods, evaluate and present the results of work performed;<br>– to apply methods of confirmatory measurements of nuclear materials;<br>**Upon completion of the course, graduates should acquire the practical experience in:**<br>– applying modern methods of research, evaluation and presentation of the results of work performed;<br>– performing instrumental measurements of nuclear materials and radioactive substances. |
| **Course Outline** | The training course is delivered through the following teaching modes:<br>– 12 lectures;<br>– 8 labs;<br>– 1 term project paper.<br>The course consists of 8 sections, which are given below.<br>**Section 1. Basic concepts and requirements when working with nuclear and radioactive materials.**<br>**Section 2. Radiation Detectors.**<br>**Section 3. Gamma spectrometric analysis.**<br>**Section 4. Basics of determining the isotopic composition of uranium.**<br>**Section 5. Alpha, Beta, and Mass Spectrometry.**<br>**Section 6. Fundamentals of X-ray fluorescence analysis.**<br>**Section 7. Basics of recording the total neutron flux. Devices for recording the total neutron flux. Principles and devices for recording neutron coincidences.** |

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| | **Section 8. Qualitative and semi-quantitative measurements.**<br>Each section includes several lectures and laboratory experiences.<br>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.<br>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.<br>The term project shall contain the following sections:<br>– 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.<br>– 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.<br>– Analytical control of materials at the facility in case of impossibility of direct confirmatory measurements.<br>– The economic feasibility of the system. |
| **Course Structure** | The content of the course covers 8 topics. Each topic is studied through lectures and labs.<br>**Section 1. Basic concepts and requirements when working with nuclear and radioactive materials**<br>Natural and artificial sources of ionizing radiation and their sources. Principles for ensuring radiation safety. The main standards established in NRB-99/2009. Requirements established by the basic sanitary rules on radiation safety. Categories of radiation objects. Sanitary protection zones and surveillance zones. Work with open sources of ionizing radiation. Groups of radionuclides by potential radiation hazard. Class of work with open sources of radiation. Requirements for premises of various classes. Basic requirements for measurements of nuclear materials and radioactive substances.<br>**Section 2. Radiation Detectors**<br>The interaction of particles with matter. The law of weakening the flow of particles when passing through a substance. Theory of Gray. Ionization current. Ionization chamber. Boron chambers, fission chambers, helium counters. The use of scintillation and semiconductor counters for detecting radiation. Activation methods for determining ionizing radiation fluxes.<br>**Section 3. Gamma spectrometric analysis.**<br>Tasks of gamma spectrometric analysis. The main errors during the gamma-spectrometric analysis of NM and RS. Methods of processing the spectra of NM and PB. Questions of spectrum analysis, determination of the radionuclide composition of emitters and their activity (quantity).<br>**Section 4. Basics of determining the isotopic composition of uranium.**<br>Atomic and weight contents of uranium and their ratio. Emission of uranium samples: the 186 keV line is often used to measure enrichment. Typically, there is no interference in the gamma radiation region, except in cases involving the |

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| | measurement of regenerated fuel. The technique of gamma measurements of infinite samples. The geometry of a collimated sample having a thickness far exceeding the mean free path of gamma rays with an energy of 186 keV is taken as infinite. Installation diagram. One-component (metallic uranium) and two-component (simple uranium compounds) tasks.<br>**Section 5. Alpha, Beta, and Mass Spectrometry**<br>Determination of the energy of charged particles by distance and ionization density. Particle energy measurement using ionization chambers, scintillation and semiconductor counters. Magnetic spectrometers of charged particles. Alpha spectrometry and its applications. Beta spectrometry and its applications. Features and capabilities of the analysis of the beta spectrum. Mass spectrometry.<br>**Section 6. Fundamentals of X-ray fluorescence analysis**<br>X-ray generation. Fluorescence yield. Photon transmission. Geometry measurement. Types of sources. The effects of attenuation in the sample. Attenuation correction methods. The basic equation of analysis. Types of devices used. Accuracy and sensitivity analyzes.<br>**Section 7. Basics of recording the total neutron flux. Devices for recording the total neutron flux. Principles and devices for recording neutron coincidences.**<br>The basic principles of applying the registration of the total neutron flux for passive analysis of materials containing uranium and plutonium are considered. Devices for recording the total neutron flux and their application in order of increasing complexity. Special applications of devices for recording the total neutron flux. Neutron coincidence method for determining the mass of uranium and plutonium samples based on neutron radiation. The contraction of neutron coincidence counters and operation features are described.<br>**Section 8. Qualitative and semi-quantitative measurements**<br>The section describes the attributive features of nuclear materials and methods for measuring them. Semi-quantitative measurements of waste are considered, confirming measurements during the inventory and transfer of materials, measurements of deposits. |
| **Facilities and Equipment** | 1. Lecture Hall with multimedia equipment: 634050, Tomsk, Lenin ave. 2, building 10, room 248.<br>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:<br>– 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.<br>– 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.<br>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. |

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| **Teaching Aids and Resources** | **Compulsory reading:**<br>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.<br>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.<br>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.<br>**Additional reading**<br>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. |
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