Name of subject	Physics and technology of modern solar cells (ECTS 4)
Subject/module code	ZQEFT2204
Science taught semester (s).	1st and 2nd semesters
Responsible teacher	Yuldashev Urishbay, professor.
Education language	Uzbek
Connection to the curriculum	Elective
Training hours (this including independent education)	**Total hours-120** **Audience Training hours – 36** Lecture training hour – 18 Practical training hour – 18 **Independent education -84 hours**
ECTS	4
The purpose and tasks of subject / learning outcomes	**The purpose of teaching the subject is** The course aims to provide students with in-depth theoretical knowledge and practical skills in the physical foundations of photovoltaic conversion processes, the structure, operating principles, materials, technological production stages and their practical applications of solar cells. Through this subject, students will learn modern methods of converting solar energy into electricity, various photovoltaic technologies, ways to increase their efficiency, and the use of PV systems in real projects. Students will also learn about innovations and promising trends in the global solar energy market. **The objective of the course** "Physics and technology of modern solar cells" is to familiarize students with the physical foundations of solar energy, the photoelectric conversion process, the structure of solar cells, the principle of operation, the selection of materials and the technologies for their preparation. The course allows students to analyze the physical factors affecting the efficiency of solar cells, calculate them, compare modern PV (photovoltaic) technologies and form the necessary theoretical knowledge and practical skills in applying them in real energy projects. Learning Outcomes: 1. Knows the physics of the process of converting solar energy into electricity; 2. Has a complete understanding of the structure, operating principle and types of PV elements; 3. Understands the differences between solar elements based on different materials (silicon, perovskite, organic, GaAs); 4. Knows how to measure and analyze the I–V characteristics of solar cells; 5. Master practical calculations of PV system efficiency; 6. Perform simple experiments related to solar panels in the laboratory; 7. Use software tools for designing solar systems (e.g. PV*Sol, HelioScope); 8. Can think freely in the field of energy sources, energy conservation and "green technologies".
Course content (topics)	**I. Main Theoretical Part (Lecture Sessions)** Topics: 1. Introduction to solar energy. Theory of the photoelectric effect. 2. Physical foundations of semiconductors: PN junction, energy bands. 3. Electrical properties and operating modes of a solar cell. 4. Silicon-based PV: monocrystalline, polycrystalline.

	5. Unconventional PV: perovskite, organic and quantum-dot elements. 6. Photocurrent generation and losses: types of recombination. 7. Efficiency: Shockley–Queisser limit and practical evaluation. 8. Production stages of PV technologies. 9. Solar cells and energy storage systems. **II. Instructions and recommendations for organizing laboratory exercises.** Laboratory work is not included in the curriculum **III. Practical training instructions and recommendations** The instructor's preparation for a practical session begins with the study of initial documents (such as the curriculum, topic schedule, etc.) and concludes with the development of a detailed lesson plan. The instructor must have a clear understanding of the objectives and tasks of the practical session, as well as the amount of work each student is expected to perform.Methodological guidelines serve as the primary instructional document for instructors in preparing and conducting practical sessions. The purpose of the practical session is to facilitate the comprehension of theoretical material, the acquisition of practical skills, the ability to consciously apply knowledge in academic and professional activities, and the development of critical thinking and confidence in forming personal viewpoints. *Recommended Practical Topics:* 1. Measuring the I-V characteristic of a solar cell. 2. Photon flux measurement and efficiency determination. 3. Analyzing the effect of anti-reflective coating. 4. Assembling and testing a small solar system. 5. Photovoltaic system design through simulation (PV*Sol, HelioScope). 6. Determining the operating point of a solar cell under load. 7. Determining efficiency in natural light conditions. 8. Study of the optical efficiency of anti-reflective coating. 9. Studying parallel and series connection modes of PV modules **IIV. Independent learning and practical exercises** Independent learning competency helps students to develop self-improvement skills and increase the efficiency of their professional activities. Students perform independent tasks on their mobile devices under the guidance of a teacher, either in traditional or electronic form. Recommended topics for practical exercises: 1. Historical Development of Solar Cells. 2. Perovskites: Opportunities and Sustainability Challenges 3. Off-grid PV System Design 4. Analysis of Smart Solar Devices 5. Economic Analysis of Solar Power Plants (LCOE, CAPEX)
Exam form	Written
Teaching/learning and examination requirements	Complete mastery of theoretical and methodological concepts and practical knowledge of the discipline, the ability to correctly reflect the results of analysis, independently reason about the processes being studied and carry out tasks in the current, intermediate forms of control and independent work, pass written work on the final control. When drawing up final exam questions, deviations from the content of the discipline program are not allowed. The bank of final exam questions for each discipline is discussed at the meeting and approved by the head of the department. No later than 1 week before the start of the final control, tickets signed by the head of the department, enclosed in an envelope, are sealed by the Dean’s office and opened 5 minutes before the start of the exam in the presence of students. Final exam duration is 80 minutes.

	Answers to final exam questions are recorded in copybooks with the seal of the Dean’s office. After completion of the final work, the work is immediately encrypted by a representative of the Dean’s office, and the copybooks are handed over to the commission for verification. From the moment of completion of the final exam, a period of 72 hours is allotted for checking and posting the results on the electronic platform. The teacher who taught the students in this discipline is not involved in the process of conducting the exam and checking the students' answers. Student(s) who are dissatisfied with the final exam results may submit a written or oral appeal within 24 hours of the publication of the final exam results. Complaints submitted after 24 hours from the publication of the final exam results will not be accepted.
Scope of assessment criteria and procedure	CURRENT CONTROL Purpose: Determining and assessing the student's level of knowledge, practical skills, and competencies on course topics. Instructions: The student's activity in daily classes is assessed through the student's mastery of course topics, as well as constructively interpreting and analyzing the educational material, developing module-specific skills, acquiring practical skills (in terms of quality and the specified number) and competencies, solving problem situations aimed at applying professional practical skills, working in a team, preparing presentations, etc. Current control form: Activity in lessons Preparing educational materials Working with sources within the subject Using educational technologies Working in a team Preparing presentations Working with projects. MIDTERM CONTROL Purpose: Assessing the student's knowledge and practical skills and level of mastery of lecture material after completing the relevant section of the course. Form and procedure of intermediate control: Midterm examination is held during the semester during the training sessions after the completion of the relevant module of the curriculum of the subject. Midterm examination is held once in written form within the framework of this subject. Midterm examination questions cover all topics of the subject. INDEPENDENT LEARNING Purpose: Independent learning is aimed at fully covering the content of this course, expanding the theoretical knowledge acquired, and establishing independent learning activities for students. Form and procedure of independent education: independent work assignments are completed in the form of an educational project, presentation, case study, problem solving, information search, digest, colloquium, essay, article, abstract, etc. Completed assignments for independent study are placed in the electronic system and checked based on the anti-plagiarism program and evaluated by the subject teacher. In this case, the uniqueness of the completed assignment should not be less than 60%, otherwise the assignment will not be accepted for assessment. The number of independent work assignments, depending on the nature of the subject, should not be less than 3 for one subject (module). Independent work assignments account for 60% of the points allocated for current and intermediate control. FINAL CONTROL Purpose: The final examination is held at the end of the semester to determine the level of mastery of the student's theoretical knowledge and practical skills in the relevant subject. The final examination is held at a specified time according to the examination schedule created by the

Registrar's Office on the electronic platform.

Requirements: The student must have passed the current control, intermediate control and independent learning assignments by the deadline for the final control type in the relevant subject. A student who has not passed the current control, intermediate control and independent learning assignments, as well as who has received a score in the range of "0-29.9" for these assignments and control types, is not included in the final control type. Also, a student who has missed 25 percent or more of the classroom hours allocated to a subject without a reason is excluded from this subject and is not included in the final control type and is considered not to have mastered the relevant credits in this subject. A student who has not passed or was not included in the final control type and has received a score in the range of "0-29.9" for this type of control is considered to be an academic debtor.

Final control form: The final examination in this subject will be conducted in written form. If the final examination is conducted in written form, the requirements for assessment must also be reflected.

Criteria for assessing student knowledge

5 grade	100 points		Assessment criteria
5	90-100	Excellent	When a student is considered to be able to make independent conclusions and decisions, think creatively, observe independently, apply the knowledge he has gained in practice, understand, know, express, and narrate the essence of the subject, and have an idea about the subject.
4	70-89,9	Good	When the student is considered to be able to observe independently, apply the knowledge he has gained in practice, understand, know, express, and narrate the essence of the subject, and has an idea about the subject.
3	60-69,9	Satisfactory	When the student is found to be able to apply the knowledge he has gained in practice, understands, knows, can express, and narrate the essence of the subject, and has an idea about the subject.
2	0-59,9	Unsatisfactory	When it is determined that the student has not mastered the science program, does not understand the essence of the subject, and does not have an idea about the science.

Course assessment criteria and procedure

Assessment type	Total points allocated	Control (task) form	Distribution of points	Qualifying score
Current assessment	30 points	System tasks	20 points (divided by the number of tasks)	18 points
		Student activity (in seminars, practical, laboratory classes)	10 points	
Midterm assessment	20 points	Supervision: Written work	10 points	12 points
		System tasks	10 points (divided by the number	

			of tasks)	
Final assessment	50 points	Written assignment (5 questions)	50 points (10 points per question)	30 points

* Note: 60% of the points allocated for current and intermediate control are allocated to independent work assignments. Independent work assignments are evaluated as system assignments through the electronic platform.

Recommended Literature

Main literature:

1. Gulyamov M.M., Rashidov A.A.Quyosh fotoelektr konvertorlari – TATU nashriyoti, Toshkent, 2020.
2. Gulyamov M.M., Abdurahmanov N.Yarimo‘tkazgichlar fizikasi – Toshkent, 2018.
3. Baxodirov Sh.B., Karimov K.K.Quyosh energiyasi va fotovoltaik tizimlar – Samarqand davlat universiteti, 2021.
4. Peter Würfel Physics of Solar Cells: From Basic Principles to Advanced Concepts – Wiley-VCH, 2016 (3rd ed.)
5. Stephen J. Fonash Solar Cell Device Physics – Academic Press, 2010 (2nd ed.)
6. Antonio Luque, Steven Hegedus (eds.) Handbook of Photovoltaic Science and Engineering – Wiley, 2011 (2nd ed.)
7. Jenny Nelson The Physics of Solar Cells – Imperial College Press, 2003.
8. Martin Green Third Generation Photovoltaics: Advanced Solar Energy Conversion – Springer, 2006.

Additional literature:

9. Mirziyov Sh.M. Tanqidiy tahlil, qat’iy tartib-intizom va shaxsiy javobgarlik – har bir rahbar faoliyatining kundalik qoidasi bo‘lishi kerak. O‘zbekiston Respublikasi Vazirlar Mahkamasining 2016 yil yakunlari va 2017 yil istiqbollariga bag‘ishlangan majlisidagi O‘zbekiston Respublikasi Prezidentining nutqi. // Xalq so‘zi gazetasi. 2017 yil 16 yanvar, №11.
10. Mirziyoyev Sh.M. Erkin va farovon, demokratik O‘zbekiston davlatini birgalikda barpo etamiz. O‘zbekiston Respublikasi Prezidentining lavozimiga kirishish tantanali marosimiga bag‘ishlangan Oliy Majlis palatalarining qo‘shma majlisidagi nutqi. –T.: “O‘zbekiston” NMIU, 2016. – 56 b.
11. Mirziyoyev Sh.M. Buyuk kelajagimizni mard va olijanob xalqimiz bilan birga quramiz. - T.: “O‘zbekiston” NMIU, 2017. – 488 b.
12. The Electric Power Engineering Handbook, Third Edition - Five Volume Set (Electrical Engineering Handbook), 2012 by Leonard L. Grigsby.

Internet sites:

13. www.gov.uz –Government portal of the Republic of Uzbekistan.
14. www.catback.ru – international scientific articles and educational materials website.
15. www.google.ru – international educational materials search website.
16. www.ziyonet.uz – national educational materials search website.
17. www.lex.uz – national database of legal documents and information.
18. www.catback.ru – scientific articles and educational materials
19. https://www.nrel.gov– National Renewable Energy Laboratory
20. https://www.ise.fraunhofer.de- Fraunhofer Institute for Solar Energy Systems.