Course Title:	**Advanced Solid State physics**
Course Code:	
Program:	**Master of Science in Condensed Matter Physics**
Department:	**Physics**
College:	**Sciences**
Institution:	**Umm Al-Qura University**
Version:	2nd
Last Revision Date:	**January 2025**

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A. General information about the course:

1. Course Identification:

1. Credit hours: (3 hrs)				
2. Course type				
A.	☐ University	☐College	☒ Department	☒ Track
B.	☒ Required		☐Elective	
3. Level/year at which this course is offered: (3rd semester / 2nd Year)				

4. Course General Description:

This course provides a comprehensive exploration of advanced topics in solid state physics, focusing on the theoretical and experimental principles that govern the behavior of materials. Students will develop a deep understanding of electronic, magnetic, and thermal properties in solids, with an emphasis on the interplay between microscopic and macroscopic phenomena.

The course covers a wide range of topics, including the behavior of electrons in periodic potentials, scattering and transport phenomena in metals, lattice vibrations (phonons), magnetism, and phase transitions. The macroscopic and microscopic theories of superconductivity, including the Ginzburg-Landau and BCS frameworks, are also introduced.

In the final weeks, the lecturer will select one of the following specialized topics for detailed exploration, tailored to the class's interests and the lecturer’s expertise:

1. Strongly Correlated Systems: Investigating electron correlations, the Hubbard model, and Mott insulators.
2. Microscopic Theory of Superconductivity: A detailed analysis of BCS theory, Cooper pairs, and energy gap phenomena.
3. Advanced Applications of Ginzburg-Landau Theory: Exploring extensions and applications to complex systems and phase transitions.

5. Pre-requirements for this course (if any)**:**

6. Pre-requirements for this course (if any)**:**

7. Course Main Objective(s):

1. Understand the Behavior of Electrons in Solids
    1. Analyze the behavior of electrons in periodic potentials and their contribution to band structure and transport properties.
    2. Investigate scattering phenomena and transport mechanisms in metals using theoretical models.
2. Explore Lattice Dynamics and Thermal Properties
    1. Understand phonon dispersion relations and their role in the thermal properties of solids.
    2. Examine interactions between lattice vibrations and electronic systems.
3. Develop Knowledge of Magnetism and Phase Transitions
    1. Study various magnetic phenomena, including ferromagnetism, antiferromagnetism, and spin interactions.
    2. Apply Landau theory to understand phase transitions and critical phenomena in solids.
4. Analyze Superconductivity
    1. Understand the macroscopic theory of superconductivity, including the London and Ginzburg-Landau equations.
    2. Explore microscopic theories such as the BCS framework to analyze the mechanisms underlying superconductivity.
5. Specialize in Advanced Topics
    1. Engage deeply with one elective topic (selected by the lecturer) to explore specialized areas in solid state physics, such as:
        1. Strongly Correlated Systems: Concepts like Mott insulators and the Hubbard model.
        2. Microscopic Theory of Superconductivity: Detailed exploration of Cooper pairs and energy gap phenomena.
        3. Advanced Ginzburg-Landau Theory: Applications in complex systems and phase transitions.
6. Prepare for Research and Applications
    1. Apply advanced solid state physics principles to solve complex problems in materials science and condensed matter physics.
    2. Build a strong theoretical foundation for research in modern physics and related interdisciplinary fields.

2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	100
2	E-learning		
3	Hybrid 1. Traditional classroom 2. E-learning		
4	Distance learning		

3. Contact Hours: (based on the academic semester)

No	Activity	Contact Hours
3.	**Lectures**	45
4.	**Laboratory/Studio**	
5.	**Field**	
6.	**Tutorial**	
7.	**Others (specify)……**	
	Total	45

B. Course Learning Outcomes (CLOs), Teaching Strategies and Assessment Methods:

By the end of the course, the students should be able to:

1. Explain band structures in metals and semi-conductors, and apply them in physical situations.
2. Determine electrical conductivity of metals and semi-conductors
3. Describe cooperative phenomena as applied to magnetic and superconductivity phenomena

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
1.0	**Knowledge and understanding**			
1.1	Explain the behavior of electrons in periodic potentials and the resulting band structures.	K1-P	Interactive lectures and discussions with visual aids.	Written exams and quizzes.
1.2	Describe the fundamental principles of lattice vibrations, magnetism, and superconductivity.	K2-M	Case-based discussions and problem-solving examples.	Research-based assignments.
1.3	Analyze the theoretical frameworks of phase transitions and their applications to solids.	K3-M	Concept-driven lectures and collaborative exercises.	Midterm and final examinations.
…				
2.0	**Skills**			
2.1	Apply mathematical and theoretical models to analyze transport phenomena and thermal properties in solids.	S1-P	Hands-on problem-solving workshops.	Analytical assignments.

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
2.2	Use advanced solid state physics theories, such as Ginzburg-Landau and BCS, to evaluate superconducting systems.	S2-M	Group projects and guided mentorship sessions.	Group presentations and reports.
2.3	Develop and present solutions for complex problems related to correlated electron systems and phase transitions.	S3-M	Research-oriented tasks and critical discussions.	Research projects and evaluations.
3.0	**Values, autonomy, and responsibility**			
3.1	Appreciate the role of solid state physics in advancing modern technologies and materials science.	V1-P	Reflective discussions on the impact of solid state physics.	Reflective essays.
3.2	Demonstrate ethical responsibility in conducting and presenting research in solid state physics.	V2-M	Discussions on ethical practices in physics research.	Case study analysis.

C. Course Content:

No	List of Topics	Contact Hours
8.	**Introduction to Solid State Physics and Crystal Structures**: Overview of key concepts, Bravais lattices, reciprocal lattice, and symmetry in crystals.	3
9.	**Electrons in a Periodic Potential (Part 1)**: Bloch's theorem, band structure, and electronic dispersion relations.	3
3.	**Electrons in a Periodic Potential (Part 2)**: Density of states, effective mass, and the concept of holes.	3
4.	**Scattering in Metals**: Drude model, electrical and thermal conductivity, and the Wiedemann-Franz law.	3
5.	**Transport in Metals**: Boltzmann transport equation, relaxation time approximation, and electrical resistivity.	3
6.	**Phonons (Part 1)**: Lattice vibrations, phonon dispersion relations, and the Debye model.	3
7.	**Phonons (Part 2)**: Thermal properties of solids, specific heat, and phonon interactions.	3
8.	**Magnetism in Solids (Part 1)**: Free electron theory, Pauli paramagnetism, and Landau diamagnetism.	3
9.	**Magnetism in Solids (Part 2)**: Ferromagnetism, antiferromagnetism, and spin interactions.	3

10.	**Landau Theory of Phase Transitions**: Symmetry breaking, order parameters, critical phenomena, and applications to ferroelectrics and magnetism.	3
11.	**Macroscopic Theory of Superconductivity**: Overview of superconductivity, London equations, and magnetic flux quantization.	3
12.	**Ginzburg-Landau Theory of Superconductivity**: Ginzburg-Landau equations, coherence length, and type-I and type-II superconductors.	3
13.	**Elective Topic 1: Strongly Correlated Systems**: Hubbard model, Mott insulators, and their connection to high-temperature superconductivity.	3
14.	**Elective Topic 2: Microscopic Theory of Superconductivity**: BCS theory, Cooper pairs, and energy gap with experimental insights.	3
15.	**Elective Topic 3: Ginzburg-Landau Theory (Advanced)**: Applications of the Ginzburg-Landau framework to complex systems and phase transitions.	3
Total		**45**

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
1.	Quizzes	All weeks	10
2.	Homework	All weeks	10
3.	Midterm	8th week	30
4.	Final exam	18th week	50

*Assessment Activities (i.e., Written test, oral test, oral presentation, group project, essay, etc.)

E. Learning Resources and Facilities:

1. References and Learning Resources:

Essential References	• **Advanced Solid State Physics**, Philip Phillips, **Edition**: 2nd (2012), **Publisher**: Cambridge University Press, **ISBN-13**: 978-0521194907 • **Introduction to Solid State Physics**, **Author**: Charles Kittel, **Edition**: 8th (2004), **Publisher**: Wiley, **ISBN-13**: 978-0471415268
Supportive References	• **Physical Properties of Materials**, Mary Anne White, **Edition**: 2nd (2011), **Publisher**: CRC Press, **ISBN-13**: 978-1439866511

	• **Materials Science and Engineering: An Introduction,** William D. Callister, Jr., **Edition**: 9th (2014), **Publisher**: Wiley, **ISBN-13**: 978-1118324578 • **Principles of Electronic Materials and Devices**, Safa O. Kasap, **Edition**: 3rd (2006), **Publisher**: McGraw-Hill, **ISBN-13**: 978-0072957914 • **Electronic Properties of Materials**, Rolf E. Hummel, **Edition**: 4th (2011), **Publisher**: Springer, **ISBN-13**: 978-1441981639
Electronic Materials	• **MIT OpenCourseWare: Solid State Physics**, **Link**: MIT OCW: Solid State Physics, **Description**: Free lecture notes, assignments, and videos covering essential topics in solid state physics, including band theory, phonons, and superconductivity. • **Khan Academy: Advanced Physics**, **Link**: Khan Academy: Advanced Physics **Description**: Interactive modules covering foundational and advanced physics topics, useful for revisiting concepts like magnetism and transport phenomena. • **Lecture Notes on Solid State Physics**, **Link**: Solid State Physics Lecture Notes **Description**: A repository of advanced solid state physics lecture notes, including topics such as band theory, superconductivity, and strongly correlated systems.
Other Learning Materials	

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	1. Classrooms: Equipped with whiteboards, projectors, and seating for interactive theoretical discussions. 2. Seminar Rooms: Spaces for collaborative discussions, presentations, and guest lectures. 3. Simulation Rooms: For visualizing quantum phenomena using computational tools.

Items	Resources
Technology equipment (Projector, smart board, software)	1. Projector and Smart Board: For presenting derivations, diagrams, and visual simulations of quantum field interactions.
Other equipment (Depending on the nature of the specialty)	▪ Access to Online Resources: Journals, databases, and virtual lecture platforms for advanced research.

F. Assessment of Course Quality:

Assessment Areas/Issues	Assessor	Assessment Methods
Effectiveness of teaching	Academic Program Coordinator	Conduct mid-term and end-of-term surveys.
Effectiveness of students' assessment	Course Instructor	Compare assessments with course learning outcomes (CLOs).
Quality of learning resources	Course Instructor	Track student engagement with electronic materials.
The extent to which CLOs have been achieved	External Academic Reviewer	Collect feedback from graduates.
Other		

Assessor (Students, Faculty, Program Leaders, Peer Reviewer, Others (specify)
Assessment Methods (Direct, Indirect)

G. Specification Approval Data:

COUNCIL /COMMITTEE	
REFERENCE NO.	
DATE	**JANUARY 2025**

Course Title:	**Semiconductors physics**
Course Code:	
Program:	**Master of Science in Condensed Matter Physics**
Department:	**Physics**
College:	**Sciences**
Institution:	**Umm Al-Qura University**
Version:	**2nd**
Last Revision Date:	**January 2025**

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A. General information about the course:

1. Course Identification:

1. Credit hours: (3 hrs)

2. Course type

A.	☐ University	☐College	☒ Department	☒ Track	
B.	☒ Required		☐Elective		

3. Level/year at which this course is offered: (3rd semester /2nd Year)

4. Course general Description:

This course provides a comprehensive introduction to the principles and applications of semiconductor physics, emphasizing fundamental concepts and their relevance to modern technology. The course explores the properties of metals, insulators, and semiconductors, focusing on energy band theory, charge carriers, and transport phenomena in semiconductor materials. Students will gain an understanding of intrinsic and extrinsic semiconductors, mechanisms of excitation and recombination, and the physical parameters that determine the behavior of semiconductor devices.

Practical applications are integrated throughout the course, including detailed studies of pn junctions, metal-semiconductor junctions, transistors, and optoelectronic devices such as LEDs and solar cells. Designed for Master's level physics students with limited mathematical backgrounds, the course emphasizes conceptual understanding, enabling students to appreciate the role of semiconductor materials in advanced technologies, from consumer electronics to renewable energy systems.

5. Pre-requirements for this course (if any)**:**

6. Pre-requirements for this course (if any)**:**

7. Course Main Objective(s):

4. Understand Fundamental Concepts:
    a. Explain the distinction between metals, insulators, and semiconductors based on band theory.
    b. Describe the formation of energy bands and their significance in determining the electronic properties of materials.
5. Analyze Semiconductor Behavior:

   a. Understand intrinsic and extrinsic semiconductors, including the effects of doping on carrier concentration and transport properties.
   b. Examine the mechanisms of charge carrier generation, recombination, and transport phenomena such as drift and diffusion.
6. Explore Device Physics:
   a. Analyze the physical principles behind key semiconductor devices, including pn junctions, metal-semiconductor junctions, transistors, and solar cells.
   b. Understand current-voltage characteristics and the role of physical parameters in determining device performance.
7. Investigate Material Properties:
   a. Evaluate the physical parameters of semiconductor materials, such as band gap, mobility, and thermal conductivity, and their impact on device functionality.
   b. Discuss the role of specific materials in advanced semiconductor devices, including optoelectronic applications.
8. Link Theory to Applications:
   a. Relate theoretical principles of semiconductor physics to practical applications in electronics, renewable energy, and optoelectronics.
   b. Explore emerging trends and technologies in semiconductor research and development.
9. Foster Problem-Solving Skills:
   a. Apply basic concepts of semiconductor physics to analyze and solve practical problems in device design and operation.
10. Prepare for Advanced Studies or Careers:
   a. Develop a solid foundation for pursuing further research or careers in semiconductor technology, electronics, and material science industries.

2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	100%
2	E-learning		
3	Hybrid 10. Traditional classroom 11. E-learning		
4	Distance learning		

3. Contact Hours: (based on the academic semester)

No	Activity	Contact Hours
12.	**Lectures**	45
13.	**Laboratory/Studio**	
14.	**Field**	
15.	**Tutorial**	

16.	**Others (specify)……**	
	Total	45

B. Course Learning Outcomes (CLOs), Teaching Strategies and Assessment Methods:

Code	Course Learning Outcomes	Code of CLOs aligned with program	Teaching Strategies	Assessment Methods
1.0	**Knowledge and understanding**			
1.1	Demonstrate the fundamental equations of determining the device physical parameters.	K1-P	Interactive lectures and discussions with visual aids.	Mid exam. Final exam. Homework. Quizzes
1.2	Integrate transport equations and charge distribution techniques in analyzing semiconductor devices.	K2-M		
1.3	Exhibit understanding of recent trends in semiconductor device physics and their applications in emerging technologies.	K3-P		
2.0	**Skills**			
2.1	Apply techniques for solving Semiconductor transport equations.	S1-P	Hands-on problem-solving workshops.	Mid exam. Final exam. Homework. Quizzes
2.3	Calculate and interpret the physical parameters in the semiconductor devises	S2-M		
2.4	Utilize tools and computational methods to model and	S3-M		

Code	Course Learning Outcomes	Code of CLOs aligned with program	Teaching Strategies	Assessment Methods
	analyze semiconductor behavior.			
3.0	Values, autonomy, and responsibility			
3.1	Collaborate effectively within multidisciplinary teams	V1-P	Discussions on ethical practices in physics research.	Oral Questions
3.2	Uphold ethical standards in semiconductor research and ensure accuracy in reporting data.	V2-M		

C. Course Content:

No	List of Topics	Contact Hours
1	Introduction to Semiconductors: Overview of semiconductor materials; distinction between metals, insulators, and semiconductors; applications in modern technology.	3
2	Crystal Structure and Bonding: Atomic arrangements in semiconductors; types of bonding; introduction to crystallography; Miller indices; importance of crystal structure on electronic properties.	3
3	Energy Band Theory: Formation of energy bands; concepts of valence and conduction bands; band gaps; comparison of band structures in metals, insulators, and semiconductors.	3
4	Charge Carriers in Semiconductors: Electrons and holes; effective mass; intrinsic carrier concentration; Fermi level and its significance.	3
5	Doping and Extrinsic Semiconductors: n-type and p-type doping; donor and acceptor states; manipulation of electrical properties through doping; position of Fermi level in extrinsic semiconductors.	3
6	Carrier Transport Phenomena: Mechanisms of carrier transport including drift and diffusion; mobility; conductivity; introduction to the Hall effect and its applications.	3
7	Carrier Generation and Recombination: Thermal generation; radiative and non-radiative recombination processes; carrier lifetime; quasi-Fermi levels; impact on device performance.	3

8	Junctions in Semiconductors: Formation and properties of p-n junctions; depletion region; built-in potential; current-voltage characteristics; applications in diodes.	3
9	Metal-Semiconductor Contacts: Schottky and Ohmic contacts; energy band alignment; current transport mechanisms; significance in device fabrication.	3
10	Bipolar Junction Transistors (BJTs): Structure and operation principles; current gain; input and output characteristics; basic amplifier configurations.	3
11	Field-Effect Transistors (FETs): Types including JFETs and MOSFETs; principles of operation; transfer and output characteristics; applications in digital and analog circuits.	3
12	Optoelectronic Devices: Principles and applications of light-emitting diodes (LEDs), laser diodes, and photodetectors; material considerations; device structures; performance parameters.	3
13	Semiconductor Materials and Properties: Overview of elemental and compound semiconductors; material properties such as band gap, mobility, and thermal conductivity; selection criteria for specific applications.	3
14	Advanced Semiconductor Devices: Introduction to devices like solar cells, charge-coupled devices (CCDs), and quantum dots; basic operating principles; current trends in semiconductor device research.	3
15	Review and Future Directions: Recap of key concepts; discussion on emerging semiconductor technologies; potential future applications; course summary and preparation for final assessments.	3
Total		**45**

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
2.	Quizzes	All weeks	10
3.	Homework	All weeks	10
4.	Midterm	8th week	30
4.	Final exam	18th week	50
…			

*Assessment Activities (i.e., Written test, oral test, oral presentation, group project, essay, etc.)

E. Learning Resources and Facilities:

1. References and Learning Resources:

Essential References	• **Physics of Semiconductor Devices**, *Authors*: Simon M. Sze, Yiming Li, and Kwok K. Ng, *Edition*: 4th Edition (2021), *Publisher*: Wiley *ISBN*: 978-1119429111

	• **Fundamentals of Carrier Transport**, *Author*: Mark Lundstrom, *Edition*: 2nd Edition (2000), *Publisher*: Cambridge University Press *ISBN*: 978-0521637244 11. **"Fundamentals of Semiconductors: Physics and Materials Properties"** Peter Y. Yu and Manuel Cardona, *Edition*: 4th (2010) *ISBN*: 978-3-642-00710-1 12. **"The Physics of Semiconductors: An Introduction Including Nanophysics and Applications"** Marius Grundmann, *Edition*: 4th (2021) *ISBN*: 978-3-030-51568-3
Supportive References	13. **"Semiconductor Physics and Devices: Basic Principles"** Donald A. Neamen, *Edition*: 4th (2012) *ISBN*: 978-0-07-352958-5 **14.** **"Physics of Semiconductor Devices"** Simon M. Sze and Kwok K. Ng, *Edition*: 4th (2021) *ISBN*: 978-1-119-43486-6
Electronic Materials	1. **"Introduction to Semiconductors"** *Institution*: Massachusetts Institute of Technology (MIT) OpenCourseWare 2. **"Semiconductor Devices: Theory and Application"** James M. Fiore (2018) *ISBN*: 978-1-7965-4353-7 **3.** **"Lecture Notes on Semiconductor Optoelectronics"** *Institution*: Cornell University
Other Learning Materials	

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	4. Classrooms: Equipped with whiteboards, projectors, and seating for interactive theoretical discussions. 5. Seminar Rooms: Spaces for collaborative discussions, presentations, and guest lectures. 6. Simulation Rooms: For visualizing quantum phenomena using computational tools.

Items	Resources
Technology equipment (Projector, smart board, software)	7. Projector and Smart Board: For presenting derivations, diagrams, and visual simulations of quantum field interactions.
Other equipment (Depending on the nature of the specialty)	1. Access to Online Resources: Journals, databases, and virtual lecture platforms for advanced research.

F. Assessment of Course Quality:

Assessment Areas/Issues	Assessor	Assessment Methods
Effectiveness of teaching	Academic Program Coordinator	Conduct mid-term and end-of-term surveys .
Effectiveness of students assessment	Course Instructor	Compare assessments with course learning outcomes.
Quality of learning resources	Course Instructor	Track student engagement with electronic materials.
The extent to which CLOs have been achieved	External Academic Reviewer	Collect feedback from graduates.
Other		

Assessor (Students, Faculty, Program Leaders, Peer Reviewer, Others (specify)

Assessment Methods (Direct, Indirect)

G. Specification Approval Data:

COUNCIL /COMMITTEE	
REFERENCE NO.	
DATE	**JANUARY 2025**

Course Title:	Characterization techniques
Course Code:	
Program:	Master of Science in Condensed Matter Physics
Department:	Physics
College:	Sciences
Institution:	Umm Al-Qura University
Version:	*Course Specification Version Number*
Last Revision Date:	January 2025

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A. General information about the course:

1. Course Identification

1. Credit hours: (3)					
2. Course type					
A.	☐ University	☐College	☒ Department	☒ Track	☐Others
B.	☒ Required		☐Elective		
3. Level/year at which this course is offered: (2nd year/3rd semester)					
4. Course General Description:					

This course provides a comprehensive overview of the fundamental and advanced techniques used to characterize materials and analyze their properties. Designed for postgraduate students, it emphasizes the principles, instrumentation, and applications of various methods employed in material science, engineering, and nanotechnology.

Key topics include structural analysis using X-ray diffraction (XRD), elemental composition through energy-dispersive X-ray spectroscopy (EDX), and optical property analysis via ultraviolet-visible (UV-VIS) and Fourier-transform infrared (FTIR) spectroscopy. Vibrational energy modes are explored through Raman spectroscopy, while scanning and transmission electron microscopy (SEM and TEM) techniques provide insights into surface morphology, high-resolution imaging, and electron diffraction.

The course also covers advanced surface characterization using atomic force microscopy (AFM) and X-ray photoelectron spectroscopy (XPS), along with electrical property measurements through I-V curves and LCR meters. Students will learn how to interpret and integrate data from these techniques for a deeper understanding of material behavior.

6. Co-requisites for this course (if any)**:**

7. Course Main Objective(s):

15. Understand Fundamental Principles:
    a. Explain the underlying principles and mechanisms of various characterization techniques, including XRD, EDX, UV-VIS, FTIR, Raman, SEM, TEM, AFM, XPS, I-V characteristics, and LCR meter analysis.
    b. Recognize the strengths, limitations, and suitable applications of each method for material analysis.
16. Apply Characterization Techniques:
    a. Select and apply appropriate techniques to analyze structural, optical, chemical, and electrical properties of materials.
    b. Use practical knowledge of instrumentation and data acquisition to perform material characterization tasks in laboratory or research settings.
17. Analyze and Interpret Data:
    a. Develop the ability to interpret experimental data from multiple characterization methods.
    b. Integrate data from complementary techniques to derive comprehensive insights into material behavior.
18. Solve Practical Problems:
    a. Design and execute experimental protocols to investigate and characterize unknown materials or systems.
    b. Address research and industrial challenges using advanced characterization methods.
19. Develop Research and Analytical Skills:
    a. Gain proficiency in modern material analysis tools and statistical methods for error analysis and data interpretation.
    b. Foster critical thinking and problem-solving skills necessary for innovative research and industrial applications.
20. Understand Advanced Applications:
    a. Explore the role of advanced techniques, such as NMR spectroscopy, SIMS, and DSC, in material science and engineering.
    b. Discuss case studies and real-world applications to link theoretical knowledge with practical relevance.
21. Promote Ethical and Professional Responsibility:
    a. Appreciate the importance of accurate material characterization in advancing technology and ensuring reliability in research and industrial processes.
    b. Demonstrate professional responsibility in reporting and interpreting results.

2. Teaching mode (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	100%
2	E-learning		
3	Hybrid 17. Traditional classroom 18. E-learning		

No	Mode of Instruction	Contact Hours	Percentage
4	Distance learning		

3. Contact Hours (based on the academic semester)

No	Activity	Contact Hours
19.	**Lectures**	45
20.	**Laboratory/Studio**	
21.	**Field**	
22.	**Tutorial**	
23.	**Others (specify)**	
Total		45

B. Course Learning Outcomes (CLOs), Teaching Strategies and Assessment Methods

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
1.0	**Knowledge and understanding**			
1.1	Explain the fundamental principles and mechanisms of material characterization techniques such as XRD, EDX, SEM, and others.	K1-P	Interactive lectures with visual aids and case studies.	Written exams.
1.2	Integrate knowledge of various characterization methods to analyze material properties and solve advanced research problems.	K2-M	Problem-solving sessions and group discussions.	Case studies and assignments.
1.3	Demonstrate understanding of data interpretation from techniques like Raman, XPS, and AFM.	K3-P	Practical workshops with hands-on experiments.	Lab reports and quizzes.
2.0	**Skills**			
2.1	Select appropriate characterization techniques for analyzing specific material properties.	S1-P	Project-based learning and real-world problem analysis.	Research projects and presentations.

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
2.2	Perform basic measurements and data acquisition using characterization equipment.	S2-M	Practical demonstrations and guided lab activities.	Lab performance evaluation.
2.3	Analyze and integrate experimental data from complementary techniques to solve research problems.	S3-M	Data analysis workshops with real datasets.	Analytical problem-solving exercises.
3.0	**Values, autonomy, and responsibility**			
3.1	Appreciate the role of characterization techniques in advancing scientific research and industrial applications.	V1-P	Discussions on real-world applications and innovations.	Reflection essays.
3.2	Demonstrate professional responsibility in reporting and interpreting results with accuracy and integrity.	V2-M	Mentoring sessions on research ethics and professionalism.	Supervisor evaluations.

C. Course Content

No	List of Topics	Contact Hours
24.	**Introduction to Characterization Techniques**: Overview of methods, principles, and applications.	3
25.	**X-ray Diffraction (XRD)**: Crystallinity, phase identification, crystallite size, strain analysis, and film thickness.	3
26.	**Energy-Dispersive X-ray Spectroscopy (EDX)**: Principles, instrumentation, and elemental composition analysis.	3
27.	**Ultraviolet-Visible Spectroscopy (UV-VIS)**: Optical properties, equipment setup, and data interpretation.	3
28.	**Fourier-Transform Infrared Spectroscopy (FTIR)**: Detection of organic, polymeric, and inorganic materials; chemical characterization.	3
6	**Raman Spectroscopy**: Vibrational energy modes, instrumentation, and applications in material analysis.	3
7	**Scanning Electron Microscopy (SEM)**: Basic concepts, imaging techniques, advantages, and limitations.	3
8	**Transmission Electron Microscopy (TEM)**: Principles, high-resolution imaging, electron diffraction, and chemical analysis.	3
9	**Atomic Force Microscopy (AFM)**: Surface force and adhesion measurement; modes (contact, tapping, lateral-force); STM, EFM, MFM; AFM-based nanolithography.	3
10	**X-ray Photoelectron Spectroscopy (XPS)**: Instrumentation, chemical shifts, quantification, and depth profiling.	3

11	**I-V Characteristic Curves**: Instrumentation setup, data measurement, and electrical circuit material analysis.	3
12	**LCR Meter Analysis**: Measurement of inductance (L), capacitance (C), resistance (R), impedance (Z), and related parameters; data interpretation for LCR circuits.	3
13	**Advanced Characterization Techniques**: NMR spectroscopy, SIMS, DSC; principles and applications.	3
14	**Data Analysis and Interpretation**: Statistical methods, error analysis, and case studies.	3
15	**Applications and Case Studies**: Real-world applications, integration of techniques, and student presentations.	3
Total		**45**

D. Students Assessment Activities

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
2.	Quizzes	All weeks	10
3.	Homework	All weeks	10
4.	Midterm	8^{th} week	30
4.	Final exam	18^{th} week	50

*Assessment Activities (i.e., Written test, oral test, oral presentation, group project, essay, etc.).

E. Learning Resources and Facilities

1. References and Learning Resources

Essential References	1. "Surface Analysis: The Principal Techniques", John C. Vickerman, Ian Gilmore, 2^{nd} Edition, John Wiley & Sons, Inc., (2009), ISBN: 978-0470017647. 2. "Organic Structural Spectroscopy" by Joseph B. Lambert, Herbert F. Shurvell, David A Lightner, Robert Graham Cooks, Prentice Hall; 1st edition, (1997), ISBN: 0132586908 3. 'Fundamentals of light microscopy and electronic imaging' Douglas B. Murphy, 2001, Wiley-Liss, Inc. USA 4. 'Encyclopedia of Materials Characterization, Surfaces, Interfaces, Thin Films,' Editors C. Richard Brundle, Charles A. Evans, Jr., Shaun Wilson, Butterworth-Heinemann, Boston, US. 5. Elements of X-ray diffraction' B.D. Cullity and S.R. Stock, 2001, Prentice Hall, Inc. USA 6. 'Transmission electron microscopy" D.B. Williams and C. Barry Carter, 4 volumes, Springer, 1996. USA

	7. 'Handbook of low and high dielectric constant materials and their applications' Hari Singh Nalwa (ed.), 1999, London, Academic Press, ISBN 0 12 5139071 and ISBN 0 12 5139063 Electrical Properties of Materials, by L. Solymar, D. Walsh, , (2004) Oxford University Press, Seven edition, ISBN-13: 978-0199267934
Supportive References	1. "Surface Analysis Methods in Materials Science" by D.J. O'Connor, Brett A. Sexton, Roger S. C. Smart, Springer; 2 edition, (2003), ISBN: 3540413308 2. Organic Spectroscopy, by Lal Dhar Singh Yadav, Springer; 1 edition, (2005), ISBN: 1402025742 1. (Surface and Thin Film Analysis: A Compendium of Principles, Instrumentation, and Applications" by Henning Bubert, Holger Jenett, Wiley-VCH, (2002), ISBN: 3527304584 2. "Scanning Probe Microscopy: The Lab on a Tip" by Ernst Meyer, Hans J. Hug, Roland Bennewitz, Springer, (2003), ISBN: 3540431802. 3. "Handbook of Surface and Interface Analysis, by John C. Riviere, CRC; 1 edition, (1998), ISBN: 0824700805 4. "Structure Determination of Organic Compounds: Tables of Spectral Data", by E. Pretsch, P. Bühlmann, C. Affolter, Springer; 3 edition, (2004), ISBN: 3540678158 Practical Guide to Surface Science and Spectroscopy by Yip-Wah Chung, Academic Press, (2001), ISBN: 0121746100
Electronic Materials	http://www.nanotech-america.com/mdocuments/mironov_book_en.pdf
Other Learning Materials	Numerous computer programs are available for analyzing materials; each technique requires a different application.

2. Required Facilities and equipment

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	22. Classrooms: Equipped with whiteboards, projectors, and seating for interactive theoretical discussions. 23. Seminar Rooms: Spaces for collaborative discussions, presentations, and guest lectures. 24. Simulation Rooms: For visualizing quantum phenomena using computational tools.
Technology equipment (projector, smart board, software)	25. Projector and Smart Board: For presenting derivations, diagrams, and visual simulations of quantum field interactions.

Items	Resources
Other equipment (depending on the nature of the specialty)	26. Access to Online Resources: Journals, databases, and virtual lecture platforms for advanced research.

F. Assessment of Course Quality

Assessment Areas/Issues	Assessor	Assessment Methods
Effectiveness of teaching	Academic Program Coordinator	Conduct mid-term and end-of-term surveys.
Effectiveness of Students assessment	Course Instructor	Compare assessments with course learning outcomes (CLOs) to ensure alignment.
Quality of learning resources	Course Instructor	Track student engagement with electronic materials and physical resources.
The extent to which CLOs have been achieved	External Academic Reviewer	Collect feedback from graduates.
Other		

Assessors (Students, Faculty, Program Leaders, Peer Reviewers, Others (specify)

Assessment Methods (Direct, Indirect)

G. Specification Approval

COUNCIL /COMMITTEE	
REFERENCE NO.	
DATE	**JANUARY 2025**

Course Title:	**Synthesis and Preparation of Materials**
Course Code:	
Program:	**Master of Science in Condensed Matter Physics .**
Department:	**Physics**
College:	**Sciences**
Institution:	**Umm Al-Qura University**
Version:	**2nd**
Last Revision Date:	**January 2025**

Table of Contents

A. General information about the course:

1. Course Identification:

1. Credit hours: (3 hrs)

2. Course type

A.	☐ University	☐College	☒ Department	☒ Track	
B.	☐ Required		☒ Elective		

3. Level/year at which this course is offered: (2^{nd} Year/3^{rd} semester)

4. Course general Description:

This course provides a comprehensive overview of the principles and techniques used in the synthesis and preparation of materials, with a particular emphasis on thin films, nanomaterials, and biopolymers. Students will explore a wide range of methodologies, including ball milling, spin coating, dip coating, ion beam epitaxy, electrodeposition, chemical vapor deposition (CVD), vacuum thermal evaporation, and RF sputtering. Each method is presented with a detailed discussion of its fundamental principles, process parameters, and real-world applications in fields such as electronics, optics, energy, and biotechnology.

Special focus is given to advanced techniques such as ion beam epitaxy, which facilitates the growth of thin films, nanostructured materials, quantum wells, and superlattices. Students will also compare various thin-film preparation techniques and evaluate their suitability for different applications.

In the final two weeks, the lecturer will select one of two advanced topics to tailor the course to specialized areas or emerging trends in material science. The elective topics are:

27. Synthesis of Magnetic Nanoparticles: Principles and applications in biomedical imaging, drug delivery, and data storage.
28. Synthesis of 2D Materials (Graphene and MXenes): Techniques and applications in flexible electronics, energy storage, and catalysis.

This course emphasizes both the theoretical understanding and practical implications of material preparation techniques, equipping students with the skills needed for advanced research and innovative applications in material science and engineering.

5. Pre-requirements for this course (if any)**:**

6. Pre-requirements for this course (if any)**:**

Academic Advice

7. Course Main Objective(s):

29. Understand the Principles of Material Synthesis
    a. Comprehend the fundamental principles and methodologies involved in the synthesis and preparation of materials, including thin films, nanomaterials, and biopolymers.
30. Explore a Range of Preparation Techniques
    a. Gain knowledge of various preparation techniques such as ball milling, spin coating, dip coating, ion beam epitaxy, electrodeposition, chemical vapor deposition (CVD), vacuum thermal evaporation, and RF sputtering.
31. Develop Analytical and Comparative Skills
    a. Analyze and compare the effectiveness and applications of different thin-film preparation methods to determine the most suitable technique for specific applications.
32. Apply Advanced Techniques
    a. Understand the advanced applications of techniques like ion beam epitaxy for growing thin films, nanostructures, quantum wells, and superlattices.
33. Engage with Emerging Trends in Material Science
    a. Explore specialized topics in material science through elective subjects, including the synthesis of magnetic nanoparticles or 2D materials, and their cutting-edge applications in technology and industry.
34. Prepare for Research and Innovation
    a. Build a strong foundation for advanced research by understanding the theoretical and practical aspects of material synthesis, enabling innovation in areas like energy, electronics, and biotechnology.

2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	100%
2	E-learning		
3	Hybrid 29. Traditional classroom 30. E-learning		
4	Distance learning		

3. Contact Hours: (based on the academic semester)

No	Activity	Contact Hours
31.	**Lectures**	45
32.	**Laboratory/Studio**	
33.	**Field**	
34.	**Tutorial**	
35.	**Others (specify) …**	
	Total	45

B. Course Learning Outcomes (CLOs), Teaching Strategies and Assessment Methods:

Code	Course Learning Outcomes	Code of CLOs aligned with program	Teaching Strategies	Assessment Methods
1.0	**Knowledge and understanding**			
1.1	Explain the principles and mechanisms behind various material synthesis techniques, including thin film preparation and nanomaterial synthesis.	K1-P	Interactive lectures with visual aids and real-world examples.	Written exams and quizzes.
1.2	Analyze the applications of material synthesis methods in fields such as electronics, biotechnology, and energy storage.	K2-M	Case-based discussions on real-world applications.	Research-based assignments.
1.3	Understand the theoretical basis for advanced synthesis topics, such as magnetic nanoparticles, 2D materials, and energy materials.	K3-P	Problem-solving sessions and instructor-led case studies.	Midterm and final examinations.
2.0	**Skills**			
2.1	Evaluate and compare different material synthesis techniques for specific applications.	S1-P	Group-based critical analysis of case studies.	Problem-solving exercises.

Code	Course Learning Outcomes	Code of CLOs aligned with program	Teaching Strategies	Assessment Methods
2.2	Integrate interdisciplinary knowledge to recommend appropriate synthesis techniques for practical scenarios.	S2-P	Group discussions and research presentations.	Individual or group projects.
2.3	Develop critical thinking by exploring advanced topics and emerging trends in material preparation techniques.	S3-M	Research-oriented tasks and guided mentorship.	Research presentations and reports.
3.0	**Values, autonomy, and responsibility**			
3.1	Appreciate the role of material synthesis in addressing global challenges in technology, healthcare, and energy.	V1-P	Discussions on the impact of materials on society.	Reflective essays.
3.2	Demonstrate ethical considerations and responsibility in material preparation and its applications.	V2-M	Lectures on ethical case studies in material science.	Ethics-based case study analysis.

C. Course Content:

No	List of Topics	Contact Hours
36.	**Introduction to Material Synthesis and Preparation Techniques**: Overview of material science laboratory techniques, importance, and synthesis methods.	3
37.	**Synthesis of Nanomaterials: Ball Milling Technique**: Principles, equipment, operating parameters, and applications in nanoparticles and nanocomposites synthesis.	3
3.	**Preparation of Thin Films: Spin Coating Technique**: Fundamentals, process parameters, film thickness control, and applications in electronics and surface modifications.	3
4.	**Preparation of Thin Films: Dip Coating Technique**: Mechanism, process parameters, drying/annealing stages, and applications in solar cells and sensors.	3

5.	**Preparation of Thin Film by Ion Beam Epitaxy Process**: Principles, methods for ion-beam deposition, and applications in thin films, quantum wells, superlattices, and nanostructured materials.	3
6.	**Biopolymer Materials: Preparation and Applications**: Fundamentals, synthesis methods, and applications in medical, environmental, and packaging industries.	3
7.	**Electrodeposition of Thin Films**: Principles, electrolyte selection, deposition parameters, film morphology control, and applications in coatings and batteries.	3
8.	**Chemical Vapor Deposition (CVD) Techniques**: Fundamentals of CVD, including thermal and plasma-enhanced methods, with applications in semiconductors and photovoltaics.	3
9.	**Vacuum Thermal Evaporation Technique**: Overview of vacuum systems, material evaporation, deposition on substrates, and applications in optics and electronics.	3
10.	**RF Sputtering Method**: Principles of RF sputtering, plasma generation, target material erosion, and applications in MEMS and transparent conductive films.	3
11.	**Comparative Analysis of Thin Film Preparation Techniques**: Comparison of methods, including spin coating, dip coating, CVD, RF sputtering, and ion beam epitaxy, with real-world case studies.	3
12	**Advanced Preparation Techniques: Atomic Layer Deposition (ALD)**: Overview of ALD, sequential deposition, atomic-level control, and applications in nanotechnology.	3
13.	**Advanced Preparation Techniques: Sol-Gel Method**: Fundamentals of sol-gel chemistry, thin film preparation, and applications in coatings and sensors.	3
14.	**Elective Topic 1: Synthesis of Magnetic Nanoparticles**: Principles of synthesis (e.g., co-precipitation) and applications in imaging, drug delivery, and data storage.	3
15.	**Elective Topic 2: Synthesis of 2D Materials (Graphene and MXenes)**: Techniques like chemical exfoliation and applications in energy storage, flexible electronics, etc.	3
Total		**45**

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
5.	Quizzes	All weeks	10
6.	Homework	All weeks	10
7.	Midterm	8^{th} week	30
4.	Final exam	18^{th} week	50

*Assessment Activities (i.e., Written test, oral test, oral presentation, group project, essay, etc.)

E. Learning Resources and Facilities:

1. References and Learning Resources:

Essential References	• **"Materials Syntheses: A Practical Guide"** *Editors*: Ulrich Schubert, Nicola Hüsing, Richard M. Laine *Publisher*: Springer, 2008 *ISBN*: 978-3-211-75125-1 *Overview*: This guide offers detailed protocols for synthesizing a variety of materials, including ceramics, polymers, and nanomaterials. It emphasizes clarity and reproducibility in synthesis procedures, making it a valuable resource for understanding fundamental synthesis techniques. SpringerLink • **"Handbook on Synthesis Strategies for Advanced Materials"** *Editors*: A. K. Tyagi, S. Banerjee *Publisher*: Springer, 2021 *ISBN*: 978-981-16-1807-9 *Overview*: This handbook provides a comprehensive overview of various synthesis methods for advanced materials, covering ceramics, films, glass, carbon-based, and metallic materials. It discusses both conventional and novel synthesis techniques, offering insights into processing and surface functionalization. SpringerLink
Supportive References	• **Particulate Materials: Synthesis, Characterisation, Processing and Modelling"** *Editors*: Andreas Öchsner, Holm Altenbach *Publisher*: Royal Society of Chemistry, 2010 *ISBN*: 978-1-84755-895-4 *Overview*: This book showcases advances in the synthesis, characterization, processing, and modeling of particulate materials. It includes discussions on advanced synthesis methods like spray-pyrolysis and supercritical fluid synthesis, providing a broad perspective on particulate material processing. Royal Society of Chemistry Books • **"Advanced Materials: Production, Characterization and Applications"** *Editors*: Mahendra Dashrath Gaikwad, Arpana Parihar, Raju Khan *Publisher*: CRC Press, 2023 *ISBN*: 978-1-003-45119-8 *Overview*: This book offers insights into the production, synthesis,

	and characterization of advanced materials, with applications across electronics, biotechnology, and medical fields. It adopts a multidisciplinary approach, making it relevant for various advanced material applications. Taylor & Francis
Electronic Materials	• **MIT OpenCourseWare: "Synthesis of Polymers"** *Instructor*: Prof. Paula Hammond *Link*: https://ocw.mit.edu/courses/10-569-synthesis-of-polymers-fall-2006/ *Description*: This course provides lecture notes and materials focusing on the synthesis of polymeric materials, emphasizing the relationship between chemical pathways, process conditions, and the resulting microarchitecture. MIT OpenCourseWare • **Coursera: Material Science Courses** *Link*: https://www.coursera.org/courses?query=material+science *Description*: Coursera offers a variety of online courses in material science, covering topics from fundamental principles to advanced synthesis techniques. These courses provide flexibility and are taught by experts in the field. Co
Other Learning Materials	

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	35. Classrooms: Equipped with whiteboards, projectors, and seating for interactive theoretical discussions. 36. Seminar Rooms: Spaces for collaborative discussions, presentations, and guest lectures. 37. Simulation Rooms: For visualizing quantum phenomena using computational tools.
Technology equipment (Projector, smart board, software)	38. Projector and Smart Board: For presenting derivations, diagrams, and visual simulations of quantum field interactions.

Items	Resources
Other equipment (Depending on the nature of the specialty)	Access to Online Resources: Journals, databases, and virtual lecture platforms for advanced research.

F. Assessment of Course Quality:

Assessment Areas/Issues	Assessor	Assessment Methods
Effectiveness of teaching	Academic Program Coordinator	Conduct mid-term and end-of-term surveys .
Effectiveness of students assessment	Course Instructor	Compare assessments with course learning outcomes (CLOs) to ensure alignment.
Quality of learning resources	Course Instructor	Track student engagement with electronic materials .
The extent to which CLOs have been achieved	External Academic Reviewer	Collect feedback from graduates .
Other		

Assessor (Students, Faculty, Program Leaders, Peer Reviewer, Others (specify)

Assessment Methods (Direct, Indirect)

G. Specification Approval Data:

COUNCIL /COMMITTEE	
REFERENCE NO.	
DATE	**JANUARY 2025**

Course Title:	**Advanced Nanoscience**
Course Code:	
Program:	**Master of Science in Condensed Matter Physics**
Department:	**Physics**
College:	**Science**
Institution:	**Umm Al-Qura University**
Version:	2nd
Last Revision Date:	**January 2025**

Table of Contents

A. General information about the course:

1. Course Identification:

1. Credit hours: (3 hrs)

2. Course type

A.	☐ University	☐College	☒ Department	☒ Track	
B.	☐ Required		☒ Elective		

3. Level/year at which this course is offered: (2nd Year/3rd semester)

4. Course general Description:

This course provides an in-depth exploration of nanoscience principles and their applications, focusing on the unique physical, chemical, and structural properties of materials at the nanoscale. The course begins with an introduction to the physics of solid-state materials, laying the foundation for understanding the behavior of nanostructured systems. Topics include advanced measurement techniques, the properties of individual nanoparticles, carbon nanostructures (such as graphene and carbon nanotubes), bulk nanostructured materials, and nanostructured ferromagnetism.

Students will also learn about optical and vibrational spectroscopy methods for characterizing nanoscale systems and explore their applications in areas such as energy, medicine, and environmental sustainability. Emphasis is placed on bridging theoretical concepts with practical applications, providing students with the skills to engage in advanced research or contribute to cutting-edge technologies in nanoscience and nanotechnology. Designed for postgraduate students, this course fosters critical thinking, problem-solving, and ethical awareness in the rapidly evolving field of nanoscience.

5. Pre-requirements for this course (if any)**:**

6. Pre-requirements for this course (if any)**:**

7. Course Main Objective(s):

8. Develop a Comprehensive Understanding of Nanoscience Principles:
    1. Explain the fundamental concepts of solid-state physics as they relate to nanostructured materials.
    2. Understand the unique physical, chemical, and electronic properties of nanomaterials and their implications for advanced applications.
9. Master Advanced Measurement and Characterization Techniques:
    1. Utilize cutting-edge methods such as optical and vibrational spectroscopy to analyze nanoscale materials.

2. Interpret data from advanced characterization techniques to evaluate the properties of individual nanoparticles and nanostructured materials.

10. Explore and Analyze Nanomaterial Properties and Applications:
    1. Investigate the synthesis, structure, and function of carbon nanostructures, including graphene and carbon nanotubes.
    2. Examine bulk nanostructured materials and their mechanical, magnetic, and electronic properties.
11. Understand Fabrication Techniques and Device Applications:
    1. Develop a basic understanding of top-down and bottom-up nanofabrication methods.
    2. Analyze the design and functionality of nanoscale devices, including their applications in energy, medicine, and electronics.
12. Foster Ethical Awareness and Professional Responsibility:
    1. Discuss the environmental, societal, and ethical implications of nanoscience and nanotechnology.
    2. Promote sustainable and responsible practices in research and the development of nanotechnology-based solutions.
13. Prepare for Advanced Research and Innovation:
    1. Equip students with the knowledge and skills to engage in interdisciplinary research and contribute to the advancement of nanoscience.
    2. Encourage innovative problem-solving and critical thinking in addressing real-world challenges using nanotechnology.

2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	100%
2	E-learning		
3	Hybrid 38. Traditional classroom 39. E-learning		
4	Distance learning		

3. Contact Hours: (based on the academic semester)

No	Activity	Contact Hours
40.	**Lectures**	45
41.	**Laboratory/Studio**	
42.	**Field**	
43.	**Tutorial**	
44.	**Others (specify)……**	
	Total	45

B. Course Learning Outcomes (CLOs), Teaching Strategies and Assessment Methods:

Code	Course Learning Outcomes	Code of CLOs aligned with program	Teaching Strategies	Assessment Methods
1.0	**Knowledge and understanding**			
1.1	Explain the fundamental concepts of solid-state physics and the unique properties of nanomaterials.	K1-P	Conceptual lectures with visual aids.	Written exams.
1.2	Analyze the properties of individual nanoparticles, carbon nanostructures, and bulk nanostructured materials.	K2-M	Problem-solving sessions.	Case studies.
1.3	Describe advanced measurement techniques and fabrication methods used in nanotechnology research.	K3-P	Hands-on demonstrations of experimental techniques.	Laboratory reports.
2.0	**Skills**			
2.1	Apply nanoscience principles to evaluate material properties and device functionality.	S1-P	Project-based learning.	Research project.
2.2	Perform basic spectroscopic analysis and interpret data for nanoscale materials.	S2-P	Practical workshops.	Data analysis reports.
2.3	Design a basic nanofabrication workflow for creating	S3-M	Collaborative learning in group tasks.	Group presentations.

Code	Course Learning Outcomes	Code of CLOs aligned with program	Teaching Strategies	Assessment Methods
	nanoscale materials or devices.			
3.0	**Values, autonomy, and responsibility**			
3.1	Appreciate the interdisciplinary nature and societal impact of nanoscience and nanotechnology.	V1-P	Discussions on the ethical and societal impact of nanotechnology.	Reflection essays.
3.2	Demonstrate professional responsibility in the analysis, synthesis, and reporting of nanoscience data.	V2-M	Supervisor-led mentoring sessions.	Supervisor evaluations.

C. Course Content:

No	List of Topics	Contact Hours
1	Introduction to Solid State Physics: Overview of crystal structures and bonding; introduction to electronic band theory.	3
2	Methods of Measuring Properties: Scanning probe microscopy techniques; spectroscopic methods for nanoscale characterization.	3
3	Properties of Individual Nanoparticles: Quantum size effects; electronic, optical, and magnetic properties.	3
4	Carbon Nanostructures I: Structure and synthesis of fullerenes and carbon nanotubes.	3
5	Carbon Nanostructures II: Graphene properties and applications.	3
6	Bulk Nanostructured Materials: Nanocomposites; mechanical properties at the nanoscale.	3
7	Nanostructured Ferromagnetism: Magnetic behavior in nanostructures; applications in data storage.	3
8	Optical Spectroscopy of Nanomaterials: Absorption and emission properties; surface plasmon resonance.	3
9	Vibrational Spectroscopy of Nanomaterials: Raman and infrared spectroscopy; phonon interactions.	3
10	Nanofabrication Techniques I: Top-down approaches: lithography and etching.	3

11	Nanofabrication Techniques II: Bottom-up approaches: self-assembly and chemical vapor deposition.	3
12	Nanotechnology in Energy Applications: Nanomaterials for solar cells; energy storage systems.	3
13	Nanomedicine: Drug delivery systems; diagnostic nanodevices.	3
14	Environmental and Ethical Implications of Nanotechnology: Safety and toxicity concerns; regulatory frameworks.	3
15	Current Trends and Future Directions in Nanoscience: Emerging research areas; commercial applications.	3
Total		**45**

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
14.	Quizzes	All weeks	10
15.	Homework	All weeks	10
16.	Midterm	8^{th} week	30
…	Final exam	18^{th} week	50

*Assessment Activities (i.e., Written test, oral test, oral presentation, group project, essay, etc.)

E. Learning Resources and Facilities:

1. References and Learning Resources:

Essential References	39. **"Introduction to Nanoscience and Nanotechnology"** Chris Binns, *Edition*: 2nd (2021) *ISBN*: 978-1-119-17225-3 **40. "Textbook of Nanoscience and Nanotechnology"** B.S. Murty, P. Shankar, Baldev Raj, B.B. Rath, James Murday (2013) *ISBN*: 978-3-642-28029-0 41. Robert W. Kelsall, Ian W. Hamley, and Mark Geoghegan, “Nanoscale Science and Technology”, John Willey & Sons, Inc., publication (2005). 42. Hilmi Unlu, and Norman J.M. Horing, “Low Dimensional Semiconductor Structures”, Springer, (2013) 43. Jeremy J. Ramsden, “Nanotechnology: An Introduction”, Second Edition. (2016). 44. Ram K. Gupta, “Energy Applications of 2D Nanomaterials”, Taylor & Francis Group 2022.

Supportive References	17. **"Nanotechnology: Principles and Practices"** Sulabha K. Kulkarni, *Edition*: 3rd (2015) *ISBN*: 978-3-319-09170-9 **18.** **"Springer Handbook of Nanotechnology"** *Editor*: Bharat Bhushan, *Edition*: 4th (2017) *ISBN*: 978-3-662-54357-3
Electronic Materials	19. **MIT OpenCourseWare: "Lecture 1: Introduction to Nanotechnology, Nanoscale Transport Phenomena"** *Institution*: Massachusetts Institute of Technology 20. **Coursera: Nanotechnology Courses**.
Other Learning Materials	

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	• Classrooms: Equipped with whiteboards, projectors, and seating for interactive theoretical discussions. • Seminar Rooms: Spaces for collaborative discussions, presentations, and guest lectures. • Simulation Rooms: For visualizing quantum phenomena using computational tools.
Technology equipment (Projector, smart board, software)	• Projector and Smart Board: For presenting derivations, diagrams, and visual simulations of quantum field interactions.
Other equipment (Depending on the nature of the specialty)	• Access to Online Resources: Journals, databases, and virtual lecture platforms for advanced research.

F. Assessment of Course Quality:

Assessment Areas/Issues	Assessor	Assessment Methods
Effectiveness of teaching	Academic Program Coordinator	**45.** Conduct mid-term and end-of-term surveys.
Effectiveness of students assessment	Course Instructor	**46.** Compare assessments with course

Assessment Areas/Issues	Assessor	Assessment Methods
		learning outcomes (CLOs) to ensure alignment.
Quality of learning resources	Course Instructor	**47.** Track student engagement with electronic materials and physical resources.
The extent to which CLOs have been achieved	External Academic Reviewer	**48.** Collect feedback from graduates.
Other		

Assessor (Students, Faculty, Program Leaders, Peer Reviewer, Others (specify)
Assessment Methods (Direct, Indirect)

G. Specification Approval Data:

COUNCIL /COMMITTEE	
REFERENCE NO.	
DATE	**JANUARY 2025**

Course Title:	**Advanced Optics**
Course Code:	
Program:	**Master of Science in Condensed Matter Physics**
Department:	**Physics**
College:	**Sciences**
Institution:	**Umm Al-Qura University**
Version:	**2nd**
Last Revision Date:	**January 2025**

Table of Contents

A. General information about the course:

1. Course Identification:

1. Credit hours: (3 hours)				
2. Course type				
A.	☐ University	☐College	☒ Department	☒ Track
B.	☐Required		☒ Elective	
3. Level/year at which this course is offered: (2nd Year/3rd semester)				

4. Course General Description:

This course provides a comprehensive overview of advanced concepts and applications in optics, building upon fundamental principles to explore cutting-edge developments in the field. It covers key topics such as geometrical and wave optics, polarization, interference, and diffraction, followed by Fourier optics with applications in spatial filtering and optical information processing.

The course delves into non-linear optics, introducing phenomena like second-harmonic generation, optical parametric oscillation, and their applications. Quantum optics is explored with a focus on quantum states of light, quantum entanglement, and their implications for communication technologies. The study of photonics emphasizes photonic crystals, optical fibers, and semiconductor optoelectronic devices, showcasing their role in modern communication systems.

For the final three weeks, the lecturer will choose from a selection of elective topics to tailor the course to the interests of the class or recent advancements in the field. Elective topics include:

21. Optical Coherence Tomography (OCT): Principles and medical applications of OCT imaging.
22. Metamaterials: Unique properties such as negative refraction and applications in superlensing and cloaking.
23. Plasmonics: Applications in high-resolution imaging, sensing, and nanophotonics.

This course equips students with theoretical knowledge and practical insights into advanced optical technologies, preparing them for research and professional practice in optics and photonics.

5. Pre-requirements for this course (if any)**:**

6. Pre-requirements for this course (if any)**:**

Academic Advice.

7. Course Main Objective(s):

49. Understand and Apply Advanced Optical Principles:
    a. Explain the fundamental principles of geometrical optics, wave optics, and polarization, and their applications in modern optical systems.
    b. Analyze and apply concepts of interference, diffraction, and Fourier optics to solve practical problems in imaging and optical information processing.
50. Explore Non-linear and Quantum Optics:
    a. Understand non-linear optical phenomena such as second-harmonic generation, sum-frequency generation, and optical parametric oscillation.
    b. Describe quantum states of light, including coherent and squeezed states, and their role in advanced optical communication and quantum technologies.
51. Examine Photonics and Optical Technologies:
    a. Analyze the principles of photonic crystals, optical fibers, and semiconductor optoelectronic devices, emphasizing their applications in communication systems and device engineering.
52. Investigate Specialized Topics in Advanced Optics:
    a. Study cutting-edge applications such as optical coherence tomography, metamaterials, and plasmonics, connecting theoretical concepts to real-world challenges in imaging and sensing.
53. Develop Analytical and Problem-Solving Skills:
    a. Formulate and solve complex optical problems using theoretical and computational approaches.
    b. Engage with advanced mathematical and experimental methods relevant to the field of optics.
54. Promote Research and Lifelong Learning in Optics:
    a. Foster an understanding of recent advancements in optics through elective topics, enabling students to explore specialized areas aligned with current research trends.
    b. Prepare students for careers in research, academia, and industry by developing critical thinking and technical proficiency in advanced optics.

2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	100%
2	E-learning		
3	Hybrid 45. Traditional classroom 46. E-learning		
4	Distance learning		

3. Contact Hours: (based on the academic semester)

No	Activity	Contact Hours
47.	**Lectures**	**45**
48.	**Laboratory/Studio**	
49.	**Field**	
50.	**Tutorial**	
51.	**Others (specify)……**	
	Total	**45**

B. Course Learning Outcomes (CLOs), Teaching Strategies and Assessment Methods:

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
1.0	**Knowledge and understanding**			
1.1	Explain the principles of geometrical optics, wave optics, and polarization and their applications in modern optical systems.	K1-P	Interactive lectures with visual aids.	Written exams and quizzes.
1.2	Describe advanced optical phenomena, including interference, diffraction, and Fourier optics, and their practical applications.	K2-M	Case-based learning and group discussions.	Problem-solving assignments.
1.3	Understand the fundamentals of non-linear and quantum optics, focusing on their theoretical foundations and technological relevance.	K3-P	Lectures combined with real-world examples.	Midterm and final examinations.
…				
2.0	**Skills**			
2.1	Apply mathematical and computational techniques to analyze optical systems and phenomena, such as Fourier transforms and diffraction patterns.	S1-P	Hands-on workshops and problem-solving sessions.	Analytical assignments.

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
2.2	Design and evaluate optical systems, including photonic crystals, optical fibers, and optoelectronic devices, for specific applications.	S2-P	Laboratory experiments and design projects.	Lab reports and project evaluations.
2.3	Conduct independent research and critically analyze advanced topics in optics, including OCT, metamaterials, and plasmonics.	S3-M	Research-oriented tasks with mentorship.	Research projects and presentations.
…				
3.0	**Values, autonomy, and responsibility**			
3.1	Appreciate the interdisciplinary nature of optics and its role in solving real-world problems in technology, communication, and healthcare.	V1-P	Group discussions and case studies.	Reflective essays.
3.2	Demonstrate ethical considerations in the research, design, and application of optical systems and technologies.	V2-M	Discussions on ethics and societal impacts.	Ethics-based case study analysis.

C. Course Content:

No	List of Topics	Contact Hours
52.	**Review of Fundamental Optics (Part 1)**: Overview of geometrical optics and wave optics, including reflection, refraction, and basic wave equations.	3
53.	**Review of Fundamental Optics (Part 2)**: Polarization—types, mathematical representation, and applications, such as stress analysis and liquid crystals.	3
54.	**Interference and Diffraction (Part 1)**: Young's double-slit experiment and applications; multiple-beam interference and Fabry-Pérot interferometers.	3
55.	**Interference and Diffraction (Part 2)**: Fraunhofer diffraction—single-slit and multiple-slit patterns; Fresnel diffraction—concepts and practical implications.	3
56.	**Fourier Optics (Part 1)**: Basics of Fourier transforms in optics; applications to image processing, filtering, and optical communication.	3
57.	**Fourier Optics (Part 2)**: Spatial filtering and holography; optical information processing.	3
58.	**Non-linear Optics (Part 1)**: Fundamentals of non-linear optical phenomena; second-harmonic generation and sum-frequency generation.	3
59.	**Non-linear Optics (Part 2)**: Optical parametric oscillation and its applications; practical examples and case studies of non-linear optical systems.	3
60.	**Quantum Optics (Part 1)**: Quantum states of light, including coherent and squeezed states; experimental realization and applications.	3

61.	**Quantum Optics (Part 2)**: Quantum entanglement and quantum teleportation; applications in quantum communication and cryptography.	3
62.	**Photonics (Part 1)**: Principles of photonic crystals and waveguides; optical fibers—properties and applications in communication.	3
63.	**Photonics (Part 2)**: Semiconductor optoelectronic devices—lasers, LEDs, and detectors; applications in modern photonic systems.	3
64.	**Advanced Topics: Optical Coherence Tomography**: Principles of OCT; applications in medical imaging and diagnostics.	3
65.	**Elective Advanced Topics (Lecturer's Choice)**: **Option 1**: Metamaterials and their unique properties; **Option 2**: Plasmonics and their applications in sensing and imaging.	3
66.	**Elective Advanced Topics (Continuation or Integration)**: Continuation of the chosen topic or integration of advanced topics with hands-on examples and discussions.	3

Total		**45**

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
24.	Quizzes	All weeks	10
25.	Homework	All weeks	10
26.	Midterm	8th week	30
27.	Final exam	18th week	50
...			

*Assessment Activities (i.e., Written test, oral test, oral presentation, group project, essay, etc.)

E. Learning Resources and Facilities:

1. References and Learning Resources:

Essential References	1.**"Optics" (5th Edition) by Eugene Hecht (2016) ISBN**: 978-0133977226
Supportive References	• **"Principles of Optics" (7th Edition) by Max Born and Emil Wolf (1999) ISBN**: 978-0521642224 • **"Introduction to Fourier Optics" (4th Edition) by Joseph W. Goodman (2017) ISBN**: 978-1319119165

	• **"Nonlinear Optics" (4th Edition) by Robert W. Boyd (2020) ISBN**: 978-0128110027 • **"An Introduction to Metamaterials and Nanophotonics" by Constantin Simovski and Sergei Tretyakov (2020) ISBN**: 978-1108492645 • **"Plasmonics: From Basics to Advanced Topics" edited by Stefan Enoch and Nicolas Bonod (2012) ISBN**: 978-3642280788 • **"Plasmonic Optics: Theory and Applications" by Yongqian Li (2017) ISBN**: 978-1510607552
Electronic Materials	• **SPIE Digital Library** **Link**: https://www.spiedigitallibrary.org/ **Description**: A comprehensive resource for research in optics and photonics, offering access to journals, conference proceedings, and books on advanced optics topics like metamaterials, plasmonics, and quantum optics. • **Optica (Formerly OSA) Publishing** **Link**: https://opg.optica.org/ **Description**: The Optica Publishing Group provides access to a wide range of journals and articles on optical science and technology, covering advanced topics like nonlinear optics and photonics. • **MIT OpenCourseWare: Optics and Photonics** **Link**: https://ocw.mit.edu/courses/physics/ **Description**: Free lecture notes and course materials on optics, including fundamental and advanced concepts, Fourier optics, and photonics.
Other Learning Materials	

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	• Classrooms: Equipped with whiteboards, projectors, and seating for interactive theoretical discussions. • Seminar Rooms: Spaces for collaborative discussions, presentations, and guest lectures. • Simulation Rooms: For visualizing quantum phenomena using computational tools.
Technology equipment (Projector, smart board, software)	• Projector and Smart Board: For presenting derivations, diagrams, and visual simulations of quantum field interactions.
Other equipment (Depending on the nature of the specialty)	Access to Online Resources: Journals, databases, and virtual lecture platforms for advanced research.

F. Assessment of Course Quality:

Assessment Areas/Issues	Assessor	Assessment Methods
Effectiveness of teaching	Academic Program Coordinator	• Conduct mid-term and end-of-term surveys .
Effectiveness of students assessment	Course Instructor	• Compare assessments with course learning outcomes (CLOs) to ensure alignment.
Quality of learning resources	Course Instructor	• Track student engagement with electronic materials and physical resources.
The extent to which CLOs have been achieved	External Academic Reviewer	• Collect feedback from graduates.
Other		

Assessor (Students, Faculty, Program Leaders, Peer Reviewer, Others (specify)
Assessment Methods (Direct, Indirect)

G. Specification Approval Data:

COUNCIL /COMMITTEE	
REFERENCE NO.	

DATE	JANUARY 2025