Syllabus for Multi-Disciplinary Minor (MDM) Degree

in

Materials Science

under

National Education Policy (NEP 2020)

(2023-2024)

DEPARTMENT OF PHYSICS

INSTITUTE OF CHEMICAL TECHNOLOGY

(University Under Section-3 of UGC Act, 1956)

Elite Status and Center for Excellence

Government of Maharashtra

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A. Preamble

Why Minor in Materials Science?

The interdisciplinary field of materials science has become crucial to many emerging areas for advancing technology and their applications. For example, materials science is extensively used in the semiconductor industry, solar cells manufacturing, renewable energy, automotive and aerospace industry, biomaterials, to name a few.

The courses offered in this Minor program in materials science will allow interested students to gain an understanding of the fundamental processes that govern materials behaviour and their pivotal role in modern technology. The students shall understand various materials properties, materials processing techniques, characterization methods and selection criterion in implementing engineering solutions, and thereby enhance their core competence as an engineer/technologist.

To summarize, the students will have the opportunity of combining knowledge of their major with the knowledge of materials, improve their marketability to employers, and consider higher studies in materials related fields.

B. Program specific Outcomes (PSOs) for Minor degree in Materials Science

PSO1	Acquiring a strong grasp over the fundamentals of Materials science which are required in addressing complex real-world problems related to use of materials in technological applications. Develop a sound understanding of materials properties from the Physico-chemical perspective and their dependance on various parameters.
PSO2	Comprehension and familiarity with optimization of experimental conditions required for a desired performance. Acquaintance about materials economy and geographical distribution of minerals/resources.
PSO3	Ability to select, design, synthesize, process, characterize, and thoroughly investigate materials from a functional viewpoint. Expertise in techniques of advanced experimental measurement, and analysis of results to determine physical quantities.
PSO4	Opportunity of combining knowledge of their major with the knowledge of materials to improve their marketability to employers and consider higher studies in materials related fields. Awareness of the importance of sustainability and environmental impact in the context of using materials for technological applications.
PSO5	Apply the knowledge gained to devise solutions that address societally relevant problems. Strict adherence and commitment to follow ethical principles and norms of the practice of physical and material sciences in all verticals of industry and society.
PSO6	Ability to work effectively as an individual, a member or leader in diverse teams, and in multidisciplinary settings. Possess skills of effective dissemination of information to a diverse audience.

C. Intake capacity of the program:

To run the program, the minimum number of students enrolled should be 15, and the maximum limit enrollment is restricted to 35. In the event the number is less than the minimum capacity, the candidate shall be offered a seat in the next available minor degree programme.

D. Eligibility criteria for minor in Materials science:

Should have cleared (i) Applied Physics and (ii) Physics laboratory courses in the UG First year.

E. Structure of Minor in Materials Science (Department of Physics)

Structure of Minor in Materials Science											
Sr. No.	**Course Code**	**Course**	**Semester**	**Credits**	**Hours/week**			**Marks distribution**			
					L	**T**	**P**	**CA**	**MS**	**ES**	**Total**
1.	PYT1301	Solid state Physics	III	2	1	1	-	20	30	50	100
2.	PYT1401	Introduction to Materials Science	IV	2	1	1	-	20	30	50	100
3.	PYT1501	Introduction to Nanophysics and Applications	V	4	3	1	-	20	30	50	100
4.	PYP1601	Materials Characterization Laboratory	VI	2	-	-	4	50	-	50	100
5.	PYT1701	Introduction to Polymer Physics	VII	2	2	-	-	20	30	50	100
6.	PYT1801	Ceramic Science and Technology	VIII	2	2	-	-	20	30	50	100

L= lecture; T= tutorial; P= Practical; CA = continuous assessment; MS: Mid-semester exam; ES= End-semester exam.

F. Pedagogy/Teaching methods:

I) Lecture/discussion:
These sessions will discuss the subject matters of the course

II) Experimental/Practical learning:
The sessions will involve practical exercises.

G. Evaluation

Evaluation for the courses will be according to revised document of R.9 credit system and mode of evaluation; the link is provided below or visit the website (ictmumbai.edu.in) for the details.

Link: https://www.ictmumbai.edu.in/uploaded_files/R_9(Revised)_Credit_system.pdf

A general evaluation process for theory and lab courses is given below

Theory Courses

Continuous Assessment Test (CAT): Continuous assessment will vary from course to course; the instructor will decide the evaluation mode. Two to three CATs (Continuous Assessment Tests) will be conducted throughout the course, usually before and after the midsemester examination. These CATs will carry a total weightage of 20%. Depending on the instructor, assignments, case studies, group discussions, and seminars could also form part of the continuous assessment.

Mid-semester exam: Total 30 Marks (theory paper)

End-semester exam: Total 50 Marks (theory paper)

Practical Courses (PYP 1601)

Continuous assessment: 50 Marks

Performing given experiments as per the instructions, submission of lab journal on time, viva voce, group/personal discussions, and quizzes can be part of continuous assessment. The course instructor will discuss the composition of marks for these at the beginning of the course.

End Semester: 50 Marks (Lab experiment performance followed by viva-voce examination)

H. Instructors:

1. Solid state Physics: Dr. Ashwin Mohan
2. Introduction to Materials science: Dr. Archana Kalekar
3. Introduction to Nanophysics and Applications: Dr. Neetu Jha
4. Materials Characterisation Laboratory: Dr. Archana Kalekar and Ashwin Mohan
5. Introduction to Polymer Physics: Dr. Paresh Salame
6. Ceramic Science and Technology: Dr. Paresh Salame

I. Detailed Syllabus:

<table>
<tr><td rowspan="3"></td><td rowspan="2">Course Code: PYT1301</td><td rowspan="2">Course Title: Solid State Physics</td><td colspan="3">Credits = 02</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>Semester: III</td><td>Total contact hours: 30</td><td>01</td><td>01</td><td>-</td></tr>
<tr><td colspan="6"></td></tr>
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Course Outcomes (students will be able to…)		
CO1	Understand bonding in solids in the context of interaction potentials.	K2
CO2	Map periodic crystal structures in real space onto reciprocal space, thereby understanding the phenomenon of diffraction in crystals.	K3
CO3	Describe the behaviour of electrons based on the band theory of solids and thereby understand conduction in metals and semiconductors.	K2
CO4	Correlate the elastic and thermal properties of solids to the concept of phonons.	K3
CO5	Understand the terminology encountered in research publications, presentations and advanced courses on solid-state and material science topics.	K2
List of Prerequisite Courses		
	Applied Physics (PYT1251 or PYT1205) in the first year of the UG courses	
	Mathematics (MAT1205 or MAT1101 or MAT1102) in the first year of the UG course	
Courses where this course will be useful		
	1. Introduction to Materials Science. (PYT1401) 2. Introduction to Nanophysics and Applications (PYT1501) 3. Ceramic Science and Technology (PYT1801) 4. Any course related to Materials Properties	
	Course Contents (Topics and subtopics)	**Reqd. hours**
1	**Binding in solids:** Materials in the solid state, origin of attractive and repulsive interactions, types of bonding in solids, derivation of Madelung constant for solids.	04
2	**Crystal structure of solids: diffraction from periodic structures:** Brief revision of crystal structures, introduction to reciprocal space and elastic scattering, Laue conditions, atomic form factor, structure factor, experimental techniques for diffraction.	10
3	**Electronic structure of solids and Band theory of solids:** Free electron models of a metal: Drude's and Sommerfeld's models, inadequacies of free electron models, Electrons in a periodic potential: Schrödinger's equation and Bloch waves, Kronig-Penny model, conduction in semiconductors.	10
4	**Elastic and Thermal properties of solids:** Einstein and Debye Models of specific heat, Introduction to lattice vibrations and quantization of elastic waves in a solid, Introduction to the concept of phonons, scattering and thermal conductivity in solids.	06
List of Reference Books		
1	Elementary Solid-State Physics: Principles and Applications, M. Ali Omar. publisher, 2017	
2	The Oxford Solid State Basics, Steven H. Simon, Oxford Publishers, 2013	
3	Solid State Physics, N. Ashcroft and D. Mermin, Cengage Publishers, 2013	
4	Solid State Physics, A. J. Dekker, Prentice Hall, 2000	
5	Electronic Properties of Materials, Rolf Hummel, 3rd Ed. Springer, 2013	
6	Introductory Solid-State Physics, H. P. Myers, CRC press, 1997	

Mapping of course outcome (CO) to the program specific outcome (PSO)						
	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	1	2	3	2	3
CO2	3	1	2	3	2	3
CO3	3	1	2	3	2	3
CO4	3	1	2	3	2	3

CO5	2	1	2	3	2	2

3, Strong Contribution; 2, Moderate Contribution; 1, Low Contribution; 0– No Contribution
K, knowledge level from cognitive domain

	Course Code: PYT1401	**Course Title: Introduction to Materials Science**	**Credits = 02**		
			L	**T**	**P**
	Semester: IV	**Total contact hours: 30**	**01**	**01**	**-**
Course Outcomes (students will be able to…..)					
CO1	Identify and classify distinct types of materials based on their composition, structure, and properties.		K2		
CO2	Understand the underlying principles governing the material properties.		K2		
CO3	Gain exposure to various smart materials and their technological applications		K2		
CO4	Analyse correlations between properties of materials and their microstructures.		K3		
CO5	Select appropriate smart materials for specific applications		K3		
List of Prerequisite Courses					
	Applied Physics (PYT1251 or PYT 1205) in the first year of UG				
	Solid State Physics (PYT1301)				
Courses where this course will be useful					
	1. Introduction to Nanophysics and Applications (PYT1501) 2. Introduction to Polymer Physics (PYT1701) 3. Ceramic Science and Technology (PYT1801)				
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	**Classification and properties of materials:** Classification of materials: metals, intermetallic, metallic alloys, ceramics, polymers, composites, silicates, carbon-based materials. Bonding-structure-property correlations to classify materials. Significant properties of materials: mechanical (defects and their implications to mechanical behaviour), physical (electrical, optical, etc.), chemical, thermal etc.		05 05		

2	**Overview of smart materials and structures:** Classification of smart materials, Components of a smart system, Applications of smart materials. Piezoelectricity,	05
	Piezo-resistivity, Electro-strictive materials, Electro-rheological fluids, Chromic materials, Conductive polymer, Shape memory alloys, Shape memory ceramics and polymers,	10
	Principles of magnetostriction, Magneto rheological fluids, Materials for energy applications: energy harvesting, conversion, and energy storage.	05
	List of Reference Books	
	1. Materials Science and Engineering: An Introduction by William Callister & David Rethwisch., Wiley, 2013 2. Smart Structures and Materials by Brian Culshaw, Artech House Publishers, 2004 3. Smart Structures by Gauenzi, P., Wiley, 2009. 4. Ultrasonic methods and application by Jack Blitz., Newnes-Butterworth, 1971	

Mapping of course outcome (CO) to the program-specific outcome (PSO)

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	2	3	2	3
CO2	3	2	2	3	2	3
CO3	3	2	2	3	2	3
CO4	3	2	2	3	2	3
CO5	3	2	2	3	2	3

3, Strong Contribution; 2, Moderate Contribution; 1, Low Contribution; 0– No Contribution
K, knowledge level from cognitive domain

	Course Code: PYT1501	**Course Title: Introduction to Nanophysics and Applications**	**Credits = 04**		
			L	**T**	**P**
	Semester: V	**Total contact hours: 60**	**03**	**01**	**-**
	Course Outcomes (students will be able to…..)				
CO1	Understand the importance of nanoscience and property variation with size.		K2		
CO2	Know the different methods of synthesis based on requirements.		K3		
CO3	Understand the Working Principle and utilization of characterization techniques		K2		
CO4	Know the properties of Special Nanomaterials and reason behind them		K3		
CO5	Understand the Applicability of Nanomaterials for commercial usage		K2		
	List of Prerequisite Courses				
	Solid state Physics (PYT1301)				
	Applied Physics in first year of the UG (PYT1251 or PYT1205)				
	Introduction to Materials Science (PYT1401)				

Courses where this course will be useful		
	1. Introduction to polymer physics (PYT1701) 2. Ceramics science and technology (PYT1801)	
	Course Contents (Topics and subtopics)	**Reqd. hours**
1	**Introduction:** Metal Nanoclusters, magic Numbers, modeling of nanoparticles, bulk to nano transitions; the effect of size reduction on the physical and chemical properties of materials; properties of nanomaterials. Quantum Nature of Nanoworld: dots, wires, well.	10
2	**Physics based experimental approaches to Nanofabrication:** Lithography: Patterning, Masks and Photolithography; High energy mechanical milling, melt mixing; Evaporation-condensation method, ionized cluster beam deposition, sputter deposition, ALD, PVD, Chemical Vapor Deposition, pulse laser methods, Chemical Reduction Method, microemulsion, sol-gel method,	12
3	**Characterization of Nanomaterials:** Structural and chemical characterization: XRD, UV-visible, near-infrared, SEM (Scanning Electron Microscope), TEM, photoluminescence, XPS, EXAFS, ESR, NMR (Nuclear Magnetic Resonance).	12
4	**Special Nanomaterials:** One-, two- and three-dimensional Nanomaterials, Band structure, property variation, Carbon nanostructures: fullerenes, carbon nanotubes.Bulk nanostructured materials, solid disordered nanostructures, nanostructured multilayers, metal nanoclusters, composite glasses, porous silicon.	13
5	**Application of Nanomaterials:** Nanofabrication, Nanoelectronics, quantum dots and quantum well devices, plasmon waveguides (optical devices), Energy sector, automobiles, space, defense, sports, and cosmetics. Commercial Status of Nanomaterials	13
	List of Reference Books	
	1. Introduction to Nanotechnology – C. P. Poole, Jr., and F.J. Owens, Wiley, 2003 2. Nanotechnology: Principles and Practices – S. K. Kulkarni, Springer, 2015 3. Nanostructures and Nanomaterials – G. Cao, Imperial College Press, 2004 4. Nanomaterials – A. S. Edelstein, R. C. Cammaratra, Institute of Physics, 1998 5. Nanostructures: Theory and Modeling – C. J. Delerue and M. Lannoo, Springer, 2010 6. Nanophysics and Nanotechnology- Edward L. Wolf, Wiley, 2006	

Mapping of course outcome (CO) to the program-specific outcome (PSO)

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	2	3	3	3	3	3
CO2	3	2	3	3	3	3
CO3	3	3	3	3	3	3
CO4	2	3	3	3	2	3
CO5	2	2	3	3	3	3

3, Strong Contribution; 2, Moderate Contribution; 1, Low Contribution; 0– No Contribution

K, knowledge level from cognitive domain

	Course Code: PYP1601	Course Title: Materials Characterization Laboratory	Credits = 02		
			L	T	P
	Semester: VI	Total contact hours: 60	-	-	4

	Course Outcomes (students will be able to…)	
CO1	Configure, handle, and use advanced, research-grade experimental setups used in the characterization of various properties of materials.	
CO2	Choose appropriate analytical techniques needed to investigate different properties of the materials.	
CO3	Understand how various advanced characterization instruments are fully controlled and operated using computers	
CO4	Use data analysis techniques to obtain relevant quantities using raw experimental data.	
CO5	Understand the infrastructural requirements and the safety protocols required to house advanced characterization facilities in a research lab/industry.	
	List of Prerequisite Courses	
	1. Introduction to materials science (PYT1401) 2. Solid state physics (PYT1301)	
	Courses where this course shall be useful	
	1. Ceramic science and technology (PYT1801) 2. Introduction to polymer physics (PYT1701)	
	Course Contents (List of Experiments)	**Reqd. hours**
1	**Structural properties**: Exploring the crystal structure of materials using X-ray diffraction techniques	8
2	**Optical Properties**: Measurement and analysis of absorbance and transmittance of materials using UV-Visible spectrophotometer.	8
3	**Mechanical properties**: Measurement and analysis of mechanical properties of materials using a Universal testing machine (Tensiometer), Measurement of viscoelastic properties of fluids using Rheometer	8
4	**Electrical properties**: Estimation of the type of semiconductor and its Carrier concentration using Hall effect	8
5	Temperature-dependent Electrical properties of materials: Measurement of resistivity using two probe/four-probe technique.	8
6	**Chemical composition studies**: Identification of functional group, analysis molecular vibrations and chemical bonding using Fourier transform infra-red spectroscopy (FTIR)	8
7	Study of thermal properties of materials using differential scanning colorimetry (DSC)	4
8	Growth of single crystalline and polycrystalline material using simple techniques.	8

Mapping of course outcome (CO) to the program specific outcome (PSO)

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	1	3	3	2	3
CO2	3	1	2	3	3	3
CO3	1	1	3	3	2	3
CO4	2	1	3	3	3	3
CO5	1	1	3	3	2	3

3, Strong Contribution; 2, Moderate Contribution; 1, Low Contribution; 0− No Contribution
K, knowledge level from cognitive domain

	Course Code: PYT1701	**Course Title: Introduction to Polymer Physics**	**Credits = 02**		
			L	**T**	**P**
	Semester: VII	**Total contact hours: 30**	**02**	**-**	**-**
Course Outcomes (students will be able to…..)					
CO1	Classify the polymers based on structure, synthesis mechanism and applications.		K3		
CO2	Understand the concept of Molecular weight, polydispersity and calculate the same for any given polymer.		K2		
CO3	Examine the polymers that can be synthesized by step and/or chain polymerization techniques and assess the chosen method's feasibility/rate and other factors.		K3		
CO4	Understand the concept of glass transition temperature (T_g), design the polymer/composite suitable for applications based on the T_g (or changing the T_g).		K2		
CO5	Applicability of various viscoelastic models for polymers and create/modify several elements of model to satisfy the given viscoelastic behaviour.		K4		
List of Prerequisite Courses					
	First year UG Chemistry course (CHT 1251 or CHT1405 or CHT1406 or CHT1407)				
	Introduction to Materials Science (PYT1401)				
Courses where this course shall be useful					
	This course will benefit students in the introduction to materials science, advanced courses in polymer science/physics, courses related to composite materials, etc.				
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	**Introduction:** General introduction to macromolecules, classification of polymers, structure of crystalline and amorphous polymers, lamellar, fibrillar, globular and spherulitic structures, domain structure of amorphous polymers, Molecular weight of Polymers, polydispersity, and their determination. Chain conformation in polymers.		08		

2	**Synthesis of polymers:** Classification of polymerization reactions. Step Polymerization: polycondensation, polyaddition polymerization. Radical polymerization, ionic polymerization, coordination polymerization. Kinetics of various polymerization processes.	06
3	**Thermal behaviour:** Glass transition temperature, melting temperature, heat distortion temperature, factors affecting T_g and its relationship with various properties, Effect of structure on thermal properties of polymers.	04
4	**Mechanical behaviour:** Fundamental concepts of rheology, elastic deformation in polymers, theory of linear viscoelasticity, concept of relaxation, stress-strain behaviour, its dependence on internal and external factors, fatigue and lifetime of polymers, viscoelastic mechanical models.	06
5	**Electrical behaviour:** Dielectric properties: dielectric measurements and its use, dielectric relaxation, and its correlation with mechanical properties of polymers. Conduction in polymers: conducting, composites, ionic conduction, inherently conducting polymers; Polymer electronics. Gel electrolytes for batteries.	06
	List of Reference Books	
	1. Textbook of Polymer Science – F. W. Billmeyer, Wiley, 2017 2. Introduction to polymers- Robert J. Young and Peter A. Lovell, CRC Press, 2011 3. Polymer Science: V. R. Gowariker, N. V. Viswanathan, New Age International Publishers, 2021. 4. Fundamental Polymer Science – U. W. Gedde. Springer, 2019	

Mapping of course outcome (CO) to the program-specific outcome (PSO)

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	3	2	2	3
CO2	3	2	3	2	3	3
CO3	3	2	3	2	2	3
CO4	3	3	3	3	2	3
CO5	3	2	2	3	3	3

3, Strong Contribution; 2, Moderate Contribution; 1, Low Contribution; 0– No Contribution

K, knowledge level from cognitive domain

	Course Code: PYT 1801	**Course Title: Ceramic Science and Technology**	**Credits = 02**		
			L	**T**	**P**
	Semester: VIII	**Total contact hours: 30**	**02**	-	-
	Course Outcomes (students will be able to….)				
CO1	Understanding the various structures of the ceramics, synthesis mechanisms and structure-property co-relationships		K2		

CO2	Identify various possible defect reactions and write them using Kröger-Vink notations for various ceramics systems and atmospheric conditions.	K2
CO3	Apply statistical models to understand and estimate mechanical behaviour (toughness) of the ceramics.	K3
CO4	Demonstrate preparation technique and measurement of samples for electrical properties.	K4
CO5	Understand the electrical behaviour of various ceramics families and classify them based on potential applications. Analyze this electrical data using various mathematical equations and circuit fitting models.	K5
	List of Prerequisite Courses	
	Applied Physics (PYT1251 or 1205) in first year UG	
	Solid state Physics (PYT1301)	
	Introduction to Materials Science (PYT1401)	
	Materials Characterization laboratory (PYP1601)	
	Courses where this course shall be useful	
	This course will be helpful for students who wish to pursue topics on advanced materials, solid state chemistry, materials synthesis, composite materials, and selection of materials based on the desired properties.	
	Course Contents (Topics and subtopics)	**Reqd. hours**
1	**Introduction:** Bonding and crystal structure, point defects, Kröger-Vink notations, effects of partial pressure of oxygen and temperature on defect concentration, effect of microstructure on the properties of ceramics.	10
2	**Ceramic Synthesis:** Synthesis of ceramic powders and nanoparticles, sintering and grain growth mechanisms, solid state sintering, Liquid phase sintering, Hot pressing and hot isostatic pressing.	06
3	**Mechanical properties:** Theoretical fracture strength, Griffith's theory of brittle fracture, fracture toughness, factors affecting mechanical properties of ceramic materials, toughening mechanisms.	06
4	**Electronic ceramics (Electro-ceramics):** Electronic ceramics, Dielectric properties of ceramics, polarization Mechanisms, Capacitors, and insulators, piezoelectric, ferro and anti-ferroelectric ceramics.	08
	List of Reference Books	
	1. Fundamentals of ceramics – M. W. Barsoum, CRC Press, 2020 2. Introduction to Ceramics – W. D. Kingery, H. K. Bowen and D. R. Ulman, Wiley, 2013 3. Ceramic fabrication processes – F. F. Y. Wang, Elsevier, 1976 4. Electroceramics, A. Moulson, J. Herbert, Wiley, 2003 5. Ceramic Materials Science and Engineering by C. Barry Carter, M. Grant Norton, Springer, 2013	

Mapping of course outcome (CO) to the program specific outcome (PSO)

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	3	3	3	3
CO2	3	2	3	2	2	3
CO3	3	3	3	2	3	3
CO4	3	3	3	2	2	3
CO5	3	2	3	2	3	3

3, Strong Contribution; 2, Moderate Contribution; 1, Low Contribution; 0− No Contribution

K, knowledge level from cognitive domain