Federal State Autonomous Educational Institution of Higher Education
PEOPLES' FRIENDSHIP UNIVERSITY OF RUSSIA
Patrice Lumumba RUDN University

Science Faculty/Institute for Physical Research and Technologies

educational division (faculty/institute/academy) as higher education programme developer

COURSE SYLLABUS

The basics of plasma physics

Recommended by the Didactic Council for the Education Field of:

03.03.02 Physics

field of studies / speciality code and title

The course instruction is implemented within the professional education programme of higher education:

Physics

higher education programme profile/specialisation title

2024

1. COURSE GOAL(s)

The goal of the course "**The basics of plasma physics**" is form physical ideas about the laws of plasma behavior in a magnetic field for the application of this knowledge when working in various fields of science and technology.

2. REQUIREMENTS FOR LEARNING OUTCOMES

Mastering the course "**The basics of plasma physics**" is aimed at the development of the following competences:

Table 2.1. List of competences that students acquire through the course study

Competence code	**Competence descriptor**	**Competence formation indicators** (within this course)
PC-2	**Ability** of **s**tudents are skilled at conducting scientific research in a selected field of experimental and (or) theoretical physical research using modern instrumentation (including sophisticated physical equipment) and information technology, taking into account domestic and foreign experience.	**PC-2.1.** Student can collect and analyze scientific and technical information on the research topic, summarizes scientific data in accordance with the objectives of the study.
		PC-2.2. Student has practical skills in using modern research methods in the chosen field.

3.COURSE IN HIGHER EDUCATION PROGRAMME STRUCTURE

The course "**The basics of plasma physics**" refers to the core of block **B1** of the higher educational programme curriculum.

Within the higher education programme students also master other (modules) and / or internships that contribute to the achievement of the expected learning outcomes as results of the course study.

Table 3.1. The list of the higher education programme components/disciplines that contribute to the achievement of the expected learning outcomes as the course study results

Competence code	**Competence descriptor**	**Previous courses/modules***	**Subsequent courses/modules***
PC-2	**Ability** of **s**tudents are skilled at conducting scientific research in a selected field of experimental and (or) theoretical physical research using modern instrumentation (including sophisticated physical equipment) and information technology, taking into	Radiophysics Introduction to Radio Electronics Radioelectronics.	Physical research methods Physical kinetics Introduction to microwave physics. Special Laboratory Additional chapters of theoretical physics Introduction to Astrophysics Academic practice Externship

Competence code	Competence descriptor	Previous courses/modules*	Subsequent courses/modules*
	account domestic and foreign experience.		

4. COURSE WORKLOAD AND ACADEMIC ACTIVITIES

The total workload of the course is 4 credits (144 academic hours).

Table 4.1. *Types of academic activities during the periods of higher education programme mastering (*full-time training).

Type of academic activities		Total academic hours	Semesters/training modules			
			5			
Contact academic hours		*72*	*72*			
including:						
Lectures (LC)		36	36			
Lab work (LW)		-	-			
Seminars (workshops/tutorials) (S)		36	36			
Self-studies		*54*	*54*			
Evaluation and assessment (exam/passing/failing grade)		*18*	*18*			
Course workload	academic hours_	**144**	**144**			
	credits	**4**	**4**			

5. COURSE CONTENTS

Table 5.1. Course contents and academic activities types

Course module title	Course module contents (topics)	Academic activities types
Module 1: **Introduction. General information**	**Topic 1.1.** Occurrence of Plasmas in Nature. Definition of Plasma. Concept of Temperature. Debye Shielding. The Plasma Parameters. Criteria for Plasmas.	LC, S
	Topic 1.2. Applications of Plasma	LC, S
Module 2 **Single-Particle Motion**	**Topic 2.1** Introduction Uniform **E** and B Fields. **E** = 0. Finite **E**.	LC, S
	Topic 2.2. Gravitational Field. Nonuniform **B** Field. ∇B⊥B: Grad-**B** Drift. Curved B: Curvature Drift. **∇B II B:** Nonuniform E Field.	LC, S
	Topic 2.3. Time-Varying E and B Fields.	LC, S
Module 3 **Adiabatic Invariants**	**Topic 3.1.** The First Adiabatic Invariant, μ. The Second Adiabatic Invariant, J. The Third Adiabatic Invariant, Φ	LC, S
Module 4 **The Fluid Equation of Motion**	**Topic 4.1.** The Convective Derivative Collisions. Comparison with Ordinary Hydrodynamics Equation of Continuity Equation of State	LC, S

Course module title	Course module contents (topics)	Academic activities types
Module 5 **Waves in Plasmas**	**Topic 5.1.** Representation of Waves Group Velocity Plasma Oscillations. Electron Plasma Waves Sound Waves. Ion Waves. **Topic 5.2.** Validity of the Plasma Approximation. Ordinary Wave, E1 ‖ B0 Extraordinary Wave, E1 ⊥ B0 **Topic 5.3.** Cutoffs and Resonances Hydromagnetic Waves. Magnetosonic Waves.	LC, S
Module 6 **Diffusion and Resistivity**	**Topic 6.1.** Diffusion and Mobility in Weakly Ionized Gases Decay of a Plasma by Diffusion. Steady State Solutions Recombination. Diffusion Across a Magnetic Field **Topic 6.2.** Collisions in Fully Ionized Plasmas. The Single-Fluid MHD Equations. **Topic 6.3.** Diffusion of Fully Ionized Plasmas	LC, S
Module 7 **Equilibrium and Stability**	**Topic 7.1.** Hydromagnetic Equilibrium. The Diffusion of Magnetic Field into a Plasma. The Concept of β. **Topic 7.2.** Classification of Instabilities. Two-Stream Instability. The “Gravitational” Instability The Weibel Instability.	LC, S
Module 8 **Kinetic Theory**	**Topic 8.1.** The Meaning of f(v) Equations of Kinetic Theory Derivation of the Fluid Equations. Plasma Oscillations and Landau Damping. The Meaning of Landau Damping. **Topic 8.2.** A Physical Derivation of Landau Damping. BGK and Van Kampen Kinetic Effects in a Magnetic Field Modes	LC, S
Module 9 **Nonlinear Effects .**	**Topic 9.1.** Sheaths. The Necessity for Sheaths. The Planar Sheath Equation. The Bohm Sheath Criterion. Ion Acoustic Shock Waves. **Topic 9.2.** The Sagdiyev Potential/ The Critical Mach Numbers. The Ponderomotive Force. Parametric Instabilities.	LC, S

* - to be filled in only for **full** -time training: *LC - lectures; S - seminars.*

6. CLASSROOM EQUIPMENT AND TECHNOLOGY SUPPORT REQUIREMENTS

Table 6.1. Classroom equipment and technology support requirements

Type of academic activities	Classroom equipment	Specialised educational / laboratory equipment, software, and materials for course study (if necessary)
Lecture	A lecture hall for lecture-type classes, equipped with a set of specialised furniture; board (screen) and technical means of multimedia presentations.	
Seminar	A classroom for conducting seminars, group and individual consultations, current and mid-term assessment; equipped with a set of specialised furniture and technical means for	List of specialised equipment, stands, visual posters, etc.

Type of academic activities	Classroom equipment	Specialised educational / laboratory equipment, software, and materials for course study (if necessary)
	multimedia presentations.	
Self-studies	A classroom for independent work of students (can be used for seminars and consultations), equipped with a set of specialised furniture and computers with access to the electronic information and educational environment.	

7. RESOURCES RECOMMENDED FOR COURSE STUDY

Main readings:

1. Francis F. Chen. The basics of plasma physics and Controlled Fusion. Springer International Publishing AG Switzerland is part of Springer Science Business Media. (www.springer.com)

2. V.I. Ilgisonis. Classical problems of hot plasma physics. Course of lectures. M., Publishing house of MEI, 2015.

Additional readings:

1. Artsimovich L.A.; Sagdeev R. Z. Plasma physics for physicists. Moscow: Atomizdat, 1979, 313 p.

2. Kenro Miyamoto. Fundamentals of Plasma Physics.
3. B.B. Kadomtsev. Collective phenomena in plasma. Moscow: Nauka, 2008.
4. Kroll N., Trivelpis A. Fundamentals of Plasma Physics. Moscow: Mir, 1975.
5. Encyclopedia of low-temperature plasma. Introductory volume. Ch. I-IV/ Edited by V.E. Fortov. M.: Nauka, 2000.
6. G. Bateman: MHD instabilities, The MIT Press, Cambridge Mass. 1978
7. M. Kruskal and M. Schwarzschield: Proc. Roy. Soc. A223, 348 (1954)
8. M. N. Rosenbluth, N. A. Krall and N. Rostoker: Nucl. Fusion Suppl. Pt.1 p.143 (1962).
9. M. N. Rosenbluth and C. L. Longmire: Annal. Physics 1, 120 (1957)
10. B. Berstein, E. A. Frieman, M. D. Kruskal and R. M. Kulsrud: Proc. Roy. Soc. A244, 17 (1958)
11. B. B. Kadmotsev: Reviews of Plasma Physics 2, 153(ed. by M. A. Loentovich) Consultant Bureau, New York 1966
12. K. Miyamoto: Plasma Physics for Nuclear Fusion (revised edition) Chap.9, The MIT Press, 106 8 Magnetohydrodynamic Instabilities Cambridge, Mass. 1988
13. V. D. Shafranov: Sov. Phys. JETP 6, 545 (1958)
14. B. R. Suydam: Proc. 2nd U. N. International Conf. on Peaceful Uses of Atomic Energy, Geneva, 31, 157 (1958)
15. K. Matsuoka and K. Miyamoto: Jpn. J. Appl. Phys. 18, 817 (1979)
16. R. M. Kulsrud: Plasma Phys. and Controlled Nucl. Fusion Research,1, 127, 1966 (Conf. Proceedings, Culham in 1965 IAEA Vienna)
17. J. W. Connor, R. J. Hastie and J. B. Taylor: Phys. Rev. Lett. 40, 393 (1978)
18. B. B. Kadomtsev and O. P. Pogutse: Reviews of Plasma Physics 5,304 (ed. by M. A. Leontovich) Consultant Bureau, New York 1970
19. H. P. Furth, P. H. Rutherford and H. Selberg: Phys. Fluids 16, 1054 (1973) A. Pletzer and R. L. Dewar: J. Plasma Phys. 45, 427 (1991)
20. S. S. Moiseev and R. Z. Sagdeev: Sov. Phys. JETP 17, 515 (1963), Sov. Phys. Tech. Phys. 9, 196 (1964)
21. F. F. Chen: Phys. Fluids 8, 912 and 1323 (1965)

22. T. H. Stix: The Theory of Plasma Waves, McGraw-Hill, New York 1962 T. H. Stix: Waves in Plasmas, American Institute of Physics, New York, 1992
23. B. D. Fried and S. D. Conte: The Plasma Dispersion Function, Academic Press, New York 1961
24. K. Miyamoto: Plasma Physics for Nuclear Fusion (Revised Edition), Chap.11 The MIT Press, Cambridge, Mass. 1989
25. S. Takakura: Fundamentals of Plasma Heating, Nagoya Univ. Press, 1986 (in Japanese)
26. I. Fidone, G. Granata and G. Ramponi: Phys. Fluids 21, 645 (1978)
27. A. G. Litvak, G. V. Permitin, E. V. Suvorov, and A. A. Frajman: Nucl. Fusion 17, 659 (1977
28. R. J. Briggs: Electron-Stream Interaction with Plasma, The MIT Press, Cambridge, Mass. 1964

Internet sources

1. Electronic libraries (EL) of RUDN University and other institutions, to which university students have access on the basis of concluded agreements:

- RUDN Electronic Library System (RUDN ELS) http://lib.rudn.ru/MegaPro/Web
- EL "University Library Online" http://www.biblioclub.ru
- EL "Yurayt" http://www.biblio-online.ru
- EL "Student Consultant" www.studentlibrary.ru
- EL "Lan" http://e.lanbook.com/
- EL "Trinity Bridge"
- Scopus abstract database http://www.elsevierscience.ru/products/scopus/

8. ASSESSMENT TOOLKIT AND GRADING SYSTEM* FOR EVALUATION OF STUDENTS' COMPETENCES LEVEL UPON COURSE COMPLETION

The assessment toolkit and the **grading system*** to evaluate the competences formation level (competences in part) upon the course study completion are specified in the Appendix to the course syllabus.

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